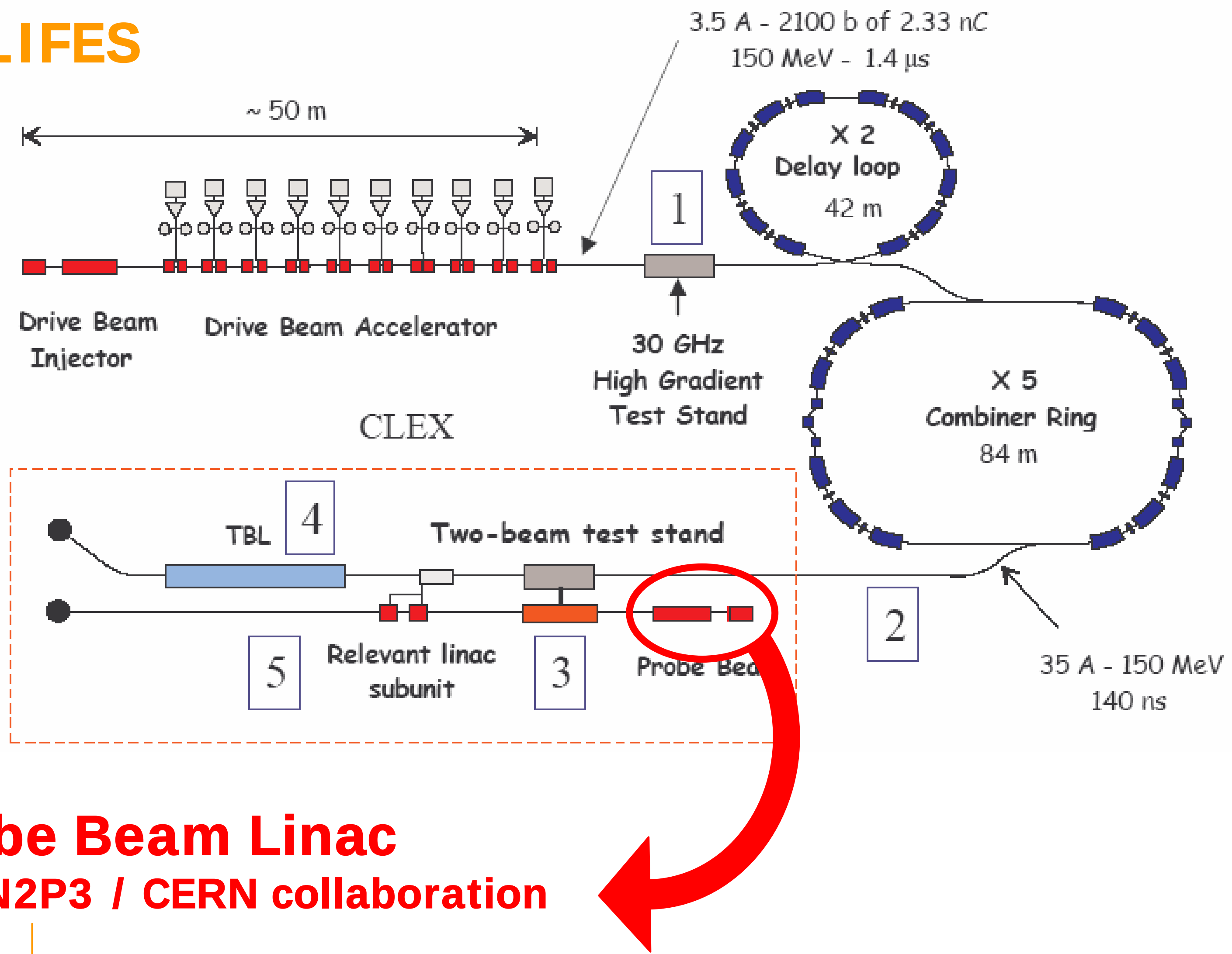
CALIFES



Probe Beam Linac

DAPNIA / IN2P3 / CERN collaboration

↓

rf-gun

Probe Beam Linac Parameters

- GOAL : to mimic the main beam in order to measure precisely the performances of the CLIC 30 GHz structures
- Installation in 2007 and Commissioning in 2008

