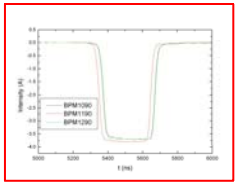
Lecture 5 : Beam Diagnostics and Feedback

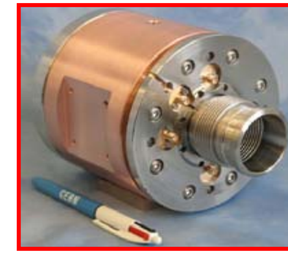
- Introduction to beam diagnostic in CLIC
  - General remarks (WWH)
  - Beam parameters and requirements
- Colliding Beams
  - Measuring small beam size
  - Measuring small beam displacement
  - Measuring short bunches
- The CLIC RF source : Drive Beam
  - Efficiency, Stability & Reliability
  - Operating a high charge accelerator

What need to be measured ?



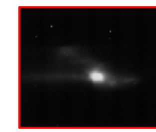
- Beam Position *(x / y)*
- Beam Current *I*

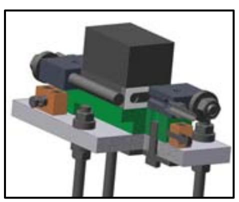
→ Beam commissioning



- Beam size (σ_x / σ_y)
- Bunch length (σ_z)

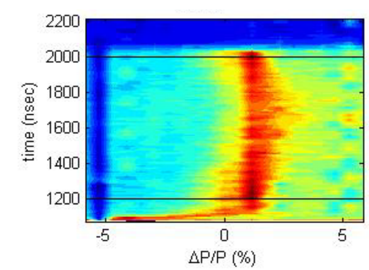
→ Machine optimization





- Beam energy *E* and energy spread ΔE

→ Machine optimization

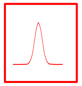


- Beam losses

→ Machine Protection and minimize radiation

→ What are the parameters susceptible to drift with time ?
Do we need Feedback system ?

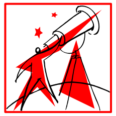
Different families of beam diagnostic

1- Profile measurements  ← → σ RMS or FWHM values

- *More precise information on the beam characteristic*

2- Single shot measurements 1 ← → n! Sampling measurements

- *Do not care about the beam reproducibility*
- *No need for precise timing/position system (fs/μm in our case)*

3- Non interceptive  ← →  Interceptive Devices

- *Can be used for beam study and beam control for on-line monitoring*
- *No risk of damage by the beam itself*

4- Time resolution t ← → ∫ Integrated measurement

↓

What you prefer

Level of Difficulty and Reliability

'Beam diagnostics should help you to understand how the beam behaves, **it should not be the opposite**'

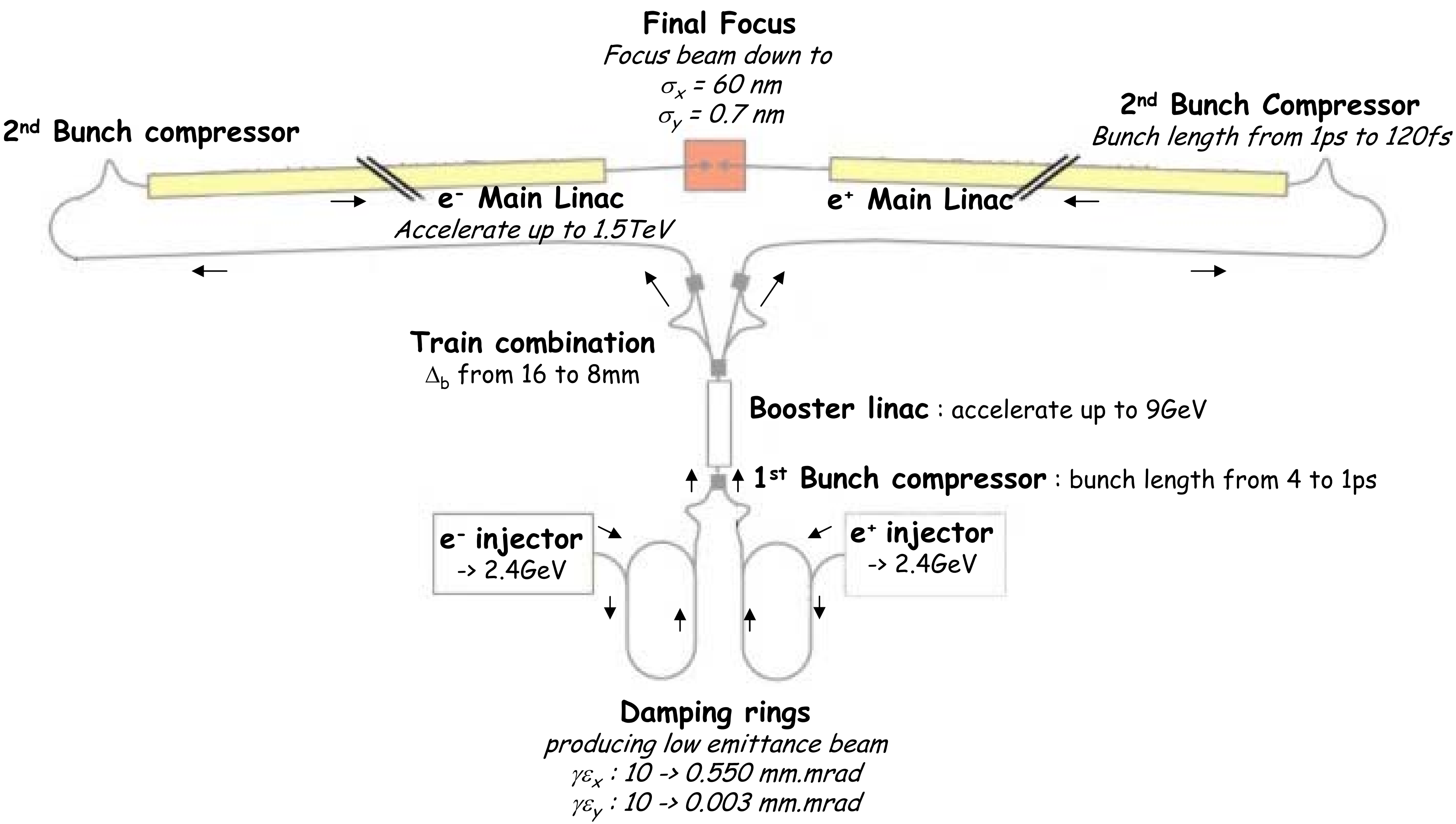
↓

A detector, what for ?

• Online Beam stability → Non-intercepting and reliable
Only have access to a partial information (RMS values,..)

• Beam characterization and beam physics study → Full information
Complexity and time consuming

' CLIC 3TeV '


Final Focus
Focus beam down to
σx = 60 nm
σy = 0.7 nm
2nd Bunch compressor
2nd Bunch Compressor
Bunch length from 1ps to 120fs
e- Main Linac
Accelerate up to 1.5TeV
e+ Main Linac
Train combination
Δb from 16 to 8mm
Booster linac : accelerate up to 9GeV
1st Bunch compressor : bunch length from 4 to 1ps
e- injector
-> 2.4GeV
e+ injector
-> 2.4GeV
Damping rings
producing low emittance beam
γεx : 10 -> 0.550 mm.mrad
γεy : 10 -> 0.003 mm.mrad

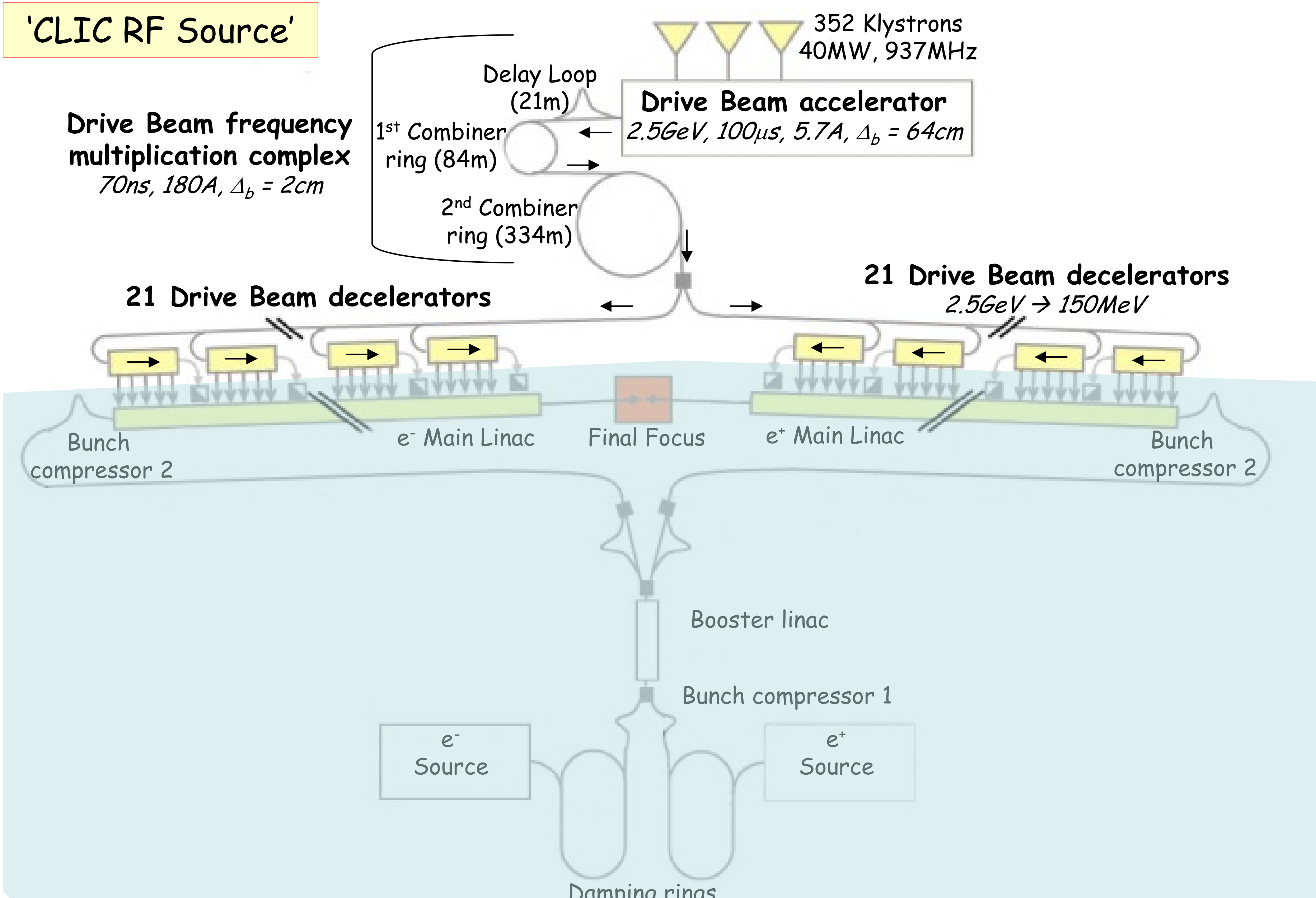
Comparison between CLIC and ILC

	CLIC	ILC
Center of mass energy (GeV)	3000	500
Main Linac RF Frequency (GHz)	30	1.3
Luminosity (10^{34} cm^{-2} s^{-1}*)*	6.5	2.5
Linac repetition rate (Hz)	150	5
Accelerating gradient (MV/m)	150	28
Proposed site length (km)	33.2	33
Total site AC power (MW)	418	140
Wall plug to main beam power efficiency (%)	12.5	23.5

Most Critical Beam Parameter

	CLIC	ILC
Bunch Length in the Linac (fs)	120	900
Typical Beam Size in the Linac (μm)	1	5
Beam size at IP : σ_x / σ_y *(nm)*	60/0.7	550/5

'CLIC RF Source'



Drive Beam Parameters

	Generation Complex	Decelerator
Electrons energy	→ 2.5 GeV	2.5 → 0.15 GeV
Beam current /charge	5.7A / 570μC	180A / 31μC
Total Beam Energy	→ 1.425MJ	31.5→ 1.9kJ
Bunch length	4-6ps	600fs
Minimum beam size	50μm	50μm
Charge density	$2.3\ 10^{10}$ nC/cm²	$1.2\ 10^{9}$ nC/cm²

'Unique type of beam'
Induction linac can generate high charge beams (>kA over 100ns) but at low energy (<100MeV)

The thermal limit for 'best' material (C, Be, SiC) is ~ $1\ 10^{6}$ nC/cm²

- Control of beam loss to prevent beam induced damage (10^{-4})
- Use of non-intercepting / non degradable beam diagnostic

This is just the RF source !!!

