Status of linear collider designs:

Main linacs

Design overview, principal open issues

G. Dugan
March 11, 2002

Linear colliders: main linacs

- The main linac is the heart of the linear collider
- TESLA, NLC/JLC, and CLIC have chosen very different technical solutions for the main linac rf.
- The differences in rf technology profoundly influence the beam dynamics issues related to the dominant challenge for achieving luminosity, which is emittance preservation.

Linear colliders: main linacs
500 GeV CM

Parameter	**TESLA**	**NLC**	**CLIC**
Initial energy (GeV)	5	8	9
Rf frequency (GHz)	1.3	11.4	30
Unloaded/loaded gradient (MV/m)	23.4/23.4	70/55	172/150
Active two-linac length (km)	21.6	10.1	3.7
Number of rf cavities/length (m)	20592/1.0	11232/0.9	7300/0.5
Total number of klystrons	572	1872	332
Klystron peak power (MW)	9.7	75	50
Rf pulse length (μs)	1370	0.4	0.13
v_g/c		5.1-1.1	10.4-5.2
Unloaded Q	10^{10}	~8500	~3600
Total AC power for linac rf (MW)	95	120	100
Wall plug->rf efficiency (%)	37	37	40
Rf->beam efficiency (%)	62	27	21

Main linacs-TESLA-rf technology

- TESLA solution: low frequency (1.3 GHz) superconducting rf
- Pros:
  - Low frequency, superconducting rf=>large iris radius (35 mm)=>low transverse wakefields (22 $V/pC/m^2$)=>reduced alignment tolerances
  - High rf->beam power conversion efficiency (62%)
  - Rf power requirements modest (600 10 MW peak power klystrons)
- Cons:
  - Limited accelerating gradient (24 MV/m)=>longer linac for a given energy (11 km for 250 GeV)
  - Extensive 2K cryogenic system required (scale of LHC)
- CM Energy upgrade goal: 800 GeV (35 MV/m 9-cell cavities+superstructures)

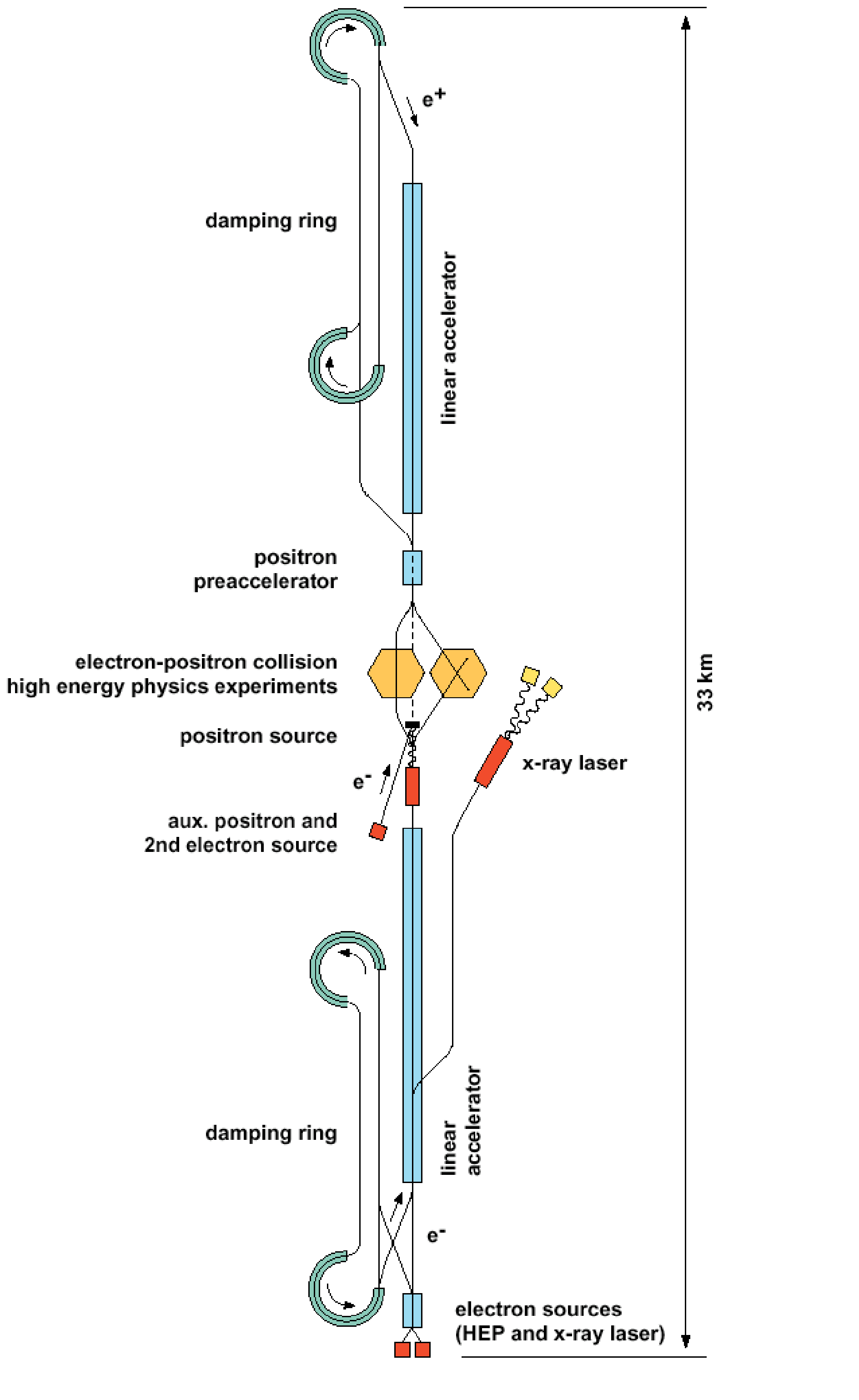


Figure 1.2.1: *Sketch of the overall layout of TESLA.*

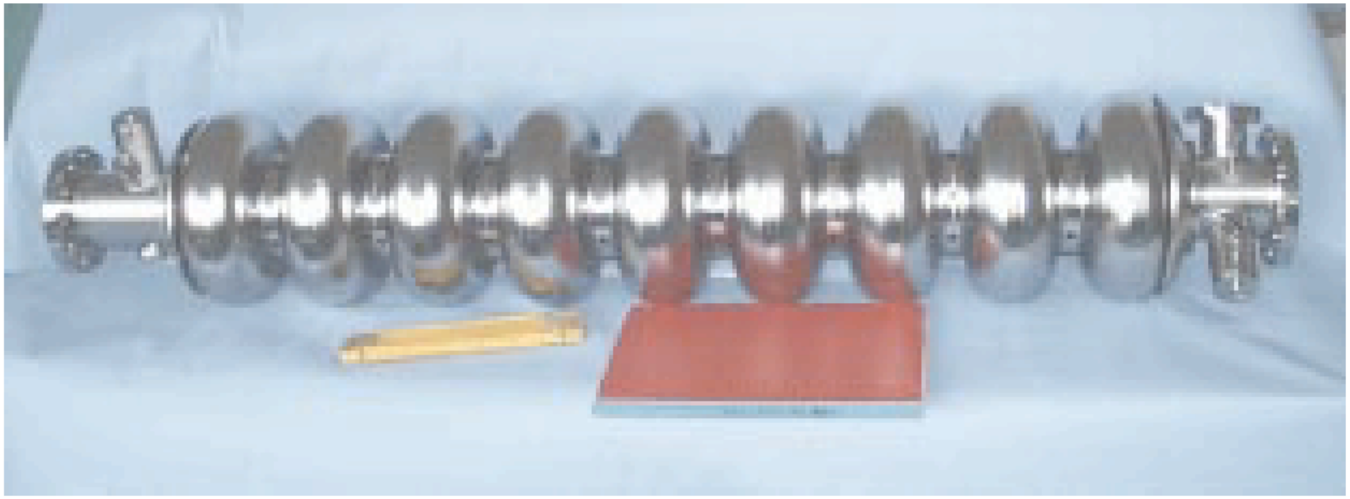


Figure 1: The 9-cell niobium cavity for TESLA.

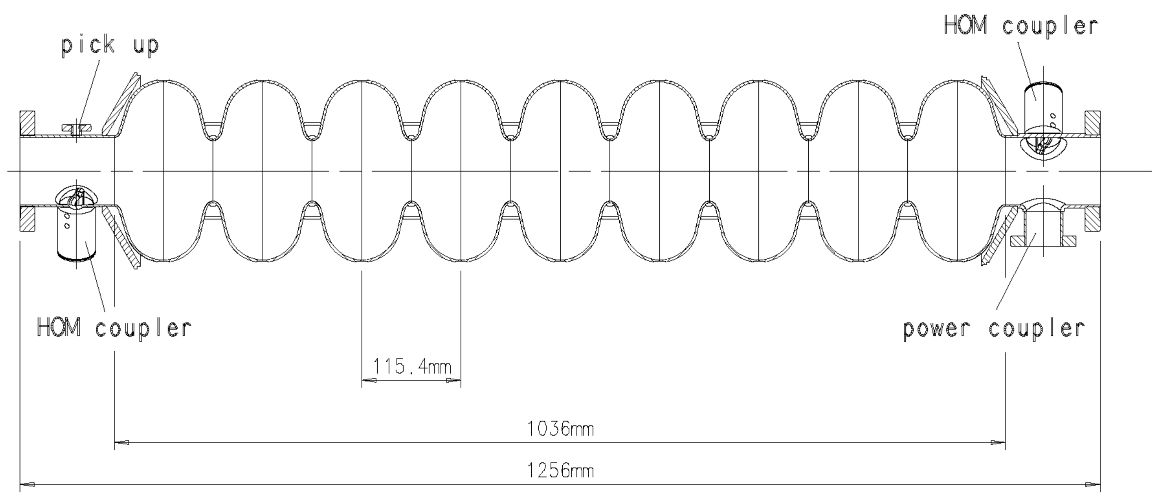


Figure 2.1.3: *Side view of the 9-cell cavity with the main power coupler port and two higher-order mode couplers.*

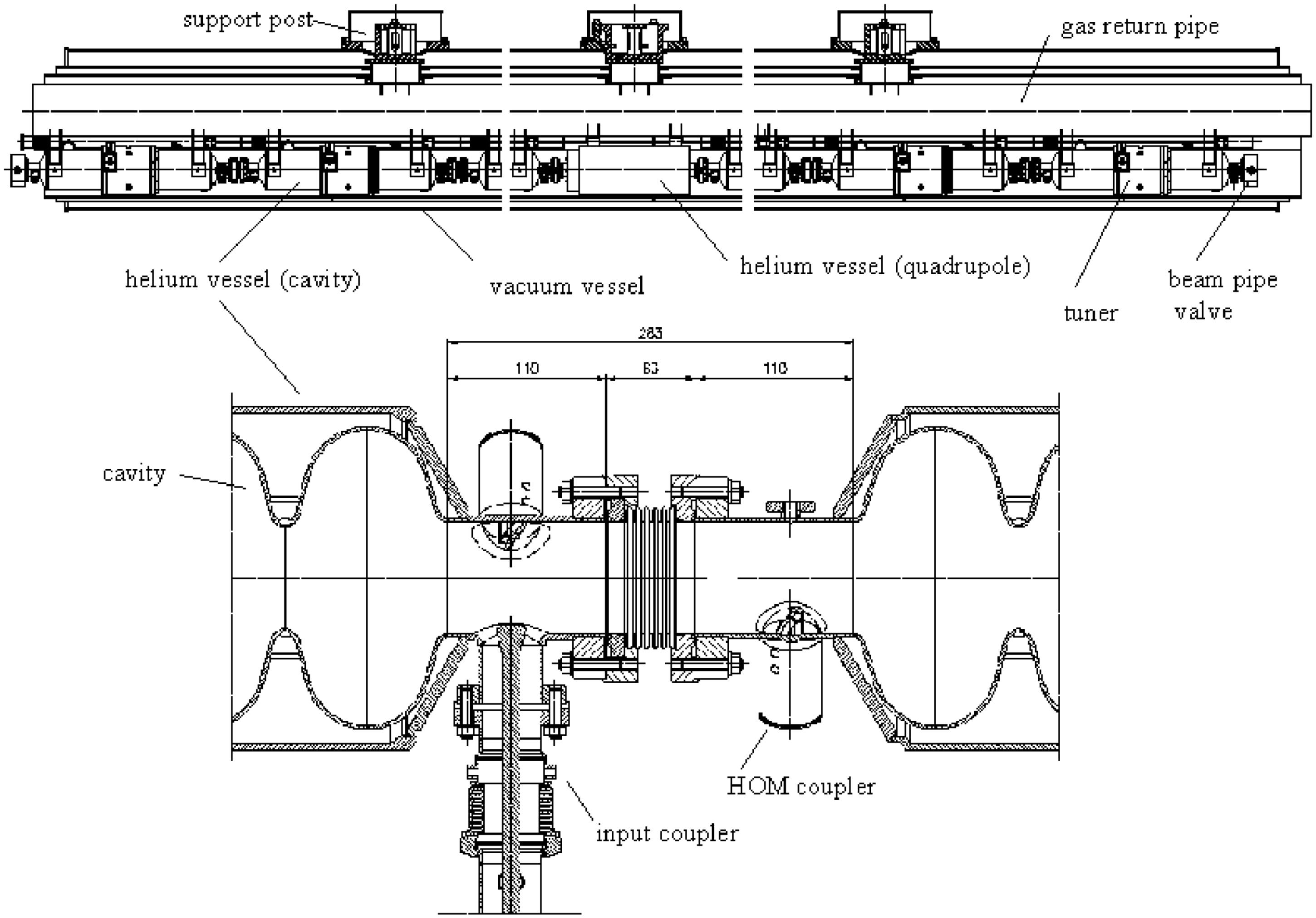


Figure 3.2.10: *Longitudinal view of a cryomodule.*

Twelve 9-cell cavitites per cryomodule

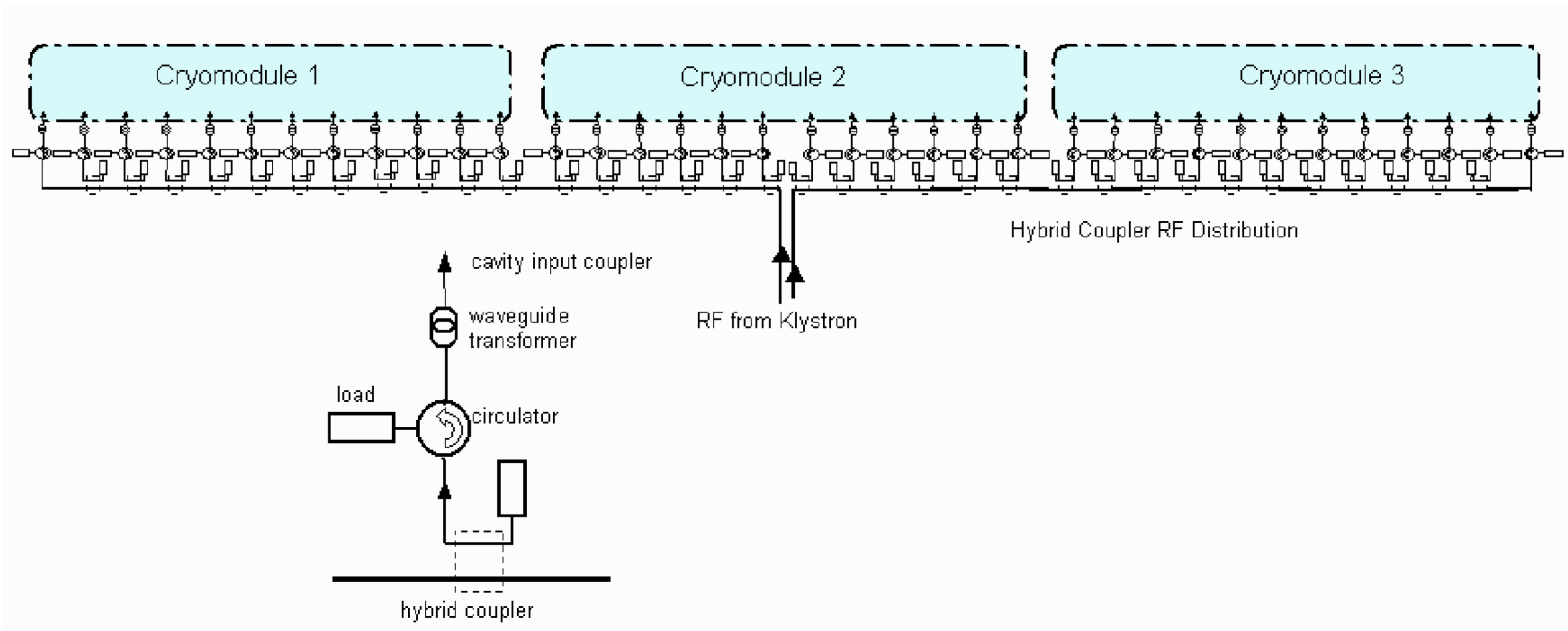
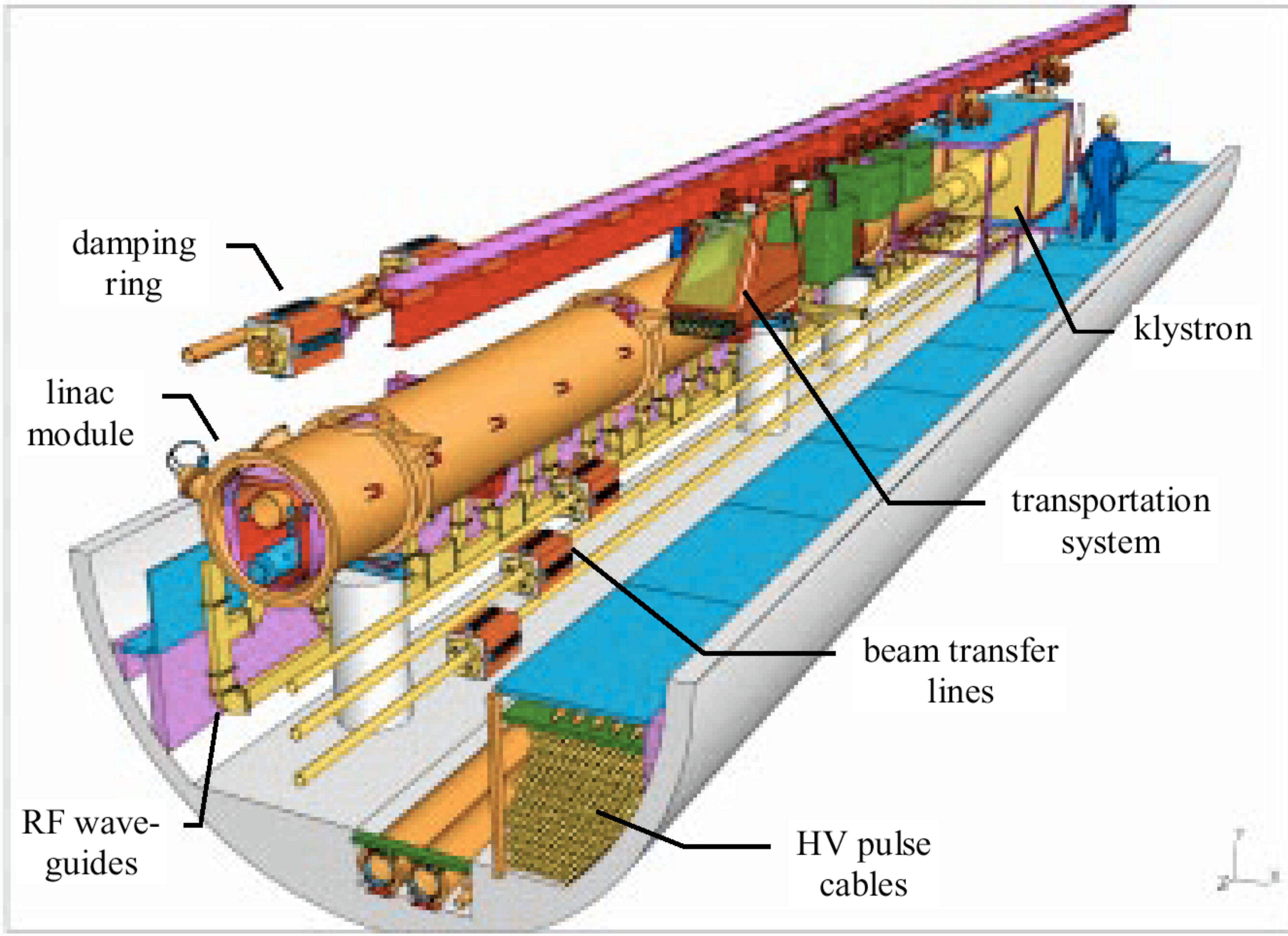


Figure 3.3.5: *RF waveguide distribution of one RF station.*


damping ring
linac module
RF wave-guides
klystron
transportation system
beam transfer lines
HV pulse cables

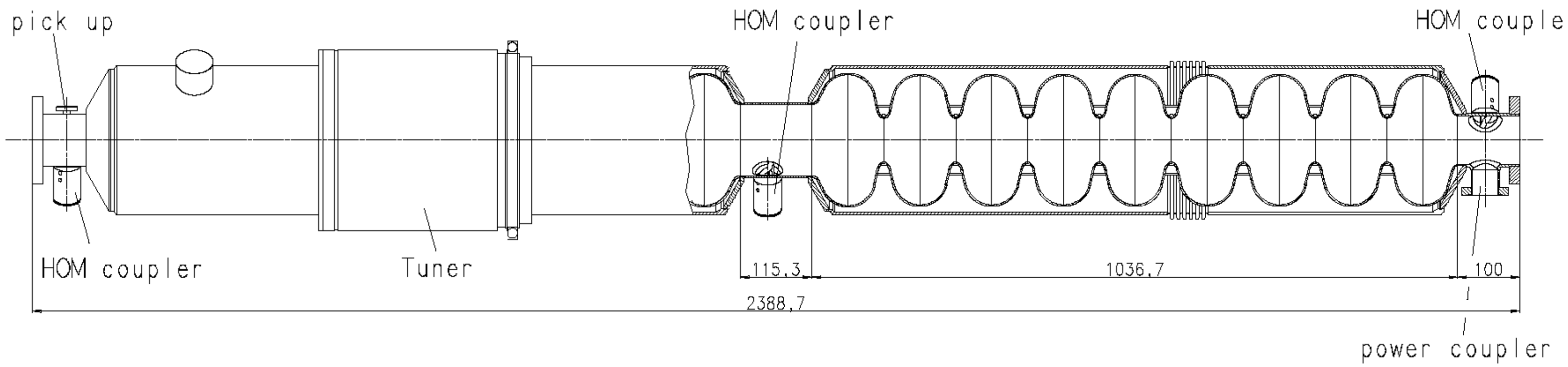


Figure 2.1.23: *Superstructure II consisting of two 9-cell resonators joined by a 114 mm diameter beam pipe.*

Superstructure concept: gains 6% in filling factor
Number of power couplers reduced by 2

Main linacs-NLC/JLC-rf technology

- NLC/JLC solution: high frequency (11.4 GHz) normal conducting rf
- Pros:
  - High accelerating gradient (55 MV/m)=>shorter linac for a given energy (6.8 km for 250 GeV)
- Cons:
  - High frequency, normal conducting rf=>small iris radius (5 mm)=>high transverse wakefields (11, 500 V/pC/m^2)=>tight alignment tolerances
  - Low rf->beam power conversion efficiency (27%)
  - Significant rf power requirements: 1900 75 MW klystrons (500 GeV)+pulse compression system
- CM energy upgrade goal: 1 TeV (2x12 km linacs)