Parameters		Motivation
Energy	~ 200 MeV	Avoid beam disruption in high RF fields
norm. rms Emittance	< 20 π mm mrad	Fit in 30 GHz structure acceptance
Energy spread	< ± 2%	Measurement resolution
Bunch charge Bunch spacing	0.5 nC 0.333 ns	~ CLIC parameters
Number of bunches	1 – 64	Measure 30 GHz structure transients
rms bunchlength	< 0.75 ps	Acceleration with 30 GHz

multibunch operation : high beam current

Q_b=0.5 nC and F_b=3GHz $\Rightarrow$ Io = 1.5 A

generation of bunches :

- **RF photo gun**

better emittance and more flexibility in time structure

acceleration :

- **re-use of LIL sections** but high beam-loading

$\Delta E/E \sim 10\%$ after 20 ns (64 bunches) for 1.5 A

bunch compression :

- **magnetic chicane** : doesn't work for multibunch mode

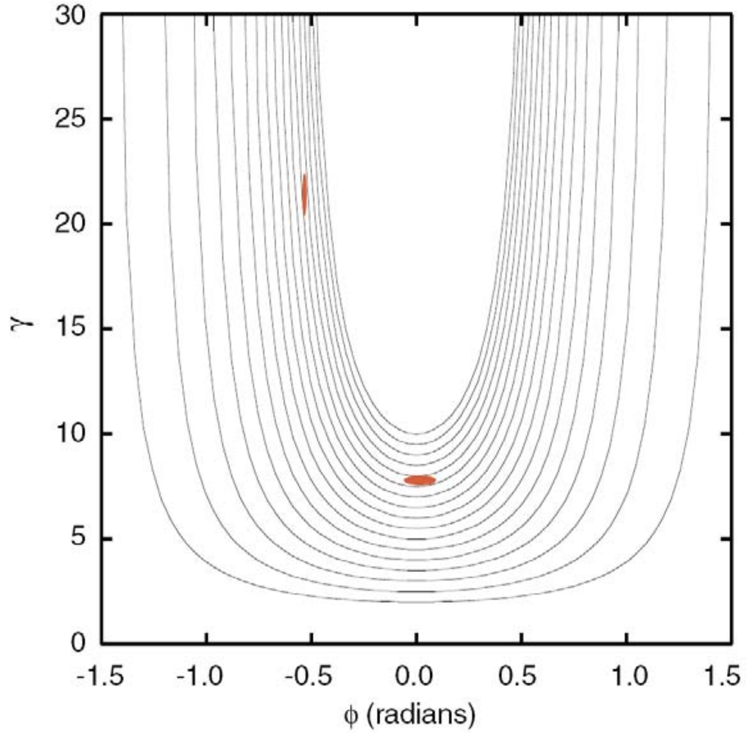
the required R_{56} correlation term for single bunch rotation
will introduce a large phase-shift between 1st and last bunch

(ex. R_{56} = 0.05 m $\Rightarrow \Delta\varphi=180°$!!! at 30 GHz)