- Guarantee the efficient production of 30GHz RF power
- With a high level of reliability and availability

Requirements on Beam Diagnostics

Technological challenges

- Performances of the Collider measured by the Luminosity (interaction rate per second per unit cross section)

$$L = \frac{n_b N^2 f_{rep}}{4\pi\sigma_x^* \sigma_y^*} \times H_D$$

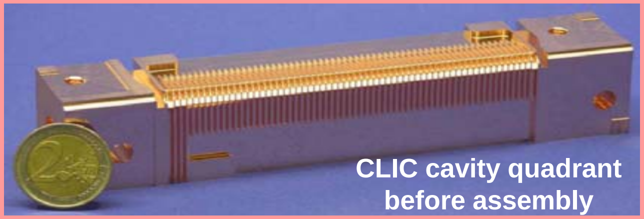
Measure nm beam size at IP

- Preservation of very low emittance beam

Measure μm beam size in the linac

COMMON TO LINEAR COLLIDERS

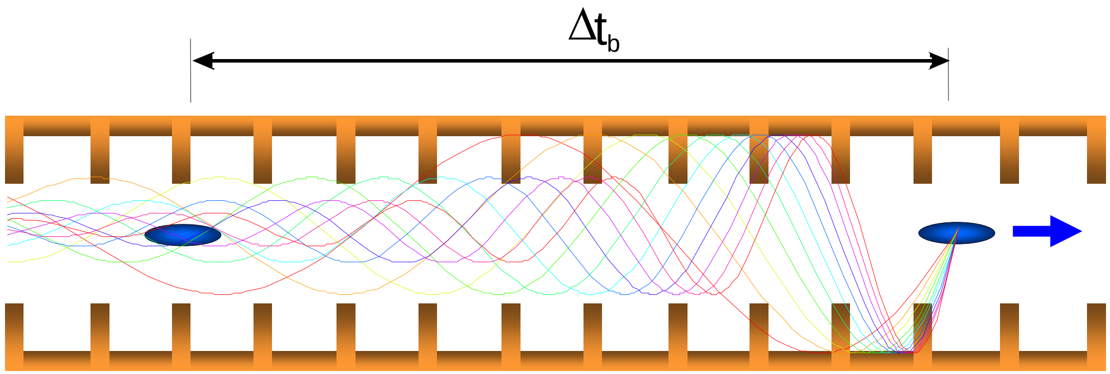
- 30 GHz components


CLIC cavity quadrant before assembly

SPECIFIC TO THE CLIC TECHNOLOGY

- Two-Beam Acceleration : Efficient and reliable RF power production

Wake field in Accelerating Structures



- Electrons traveling in accelerating structures induce fields which perturbs the particles arriving later
- Bunches passing off-centre excite transverse higher order modes (HOM)
- Later particles are kicked transversely

Beam Break-Up $\Rightarrow$ Emittance growth !!!

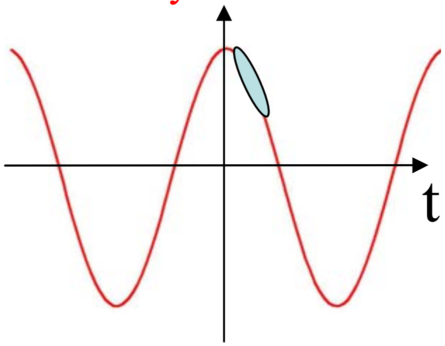
Slide from R. Corsini

Minimize Wake field for Emittance preservation

- Short-range wake field (single bunch) → BNS Damping

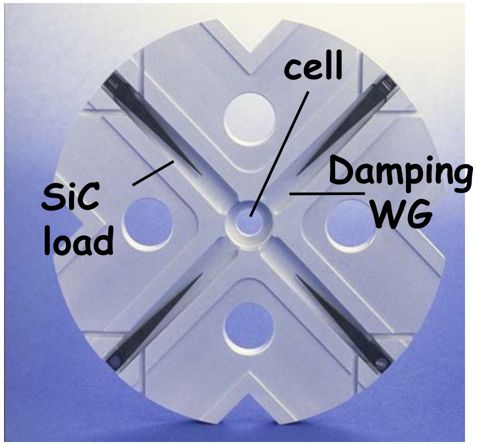
V. Balakin, A Novokhatsky and V. Smirnov, **12th International Conference on High Energy Accelerator, Fermilab, (1983)**

$E_{acc\ cavity}(t)$



Compensate the single bunch head-tail effect by an energy correlation within the bunch

- Long-range wake field (multi-bunch) → Damped and Detuned accelerating structures



Alignment

• Pre-align cavities and BPMs in linac to 10 microns
(referring to the talk of H. Mainaud on alignment procedure)

• Beam Based Alignment

↓

Several steps method

• Switch off quadrupoles
• Steer beam into last BPM
• Re-align BPMs to beam position
• Switch on quadrupoles (one by one)
• Move quadrupoles to center the beam in BPMs
• Re-align Accelerating structures (by moving girder) to new beam position in BPMs (structures BPM's)

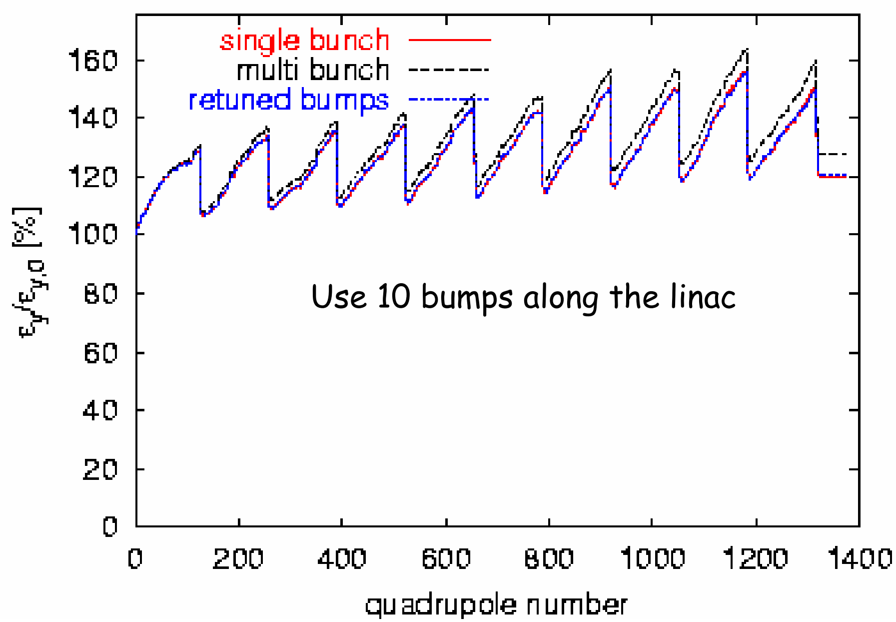
↓

Measure beam position with a 100nm resolution, 1μm precision

D. Schulte and T.O. Raubenheimer, 'The Ballistic Alignment Method', PAC conference, New York, (1999), p3441

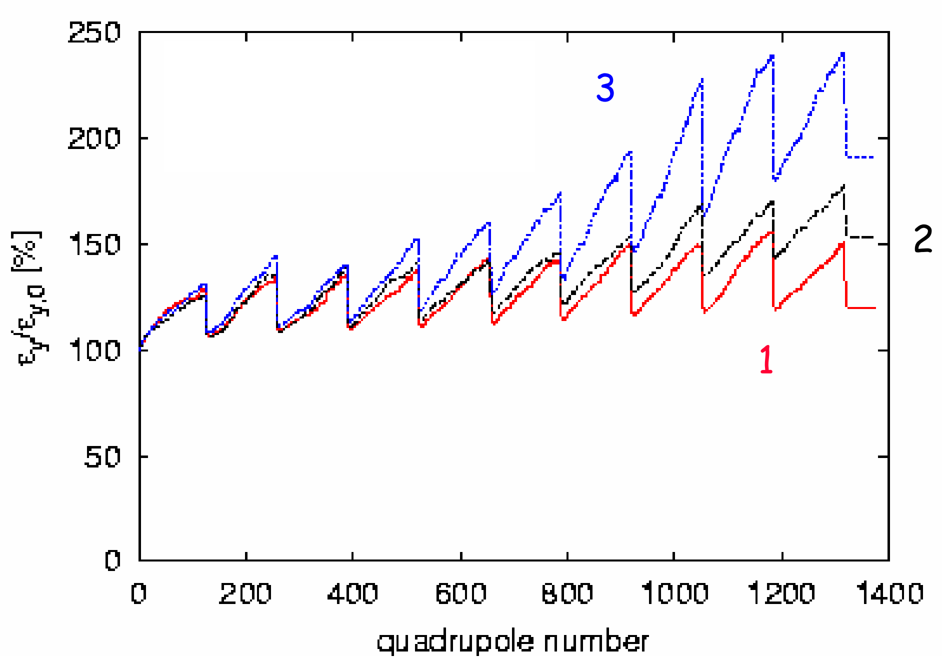
Emittance Tuning Bumps

- Remaining small misalignments leading to continuous emittance growth can be compensated by emittance tuning bumps.
- Introduction of trajectory oscillations over a finite length of the linac which generate errors which cancel emittance growth from random alignment errors.
- Done by small transverse displacement of accelerating structures and/or quadrupoles
- Can reduce locally emittance by 30-50%



- Measure small beam emittance difference close to Bumps
- Measure micron beam size with at least 300nm resolution

J.T. Seeman et al, SLAC-PUB-5705, (1992), A Chao et al, NIMA 178, (1980),
K. Bane, IEEE trans. Nucl. Sci. 32, (1985), 2389, R. Assmann et al, EPAC Conference, Stockholm, (1998), p445



Sensitivity to beam jitter & ground motion
Talk of S. Redaelli

Emittance deteriorate with time unless we apply beam correction schemes and readjust our initial settings

1) **Initial condition** at start of run after beam alignment

2) After about **one day** (10^5 s) of running and continuous one-to-one correction in feedback mode

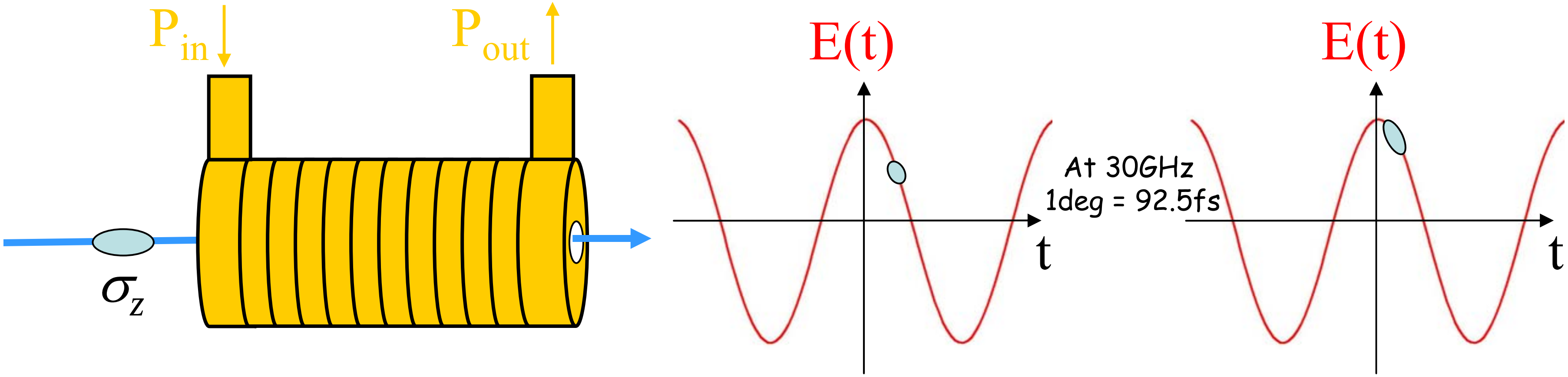
3) After about **10 days** (10^6 s) of running with continuous one-to-one correction and readjustment of emittance bumps

Operational procedure

- Emittance bumps readjusted every day
- BPMs realigned by "ballistic method" every week

Slide from R. Corsini

Acceleration @ 30GHz



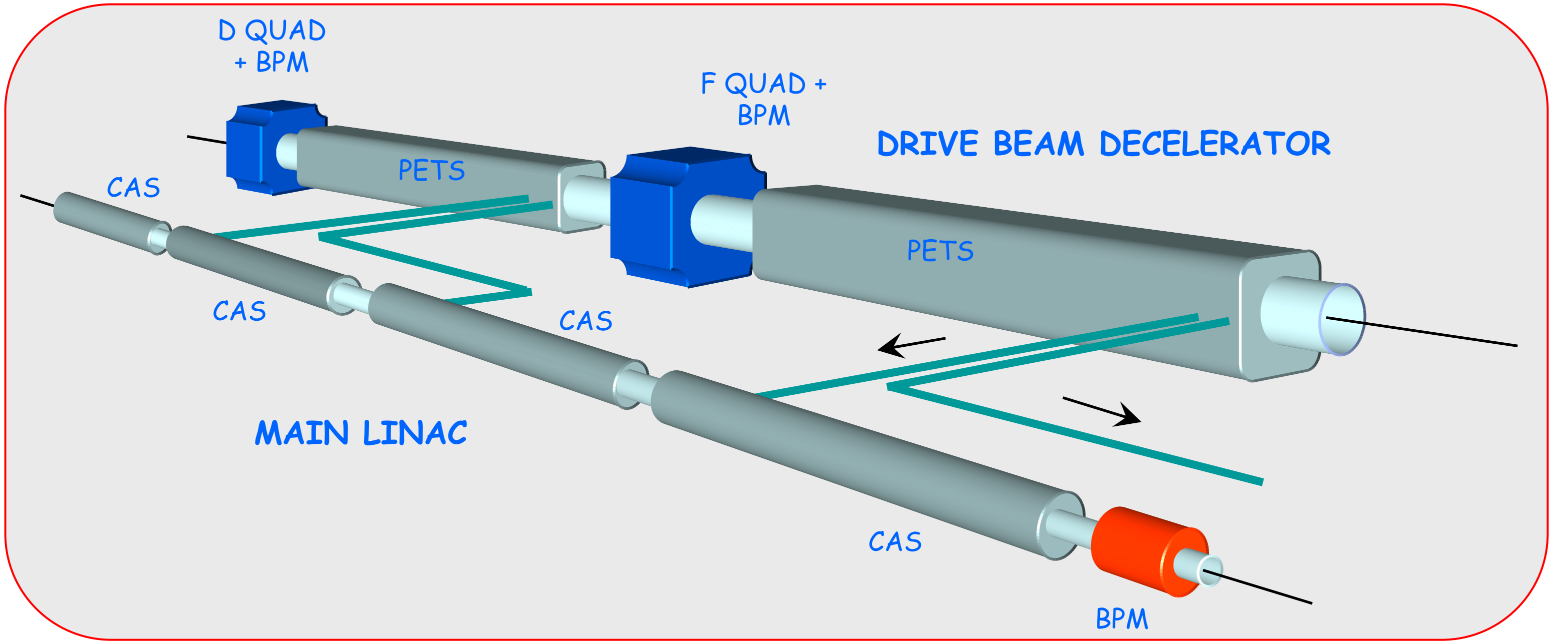
- For collider performances, the shorter bunch length the better
- If bunch are too short, BNS damping imposes a strong off-crest accelerating phase which leads to RF inefficiency