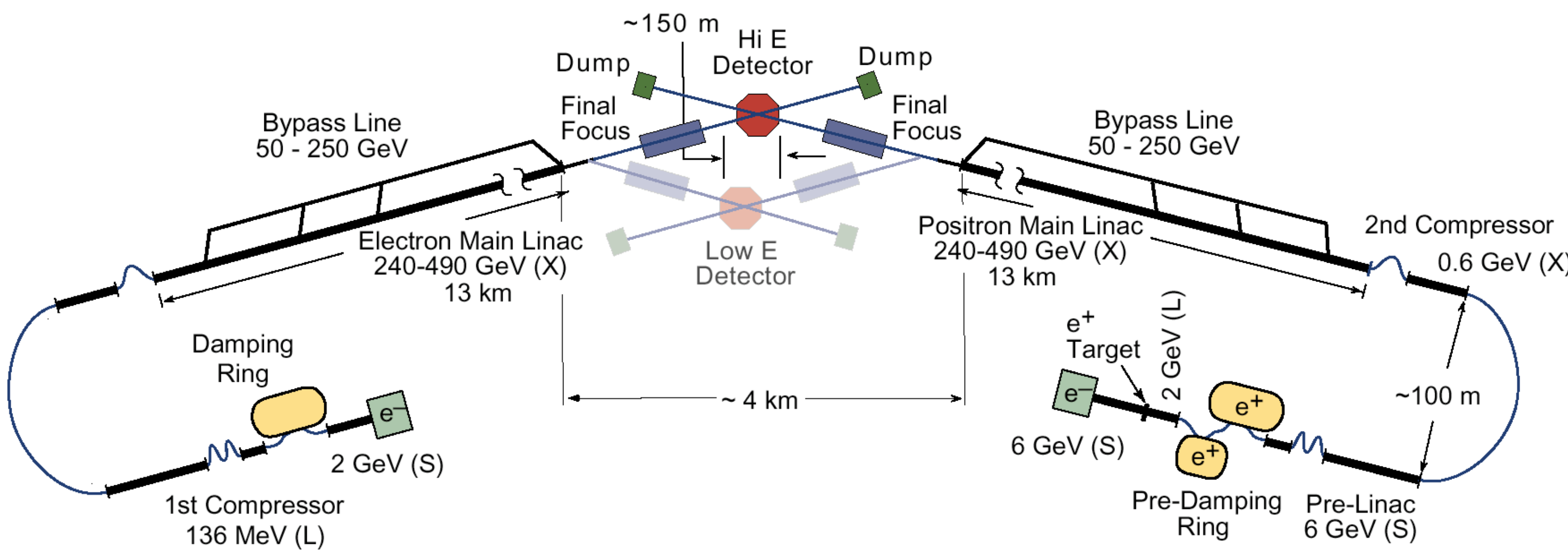


Figure 1.1: Schematic of the JLC/NLC

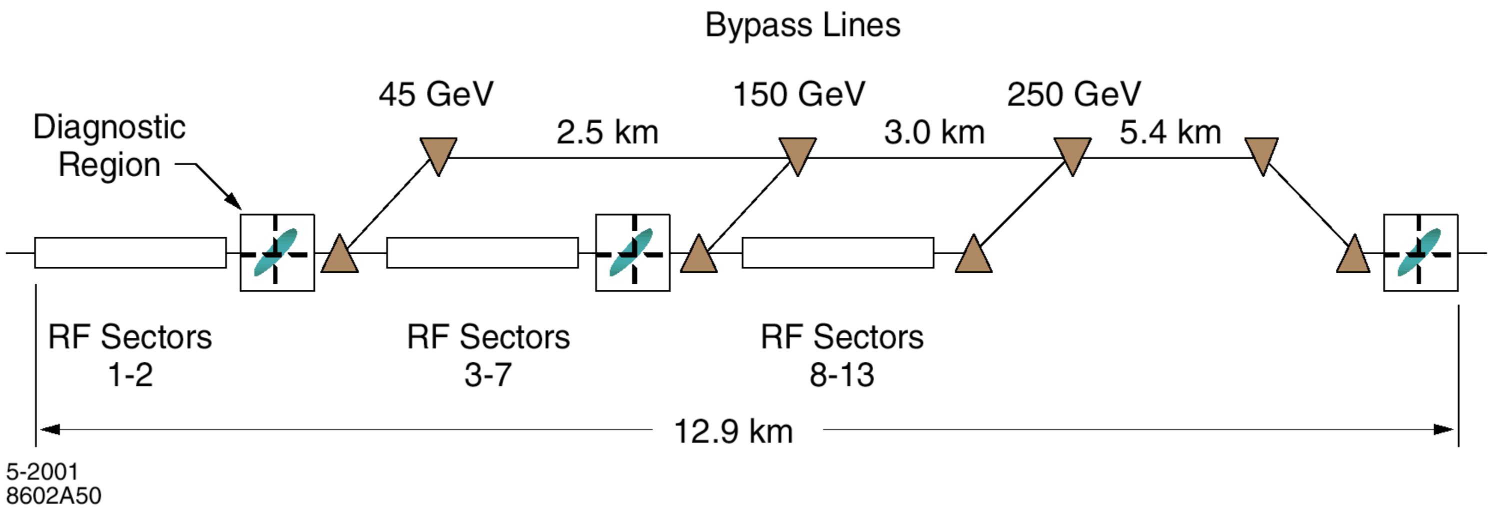
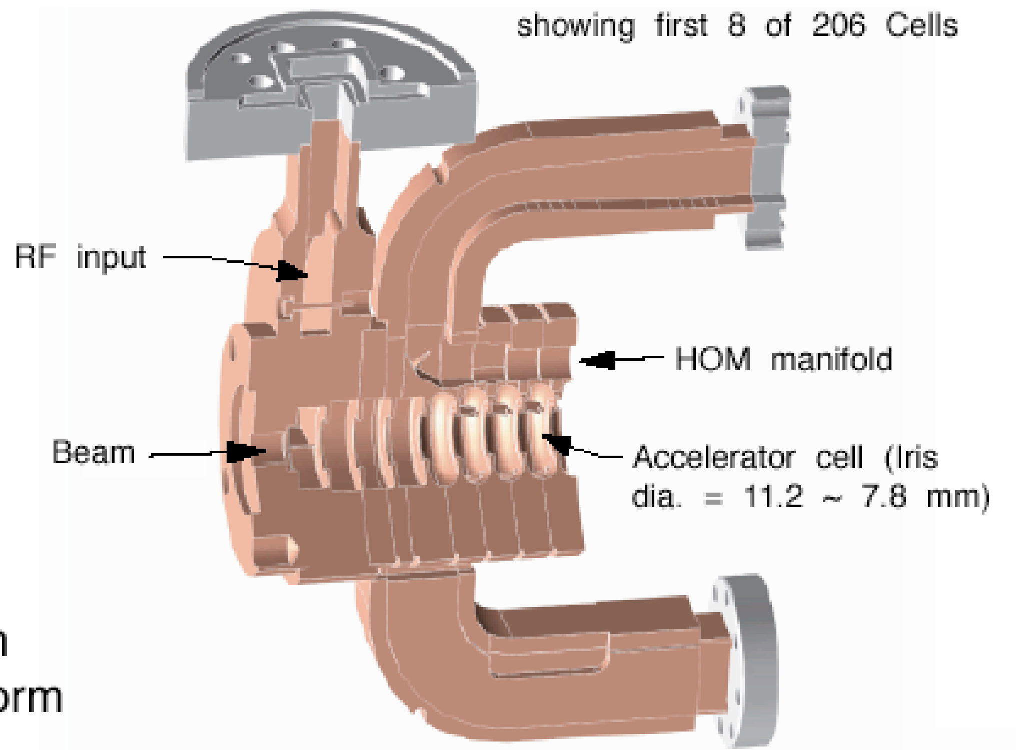


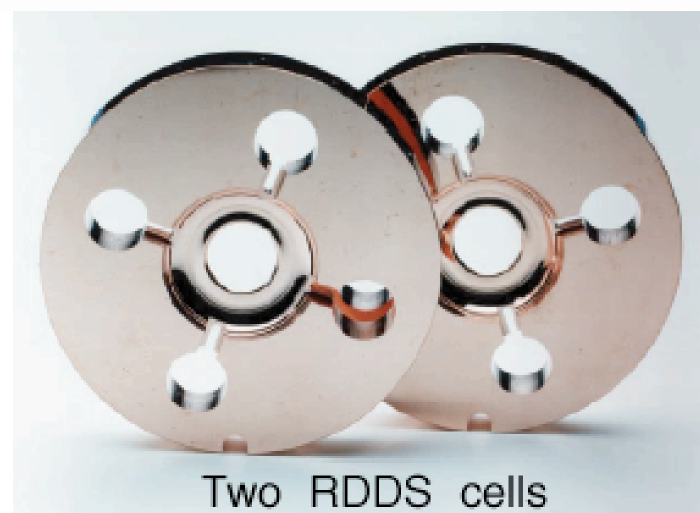
Figure 4.3: Linac beam-line layout.

NLC/JLC Rounded Damped-Detuned Structure (RDDS)

RDDS Cutaway View
showing first 8 of 206 Cells



- Made with Class 1 OFE copper.
- Cells are precision-machined (few μm tolerances) and diffusion-bonded to form structures.
- 1.8 m length chosen so fill time ~ attenuation time ~ 100 ns.
- Operated at 45 deg C with water cooling. RF losses are about 3 kW/m.
- RF ramped during fill to compensate beam loading (21%). In steady state, 50% of the 170 MW input power goes into the beam.



Two RDDS cells

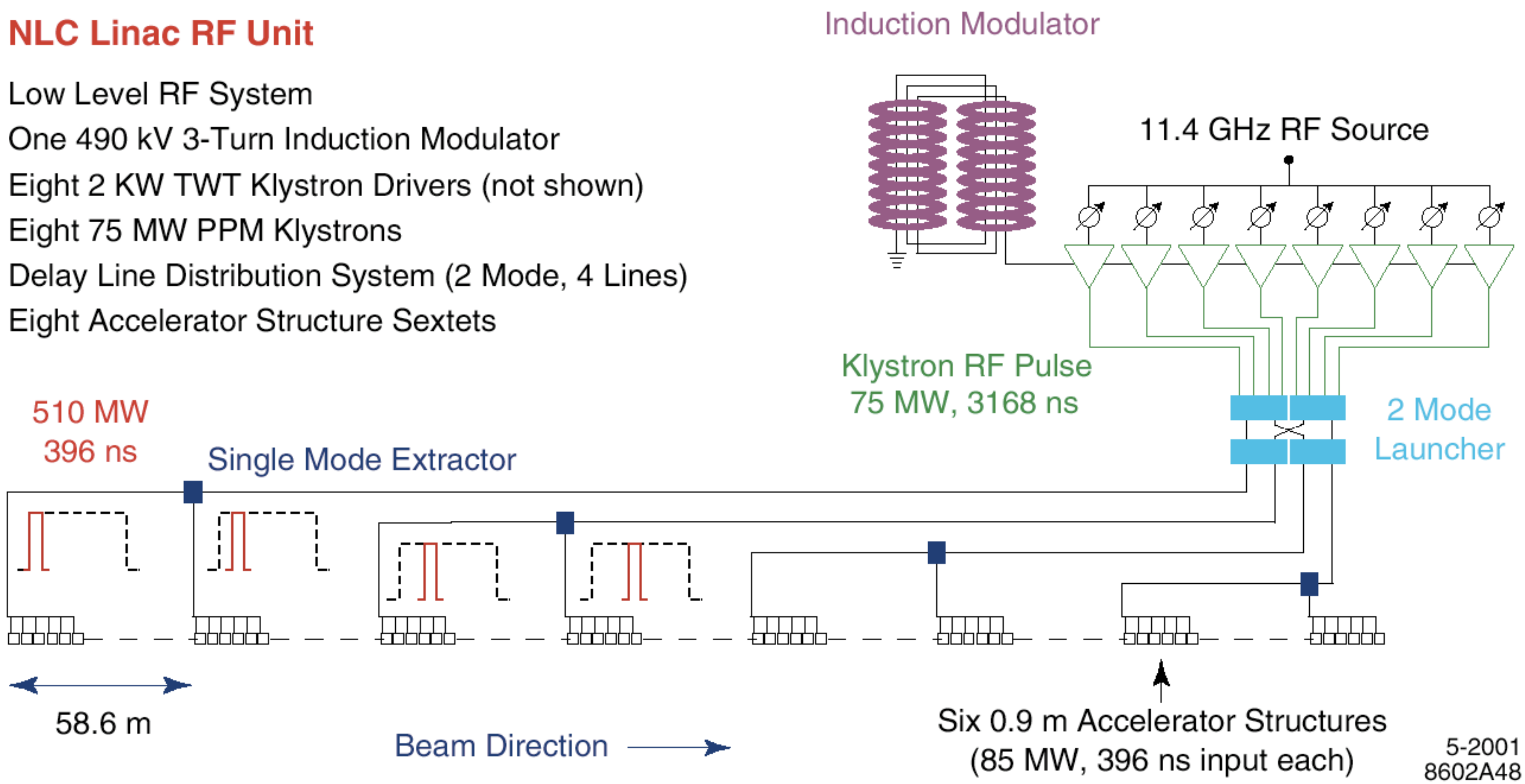


Figure 4.1: Schematic of a linac rf unit (one of 117 per linac).

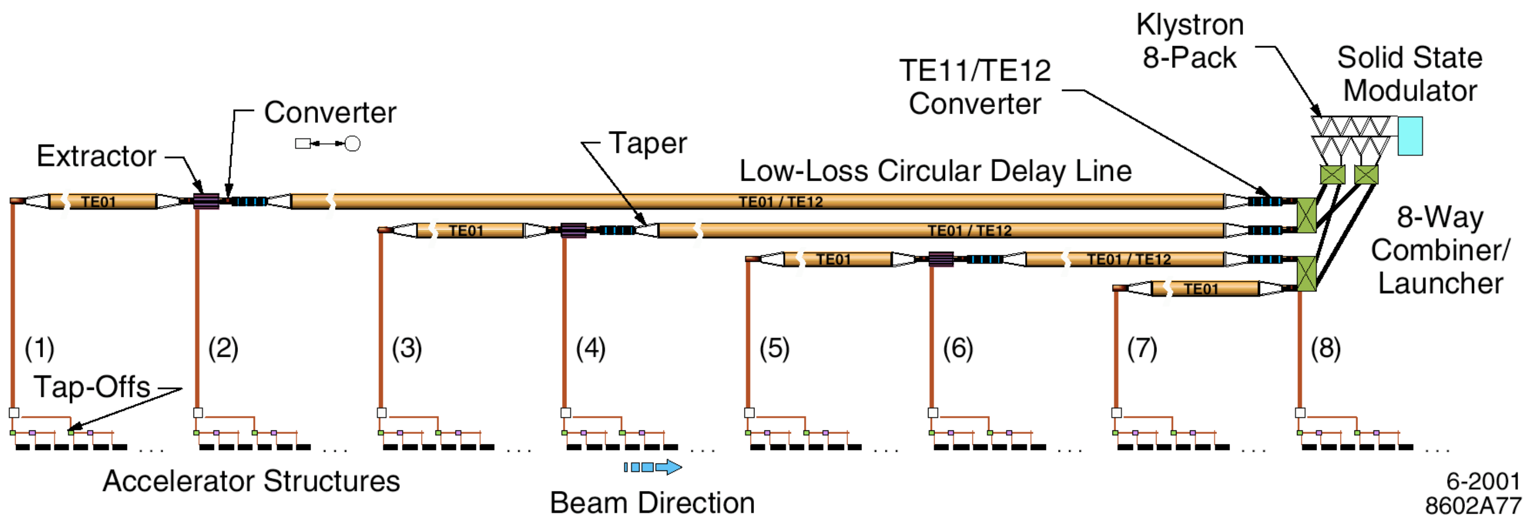


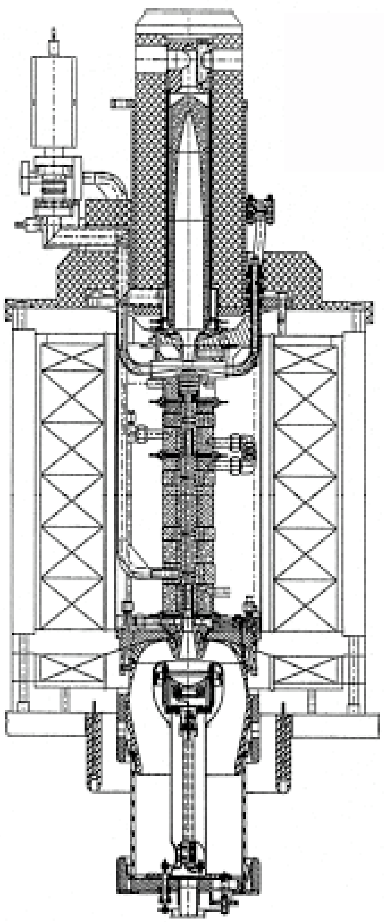
Figure 4.16: Schematic of the four-arm, dual-moded DLDS with eight accelerator feeds. The feeds are numbered by the order in which power is received.

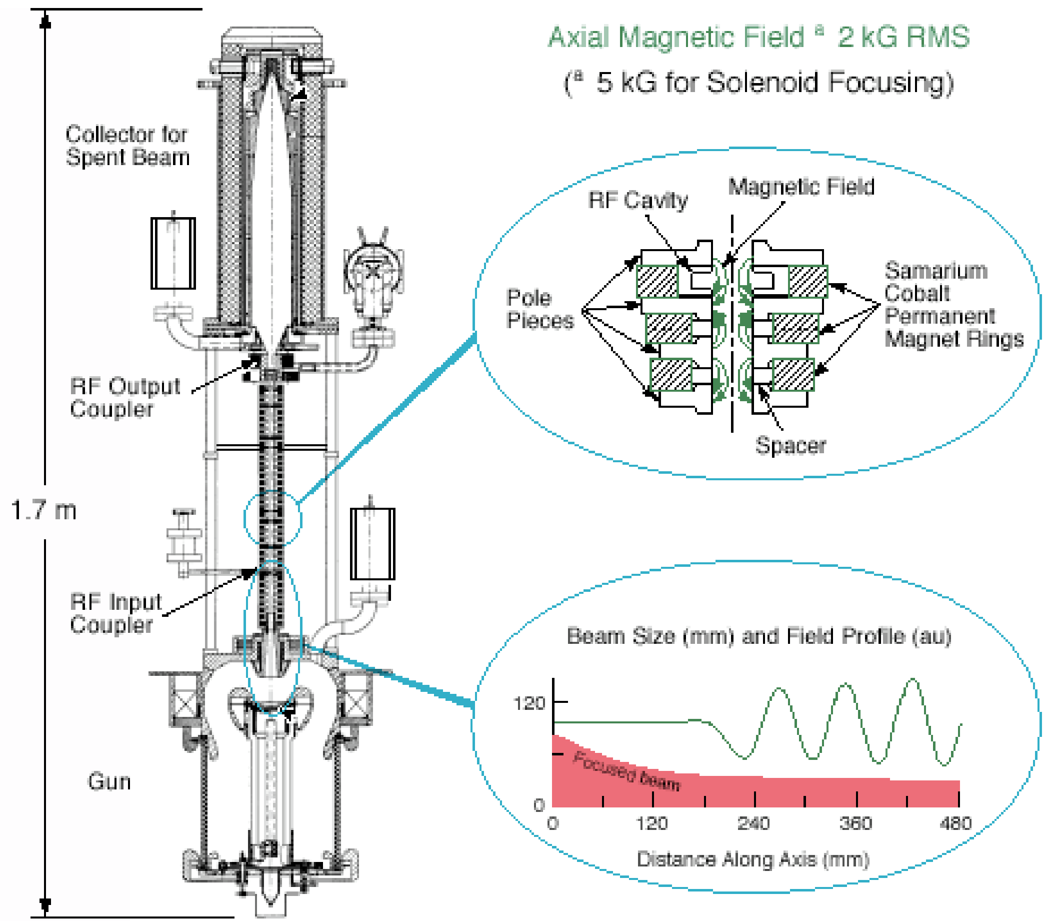
NLC pulse distribution system

X-Band (11.4 GHz) KLYSTRONS

Solenoid Focused Tubes:
SLAC has ten, 50 MW tubes for testing,
Solenoid power = 25 kW.

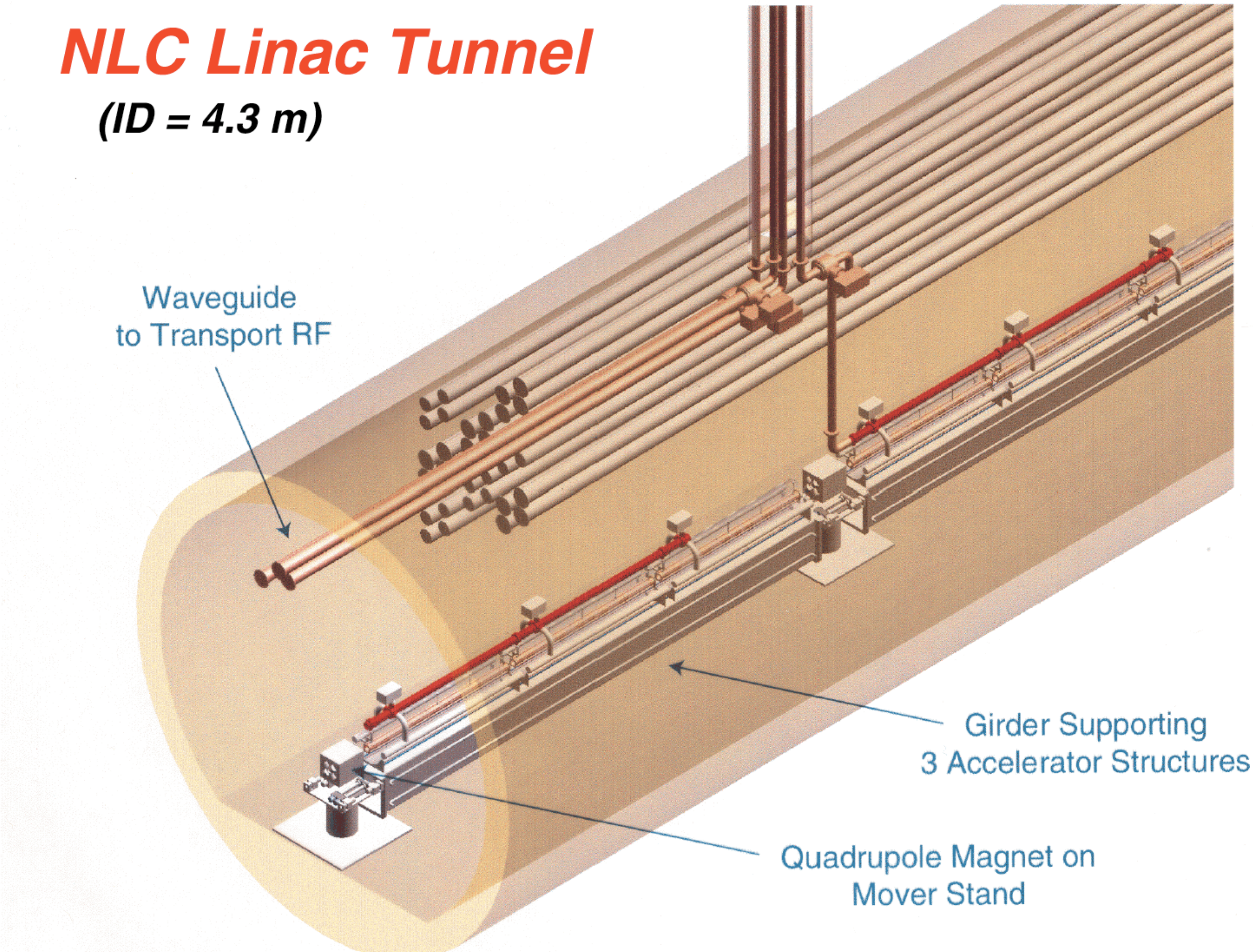
Developing Periodic Permanent Magnet (PPM)
Focused tubes. Eliminate the
power-consuming solenoid.