- **velocity bunching :** 3 LIL sections are required

1 for compression and 2 for acceleration

Velocity bunching

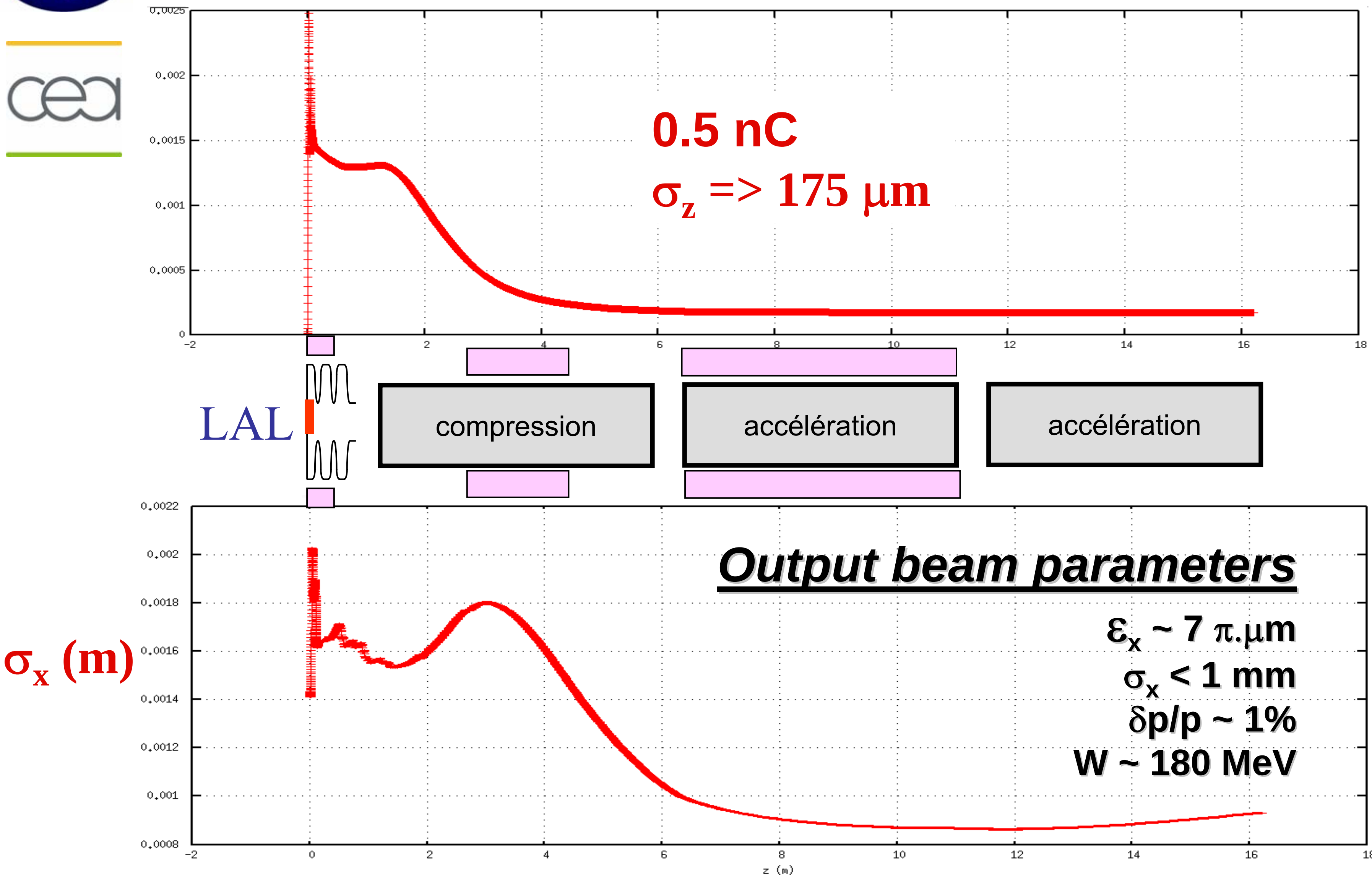


$$\Delta\phi_\infty = \frac{\sin\phi_0}{\sin\phi_\infty}\Delta\phi_0 + \frac{1}{2\alpha\gamma_0^2\sin\phi_\infty}\Delta\gamma_0 + \frac{1}{2}\left[\frac{\cos\phi_0}{\sin\phi_\infty} - \frac{\cos\phi_\infty\sin^2\phi_0}{\sin^3\phi_\infty}\right](\Delta\phi_0)^2$$