➡ Optimum at 120fs

➡ Measure bunch length with a 20-30fs resolution

The use of bunch compressor are assumed to not degrade the emittance

Efficiency of the 30GHz RF production

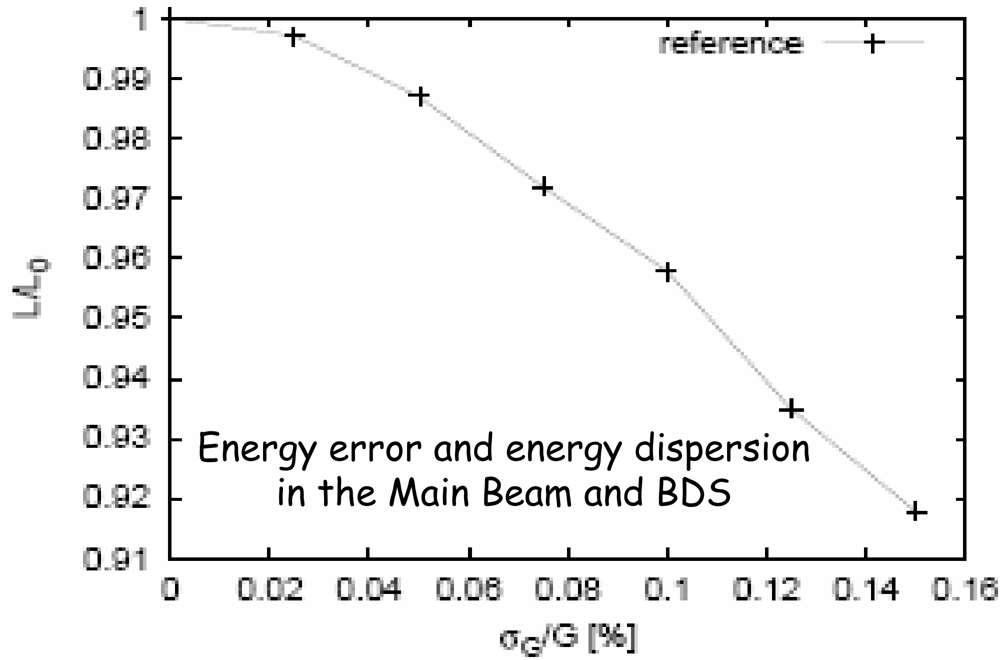


'Need a perfect 30GHz bunched beam'

- Error in the bunch combination → less power production

➡ Measure bunch combination with a good resolution (~ ps)

Luminosity as a function of accelerating gradient error



' 4% luminosity reduction'

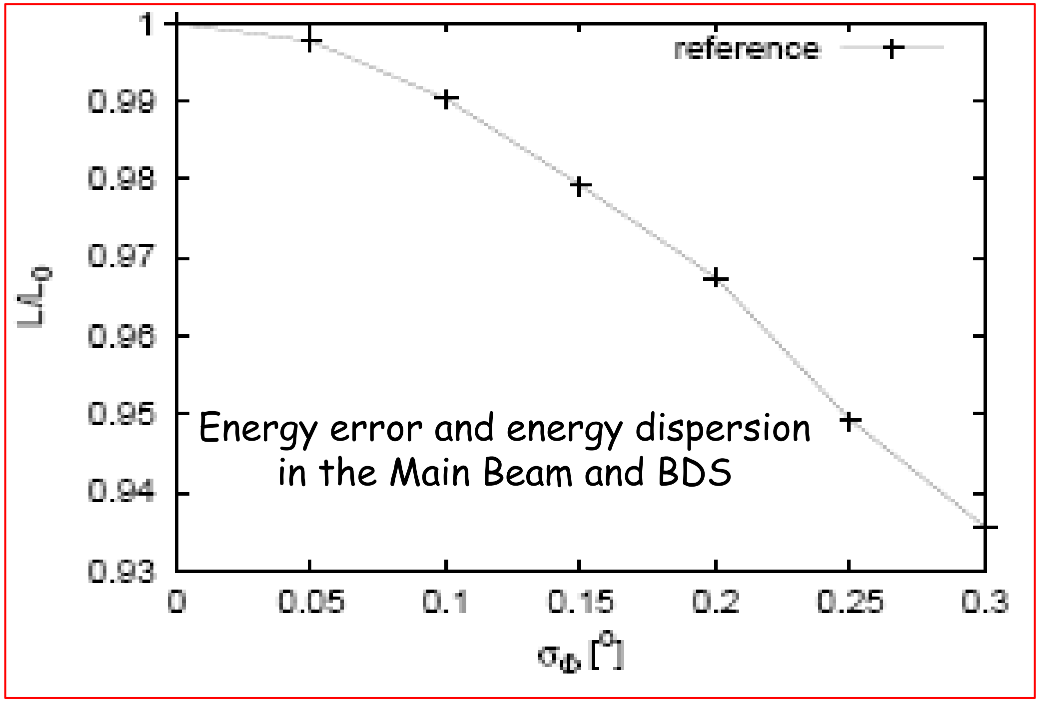
Average accelerating gradient error over the linac $\sigma_G/G = 10^{-3}$

Drive beam intensity tolerance $\Delta I/I = 10^{-3}$

D. Schulte, E.J.N Wilson and F. Zimmermann, 'Phase and Amplitude Tolerance in the CLIC Main Linac', Linac Conference, Lubeck, (2004), p138

Accelerator performances

Luminosity as a function of accelerating phase error



' 4% luminosity reduction'

➡ Average accelerating phase error over the linac σ_ϕ = 0.225°

➡
- Longitudinal Drive beam tolerance Δ_z = 6µm
- Feedback/feedforward for optimization

Lecture 5 : Beam Diagnostics and Feedback

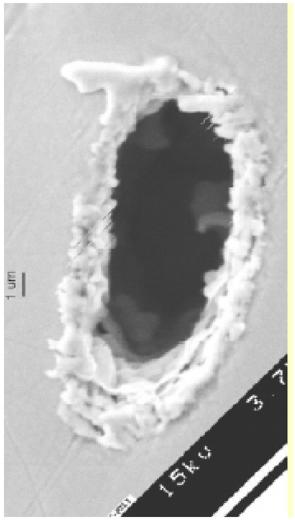
- Introduction to beam diagnostic in CLIC
  - General remark (WWH)
  - Beam parameters and requirements
- **Colliding Beams**
  - **Measuring small beam size**
  - **Measuring small beam displacement**
  - **Measuring short bunches**
- The CLIC RF source : Drive Beam
  - Efficiency, Stability & Reliability
  - Operating a high charge accelerator

Measuring small beam size

- In linac → $\sigma \sim 1\mu m$
- In Final Focus → $\sigma \sim 1nm$

Small beam size means high charge density
10^9 - 10^{12} nC/cm^2

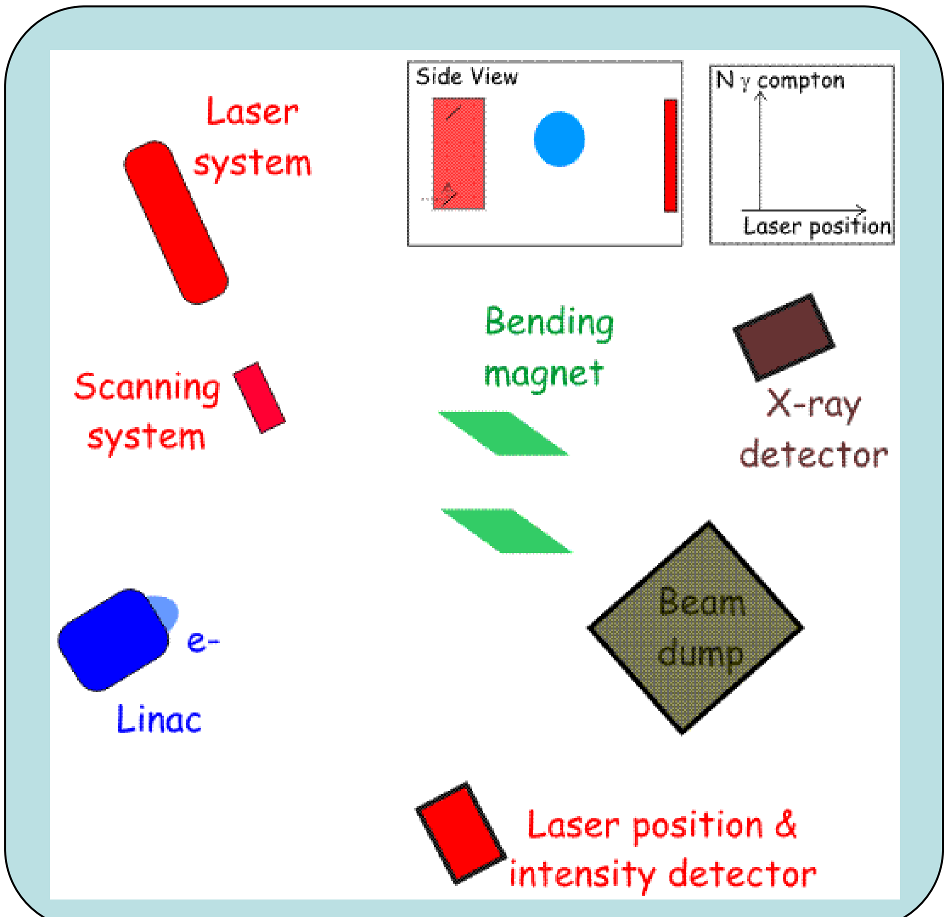
The thermal limit for 'best' material (C, Be, SiC) is ~ 1 10^6 nC/cm^2

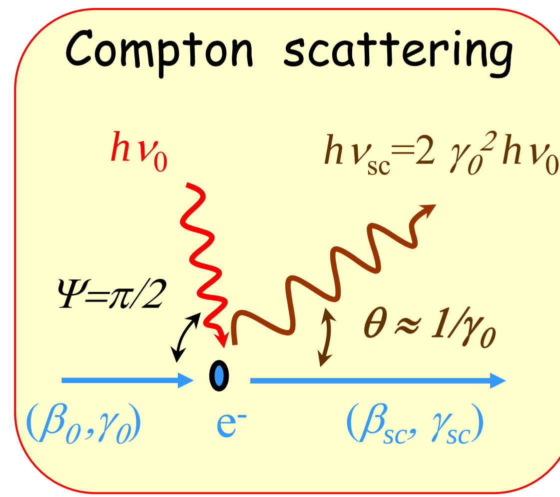


High resolution non intercepting beam size monitor

Laser Wire Scanner Principle

- *Scattered photons are produced by 90 Compton scattering sending a high power ultra-short laser onto the beam*
- *By measuring the number of Compton photons as a function of the laser position, the beam size is reconstructed*



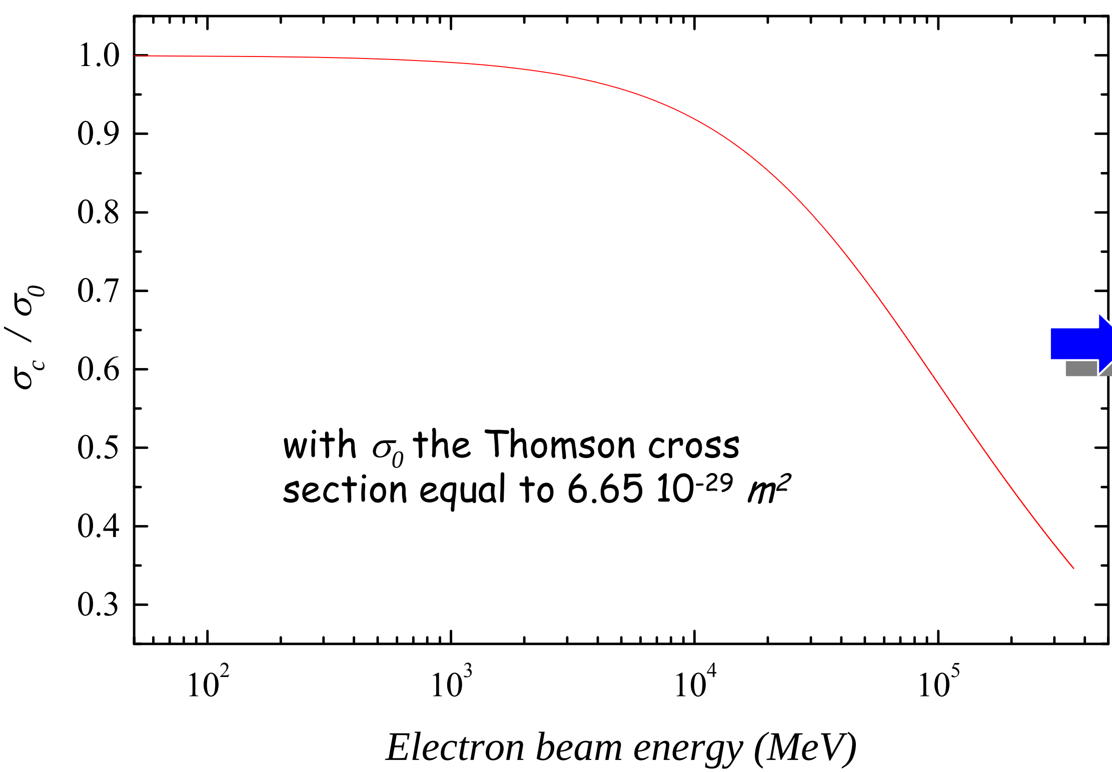


Laser Wire Scanner Parameter

- The number of X-rays produced is given by

$$N_{X-rays} \approx \frac{\sigma_c \cdot N_e \cdot N_{laser} \cdot \tau_{laser}}{A \cdot \tau_e}$$

with A the interaction area, N_e and N_{laser} are the number of electrons and photons in *A*