NLC Linac Tunnel

(ID = 4.3 m)



Main linacs:CLIC-rf technology

- CLIC solution: even higher frequency (30 GHz) normal conducting rf
- Pros:
  - Very high accelerating gradient (150 MV/m)=>shorter linac for a given energy (2 km for 250 GeV)
- Cons:
  - Very high frequency, normal conducting rf=>small iris radius (2 mm)=>very high transverse wakefields (81,000 V/pC/m^2)=>very tight alignment tolerances
  - Low rf->beam power conversion efficiency (21%)
  - There are no existing power sources of the required size at 30 GHz. rf power must be delivered via a novel "two-beam" scheme. An elaborate drive beam complex is required, in which rf power is delivered to the high energy beam by deceleration of a high-current (150 A), low energy (2 GeV) beam.
- CM energy goal: 3 TeV (2x14 km linacs)

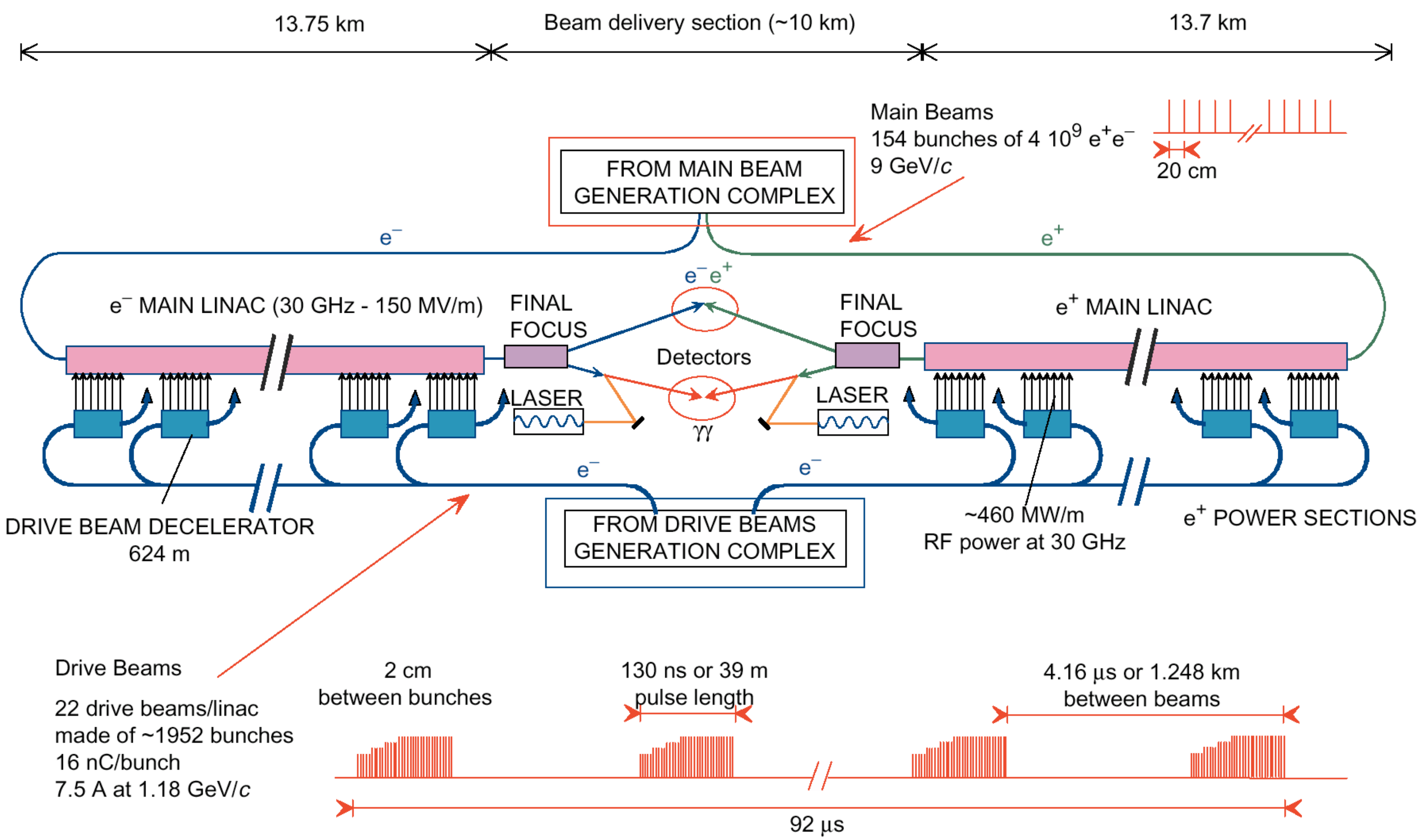
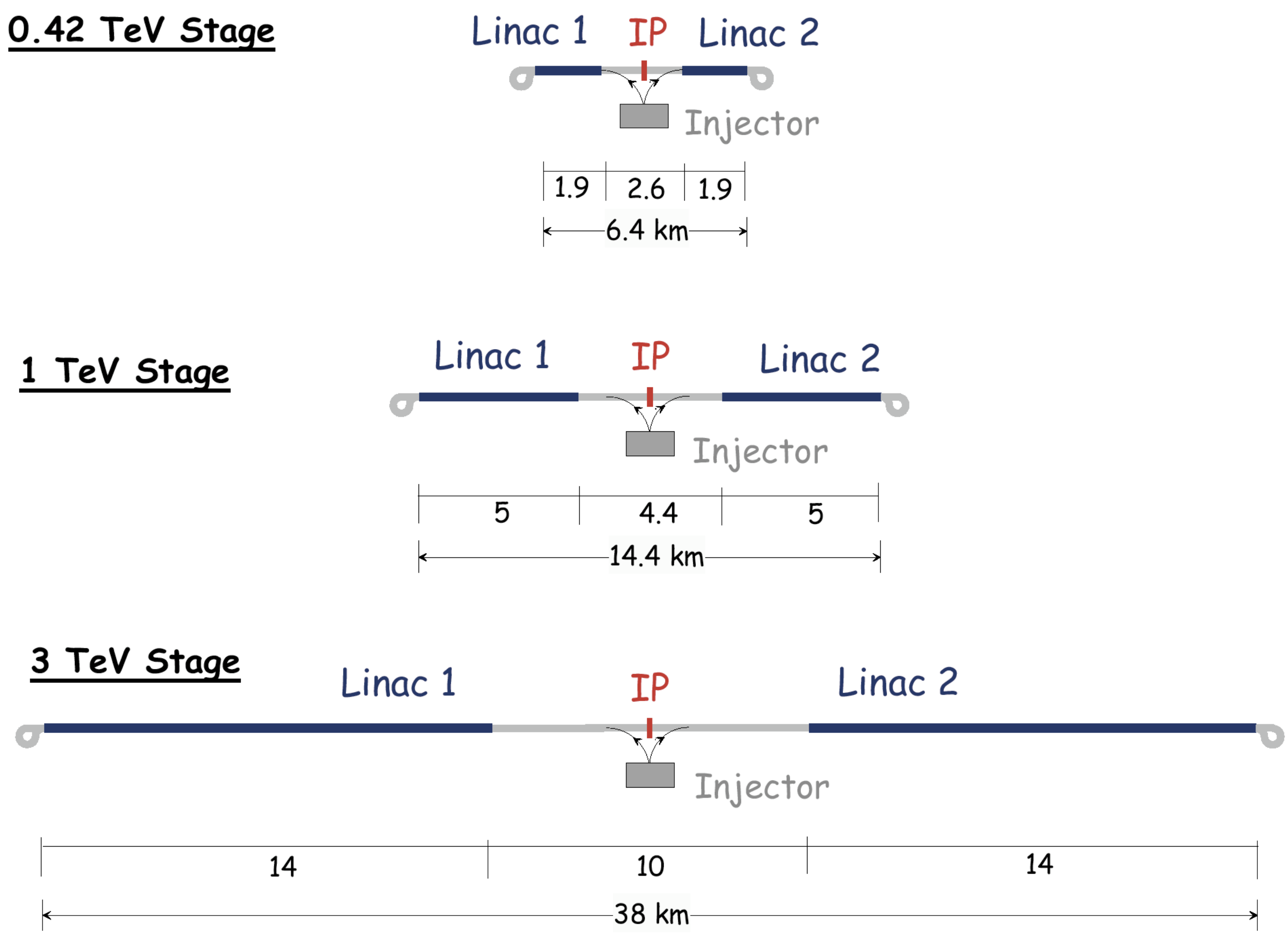


Fig. 1.1: *Overall layout of CLIC for a centre-of-mass energy of 3 TeV.*


0.42 TeV Stage
Linac 1
IP
Linac 2
Injector
1.9
2.6
1.9
6.4 km
1 TeV Stage
Linac 1
IP
Linac 2
Injector
5
4.4
5
14.4 km
3 TeV Stage
Linac 1
IP
Linac 2
Injector
14
10
14
38 km

CLIC scale

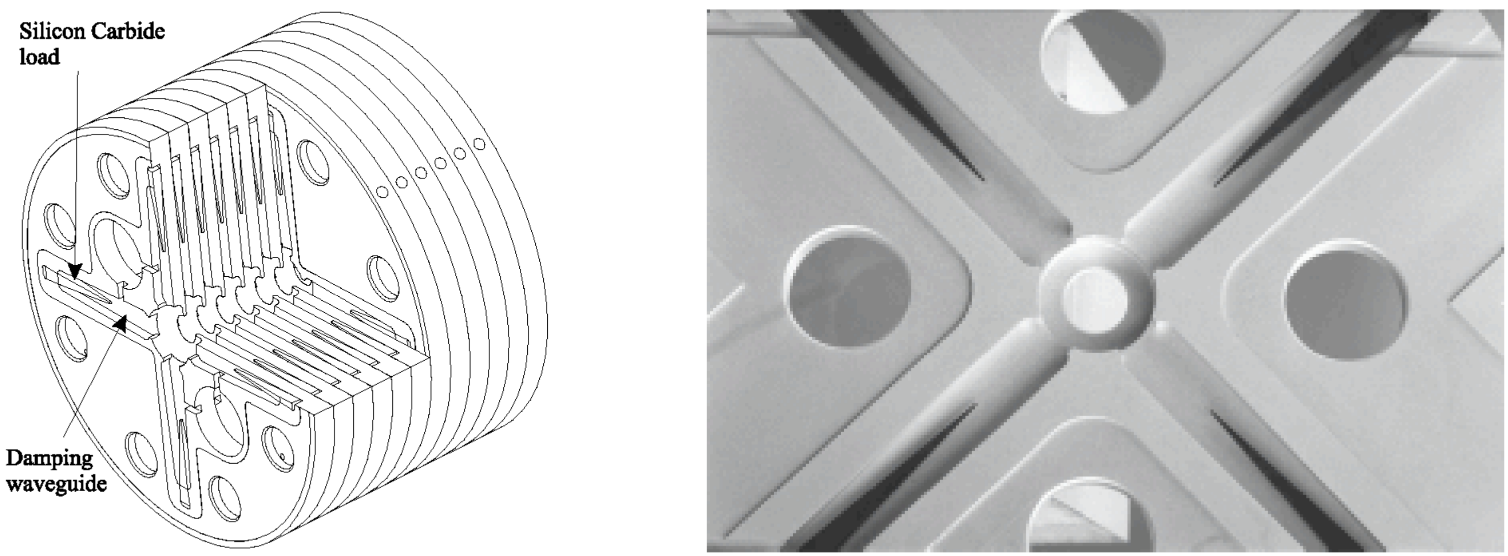


Figure 6: Left : Cross-sectional view of the TDS geometry. Right : Photograph of a TDS cell with damping waveguides and SiC loads.

CLIC main linac “Tapered damped structures”

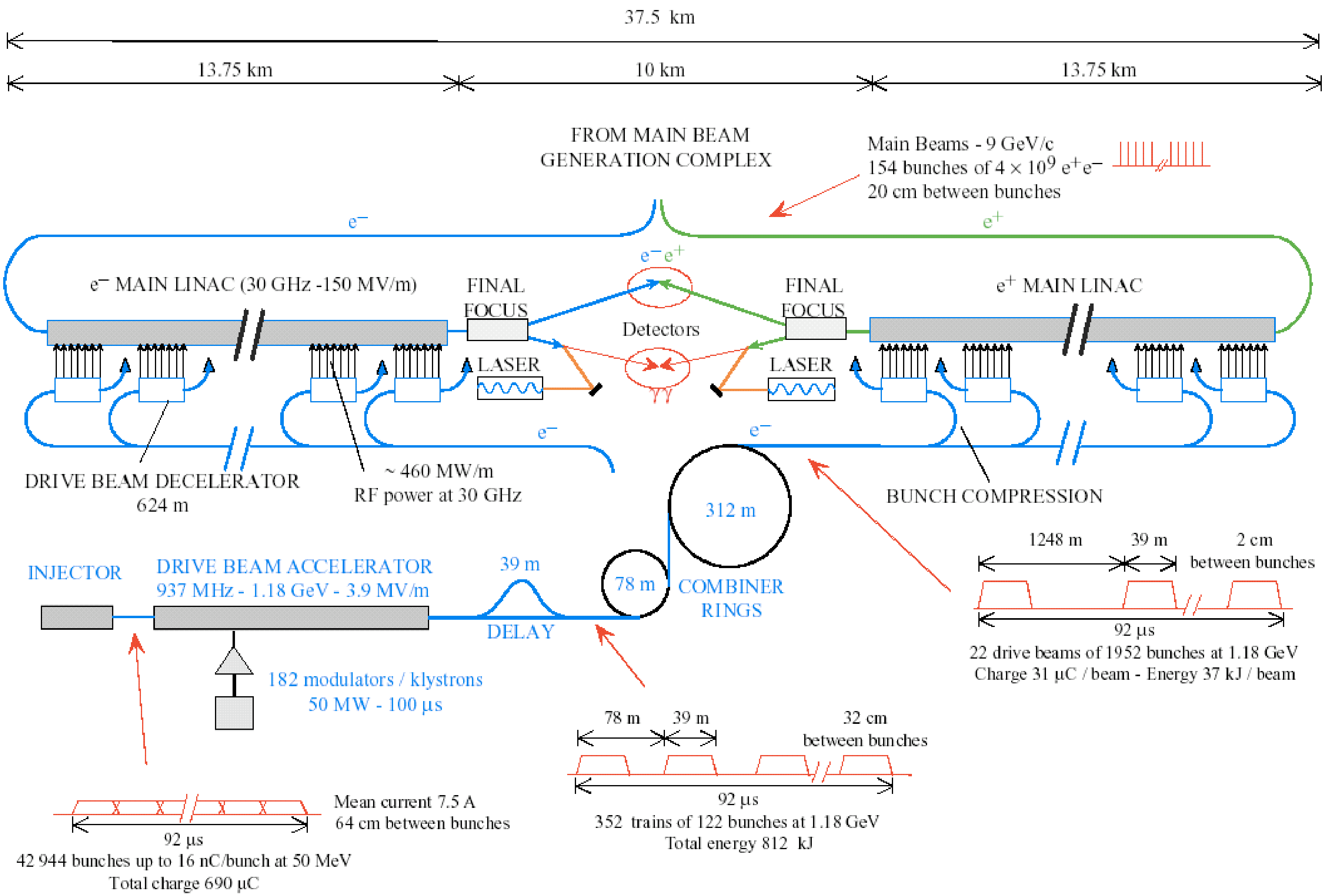
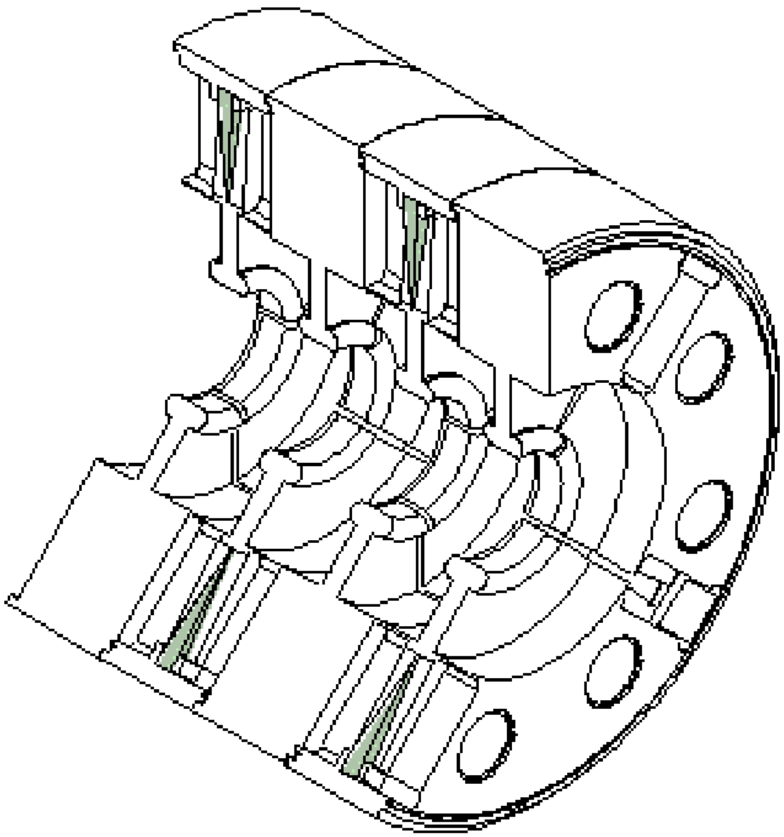


Fig. A.1: Overall layout of the CLIC complex at 3 TeV centre of mass.

CLIC Power source



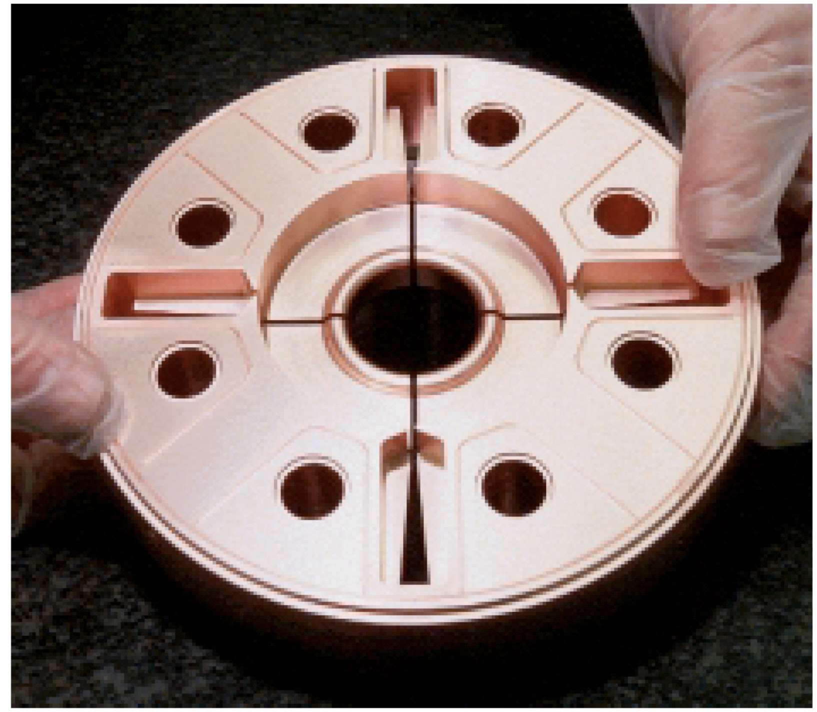
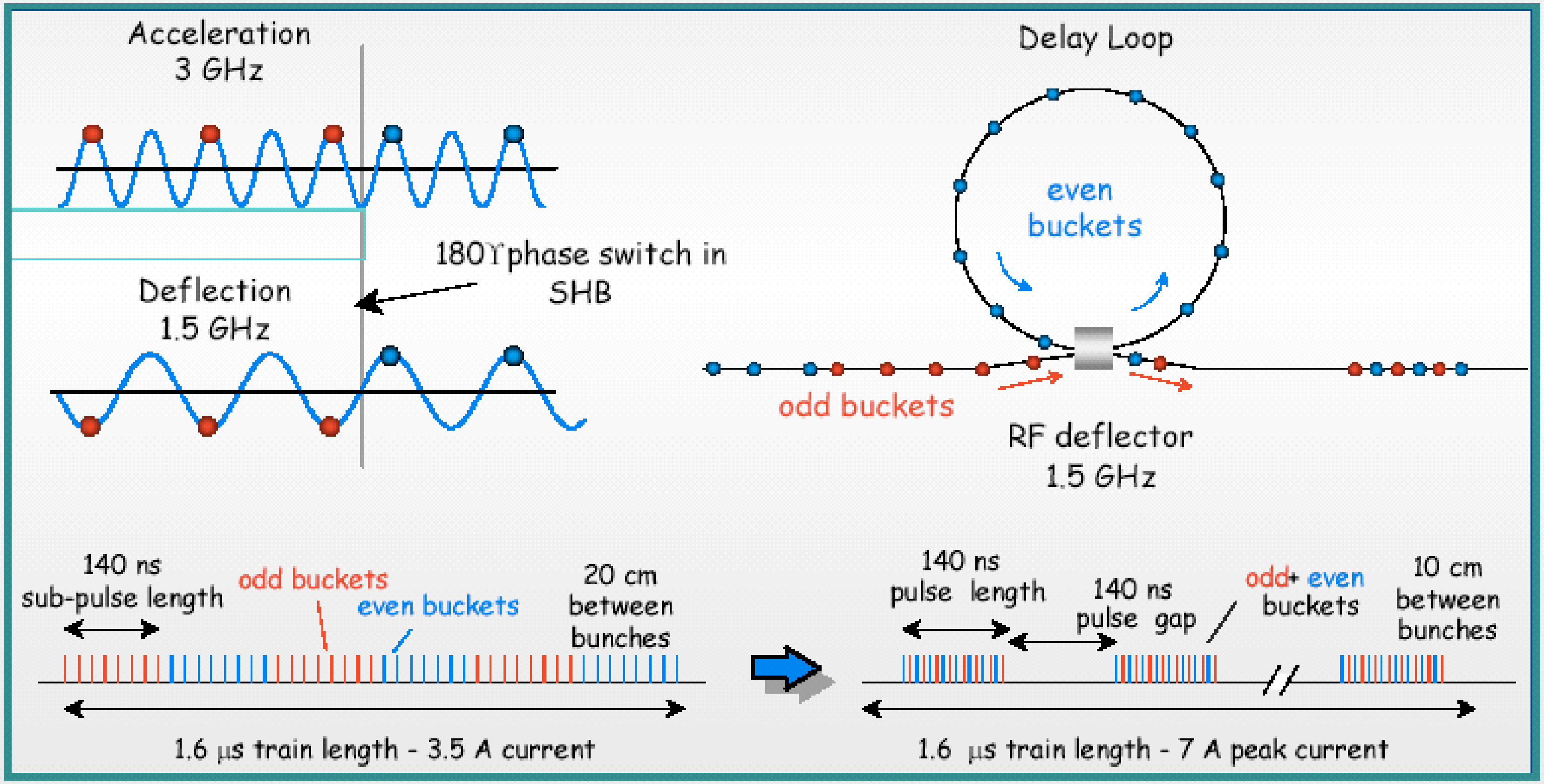


Figure 17: Left : Conceptual view of the SICA accelerating structure. Right : Machined disc of the 3 GHz version of the SICA structure.

CLIC drive beam accelerating structure: “Slotted-iris constant aperture” (SICA) Slots reduce Q of dipole modes. Outer diameter 550 mm @937 MHz.