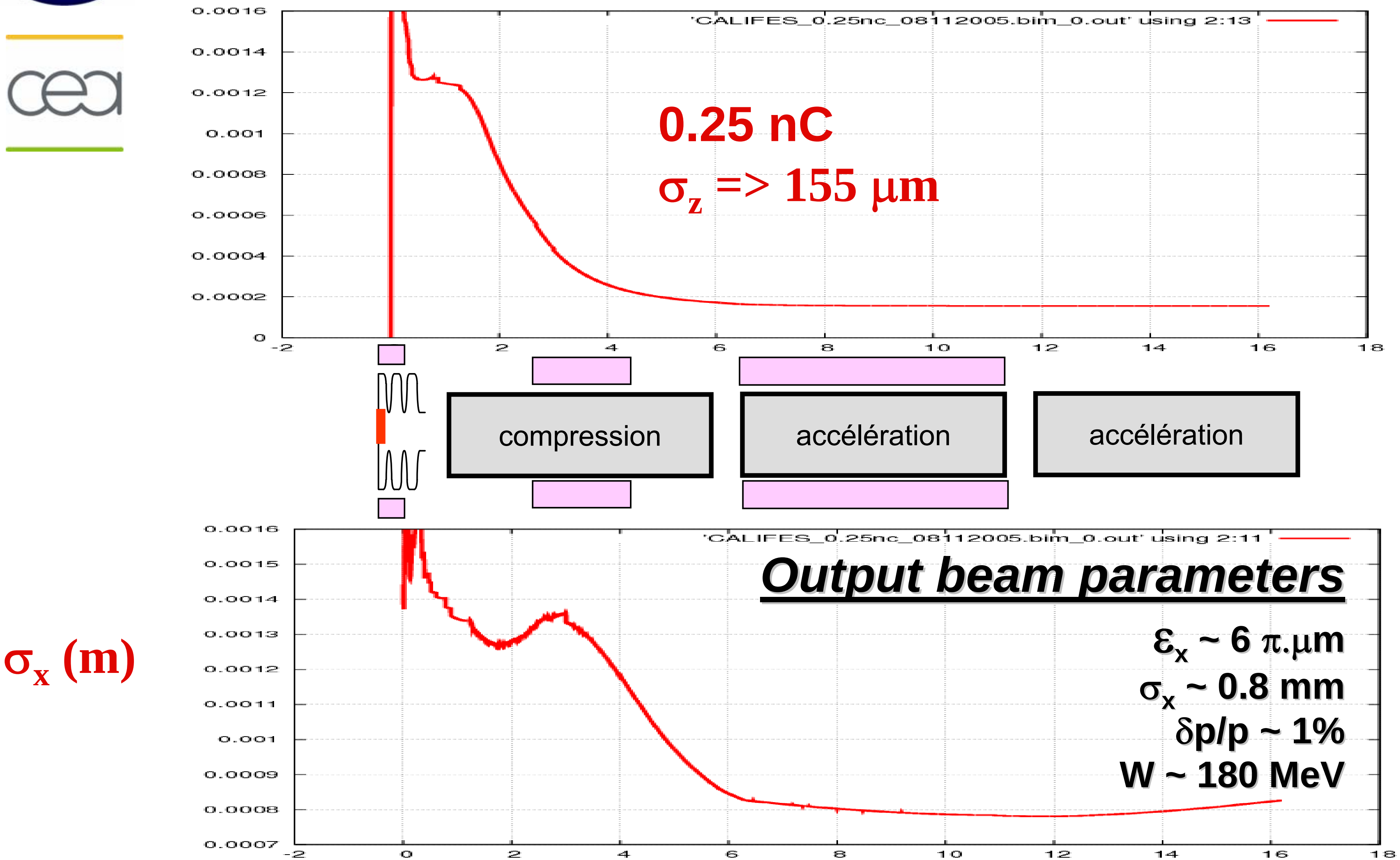
bunchlength after compression dominated by

- initial energy spread and
- space charge

Velocity bunching (single bunch results)



Velocity bunching (single bunch results)