- Low Cross Section : Need High Power Laser (expensive)
- Typical number of events 10^3-10^5
- Measurements sensitive to beam loss (background subtraction technique)

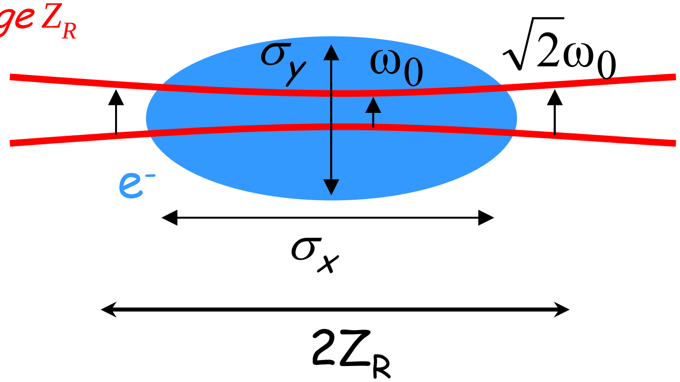
Laser Wire Scanner Resolution

Laser Beam

Wavelength λ_0, pulse duration τ_l
Waist size ω_0 and Rayleigh range Z_R

Electron Beam

Bunch length τ_e
Beam size σ_x and σ_y



Laser set-up

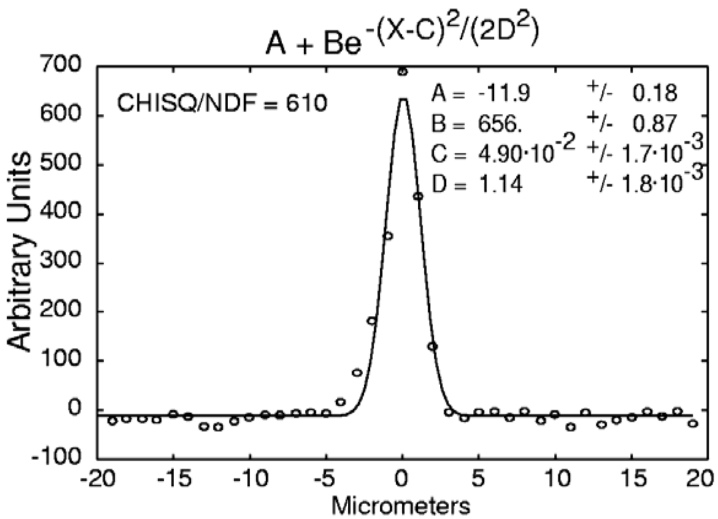
- $2Z_R > \sigma_x$
- $\omega_0 < \sigma_y$

- Problem for beam with aspect ratio σ_x:σ_y stronger than 12:1
- Intrinsic limitation : Cannot focus a laser beam stronger than the wavelength
  - Limit in resolution between 300-400nm (using 5th harmonic of YAG, 210nm)
- Some Concerns about:
  - Very precise alignment of the focusing element (lenses or parabolic miror)
  - Laser power density limit on the optics : 5GW/cm2, 1J/cm2 as safe number
  - Radiation damage on the optics

Brief History on LWS

• Early work on Compton scattering in the 70's but become more popular with the availability of high power laser in the 90's

• Test done a SLAC on a 30GeV, few microns size electrons beam using 350nm Nd:YAG laser and reflective optics in order to achieve a sub micron laser spot size



R. Alley et al, NIM A 379 (1996) 363
P. Tenenbaum et al, SLAC-PUB-8057, 1999

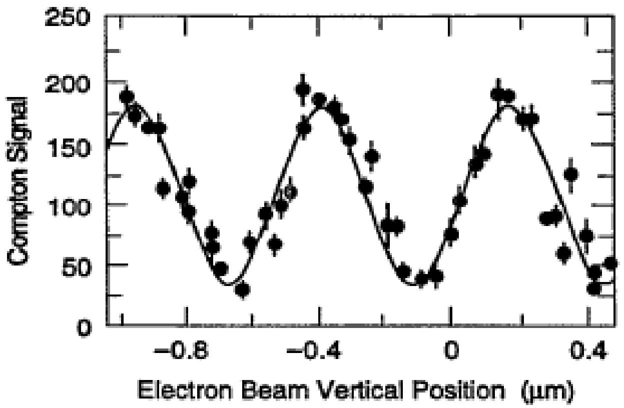
• At the moment lot of activities on LWS at KEK-ATF

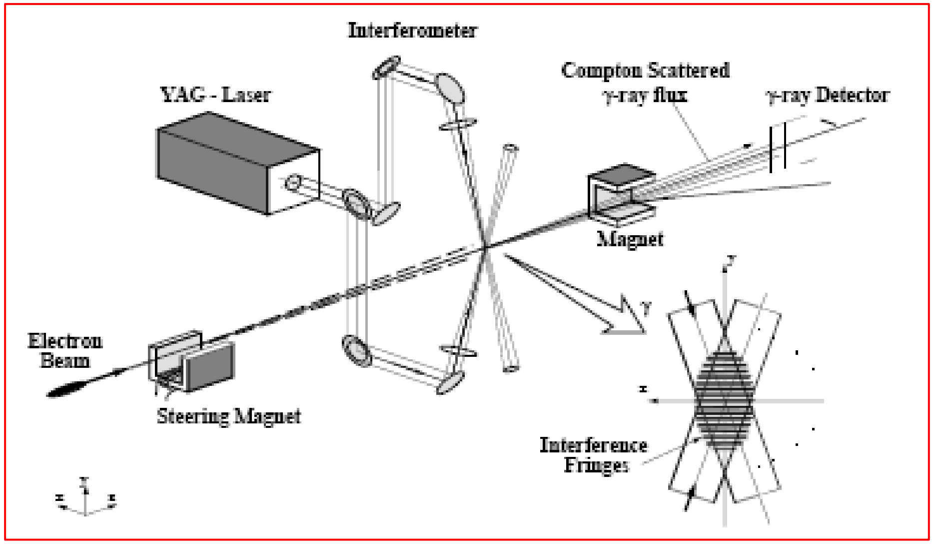
H. Sakai et al, Physical Review ST AB 4 (2001) 022801 & ST AB 6 (2003) 092802

T. Kamps et al, EPAC Conference, Lucerne, (2004), p2529

LWS interferometry to improve the resolution

- Use two laser beams
- Get fringe spacing pattern of $\lambda/2(\sin(\theta/2)$
- Scan the electron beam and measure modulation depth





V. Balakin et al, PRL 74, 2479, (1995)

- Possibility to measure nanometer beam size if using UV (200nm) laser
- Limits depends on tails and vibrations, background for synchrotron radiation in the final quadrupole

Measuring small beam size

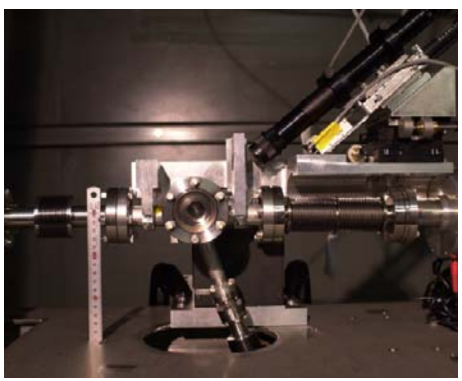
Device	Optical Transition radiation	Optical Diffraction radiation	Solid Wire Scanner	X-ray Optic Fresnel zone plates
Performance	5μm measured at KEK-ATF	3.5μm measured at KEK-ATF	Few microns (KEK)	10μm measured at KEK-ATF using 3.235keV X-ray
Limitations	Damage threshold	• No profile (just σ) • Cross calibration	Damage threshold	No evident X-ray source in a linac
Intercepting	Yes	No	Yes	No
Simplicity	Yes	Yes	Yes	Not really

S. Anderson et al, KEK-ATF-2001-08

T. Muto et al, PRL 90, 104801, 2003
P. Karataev et al,PRL 93, 244802, 2004

C. Field, NIM A 360 (1995) 467

K. Iida et al, NIM A 506 (2003) 41-49



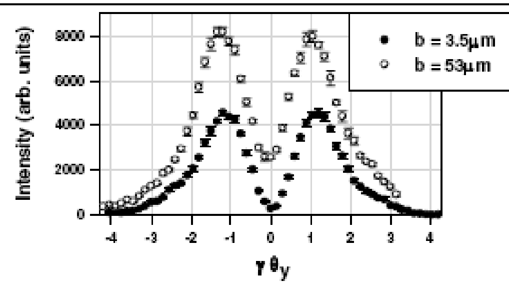


FIG. 5. ODR projected vertical polarization component measured at two different offsets with respect to the slit center.

Proposal to use forward XDR or beamstrahlung

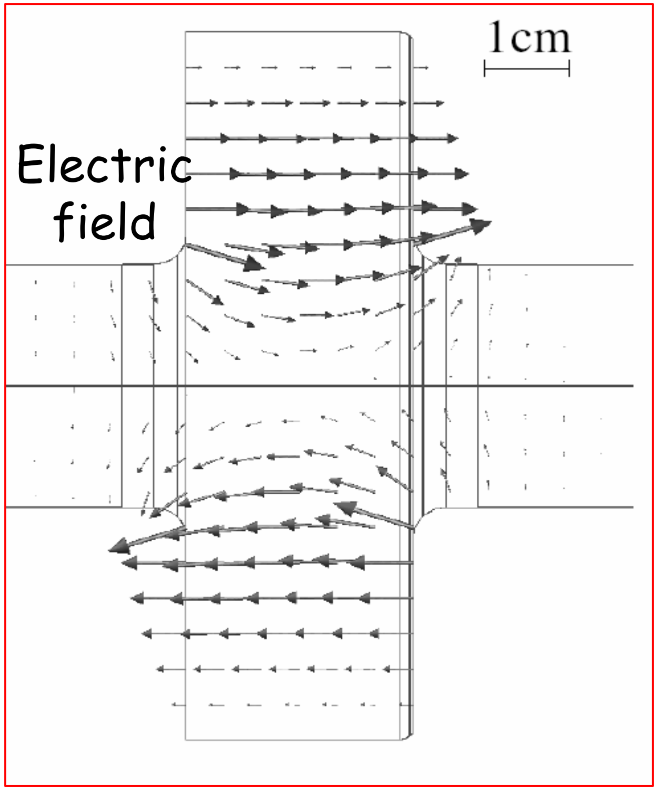
M.A. Piestrup, et al., Phys. Rev. A 45 (1992) 1183

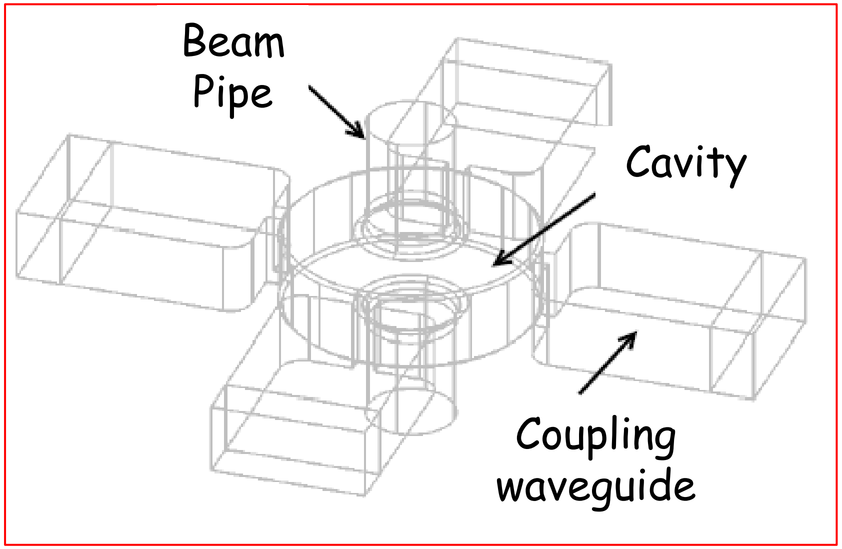
K.A. Ispirian, NIM A 522 (2004) 5-8

' Measuring Small Beam Displacement '