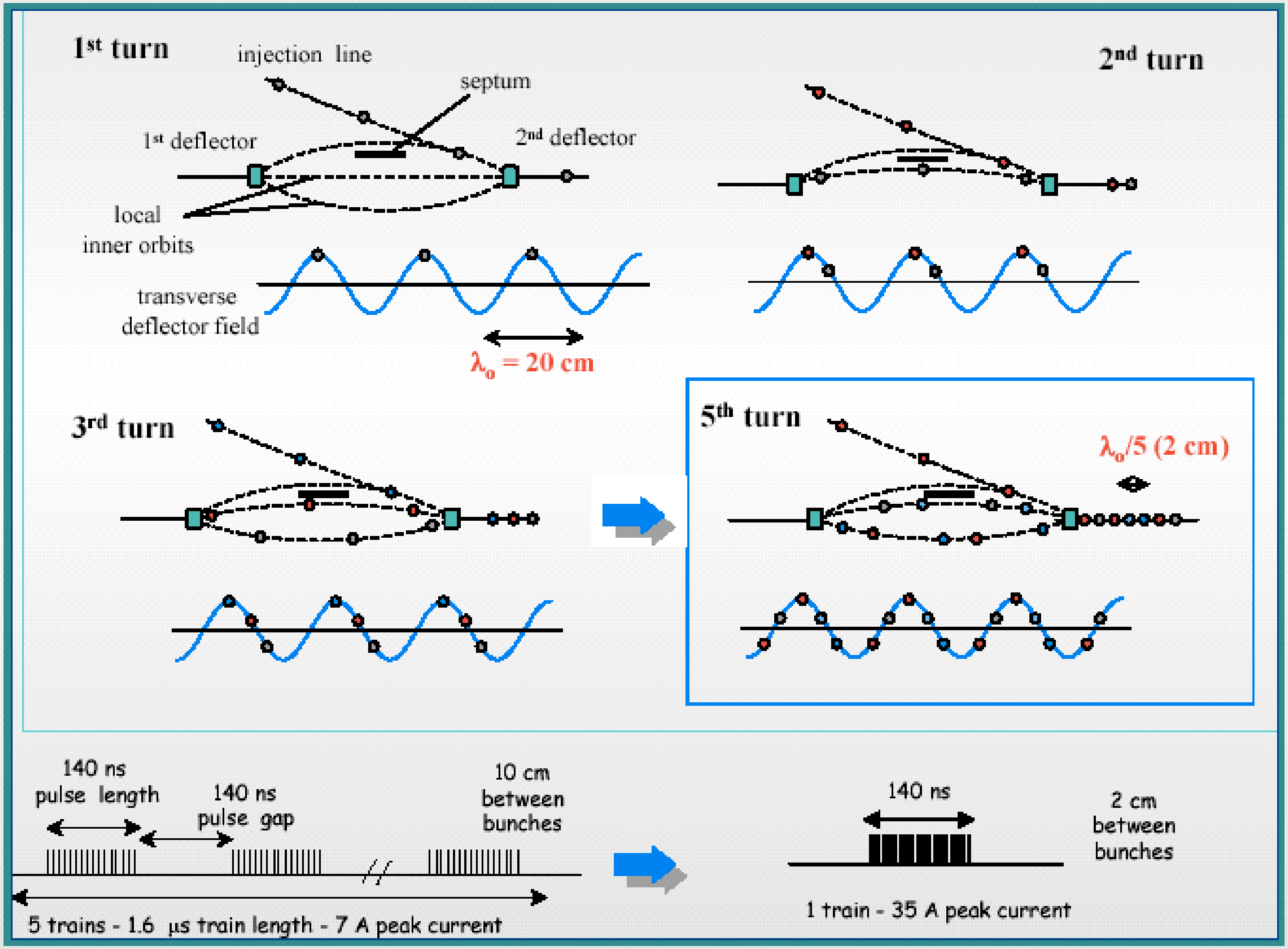
For CTF3-not CLIC-but idea is similar

Multiplication x 2 - Delay Loop



For CTF3-not CLIC-but idea is similar

Multiplication x 5 - Combiner Ring



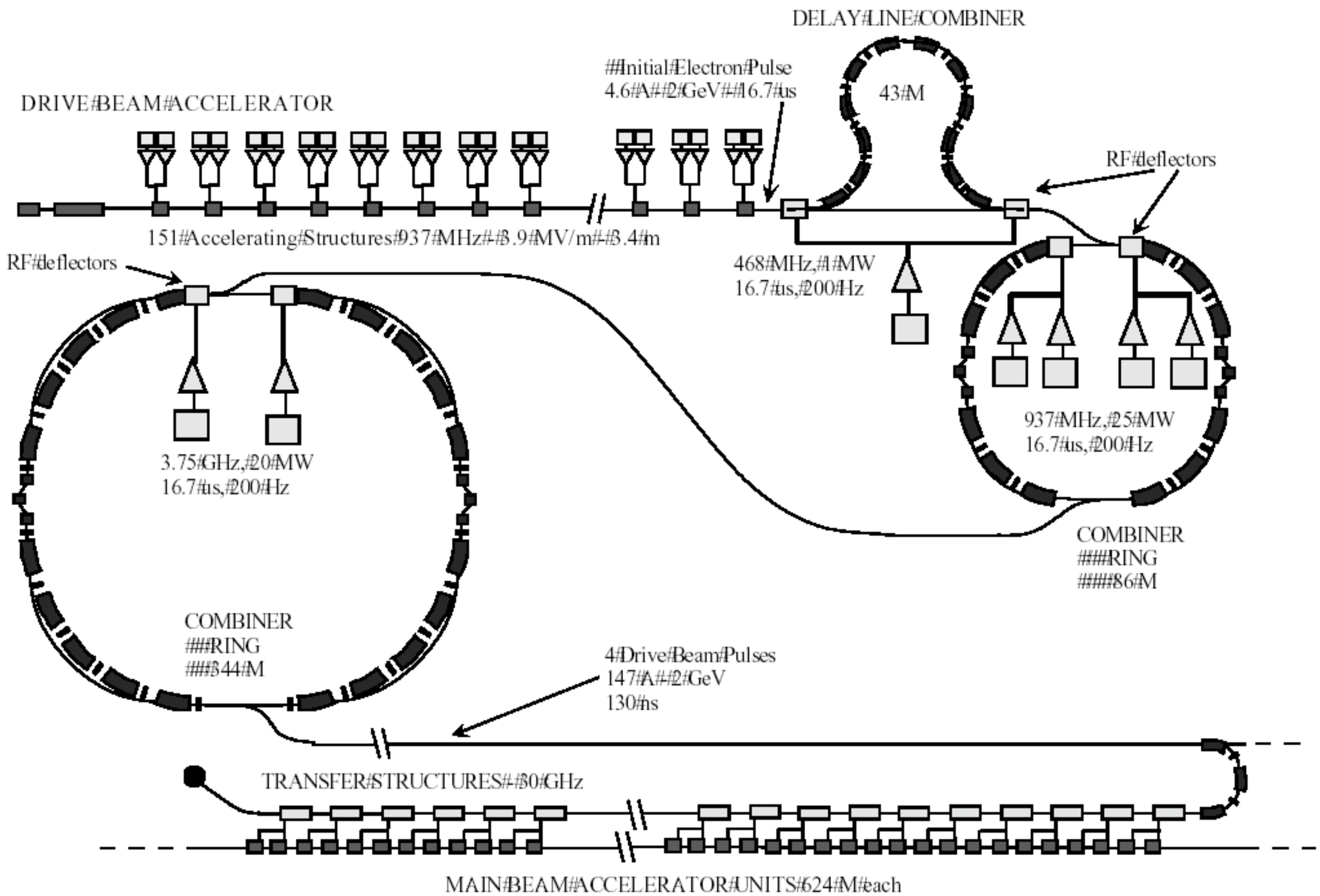


Figure 18: Drive-beam klystron-modulators.

CLIC power source’s power sources

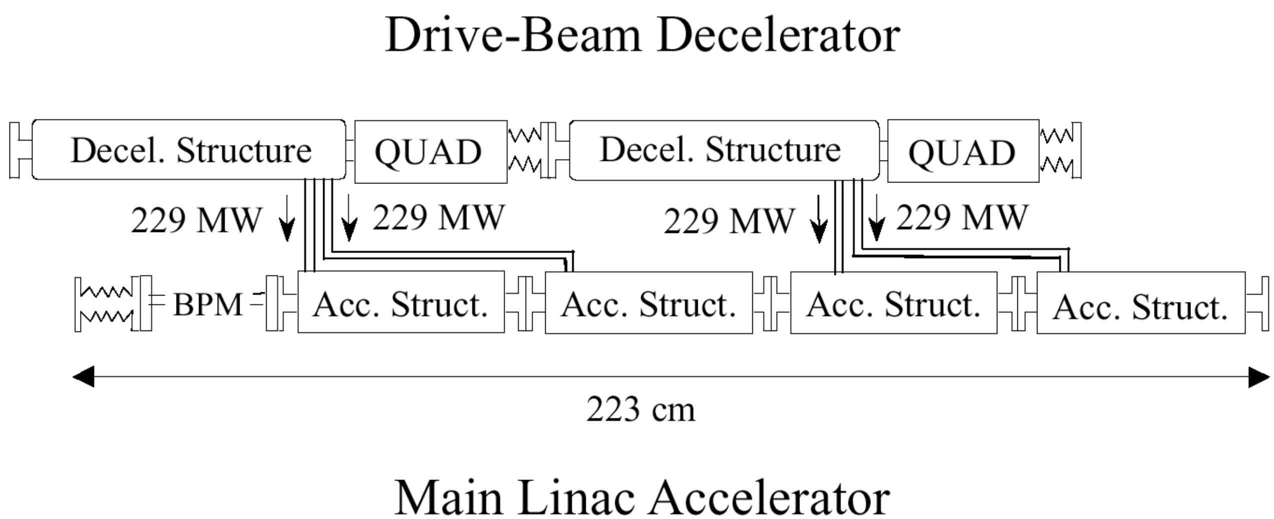


Fig. 2.1: *One basic main-beam module and one drive-beam module.*

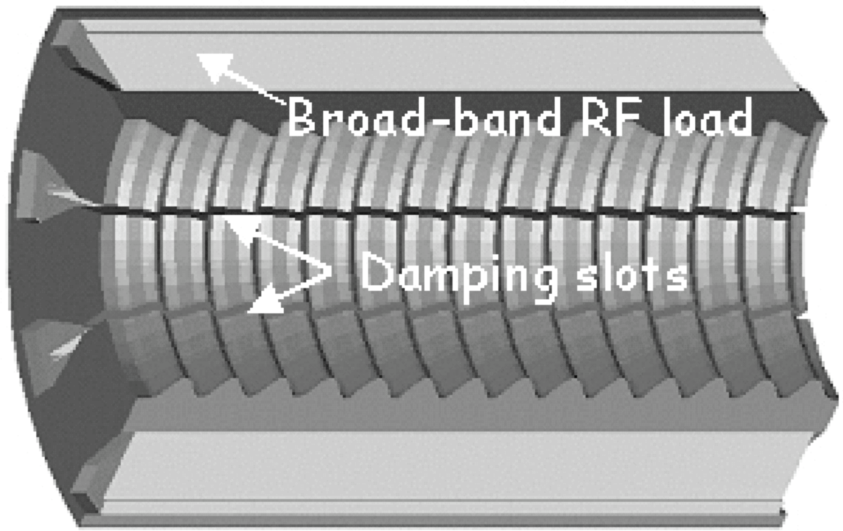


Figure 23: A quarter geometry of the C-PETS with 12 damping slots and SiC loads.

Circular Power Extraction and Transfer Structure (C-PETS) for CLIC drive beam decelerator. The drive beam will excite the TM01 mode at 30 GHz, and the rf power is collected at the downstream end of the structure by the Power Extractor (not shown) and conveyed to the Main Linac TDS structures by rectangular waveguides.

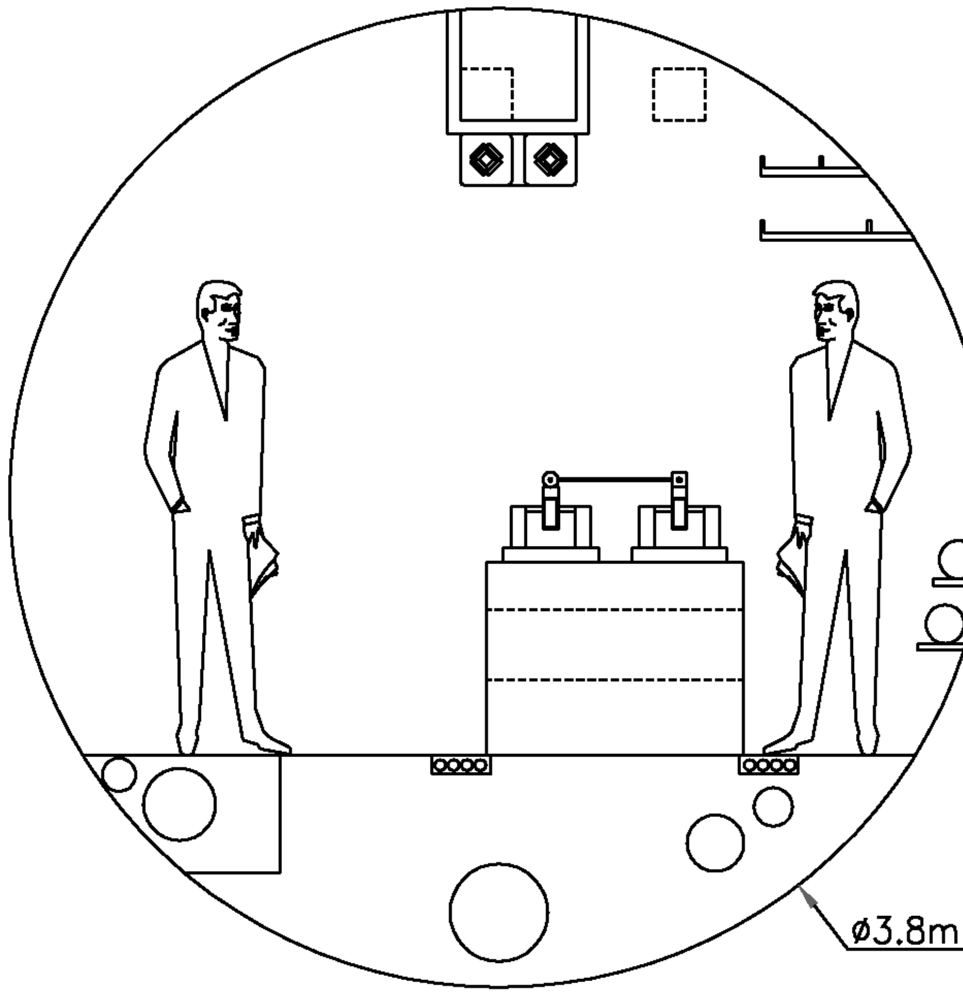


Fig. 1.2: *CLIC tunnel cross-section.*

Main linacs-rf technology-issues

- Accelerating gradient
  - TESLA-
    - scrf gradient goal 35 MV/m->(800 GeV); needs to be demonstrated in multi-cell cavities (TTF2, 2003+)
  - NLC/JLC-
    - Major concerns recently with breakdown/field emission limits, forced redesign of structures; wakefield design pending
  - CLIC-
    - Major concerns recently with breakdown/field emission limits, forced redesign of structures; tests and wakefield design pending

Main linacs-rf technology-issues

- Power sources
  - NLC/JLC-
    - DLDS pulse compression scheme needs high power testing
    - High power system test (“8-pack”) scheduled for 2004+ test at NLCTA
  - CLIC-
    - “Two-beam” power source scheme needs to be tested at CTF3: 2005+

Main linacs-beam dynamics

- To achieve high luminosity, very small vertical emittances must be accelerated in very long linacs with small emittance growth and small beam jitter
- Normalized vertical emittance budget (500 GeV CM, units are μm)

Location	NLC/JLC	TESLA	CLIC
Damping ring exit	0.02	0.02	0.003
Linac entrance	0.022	0.02	0.005
Linac exit	0.032		0.01
IP	0.04	0.03	0.02

- Jitter budgets typically 0.1σ (1000 nm to 60 nm in main linacs)

Main Linacs-beam dynamics

- Emittance growth is a quasi-static problem-requires component alignment at the micron level.
- Jitter is a dynamic problem, but control is needed at the tens of nanometer level.
- For both problems, beam diagnostics, tuning algorithms, and feedback are the keys to achieving the requirements.

Main linacs-beam dynamics: Sources of emittance growth

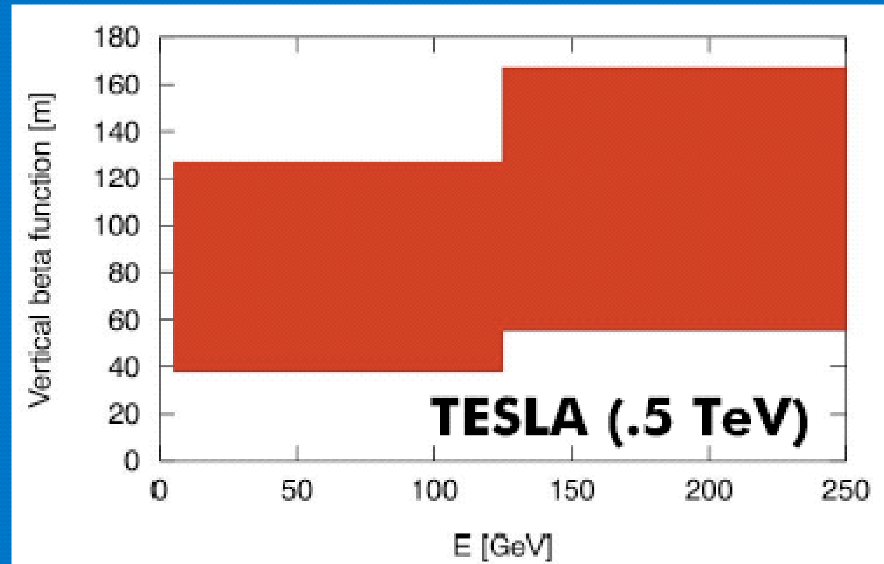
- Dispersive filamentation due to beam energy spread, together with
  - Quadrupole position misalignments and rolls, and BPM errors, resulting in the generation of coupling and vertical dispersion.
  - coherent oscillations at injection and/or component jitter
- Head-tail relative motion caused by transverse short-range wakefields, and relative motion of bunches in the train caused by transverse long-range wakefields, together with
  - rf structure misalignments
  - coherent oscillations at injection and/or component jitter

(in what follows, blue background slides have been ripped off from Snowmass ‘01 talk by Ralph Assmann)

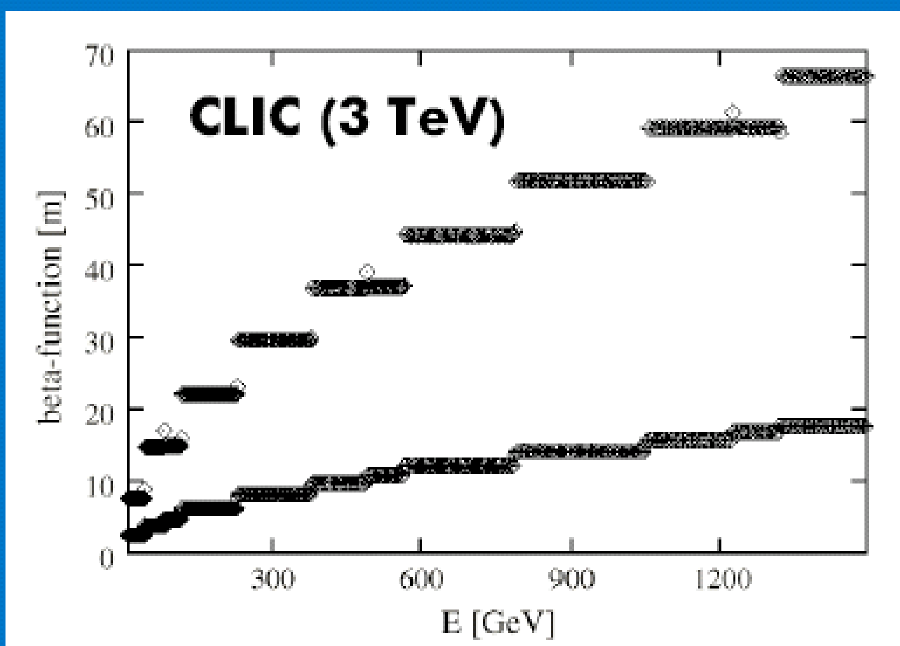
Vertical beta function

TDR

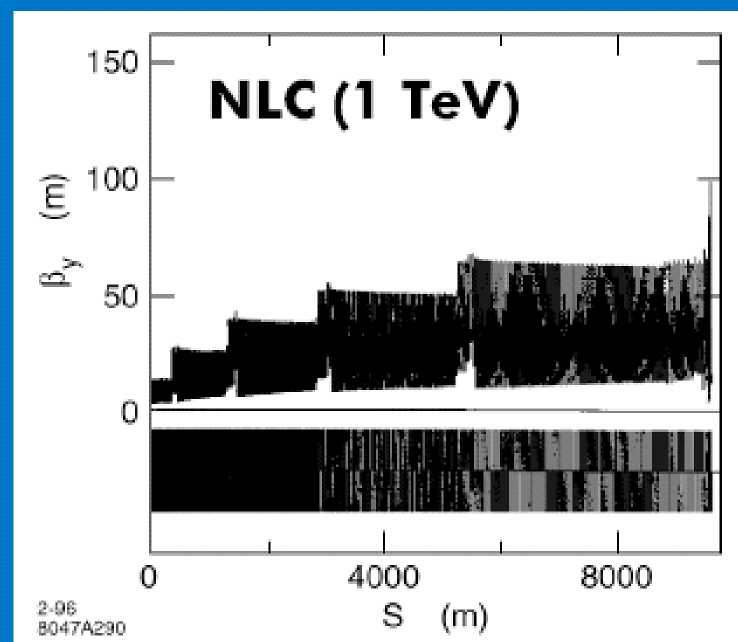
Dispersion-dominated optics design



Wakefield-dominated optics design



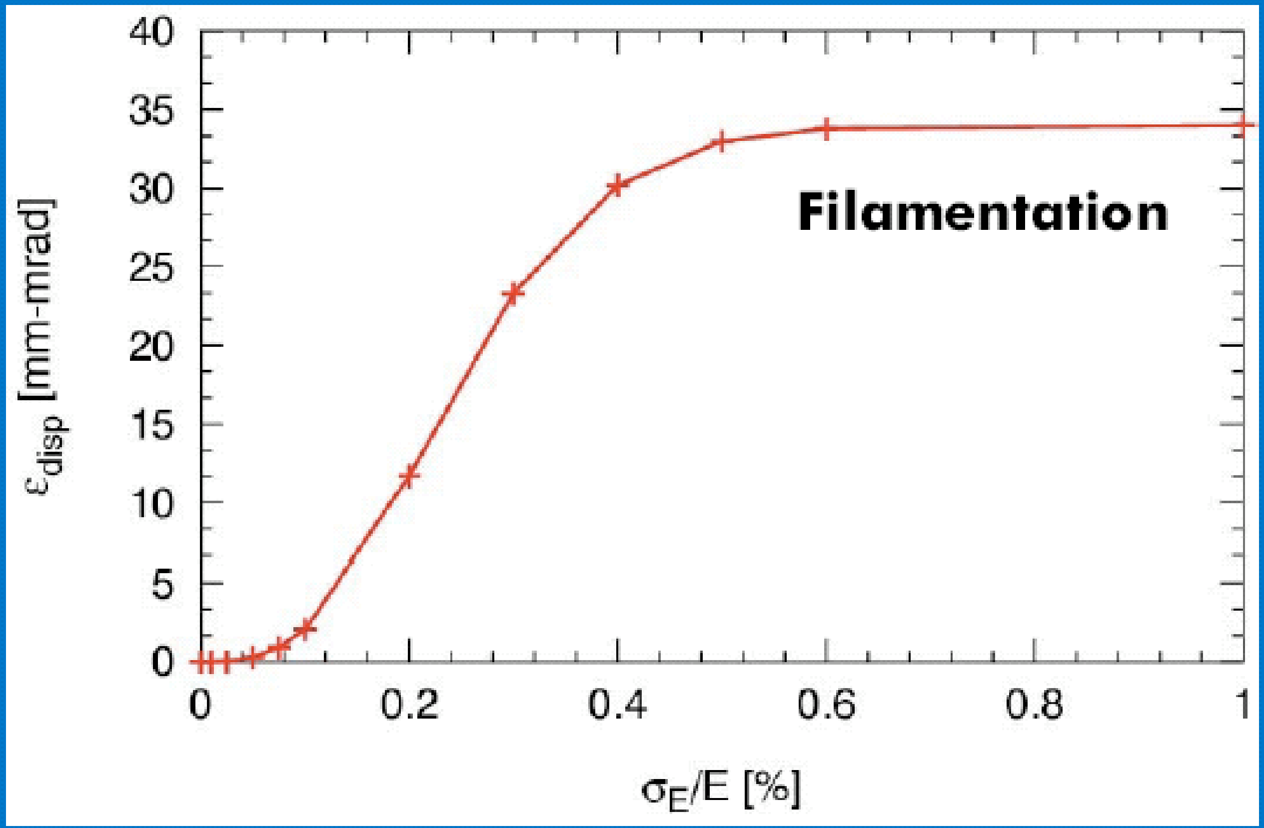
Yellow report



ZDR

Sensitivity to dispersion

Example case CLIC type – no acceleration – no wakefields
QD misaligned by 50 μm



Emittance saturates due to filamentation for large energy spread
(chromatic phase mixing)

Energy spread

Correlated, fractional energy spread (CLIC/NLC: BNS)

	Linac	Linac exit	RF curvature contribution
TESLA:	< 0.06 %	0.06%	0.004 %
NLC:	< 0.80 %	0.25 %	0.042 %
CLIC:	< 0.55 %	0.35 %	0.023 %

QD offset by 0.3 μm -> Y oscillation with amplitude ~ 1μm

Example:

	σ_E/E	ε_{disp}	ε_{inj}
CLIC type	0.4%	0.0010 mm-mrad	0.004 mm-mrad
NLC type	0.6%	0.0006 mm-mrad	0.030 mm-mrad
TESLA type	0.05%	0.0000 mm-mrad	0.020 mm-mrad

Dispersion no problem, if trajectory controlled on 1 μm level!