Effect of beam-loading

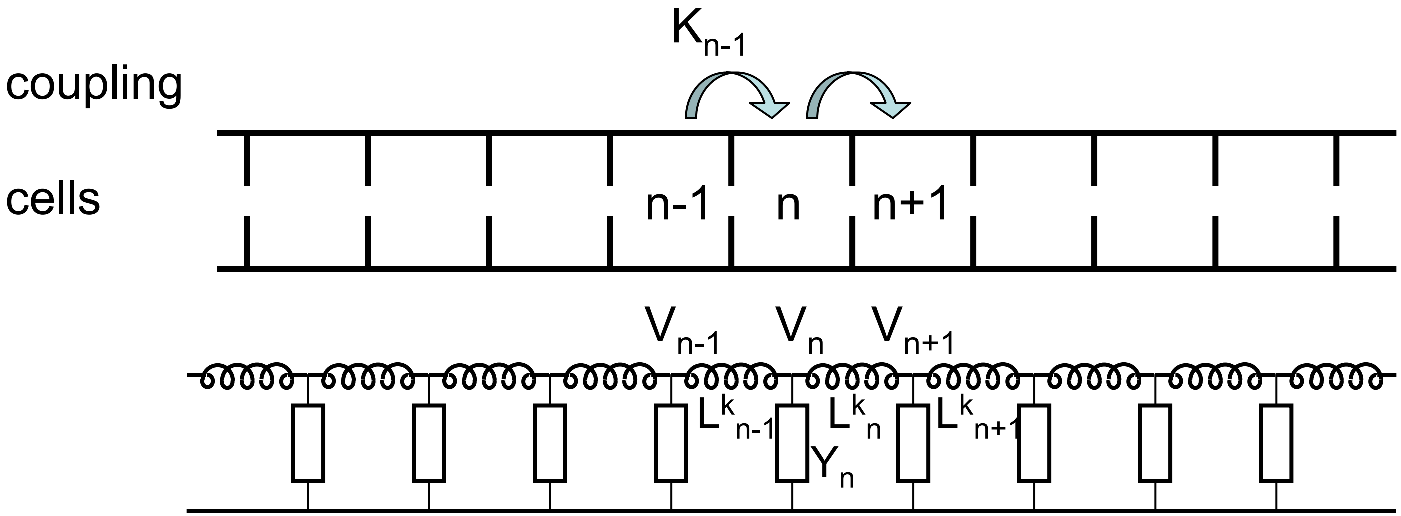
LIL section = quasi-constant gradient structure

9 constant impedance families linked by 4 linearly tapered transition cells

⇒ Transient calculations for field set up and beam loading

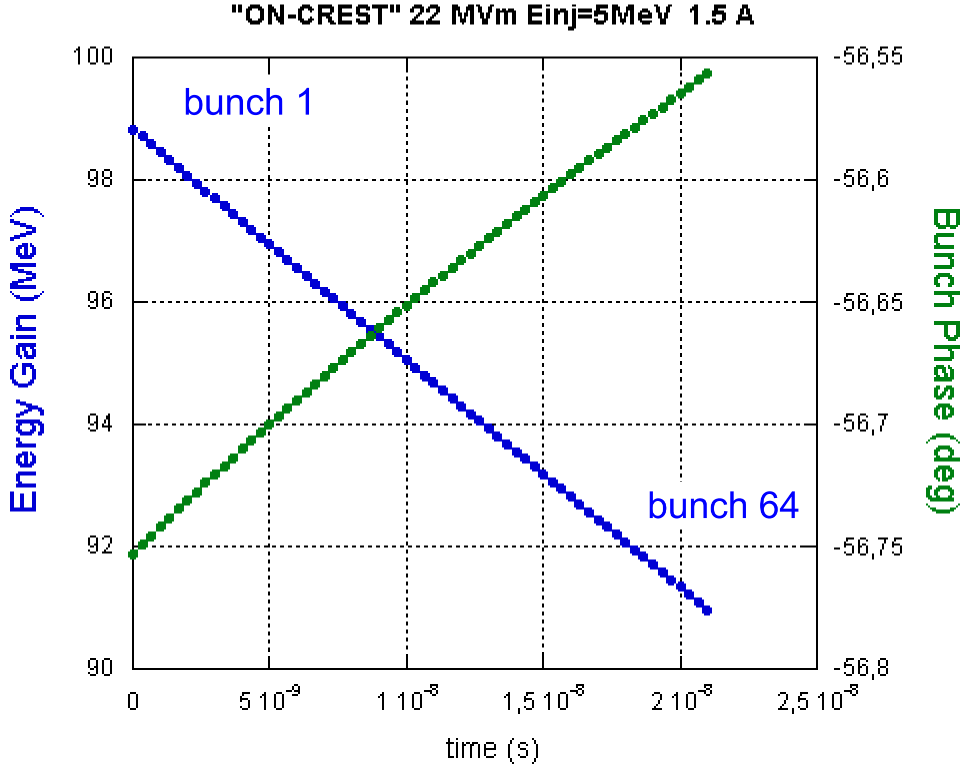
Analysis using the coupled-resonator model