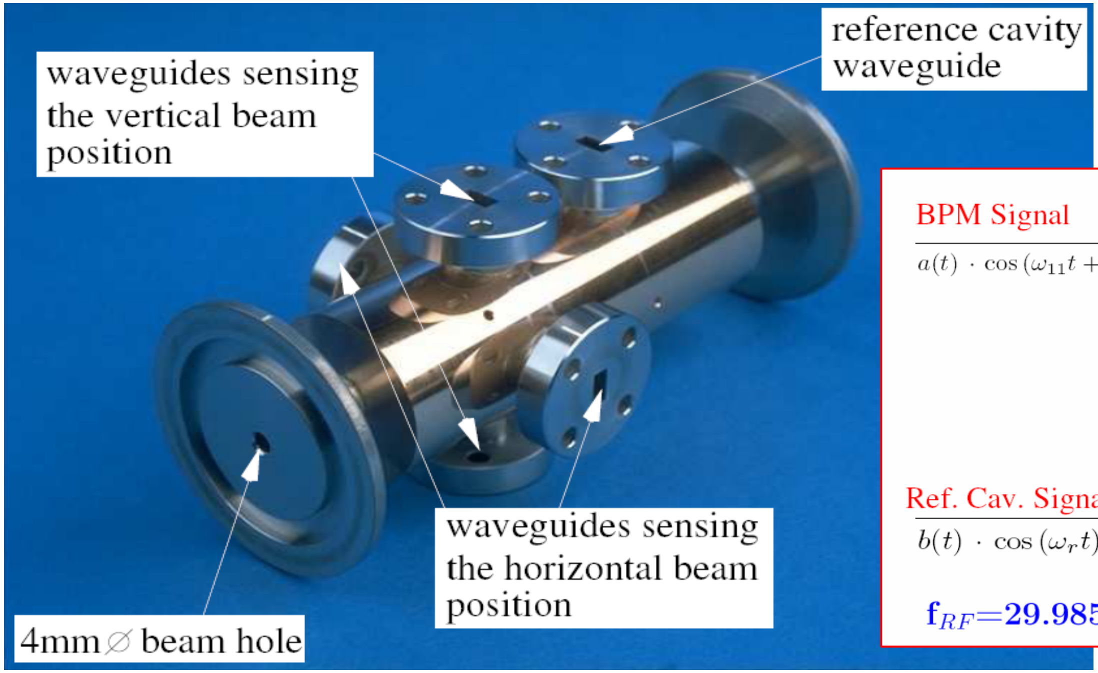
Principle of Cavity Beam Position Monitor

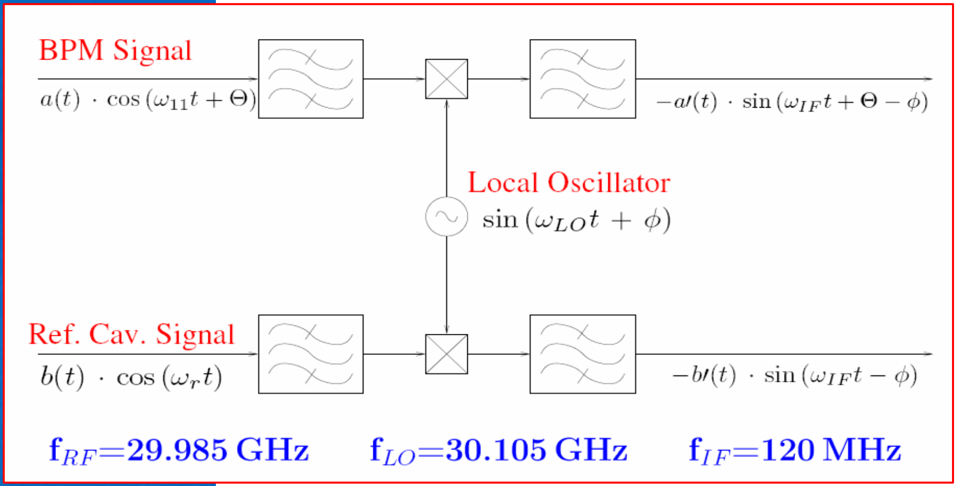
- Pill box cavity resonating at 30GHz in TM_{11} Mode
- Excitation proportional to the electric field component along the beam trajectory
- The induced power is extracted via irises and waveguide

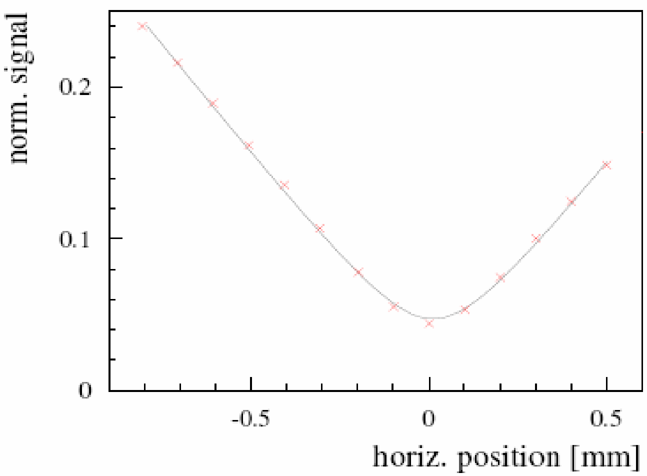


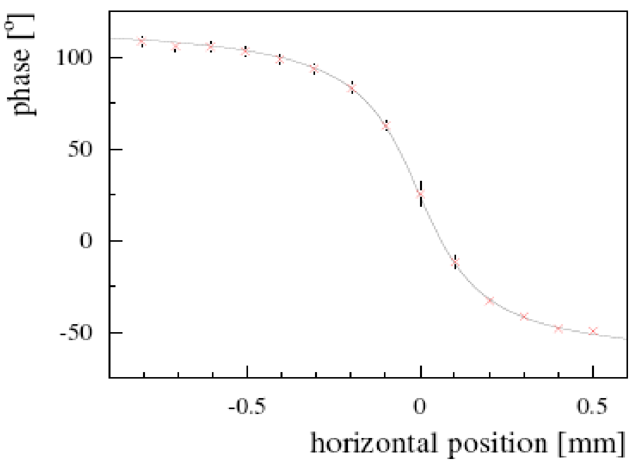


Principle of Cavity Beam Position Monitor









Phase measurements more sensitive to small beam offsets

Cavity Beam Position Monitor

- 25nm resolution already achieved at SLAC/FFTB
- Limitations by electronic noise and losses in the waveguide
- Possibility to include RF-BPM in accelerating structures
- Cavity BPM can be used as well to measure beam angle and beam correlation

Quite a lot of Activities, SLAC, KEK, CERN, DESY

- T. Slaton et al, “Design of nm Resolution C-Band RF BPM in the FFTB”, Linac Conference, Chicago, p.911, (1998)
- C. Adolphsen et al, “Wakefield and Beam Centering Measurements on a Damped and Detuned X-band Accelerator structure” PAC conference, New York, p.3477, (1999)
- T. Shintake, “Development of Nanometer Resolution Rf-BPMs”, KEK Preprint 98-188 (1998)
- J. Prochnow et al, “Measurement of Beam Position using a Highly-Damped Accelerating Structure”, PAC conference, Portland, p.2467, (2003)
- M. Ross et al, “Very High Resolution RF Cavity BPM”, PAC conference, Portland, p.2545, (2003)
- M. Ross et al, “RF Cavity BPM’s as Beam Angle and Beam Correlation Monitors”, PAC conference, Portland, p.2548, (2003)
- Z. Li et al, “Cavity BPM with Dipole-Mode-Selective Coupler”, PAC conference, Portland, (2003)
- S. Dobert et al, “Beam Position Monitoring using the HOM-signals from a Damped and Detuned Accelerating Structure”, PAC conference, Knoxville, p.2804, (2005)

' Measuring Short Bunch Length '

' Measuring Short Bunch Length '

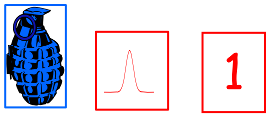
• Since the last 15 years, a lot of different methods have been investigated to measure sub-ps electron bunch

• Linear Collider, 4th Generation light source, Plasma and laser acceleration,..

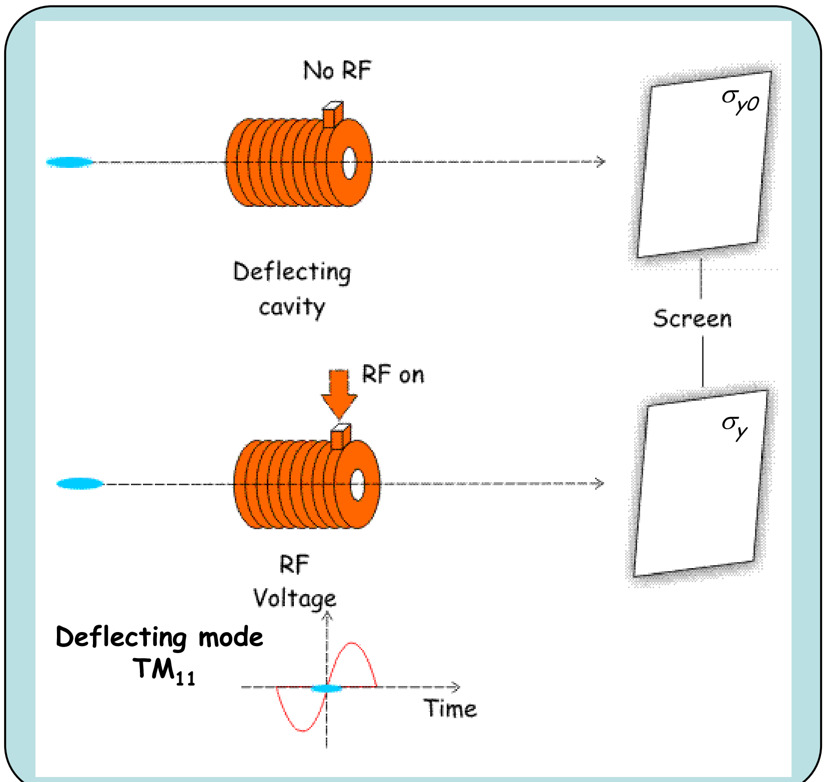
- Optical radiation (OTR / ODR)
  - **Streak camera** — *Mitsuru Uesaka et al, NIMA 406 (1998) 371*
  - **Shot noise frequency spectrum** — P. Catravas et al, Physical Review Letters 82 (1999) 5261
- **Coherent radiation** (CTR / CDR) — T. Watanabe et al, NIM A 437 (1999) 1-11 & NIM A 480 (2002) 315-327
- **RF Pick-Up** — C. Martinez et al, CLIC note 2000-020
- **RF accelerating phase scan** — D. X. Wang et al, Physical Review E57 (1998) 2283
- **Electro Optic Method** — A. M. MacLeod et al, Physical Review Letters 88 (2002) 124801

Principle of an RF Deflector

Old (1960-70's) idea to use RF deflector as a bunch length monitor



'The RF Deflector can be seen as a relativistic streak tube. The time varying deflecting field of the cavity transforms the time information into a spatial information The bunch length is then deduced measuring the beam size at a downstream position using a screen or (LWS)

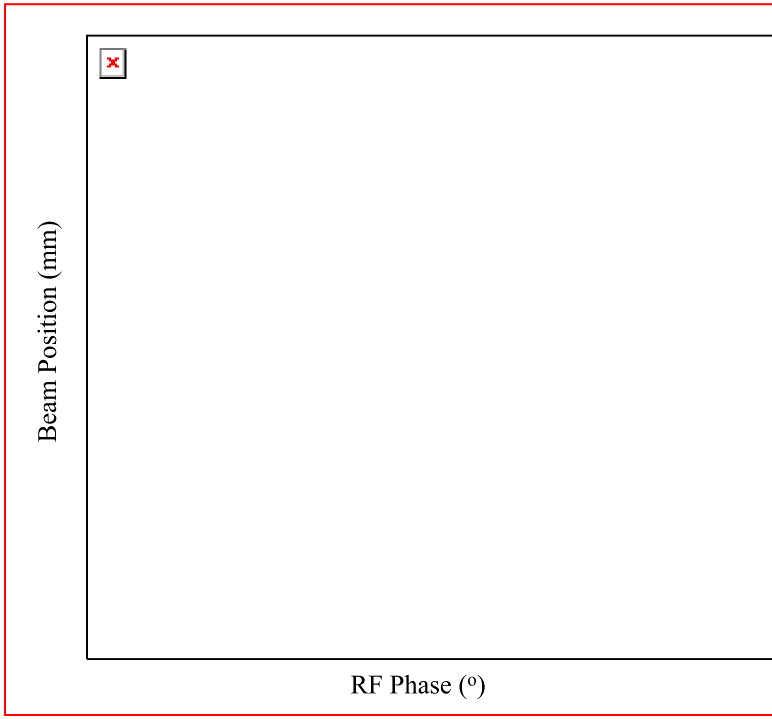


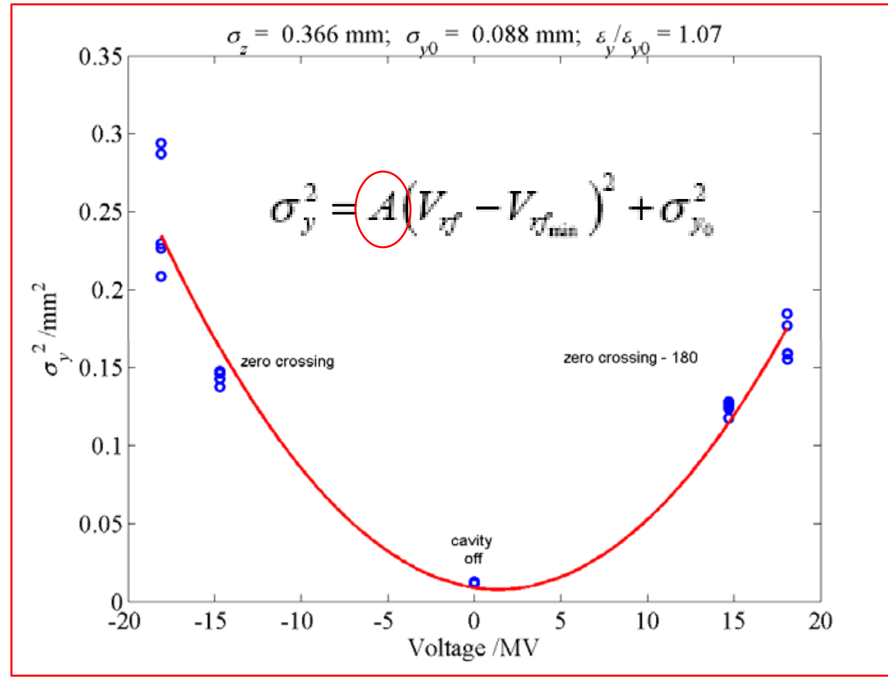
$$\sigma_y = \sqrt{\sigma_{y0}^2 + \sigma_z^2 \underbrace{\beta_c \beta_p} \left(\frac{2\pi e V_0}{\lambda_{rf} E_0} \sin \Delta\psi_y \cos\varphi_{rf} \right)^2}$$