(pessimistic assumptions: No wakefields would mean no BNS)

Main Linac-Beam dynamics-dispersive emittance growth

- Quadrupole and BPM position alignment at the micron level is required- the initial survey cannot be done with sufficient accuracy to satisfy this requirement.
- The beam itself (via the BPM's) must be used to find the centers of the quadrupoles.
- One of many possible methods: vary the strength of a quad, measure the orbit change, deduce the center of the quad. Quads are then moved onto the reference orbit using movable stands.
- Procedure is limited by systematic errors: e.g., motion of quad center with quad strength

Ballistic alignment: Divide beam line into bins with 12 quads each. Switch off all quads but one, steer to last BPM, align all other BPM's in bin to the beam. Switch on quads, align to BPMS's

From CLIC design study:

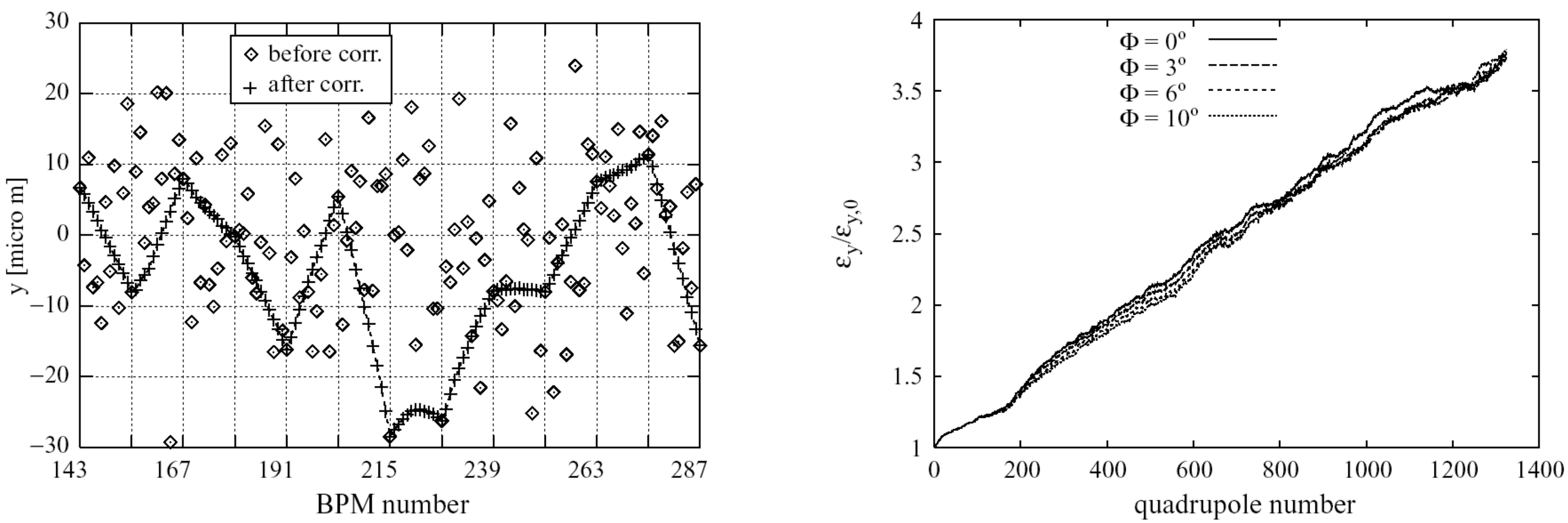


Fig. 2.12: *Left-hand side: The BPM positions before and after the ballistic correction. Right-hand side: The emittance growth after ballistic correction for different RF phases.*

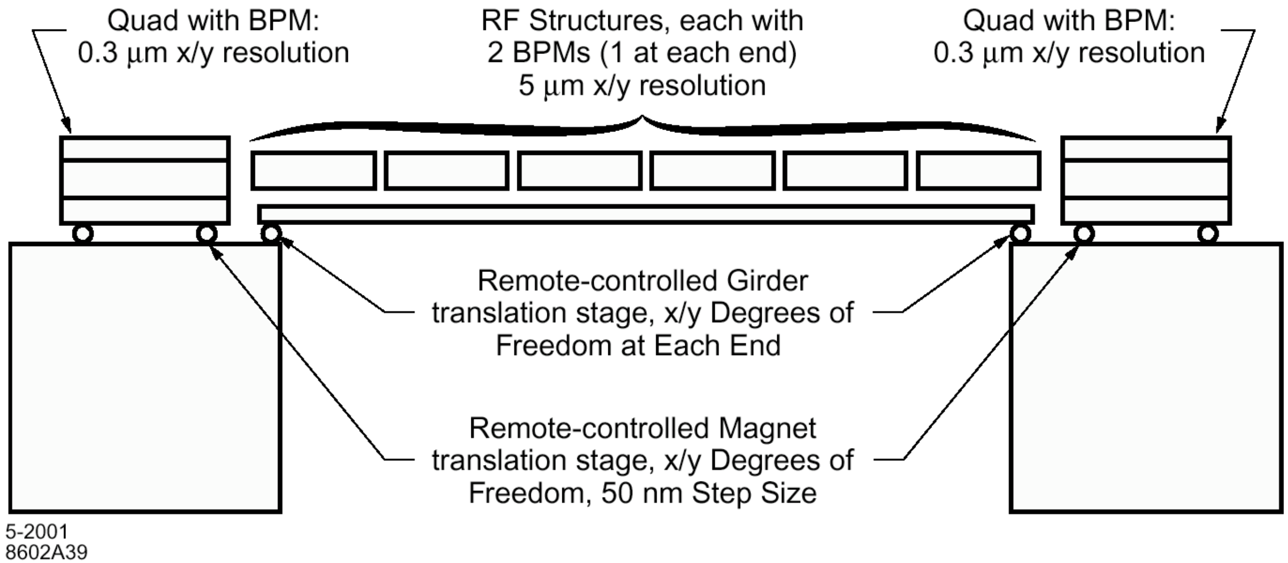


Table 1.12: Requirements for JLC/NLC diagnostic and correction devices, compared with achieved capabilities of existing equipment

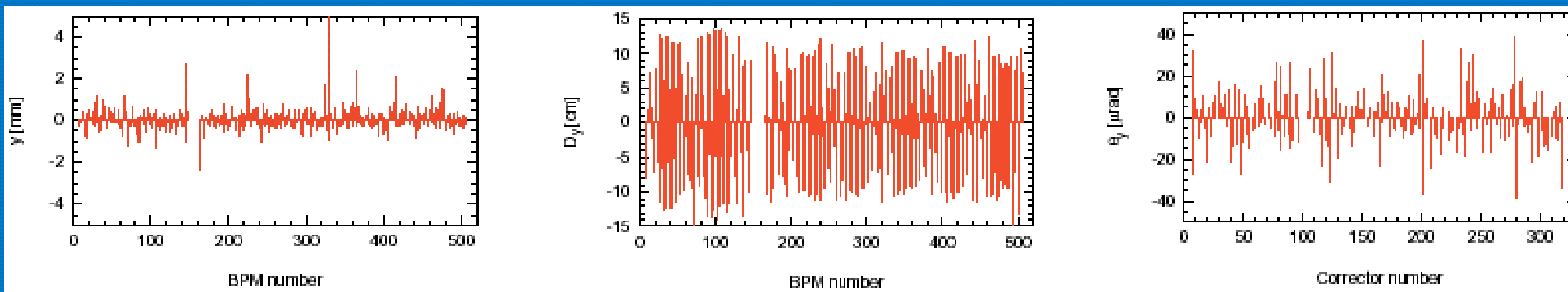
Item	Specification	Achieved	Improvement
Quadrupole BPMs	0.3 μm resolution	1 μm resolution (FFTB striplines) 0.025 μm resolution (FFTB cavities)	3× None
RF structure BPMs	5.0 μm resolution	2 μm resolution (DDS3 and RDDS1 structure prototypes)	None
Magnet Movers	0.05 μm step size	0.3 μm step size (FFTB magnet movers)	6×
RF Girder Movers	1 μm step size	0.3 μm step size (FFTB magnet movers)	None
Laser Profile Monitor	1 μm RMS beam size	1 μm RMS beam size (SLC laser wire) 0.06 μm RMS beam size (FFTB laser interferometer profile monitor)	None None
Magnet/Girder Supports	Add $<$ 3 nm vibration w.r.t. tunnel floor	Add $\sim$ 2 nm vibration w.r.t. tunnel floor (FFTB quadrupole supports)	None

Main linacs-beam dynamics - dispersive emittance growth

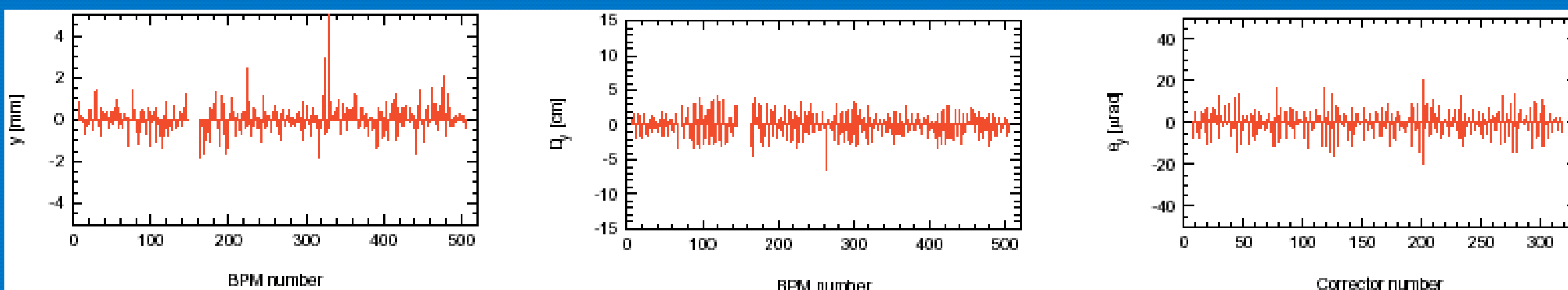
- Errors in this procedure (due to finite BPM resolution, beam jitter, etc). lead to some residual dispersion, which can be further reduced by "DFS" ("dispersion-free steering"). This procedure looks at linac trajectories at different energies and adjusts the quadrupole positions to achieve a "gold orbit" for which the dispersion is minimized.

Dispersion free steering at LEP

ORBIT | **DISPERSION** | **CORR. KICKS**



DFS: Simultaneously optimize orbit, disp., corr.



Suggested for NLC (Raubenheimer et al). Developed for SLC (Assmann et al)!

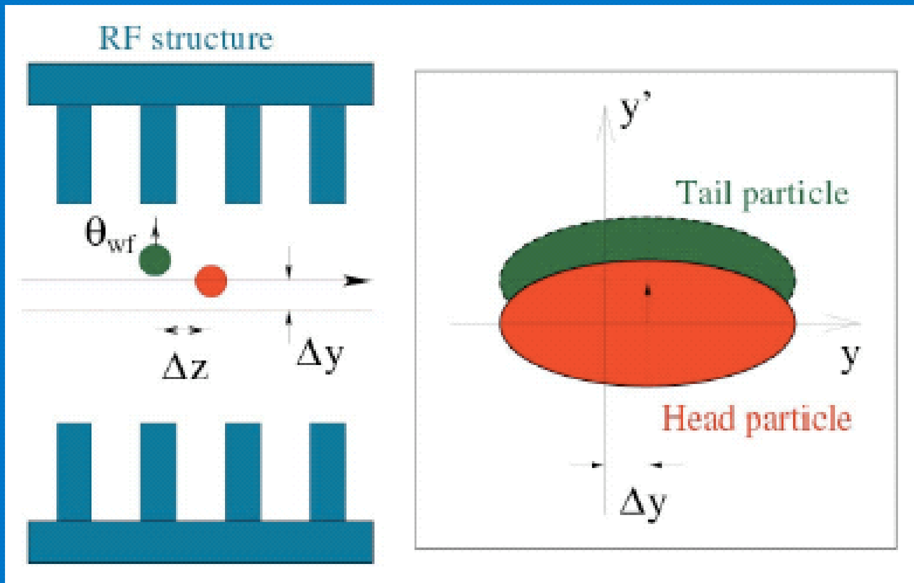
It even works for storage rings... (it should work for future LC!)

Main linacs: beam dynamics- short range wakefields

- The "beam breakup instability" refers to a collective effect in which the head of the bunch, when moving off-axis through an rf structure, generates a force on the tail via short range transverse wakefields associated with the rf structures.
- If the head and the tail have the same natural oscillation frequency, the tail will be resonantly driven and can acquire a large amplitude. This causes the effective emittance of the bunch to grow.

Multi-particle beam dynamics

Interaction: Accelerated charge ⟺ RF structures (small[illegible]ESLA)



$$\theta_{wf} = W_t(\sigma_z) \cdot \frac{e N_e L_{struc}}{2 E_0} \cdot \Delta y_1$$

Wakefield effect depends on:

Intra-bunch and inter-bunch wakefields
Offsets in rf structures (imperfections)
Longitudinal distribution
Charge
Energy
Optics
RF phases

⟹

Calculate effect with programs:

- Multi-particle beam dynamics
- Multiple interacting imperfections
- Chromatic, dispersive + wakefield errors
- Single-bunch and multi-bunch ...

R. Assmann
et al

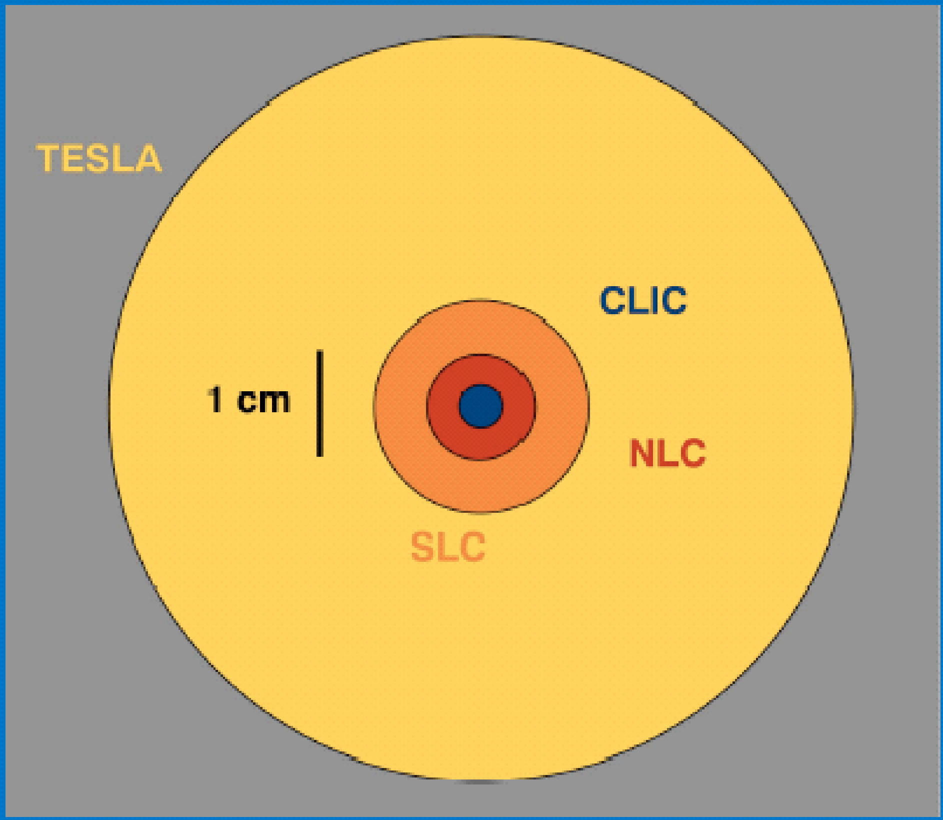
THE LIAR Linear Accelerator Research PROJECT

Amplitude of wakefields

Choice of technology determines radius of structure iris a:

High frequency – small a

Low frequency – large a



Stronger wakefields (beam induced electro-magnetic fields) with smaller iris radius!

Beam is closer to metallic walls...

“Wakefield” parameters

Bunch length:

TESLA	300 μm
SLC	1100 μm
NLC	110 μm
CLIC	30 μm

Transverse wakefield (at 1 σ_z):

TESLA	22 $V/pC/m^2$
SLC	1990 $V/pC/m^2$
NLC	11460 $V/pC/m^2$
CLIC	81000 $V/pC/m^2$

Injection energy:

TESLA	5.0 GeV
SLC	1.2 GeV
NLC	8.0 GeV
CLIC	9.0 GeV

+

Bunch intensity:

TESLA	2.00×10^{10}
SLC	4.00×10^{10}
NLC	0.75×10^{10}
CLIC	0.40×10^{10}

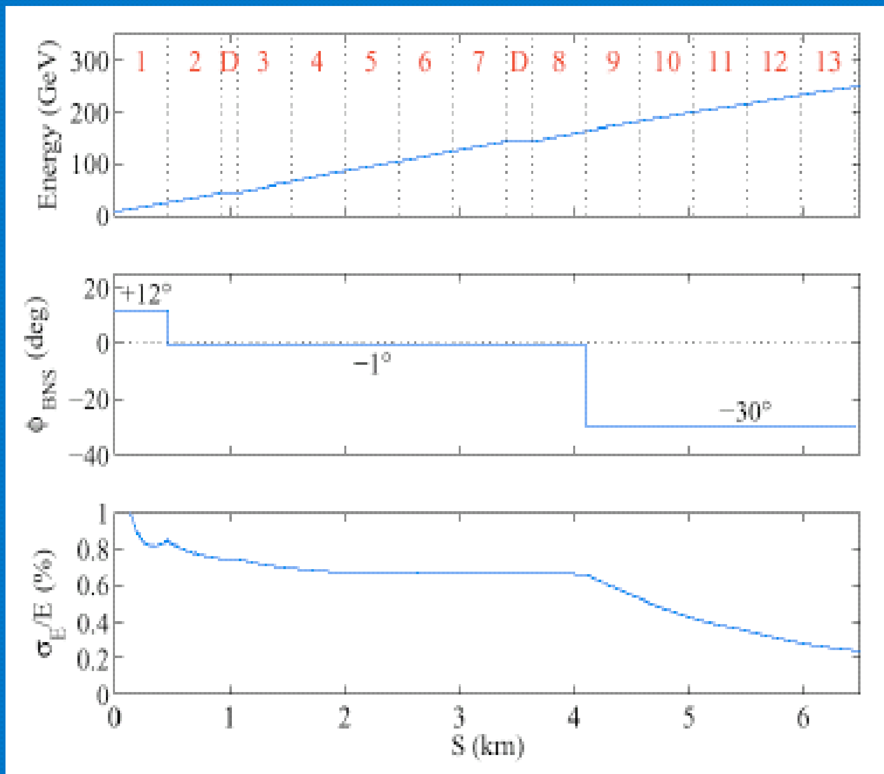
BEAM

Main linacs: beam dynamics - short range wakefields

- The development of head-tail growth due to coherent oscillations at injection is controlled through the use of "BNS damping": this is the establishment of a tune difference between the head and tail of the bunch, which suppresses the resonant driving of the tail.
- The tune difference is typically established by phasing the bunch off-crest in the rf wave, which results in a difference in energy between the head and the tail. The dependence of the tune on energy (chromaticity) then produces a tune difference between the head and the tail.
- The required energy spread, however, makes the dispersive effects noted above worse.

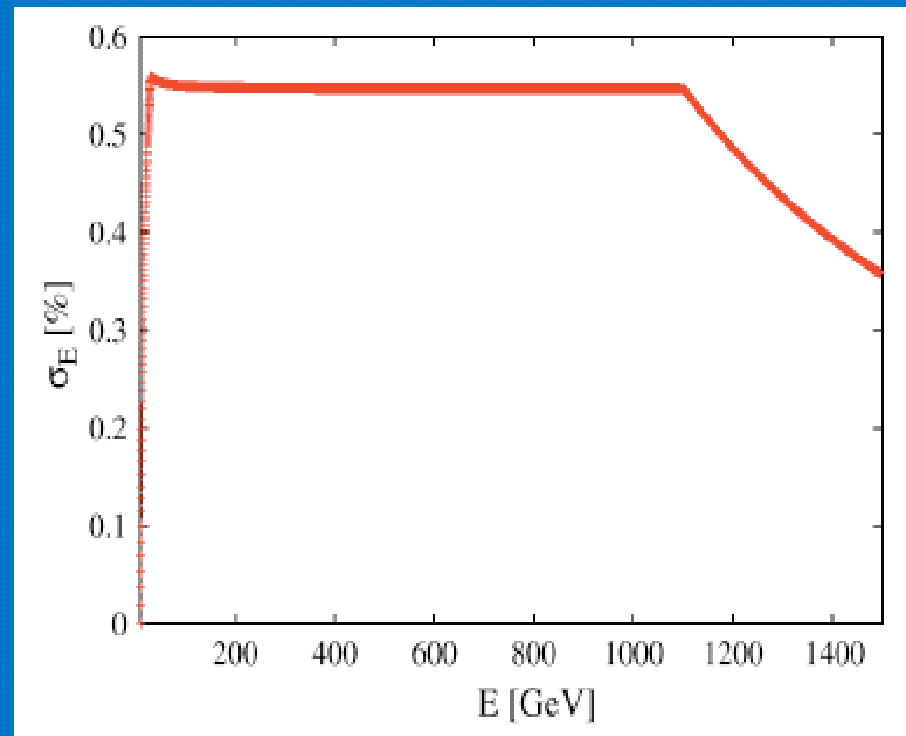
Introduce correlated energy spread (RF phase) so that head and tail move together (same phase advance). No beam-breakup.

NLC



M. Woodley et al, PAC01

CLIC



CLIC yellow report

RF phase CLIC: ~ 6 degree

No BNS damping required for TESLA...