- any accelerating structure (CI, CG, quasi-constant, etc)
- space harmonics included
- dispersive effects included (section = passband filter)
- any waveform of input *rf* pulse
- beam interaction : propagation of the induced waves with dispersive effects



Beam-loading « on crest » acceleration

64 bunches Q_b=0.5 nC F_b=3 GHz $\Rightarrow$ 1.5 A



Phase and energy deviation :

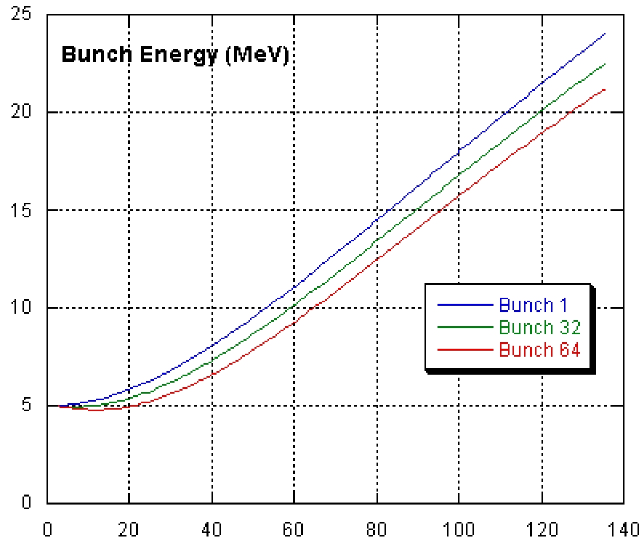