- Deflecting Voltage
- RF deflector phase
- Bunch length
- Beta function at cavity and profile monitor
- RF deflector wavelength
- Beam energy
- Betatron phase advance (cavity-profile monitor)

P. Emma et al, LCLS note LCLS-TN-00-12, (2000)

Calibration of RF Deflector





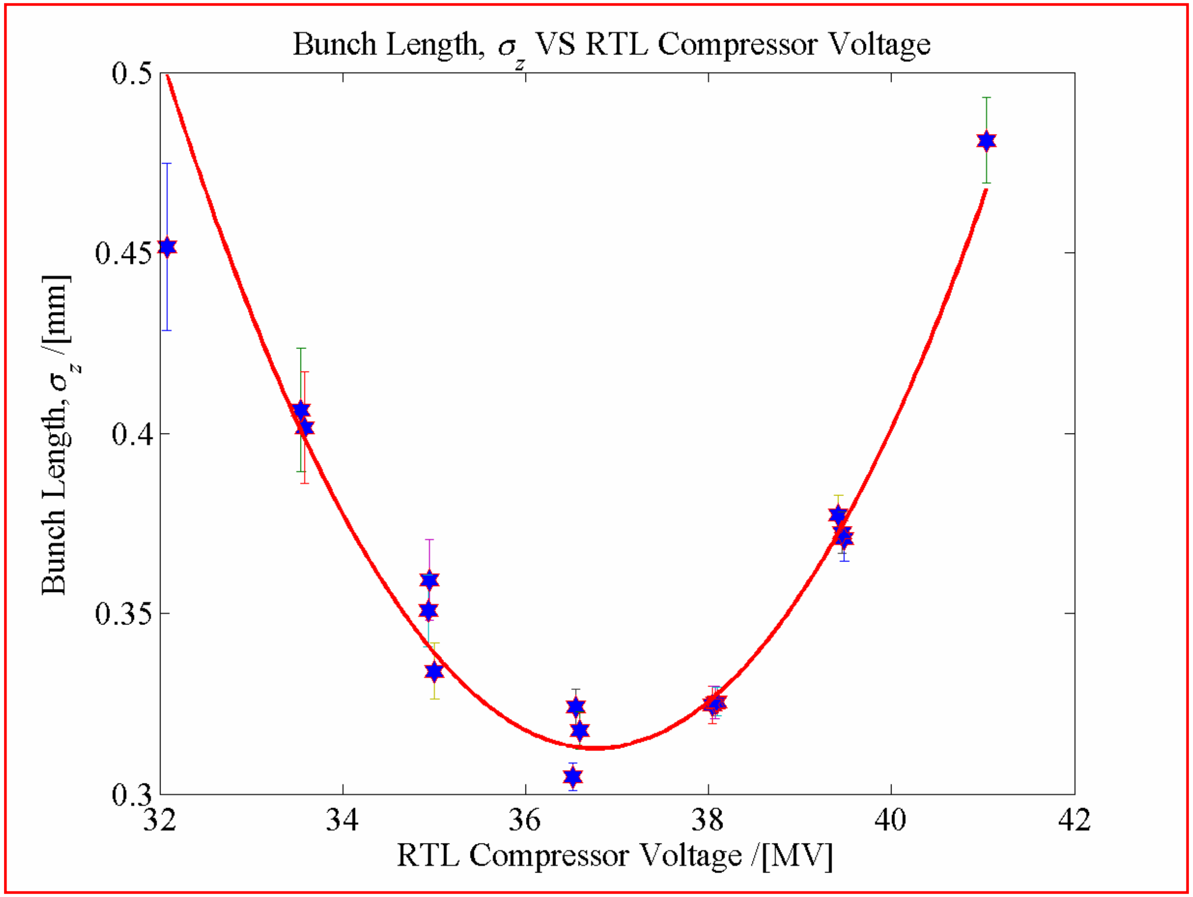
Use a Beam Position Monitor close to the Profile monitor to calibrate the deflection angle

R34 = transfer Matrix element from cavity to the BPM

Make a power scan at zero crossing and (zero crossing – 180°) to check if there is no perturbation from linac wakefields

$$\sigma_z = A^{1/2}\frac{E_0\lambda_{rf}}{R_{34}2\pi}.$$

RF Deflector : Performances



R. Akre et al, SLAC-PUB-8864, SLAC-PUB-9241, 2002

- σ_z = 300µm already measured
- In principle no real limitation

RF Deflector : Performances

- Can extract even more information than the bunch length

  ex: coupled the RF Deflector to a bending magnet and a profile monitor in a dispersive area, one can extract the longitudinal phase space

- For CLIC, the profile monitor would not be a screen but a LWS

- It is relatively expensive, Need an High Power RF source

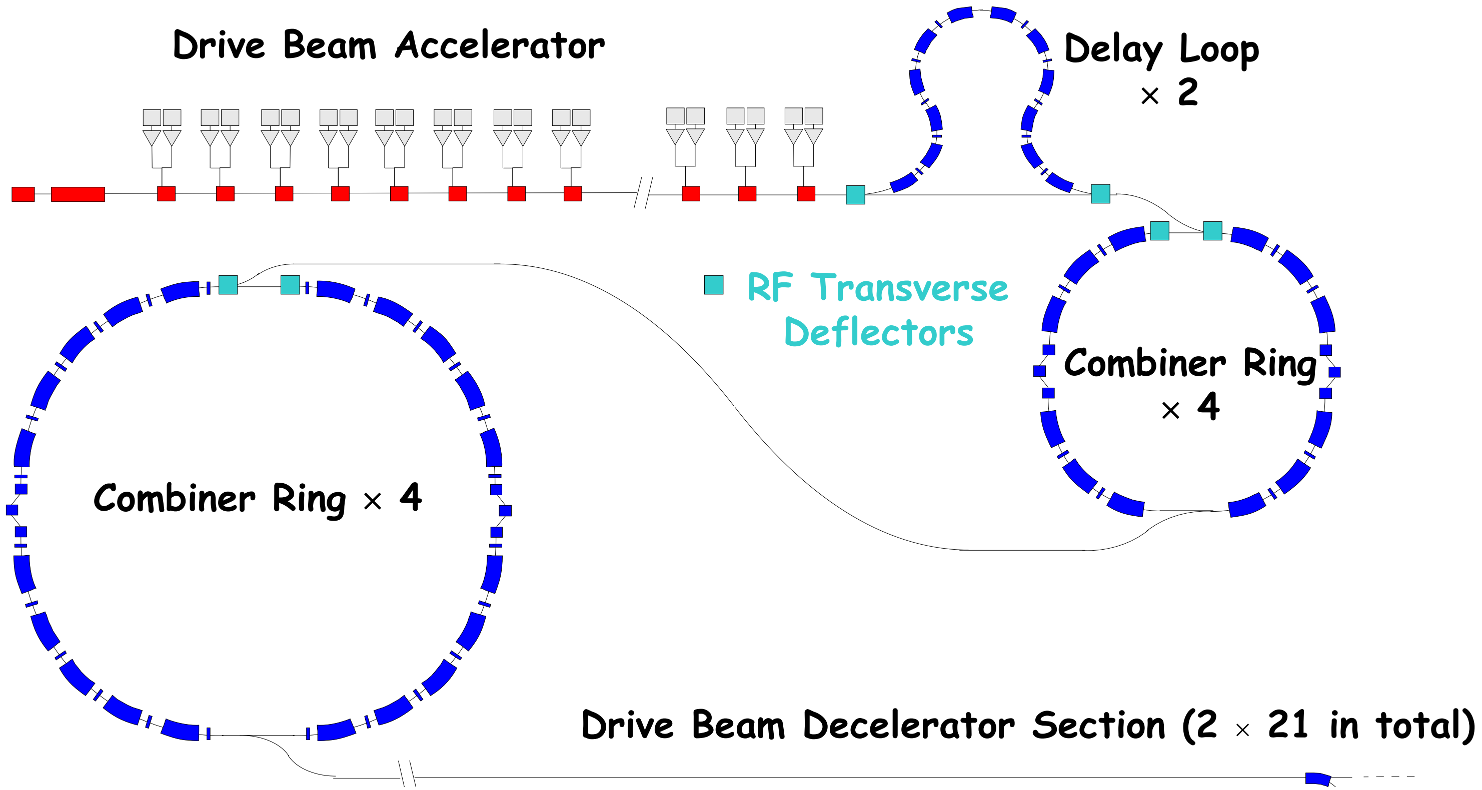
Lecture 5 : Beam Diagnostics and Feedback

- Introduction to beam diagnostic in CLIC
  - General remark (WWH)
  - Beam parameters and requirements
- Colliding Beams
  - Measuring small beam size
  - Measuring small beam displacement
  - Measuring short bunches
- **The CLIC RF source : Drive Beam**
  - **Efficiency, Stability & Reliability**
  - **Operating a high charge accelerator**

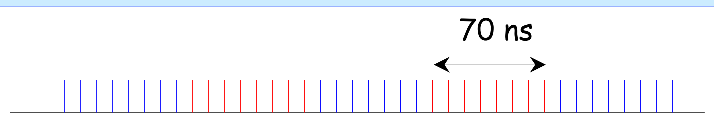
Efficiency of the 30GHz RF production

- Stability of the Drive Beam Combination
- Drive beam intensity tolerance $\Delta I/I = 10^{-3}$
- Longitudinal Drive beam tolerance $\Delta_z = 6\mu m$

Bunch Frequency Multiplication

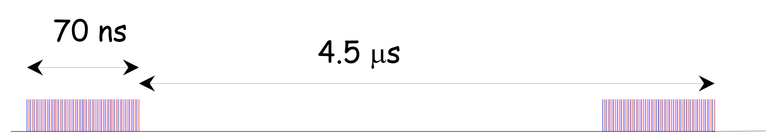


Drive beam time structure - initial



100 μs train length - 32 × 21 × 2 sub-pulses - 5.7 A
2.5 GeV - 64 cm between bunches

Drive beam time structure - final

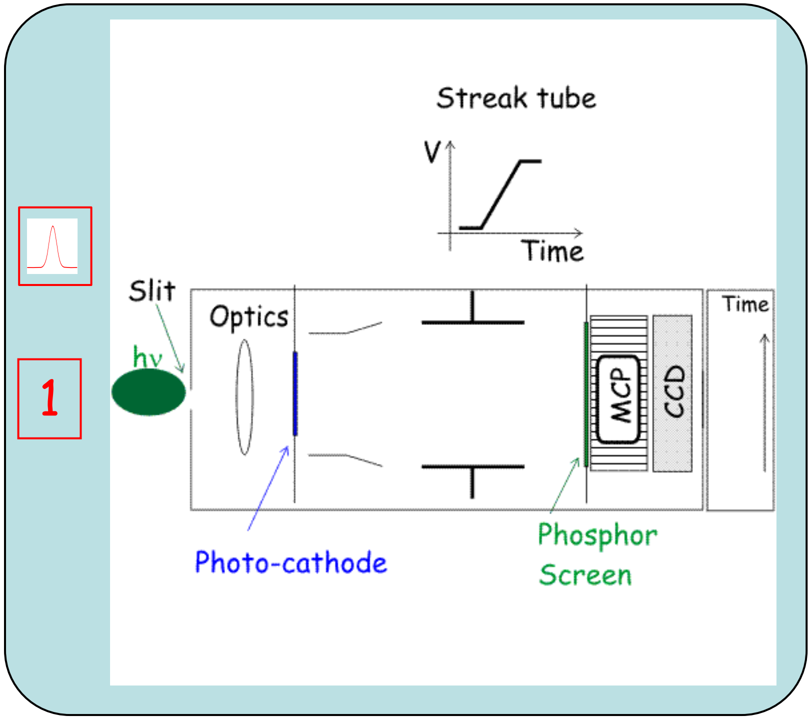


2 × 21 pulses – 180 A - 2 cm between bunches

Monitoring Bunch frequency multiplication

- Extract synchrotron light produced in the rings
- Use a streak camera to measure bunch combination