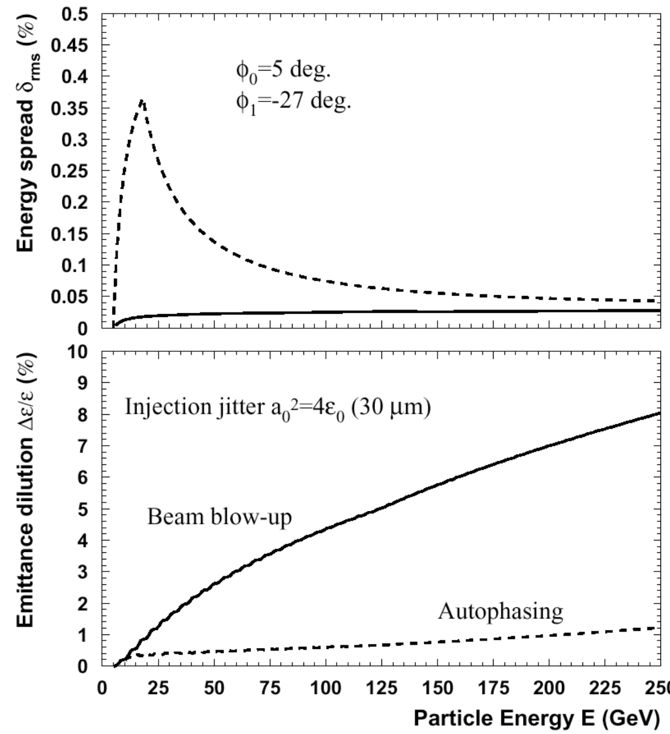


Figure 9: Illustration of BNS damping in TESLA. The correlated energy spread (dashed curve in upper figure, full curve without BNS) is generated in the 5 to 25 GeV section of the linac and the beneficial effect is shown in the dashed autophasing curve.

Main linacs: beam dynamics - short range wakefields

- Rf structure misalignments are minimized by the use of "structure BPM's" which measure directly the beam offset in the rf structure.
- The remaining residual effects may be partially cancelled by the introduction of "non-dispersive bumps" which produce wakefield effects which just cancel those of the structure misalignments.
- To tune the bumps: must measure the emittance->laser devices. Beam size at □=50 m is about 1 micron->want to measure size to 10%, need resolution of 100 nm=>laser interferometer devices (resolution 60 nm seen at FFTB)

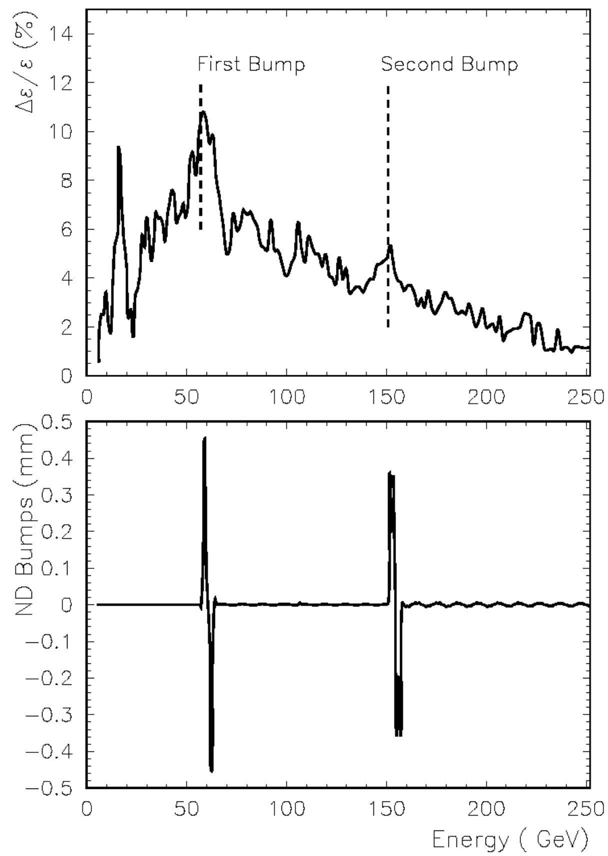


Figure 10: Example of (non-dispersive) wakefield correction bumps for one particular random seed of misalignments. With two bumps, the emittance growth is reduced by one order of magnitude.

Non-dispersive bumps in TESLA

Main linacs-beam dynamics-single bunch emittance growth

- Tolerance/instrumentation requirements:

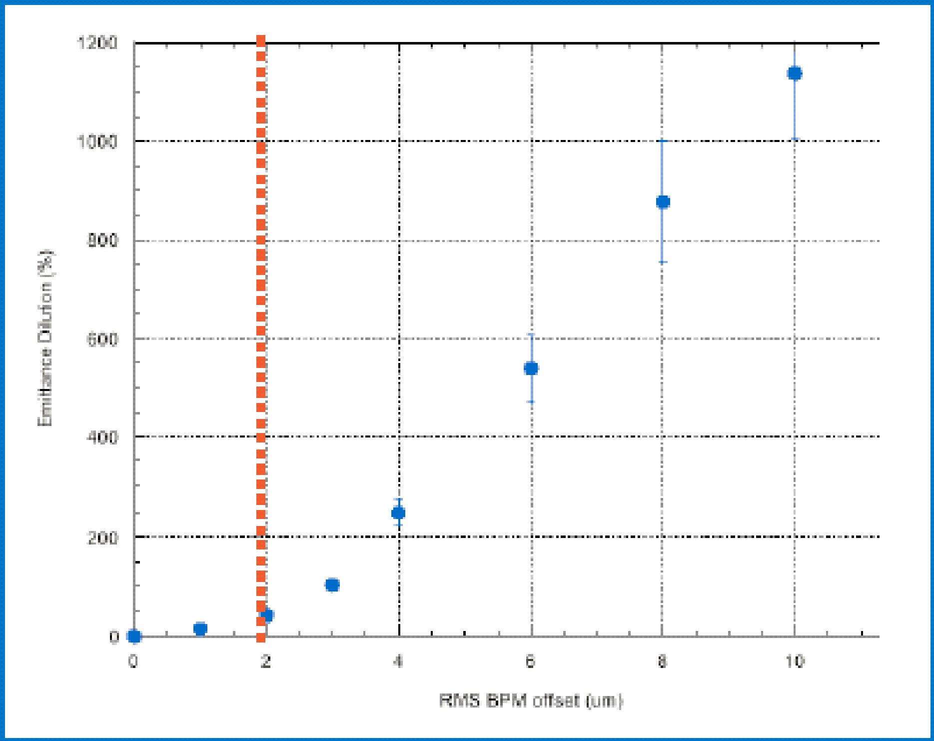
Machine	Quad BPM resolution	BNS energy spread	Structure misalignment	Structure BPM resolution
TESLA	10 μm	0.35%	300 μm	
NLC/JLC	0.3 μm	0.8%	30 μm	5 μm
CLIC	0.1 μm	2%	10 μm	

- Emittance growth:

Machine	Static Quadrupole misalignments, after orbit correction with DFS	Transverse wakes from structure misalignment, after ND bumps
TESLA	2%	2%
NLC/JLC	25%	7%
CLIC	Small	22%

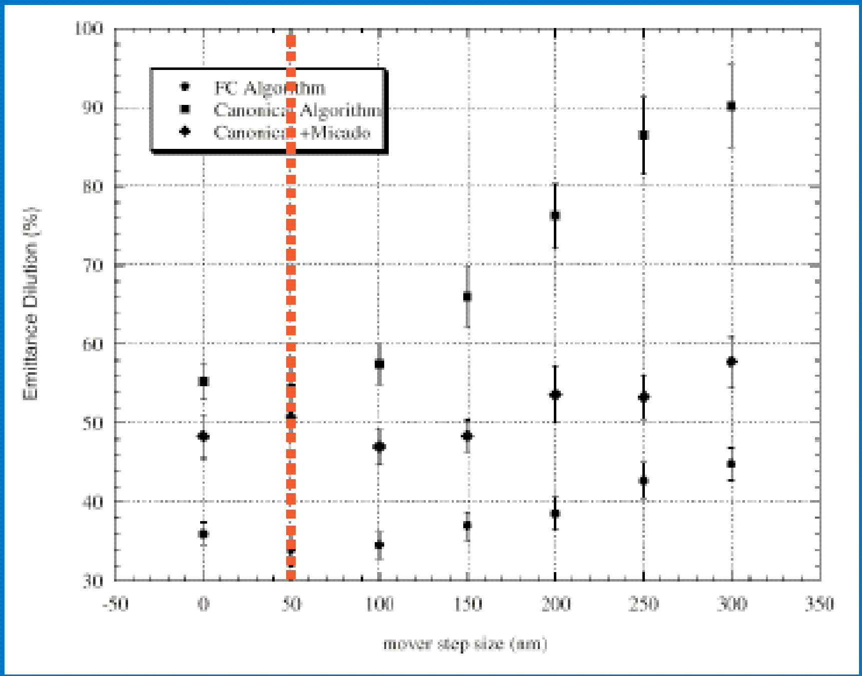
Dependency on assumptions

BPM to QUAD offset (NLC)



Tenenbaum/Raubenheimer, LINAC2000

Mover setp size (NLC)



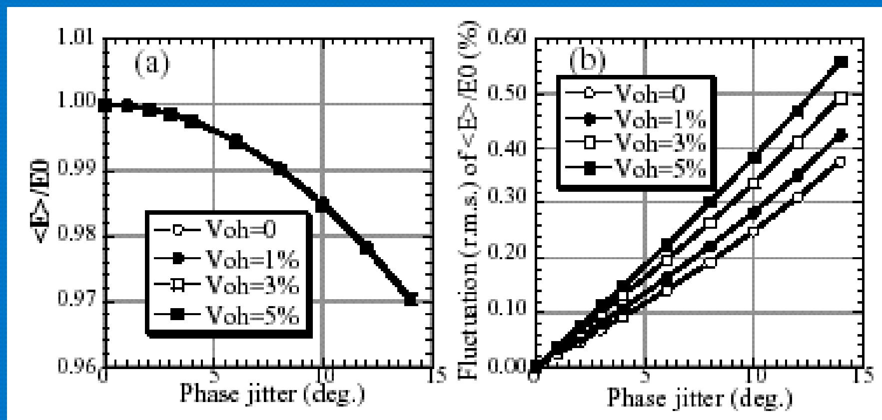
P. Tenenbaum, PAC99

If specifications are not met, then performance deterioration!

Many other effects studied!

Tolerances for the RF system:

Energy

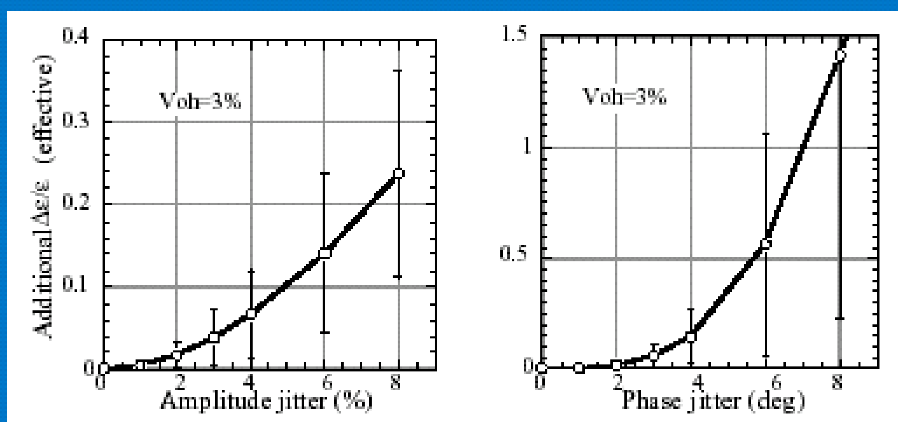


Energy spread

Phase jitter

50 cases simulated

Emittance growth



Emittance growth

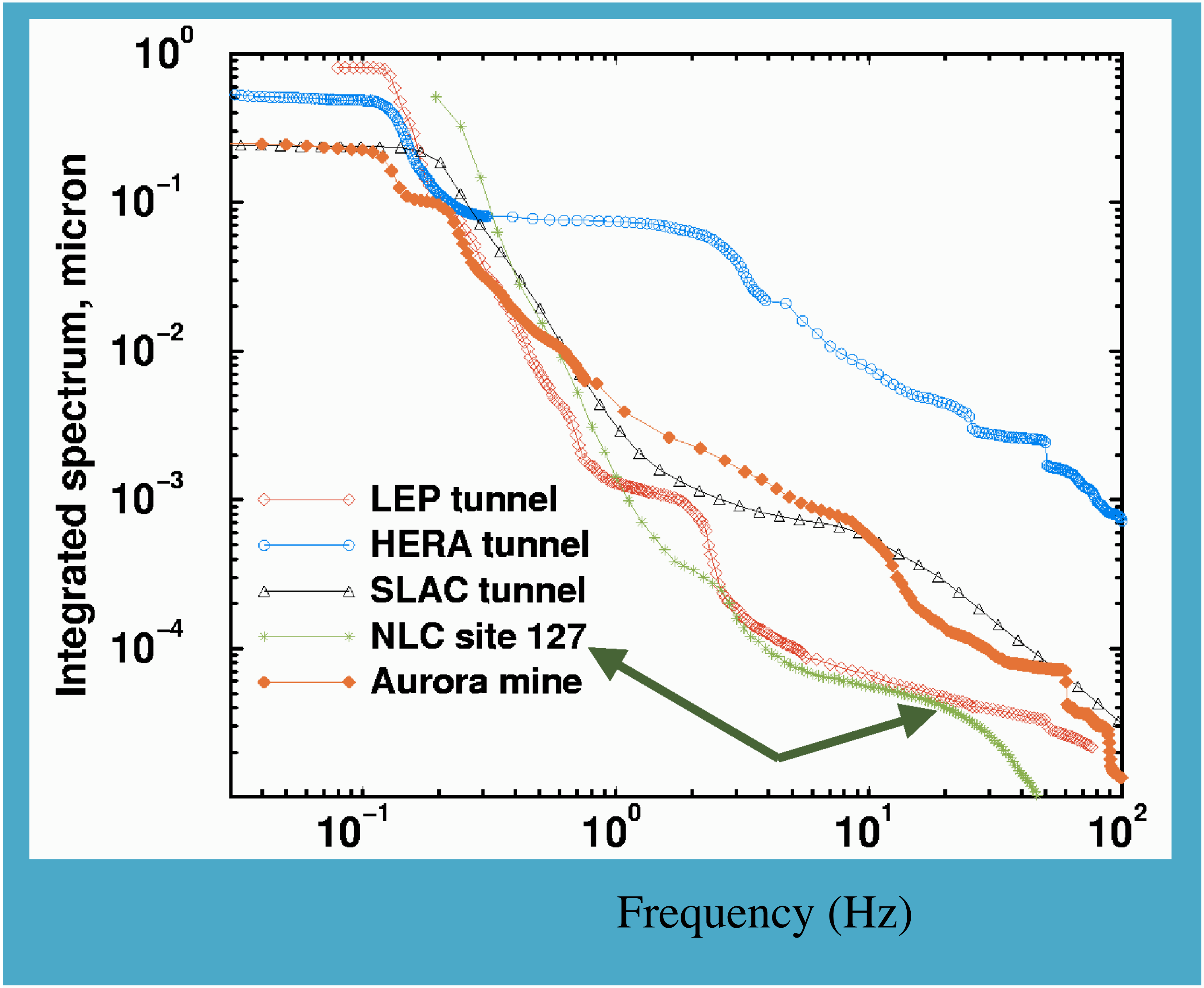
Tolerances JLC/NLC:

Energy: 0.1 %
RF amplitude: 2%
RF phase: 3 degree

T. Higo, K. Kubo and K. Yokoya, PAC99

Main linacs: beam dynamics- ground motion

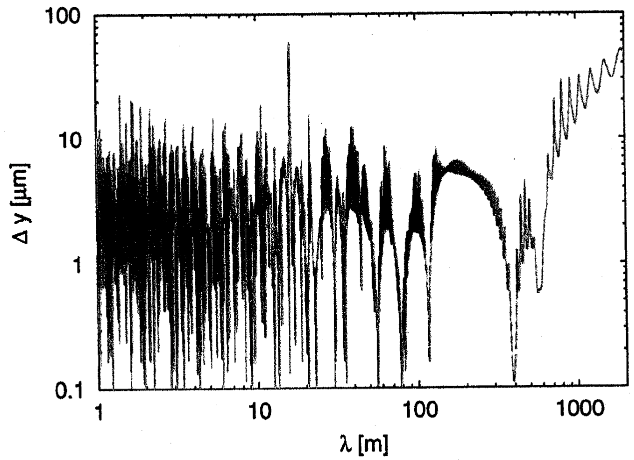
- Ground motion- at frequencies above 1 Hz, typically it is at the 10 nm level or less. OK for most of main linacs-final doublet needs active stabilization.
- At lower frequencies (< 1Hz)-can be large, up to 100 nm-1 μm. However, such motion tends to be highly correlated (long-wavelength)-tolerance is greater.



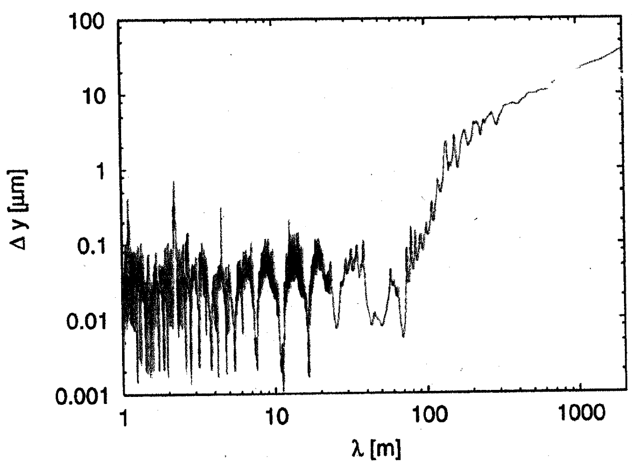
Integrated spectrum, micron
LEP tunnel
HERA tunnel
SLAC tunnel
NLC site 127
Aurora mine
Frequency (Hz)

Tolerance for Waves

TESLA



CLIC

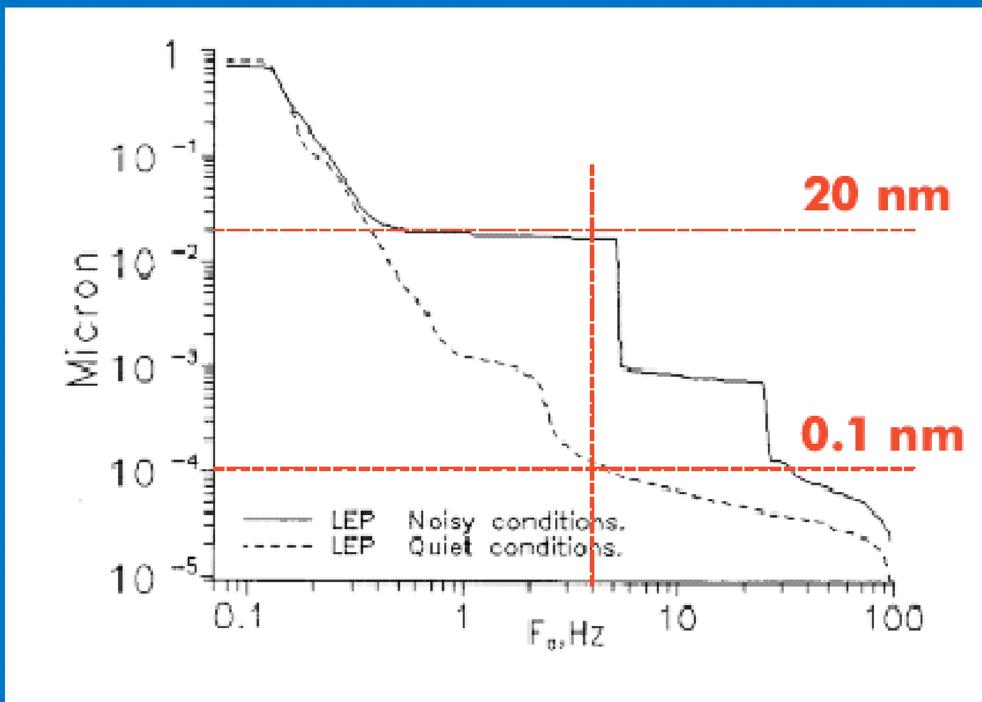


From Daniel Schulte (CERN)

Magnet vibration

CLIC tolerance on vertical quadrupole vibration: 1.3 nm
(vibration above 4 Hz)

Measurements in the LEP tunnel



A. Seryi et al, CERN 1993

Man passing by magnet

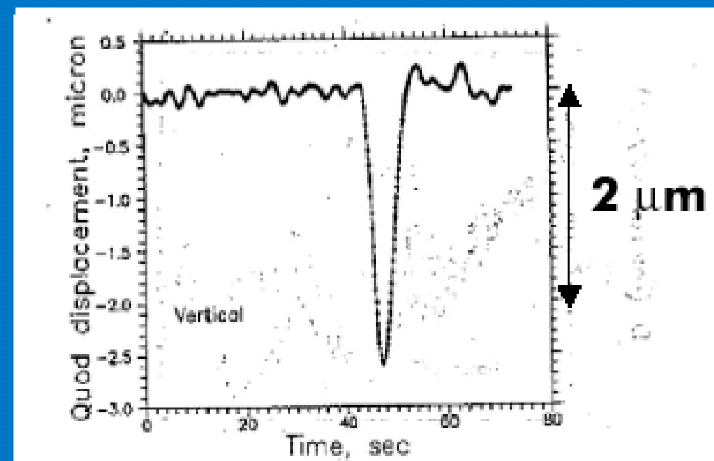


Figure 2. Low frequency vertical motion of the APS quad and effect of a man passing closely.

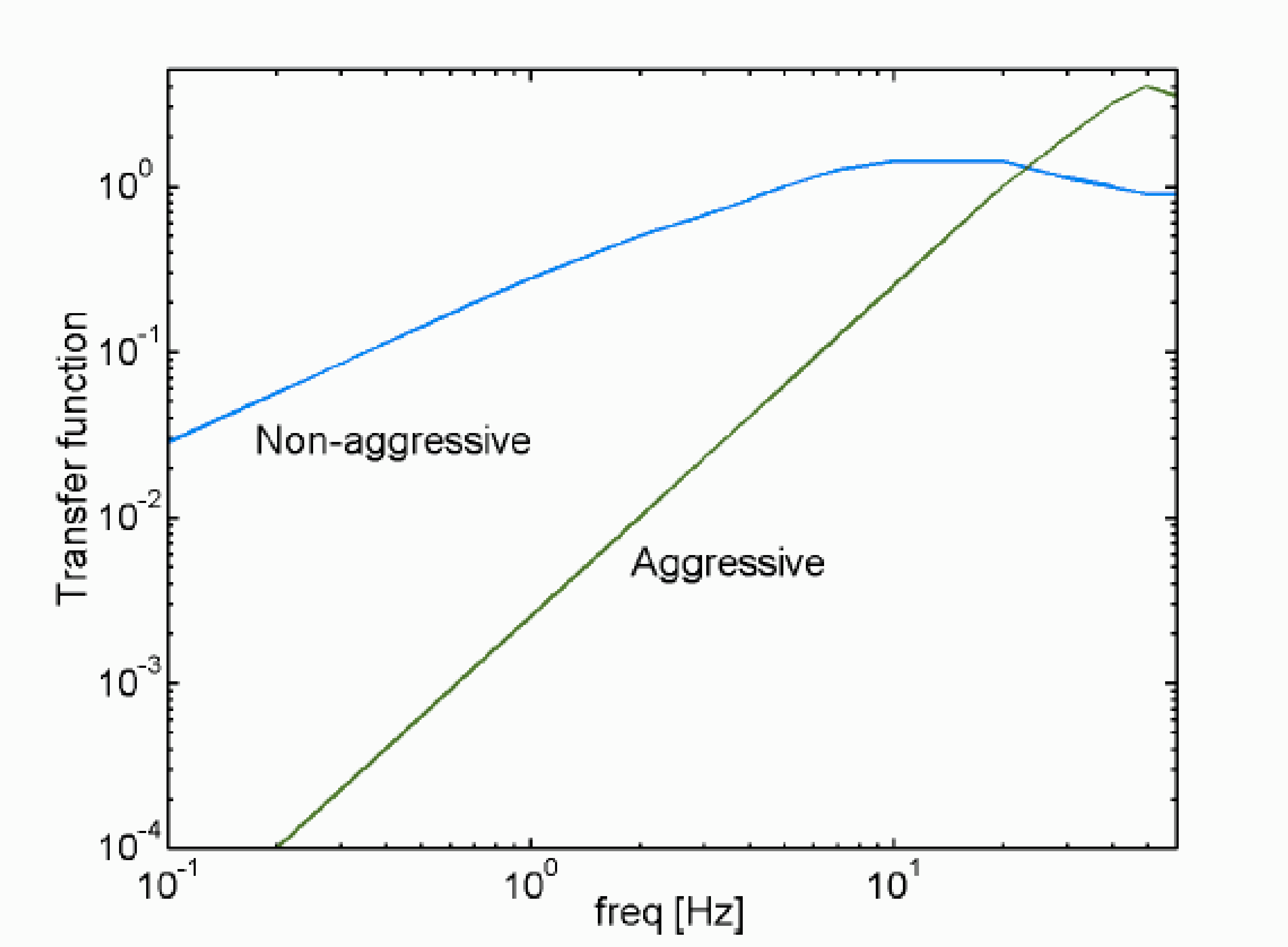
V. Shiltsev 1994

Ground stability in LEP tunnel much below required 1.3 nm (quiet)
However, easily surpassed from human induced noise (running equipment)

Main linacs-beam dynamics-ground motion

- It is possible to use beam-based feedback (using BPMs' and linac correction dipoles) at low frequencies (~5 % of the cycle rate) to suppress jitter.
- Suppression of low frequency noise comes at the expense of high frequency noise amplification.
- Collision feedback at the IP within the bunch train will be very effective for high frequencies, but is difficult, except for TESLA, because of the small bunch separation.