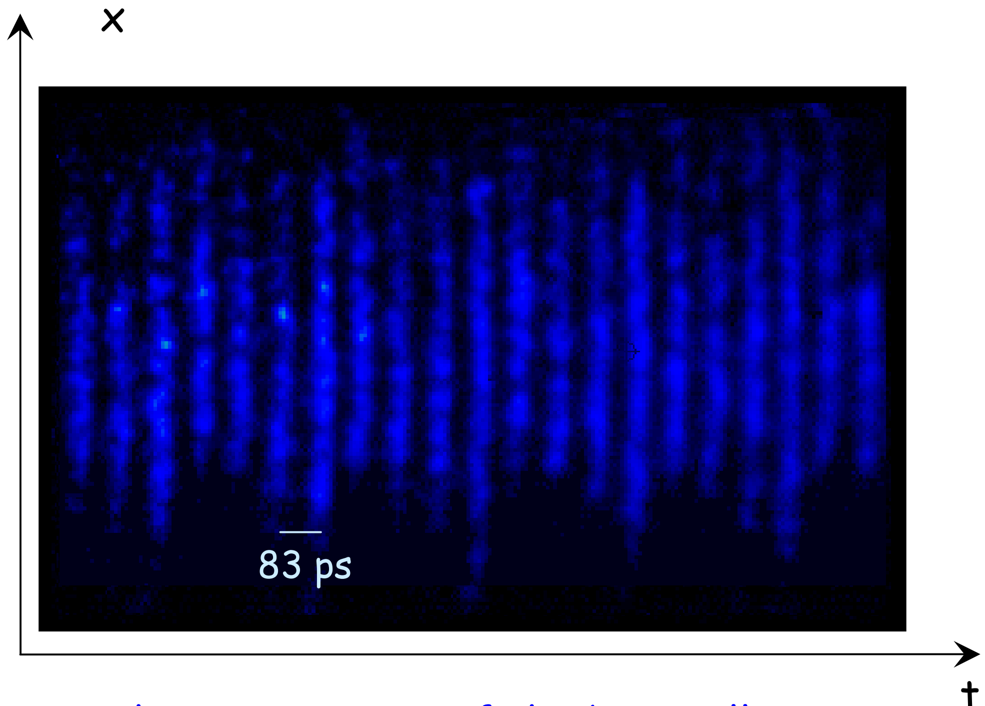
'Streak cameras uses a time dependent deflecting electric field to convert time information in spatial information on a CCD'



- 200fs time resolution at best
- Limitations :

(i) Initial velocity distribution of photoelectrons : *narrow bandwidth optical filter*
(ii) Spatial spread of the slit image: *small slit width*
(iii) Dispersion in the optics

Bunch combination (factor 4)
2003 CTF3 Preliminary Phase results

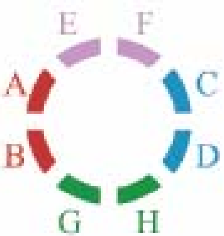


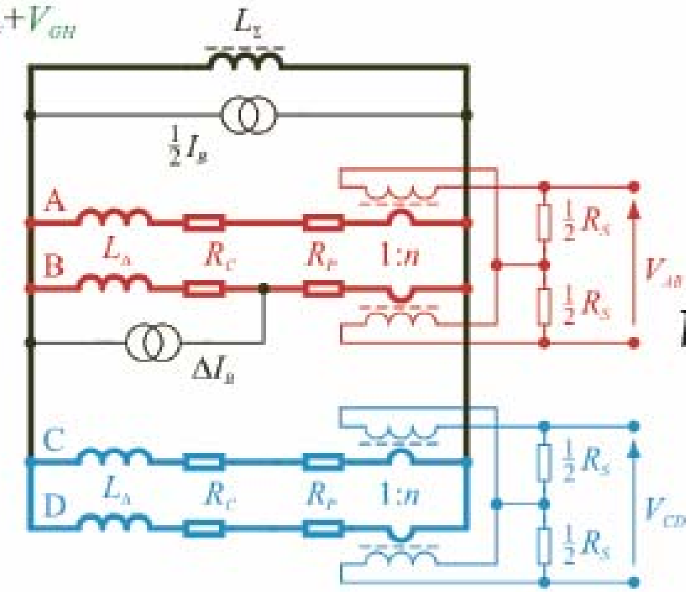
Streak camera image of the beam, illustrating the bunch combination process

Stability of the Drive Beam Current

Inductive Pick-up @ CTF3

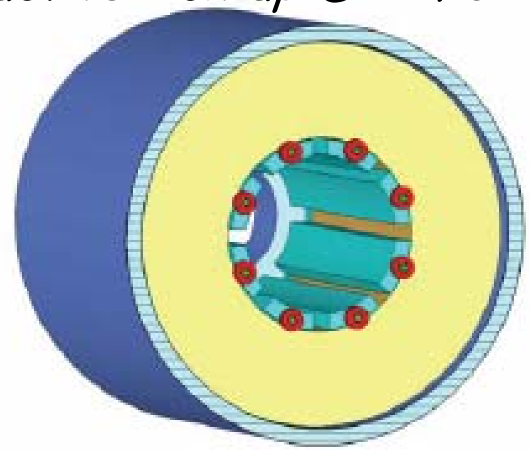
$$V_\Sigma = V_{AB} + V_{CD} + V_{EF} + V_{GH}$$
$$V_{\Delta H} = V_{AB} - V_{CD}$$
$$V_{\Delta V} = V_{EF} - V_{GH}$$





$$R_P = \frac{R_S}{2n^2}$$

$$V_{Out} = \frac{I_{Beam} * R_{Load}}{n}$$



Dipole mode:

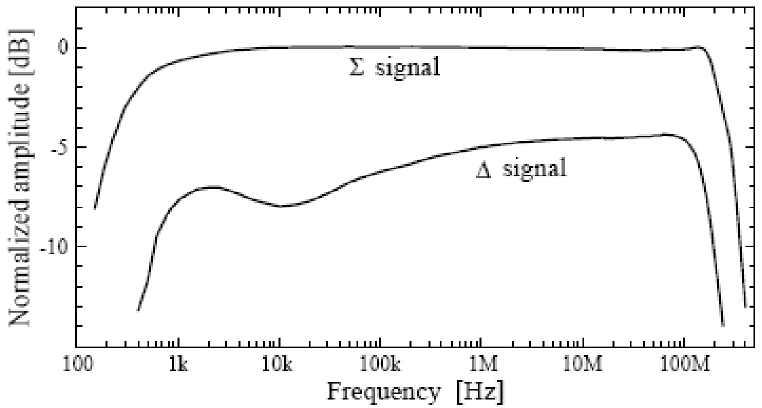
$$f_{Low-Delta} = \frac{R_s}{n^2 \cdot 2 \cdot \pi \cdot L_{Electrodes}}$$

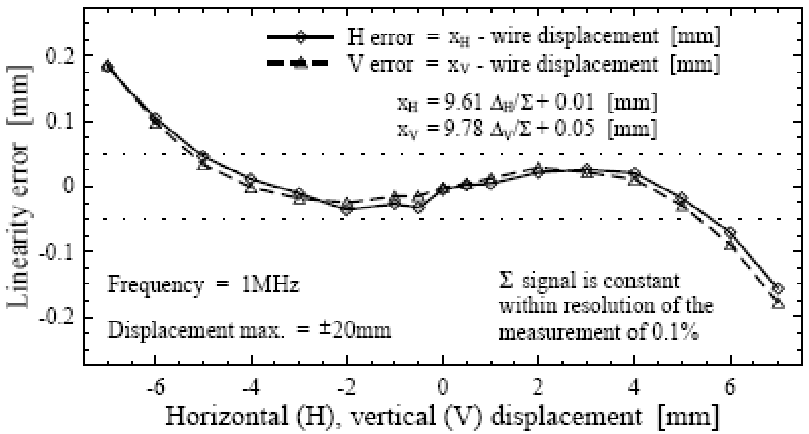
- Measure the beam image current on the beam pipe using 8 electrodes
- Electrodes are combined in pairs so that each transformer sees half of the load
- Frequency low cut-offs are limited by connection parasitic resistances and primary electrode inductance

Design by Marek Gasior : CERN-AB-2003-063

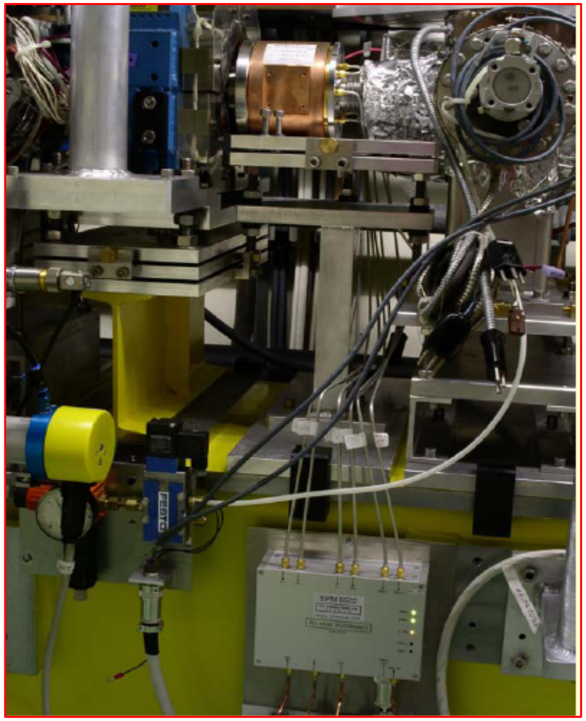
Inductive Pick-up @ CTF3

Transverse sensitivity	$\Delta = \Sigma$ @ ~10mm
Resolution	10um / 50um
Relative precision (±5mm)	1%
Longitudinal coupling impedance	0.1 / 1 ohm
Resolution	6mA / 3mA
Absolute precision [I]	~ 1%
Low frequency cut off	1kHz
High frequency cut off	200MHz
Calibration	Yes
ID / Length	40mm / 168mm
Number of feedthroughs	0
Flange types	DN40CF
Max. bake-out temperature	130 °C

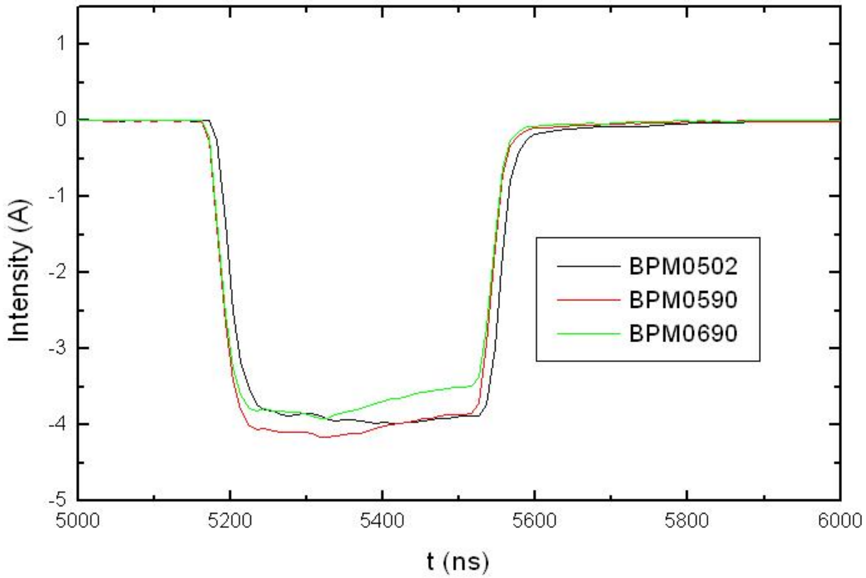




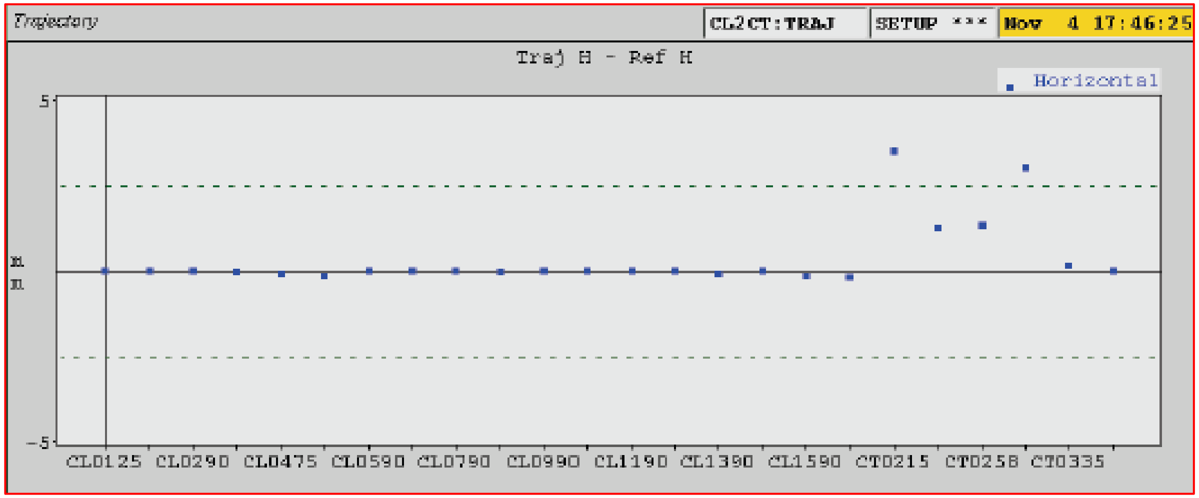
- Resolution already $\Delta I/I = 10^{-3}$
- For CLIC Drive Beam (100μs pulse duration) need to lower the low frequency cut off



Inductive Pick-up @ CTF3



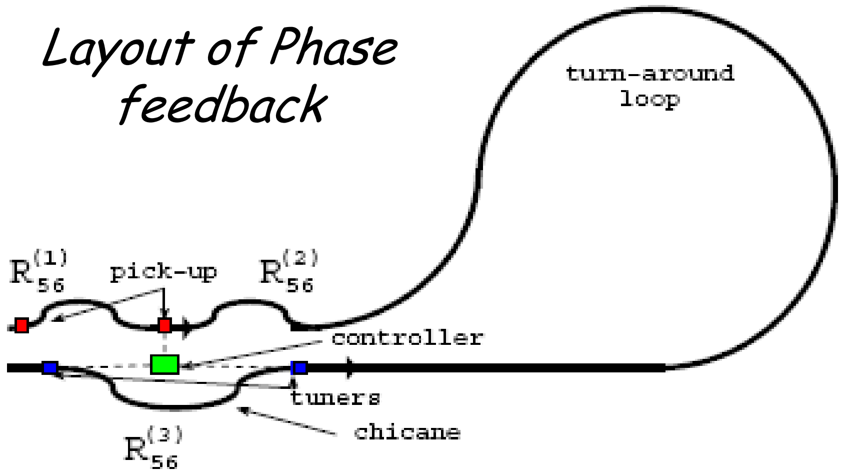
>15 BPMs already installed in CTF3



Drive Beam Longitudinal stability

- Use RF pick-up (30GHz) to measure the Drive Beam phase at 2 locations (≠ longitudinal dispersion)
- Use tuners to correct the phase error

Layout of Phase feedback



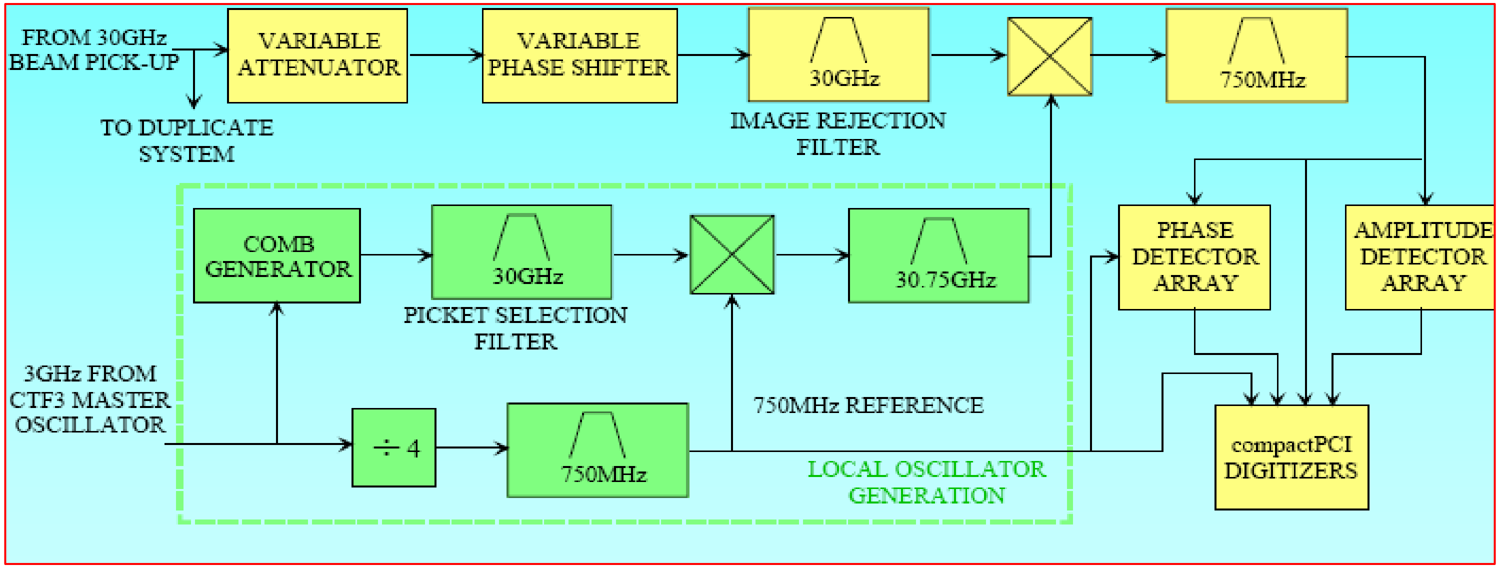
Controller

- Single shot device
- +/- 50MHz bandwidth (react fast)
- 10fs resolution for phase measurement (0.1° @ 30GHz)
- +/- 5degrees range
- 6dB amplitude range

Possible candidates for Tuners
- RF deflectors in a dispersive and anisochronous area
- Accelerating structures and chicane

Femtosecond Phase detection

- Mixing the 30GHz signal from the beam down to 750MHz
- Measure the 750MHz signal Phase and Amplitude



- Goal to find a phase detector@750MHz with noise below 0.03°
- Phase detector can be multipliers or mixers

By J. Sladen and A. Andersson

Something Special in Manipulating High Charge Beam

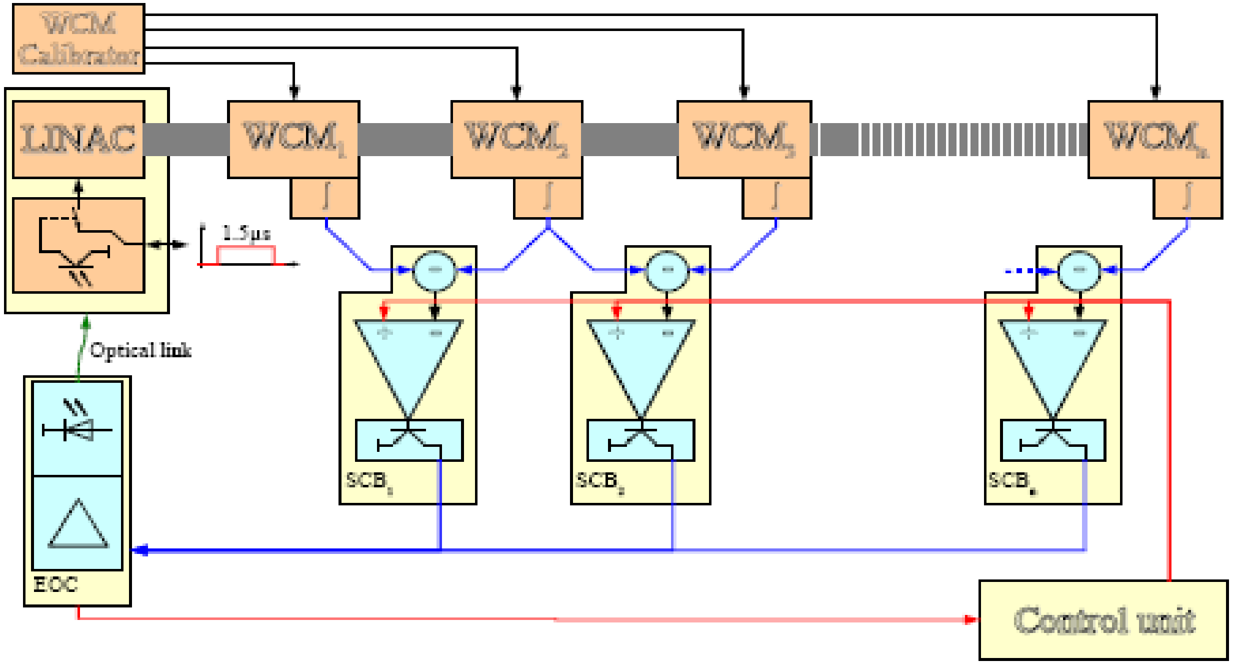
	Generation Complex	Decelerator
Electrons energy	→ 2.5 GeV	2.5 → 0.15 GeV
Beam current /charge	5.7A / 570μC	180A / 31μC
Total Beam Energy	→ 1.425MJ	31.5→ 1.9kJ
Bunch length	**4-6ps**	**600fs**
Minimum beam size	50μm	50μm
Charge density	**2.3 10^{10} nC/cm^2**	**1.2 10^9 nC/cm^2**

The thermal limit is ~ 1 10^6 nC/cm^2

- Control of beam loss to prevent beam induced damage ($\Delta I/I = 10^{-4}$)
  For Drive Beam Generation complex (Linac and Rings)
  need to protect almost everything (even the beam dump)
- High Charge would mean strong signals ?
- Use of non-intercepting / non degradable beam diagnostic
  How can we make profile monitors ?

Machine protection system @ CTF3

- Compare signals from consecutive Wall Current Monitors
- If losses is detected, the electron gun is switched off
- Time response dominated by cable length (>311ns)



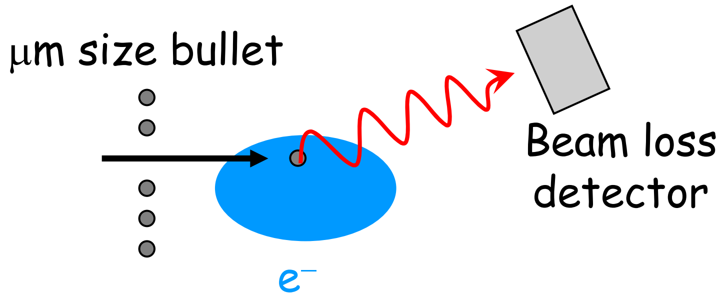
D. Belohrad, Dipac Conference, Lyon, p.255, (2005)
P. Odier, CERN-AB-2003-069

For CLIC DB the system will have to rely on Beam Loss Monitors

How can we make profile monitor for the Drive Beam Linac

• No non-intercepting transverse profile monitor available for low energy electron beams in a linac

- Degradable profile monitor
  - 'Kalachnikov' : bullet scanner

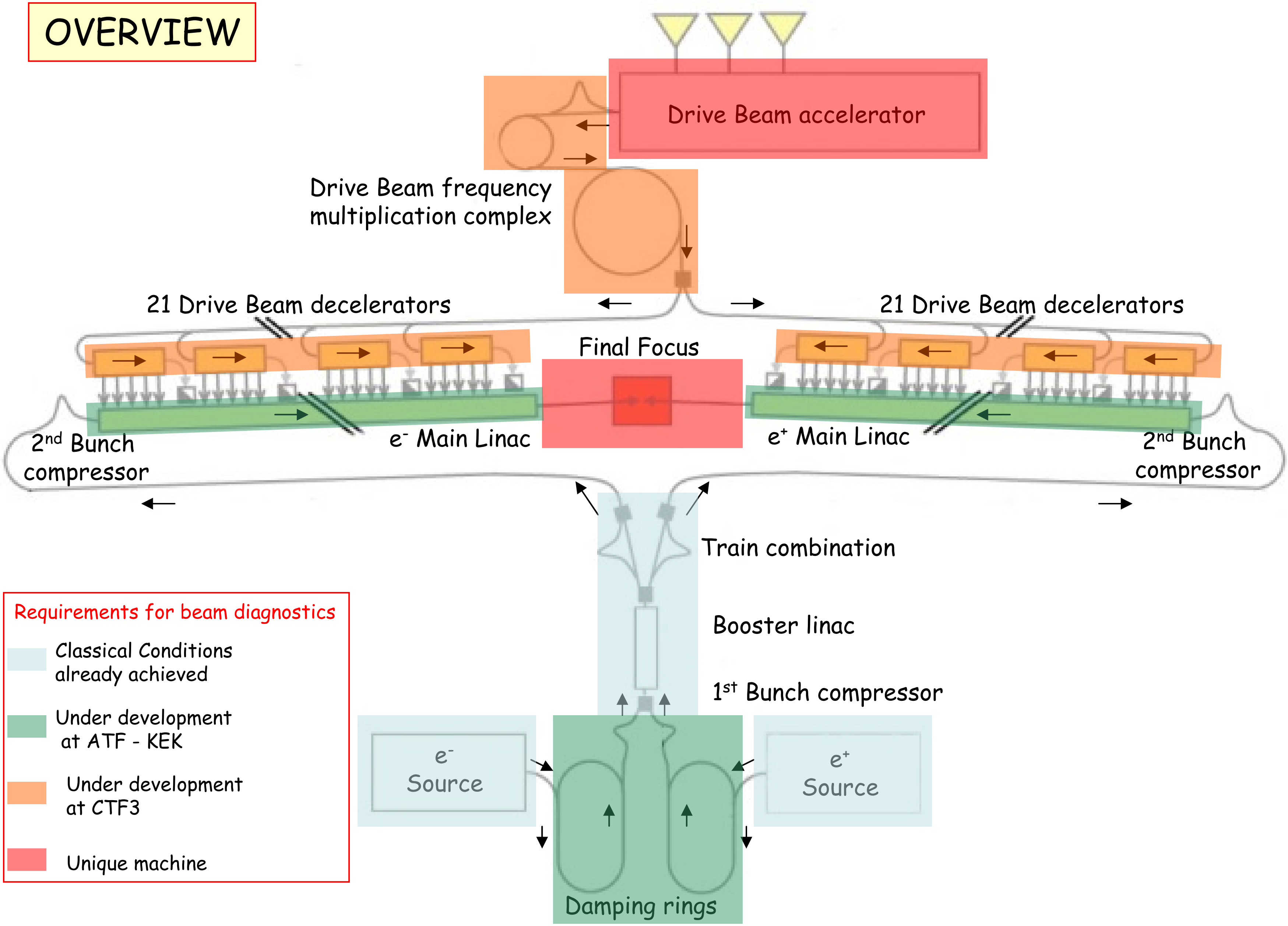


- Neutral beam scanner : Gas jet

C. Dimopoulou, PS/BD note 99-12

- Any new idea highly welcome…

OVERVIEW


Drive Beam accelerator
Drive Beam frequency multiplication complex
21 Drive Beam decelerators
21 Drive Beam decelerators
Final Focus
2nd Bunch compressor
e- Main Linac
e+ Main Linac
2nd Bunch compressor
Train combination
Booster linac
1st Bunch compressor
e- Source
e+ Source
Damping rings
Requirements for beam diagnostics
Classical Conditions already achieved
Under development at ATF - KEK
Under development at CTF3
Unique machine