Simulated Beam - Beam Feedback



Main linacs-beam dynamics-ground motion

- At very low frequencies (hour-day-month time scale), ground motion is diffusive:
- ATL law: □x^2 =A*T*L: amplitudes can be large.
- May also have systematic long term motion such as settling.
- This large amplitude motion can cause misalignments to develop, leading to emittance dilution. It requires periodic realignment. The time between (invasive) realignments can be increased by the use of steering feedback.

- **Some data for diffusive or ATL motion:** $\Delta X^2 \sim A_D T L$ (min.-month)
  (T - elapsed time, L - separation between two points)

Place	A $\mu m^2/(m{\cdot}s)$
HERA R.Brinkmann,et al.	$\sim 10^{-5}$
FNAL surface * V.Shiltsev,et al.	$(1\text{-}10)*10^{-6}$
SLAC*	$\sim 5*10^{-7}$
Aurora mine* V.Shiltsev,et al.	$(2\text{-}20)*10^{-7}$
Sazare mine S.Takeda,et al.	$\sim 5*10^{-8}$

* Further measurements in Aurora mine, SLAC & FNAL are ongoing

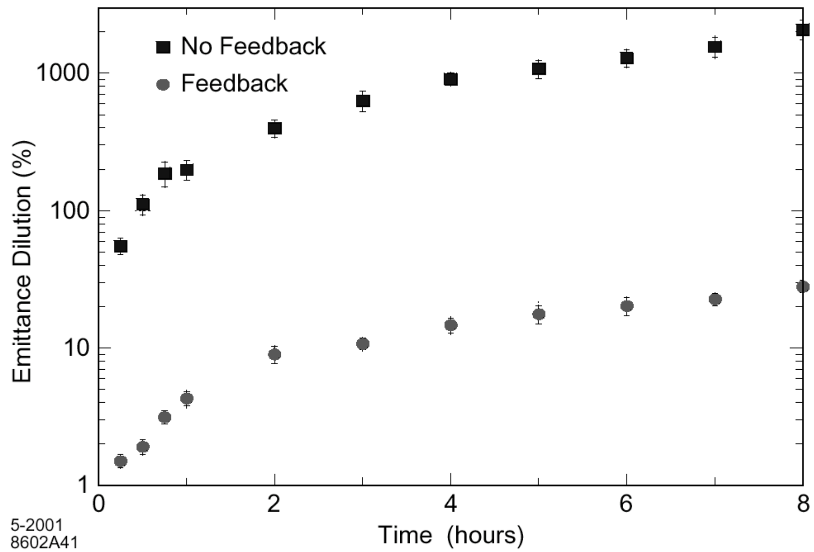


Figure 1.20: Emittance dilution (%) in the NLC main linacs due to diffusive ground motion, assuming an ATL coefficient comparable to that measured at SLAC. A case with no linac feedbacks (squares) and a case with the proposed NLC steering feedback architecture (circles) are both considered.

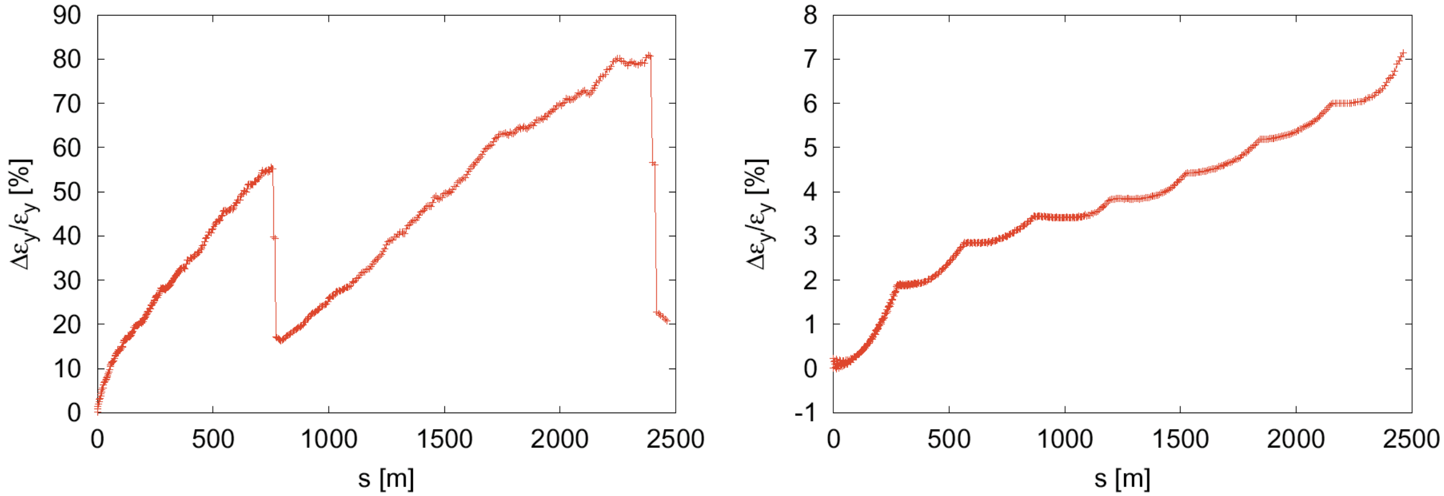
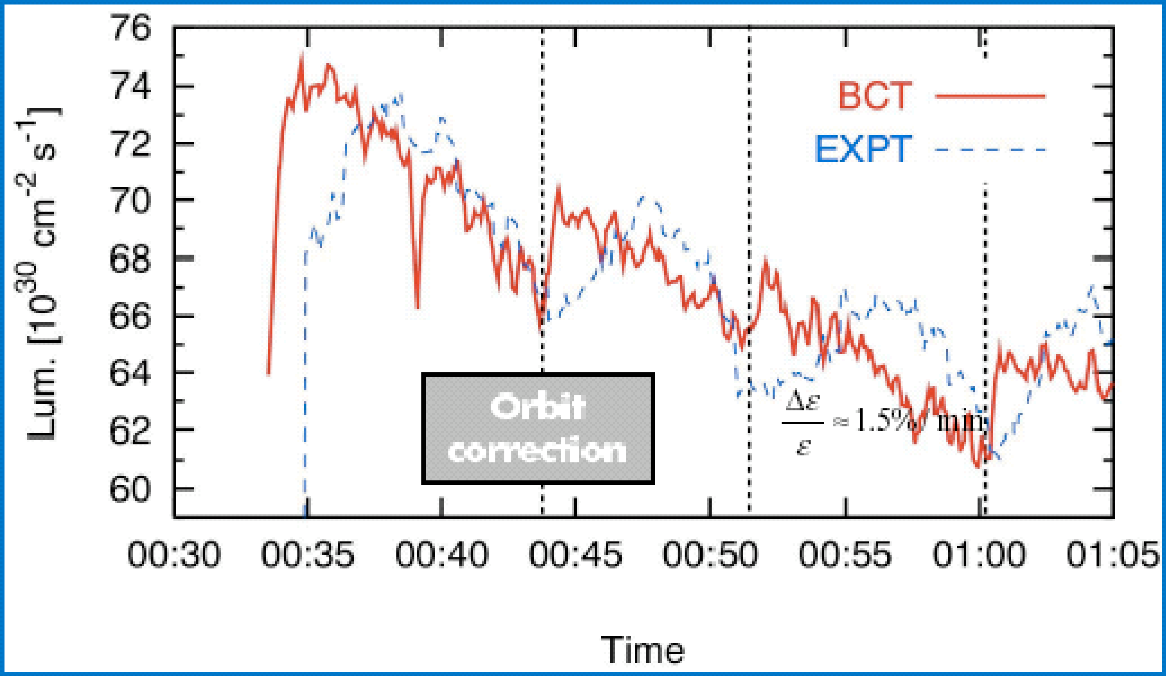


Figure 5: Left: The emittance growth in the linac after the ballistic alignment and optimisation of the emittance tuning bumps. Right: The emittance growth after 1000 s of ground motion if seven feedbacks are used.

CLIC emittance growth-500 GeV CM

LEP orbit correction loop

Luminosity decay due to vertical orbit drifts:



$\Delta L \approx 0.3 \cdot 10^{30}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ per minute

$\Delta \varepsilon \approx 0.002$ nm per minute

$\Delta\varepsilon/\varepsilon \sim 1.5$ % / min

for best performance

Luminosity stabilized with the vertical orbit feedback ("autopilot") every 7-8 minutes (3% effect). Orbit stabilization: ~ 20 μm level.

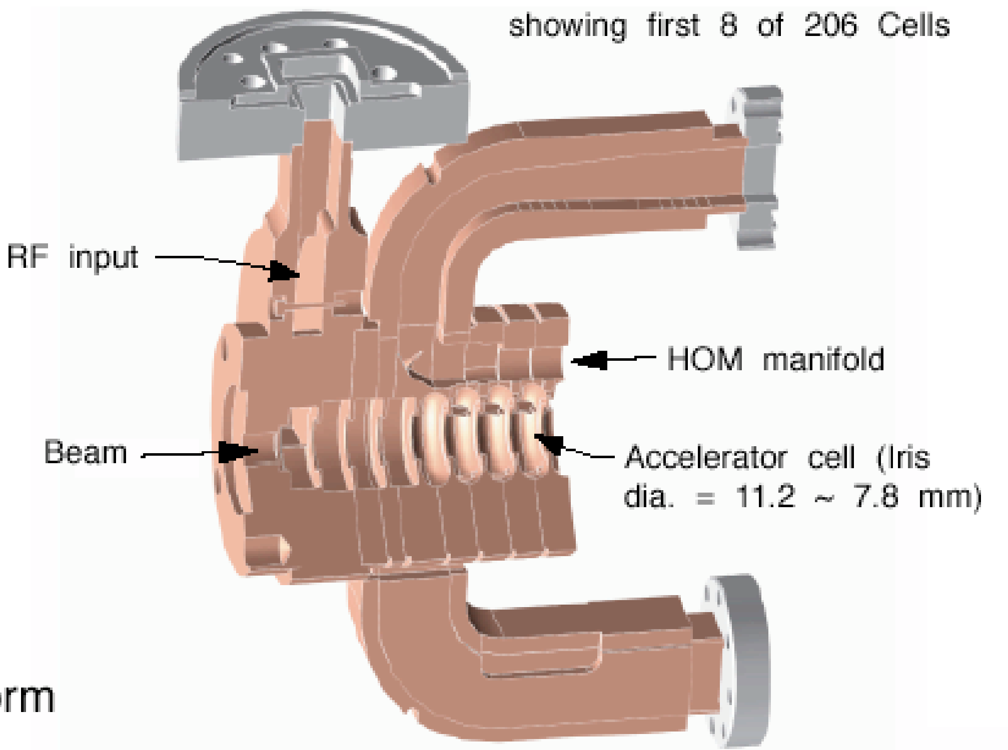
Both visible from experiments and beam lifetime BCT (faster)!

No reason to be afraid of "fast" orbit stabilization

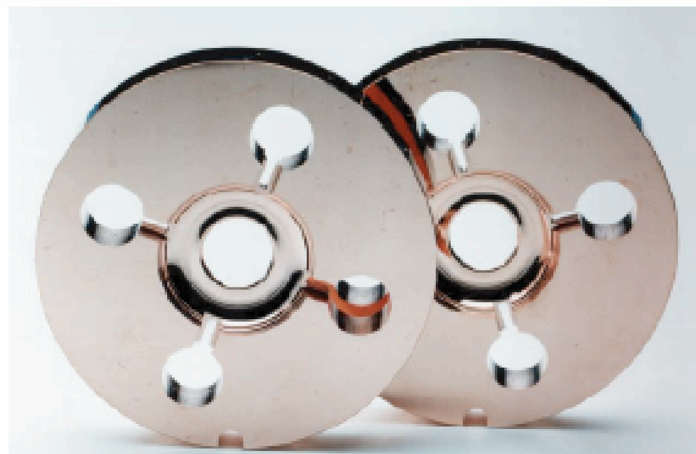
Main linacs: beam dynamics-multibunch emittance growth

- Multibunch emittance growth is driven by long-range wakefields
- Long-range wakefields in the warm structures (NLC/JLC, CLIC) are suppressed using damped, detuned cells: Cells are fabricated with a range of dipole frequencies=>destructive interference. In addition, dipole modes are also damped.
- Long range wakefields at TESLA are suppressed using HOM dampers at the ends of the cavities.

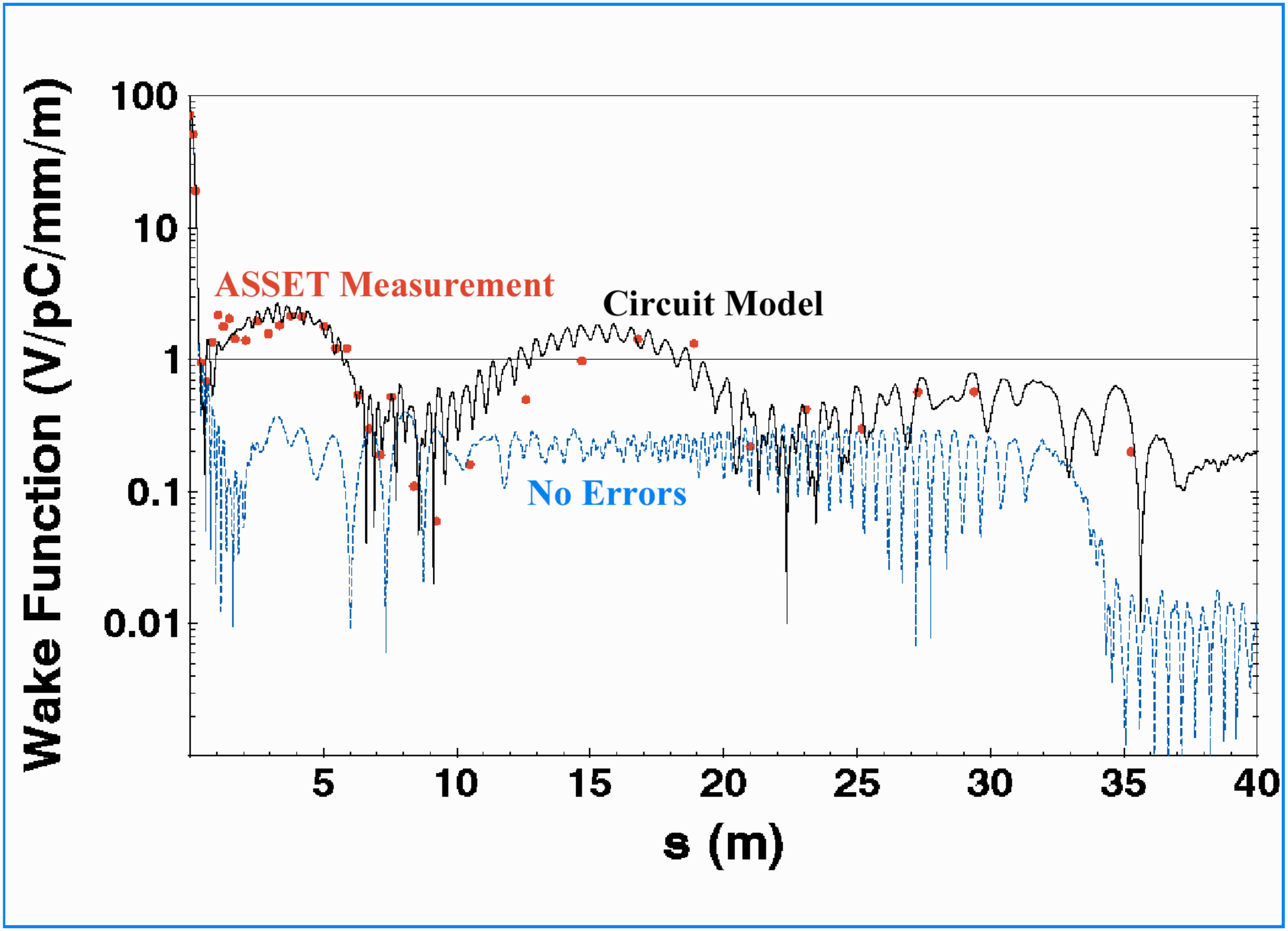
NLC/JLC Rounded Damped-Detuned Structure (RDDS)



- Made with Class 1 OFE copper.
- Cells are precision-machined (few μm tolerances) and diffusion-bonded to form structures.
- 1.8 m length chosen so fill time ~ attenuation time ~ 100 ns.
- Operated at 45 deg C with water cooling. RF losses are about 3 kW/m.
- RF ramped during fill to compensate beam loading (21%). In steady state, 50% of the 170 MW input power goes into the beam.



Two RDDS cells



RDDS1 NLC structure long range wakefield

Production errors / damage

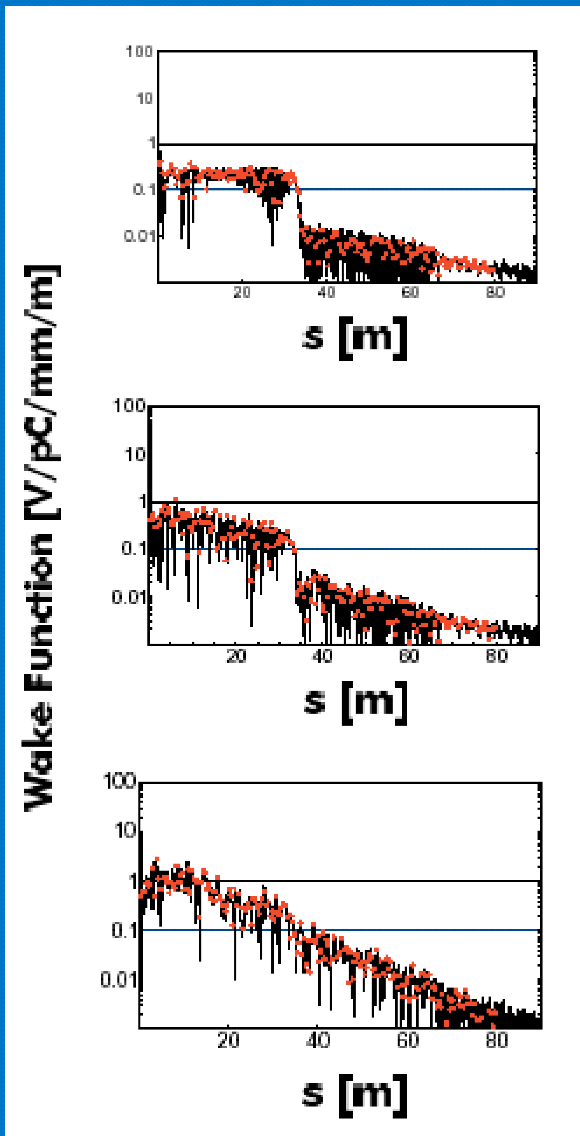
Envelope of wakefield:

(a) ideal

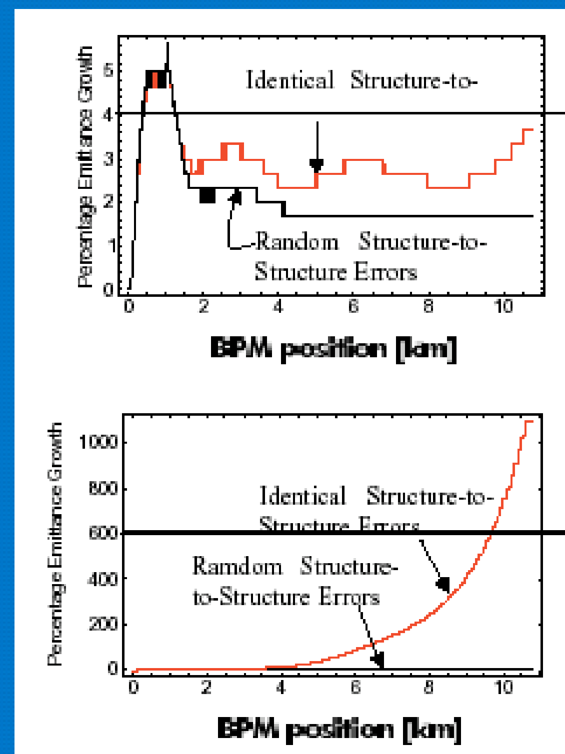
R. Jones et al, EPAC2000

(b) 2 MHz rms error

(c) 5 MHz rms error



Emittance growth:



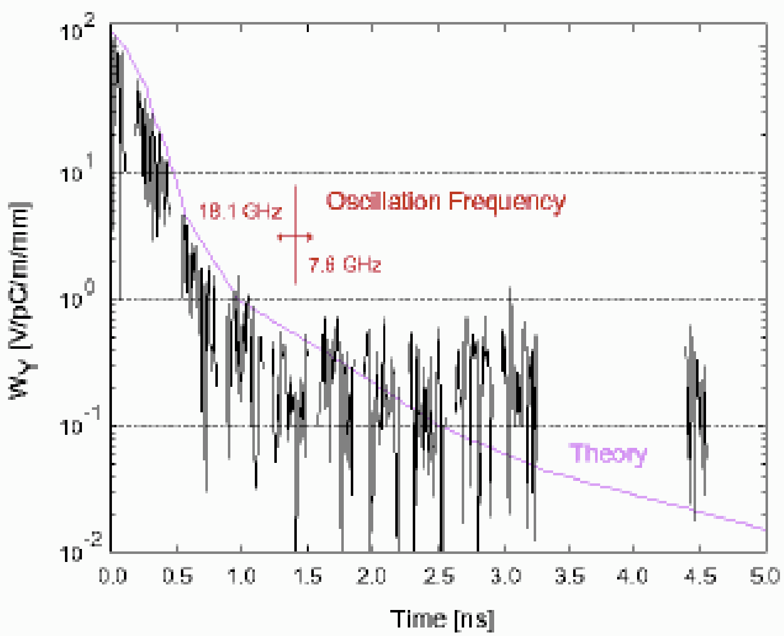
4%

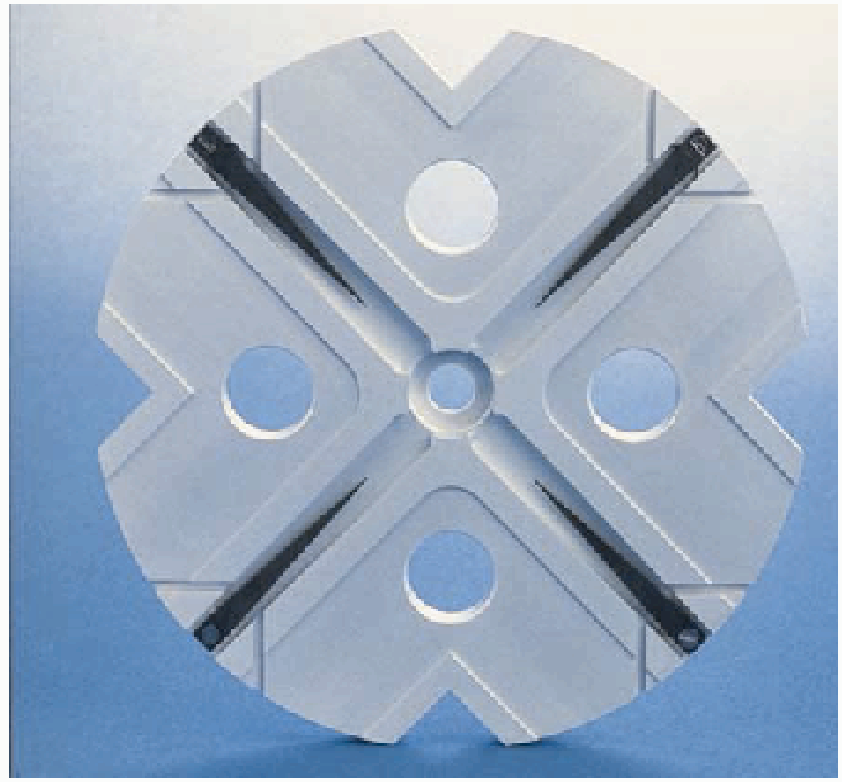
600%

TDS design and modeling

•Strong damping, moderate detuning

•Damping computed via double-band circuit model. Circuit elements determined from MAFIA frequency-domain calculations. Load modeled using HFSS.





ASSET demonstration of damping

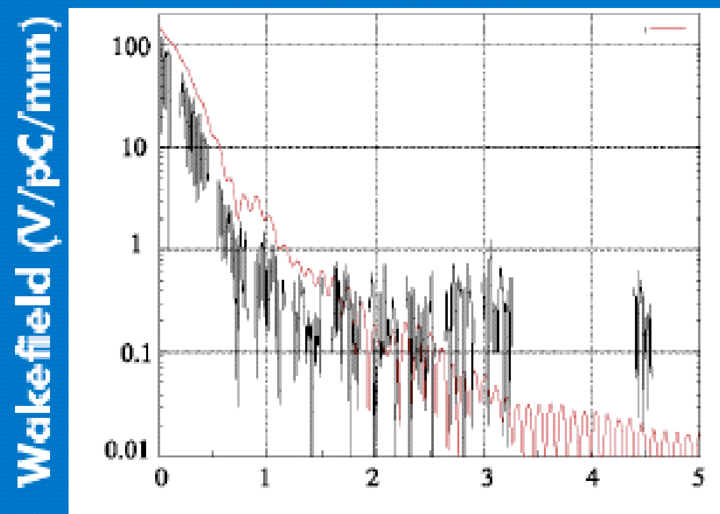
CLIC TDS structure

Long-range wakefields

Input: Calculations + ASSET tests. **Optimize design...**

CLIC structure:
(scaled to 15 GHz)

Measured (black) and calculated (red) transverse wakefield versus time [ns]

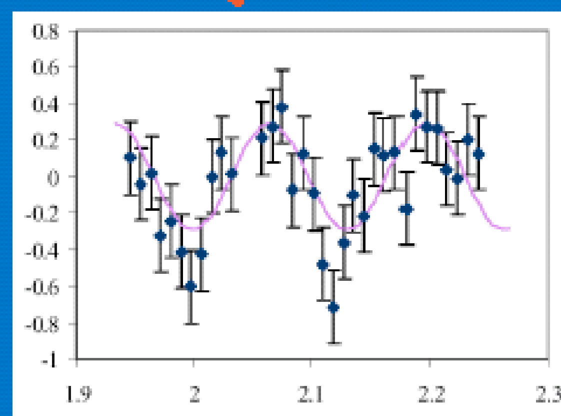


I. Wilson et al EPAC2000

Time [ns]

Very good agreement, except unexpected 7.6 GHz component

HFSS: vacuum chamber to beam pipe transition, not the structure itself



Time [ns]

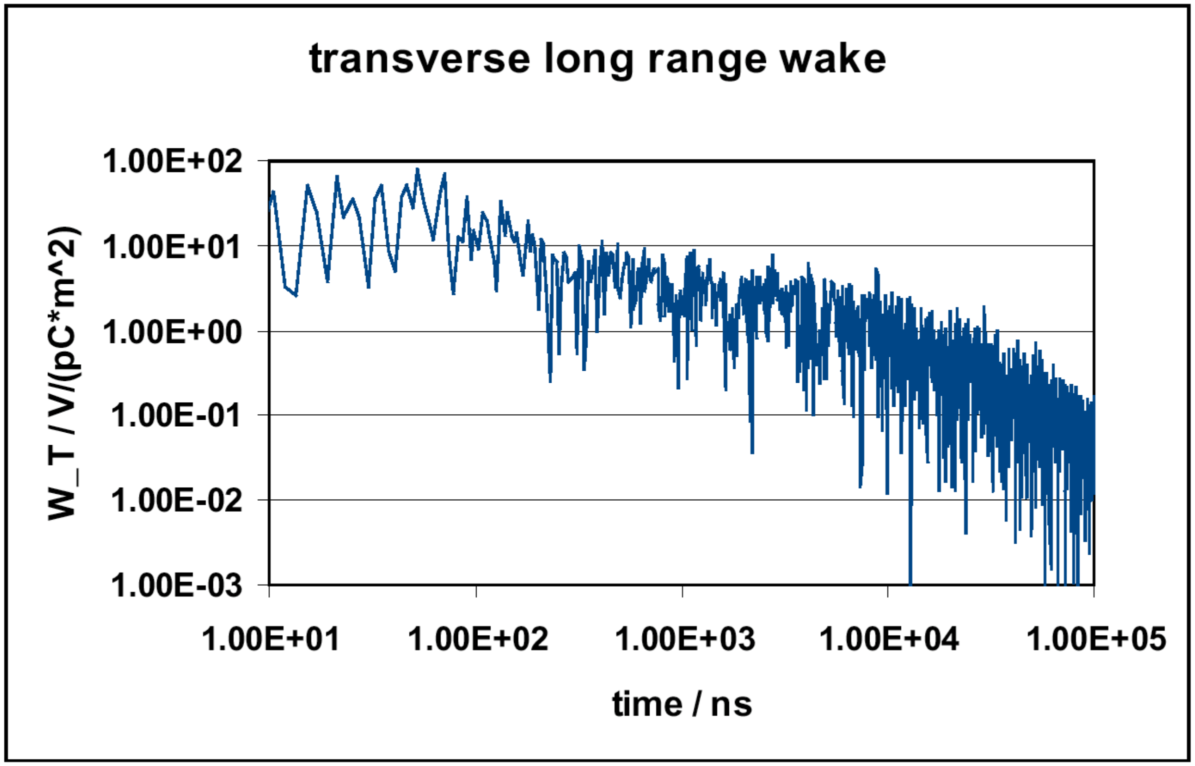


Figure 3.2.7: *Transverse long-range wake, calculated with the HOMs listed in table 3.2.2, and averaged over 36 cavities with a frequency spread of 0.1%.*

Long-range wakefield at TESLA

Multi-bunch in TESLA

HOM damping requirements for the TESLA super-structures

Worst result (10 cases)

Cavity misalign-ment 500 mm

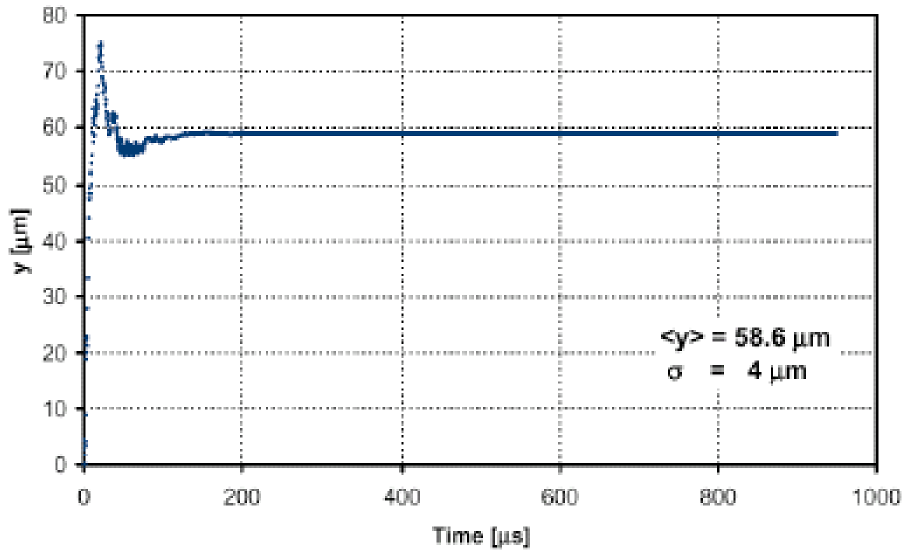
21.7 MV/m gradient

27 modes: Q = 2e5

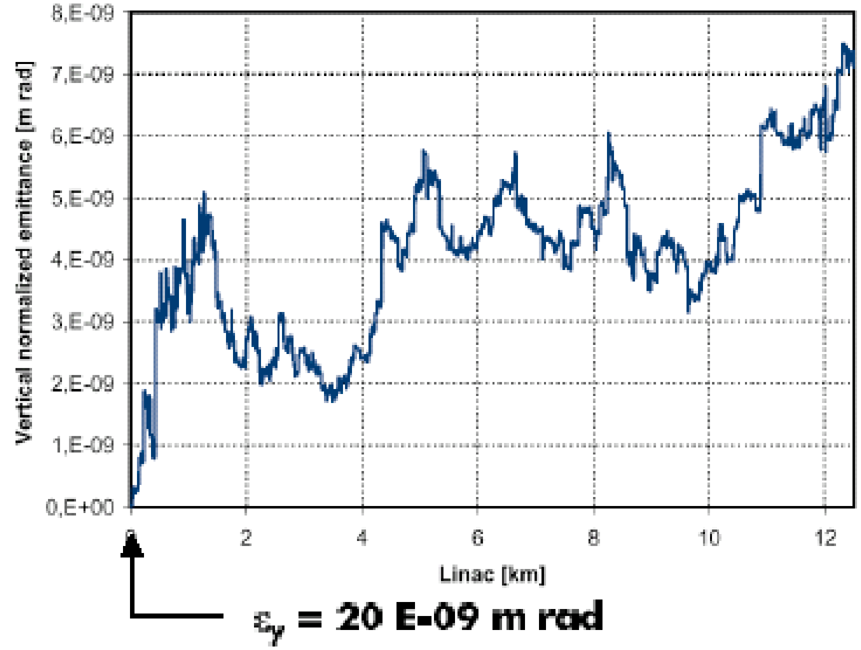
4 modes: Q = 1e5

N. Baboi et al EPAC2000

Measured HOM OK for TESLA…



Multi-bunch offsets at the end of the TESLA linac



Calculated multi-bunch emittance growth along the TESLA linac

Main linacs: beam dynamics Issues

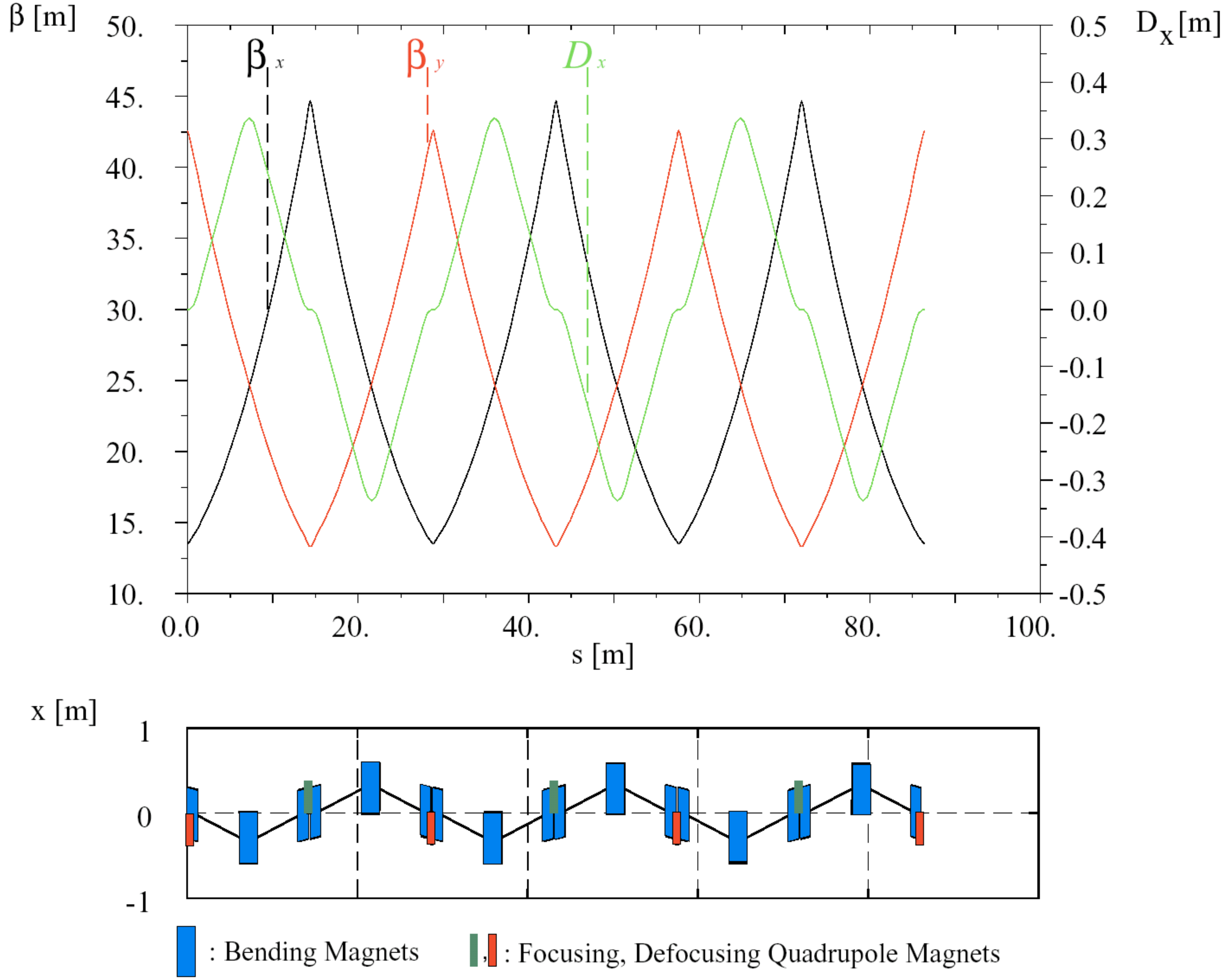
- Long range wakefield suppression in rf structures.
- Beam diagnostic device requirements for beam-based alignment.
- Tuning algorithms for beam-based alignment.
- Simulations-are they accurate and inclusive?
- Feedback system development.
- Vibration and beam jitter suppression.

Main linacs: bunch compressors

Parameter	**TESLA**	**NLC**	**CLIC**
First stage input energy (GeV)	5	1.98	2
First stage input bunch length (mm)	6	4	3
First stage length (m)	140	51	35
First stage RF frequency (GHz)	1.3	1.4	3
First stage RF voltage (MV)	890	139	103
First stage output bunch length (mm)	0.3	0.5	0.25
Second stage input energy (GeV)		8	9
Second stage length (m)		212	80
Second stage RF frequency (GHz)		11.4	30
Second stage RF voltage (MV)		583	1026
Second stage output bunch length (mm)		0.1	0.03

TESLA bunch compressor

- 3 TESLA rf modules are used to establish an energy-longitudinal position correlation in the bunch
- A 90 m wiggler section is used to establish an energy dependence to the path length, which, together with the energy-position correlation, compresses the bunch length (by a factor of 20).
- Energy spread reaches 3% in the wiggler



β [m]
50.
45.
40.
35.
30.
25.
20.
15.
10.
βx
βy
Dx
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
Dx [m]
0.0
20.
40.
60.
80.
100.
s [m]
x [m]
1
0
-1
: Bending Magnets
, : Focusing, Defocusing Quadrupole Magnets

NLC/JLC bunch compressor

- A two stage system-first stage compression by a factor of 8, second stage a factor of 5.
- The stages are separated by a 6 GeV linac.
- The design decouples multibunch phase errors generated in the damping ring from energy variations at the final focus.
- Two-stage design limits energy spread to less than 2%.

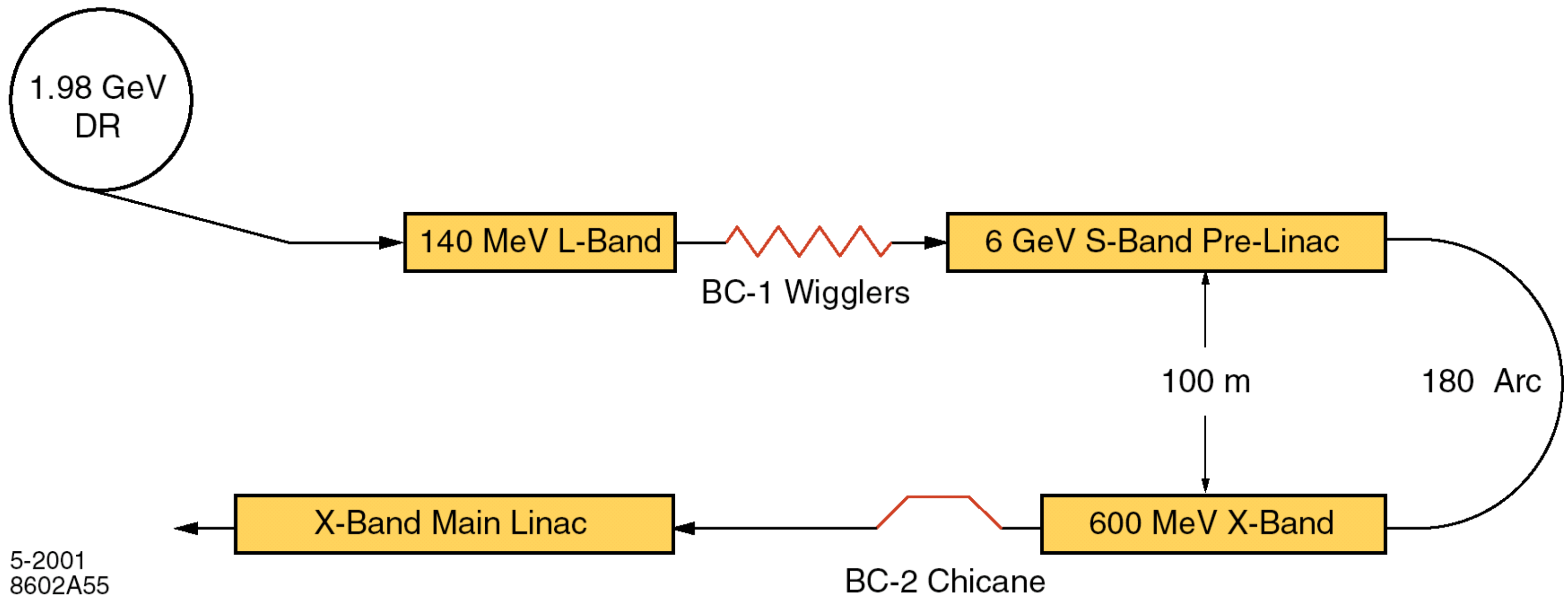
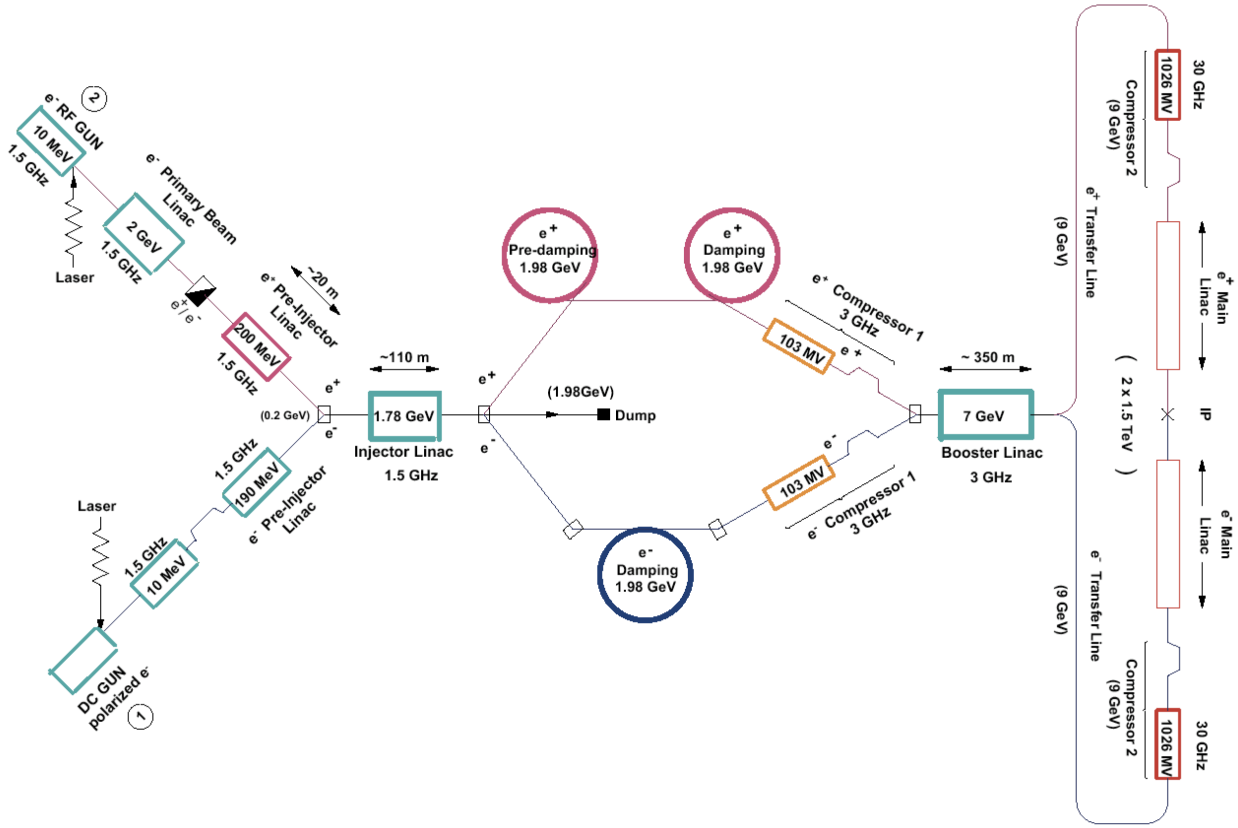


Figure 5.7: The NLC two-stage bunch length compression system. The first stage of compression consists of an L-band rf section followed by a dipole wiggler, operating and 1.98- GeV. The second stage of compression includes the 6-GeV prelinac, 180° turn-around arc, a 600-MeV X-band rf section and a dipole chicane. Beam diagnostics are included to permit full tune-up and control.

CLIC bunch compressor

- A two stage system-first stage compresses by 12, second stage by 8.
- Stages are separated by a 7 GeV linac.
- Two stage system limits energy spread to less than 2%.



CLIC INJECTOR COMPLEX FOR THE e+ and e- MAIN BEAMS

February 2001

Figure 2: CLIC injector complex for the e^+ and e^- main beams.

Bunch compressors-issues

- Emittance growth in the bunch compressors can result from
  - Chromatic aberrations in the dispersive elements
  - Coherent and incoherent synchrotron radiation.
    - CSR will produce a correlation between longitudinal position and transverse position, similar to the effect of short-range wakefields.