ΔE = 8.87 MeV

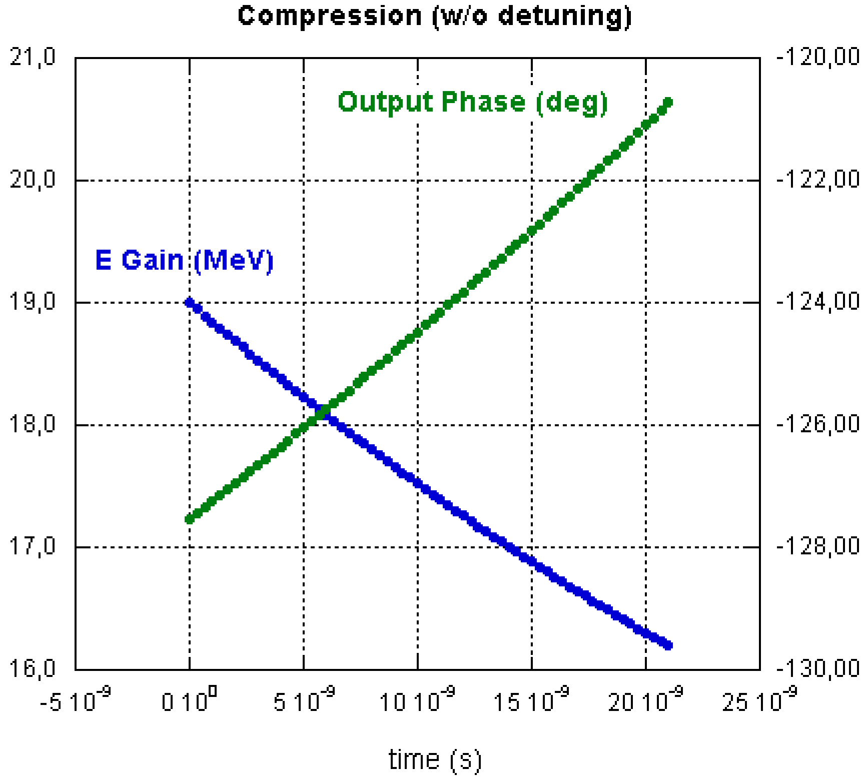
$\Delta\phi$ = 0.2° @ 3GHz

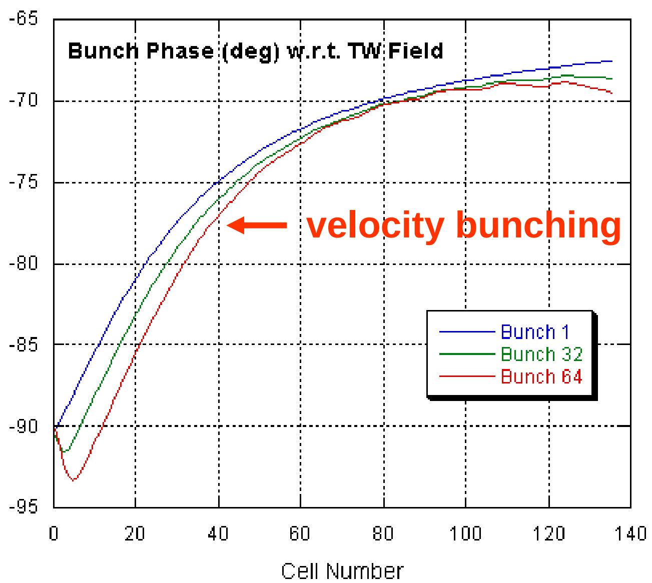
$\Rightarrow$ 2° @ 30GHz

For the whole linac => $\delta p/p$ ~ 11% !!

compression : « off-crest » beam-loading
⇒ energy drop + large phase shift







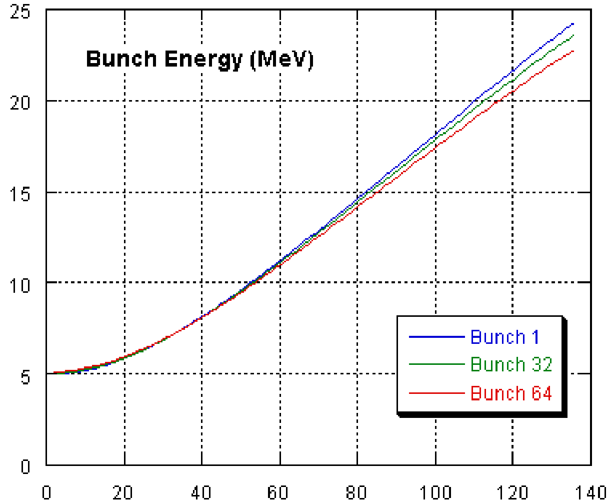
Energy and Phase deviations :

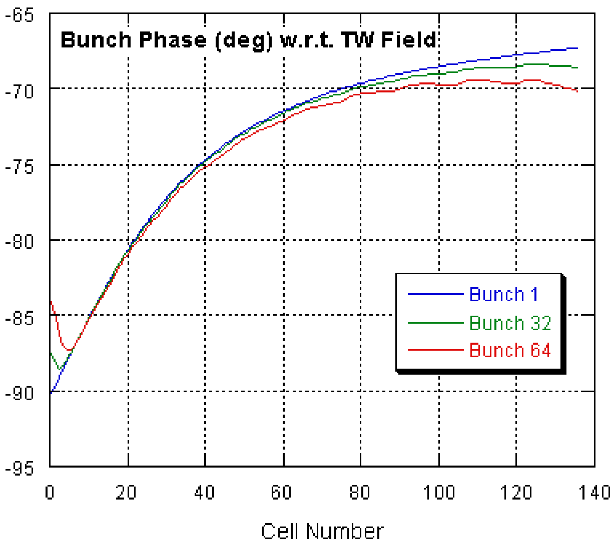
$\Delta E = 2.8$ MeV $\Delta\phi = 6.8°$ @3GHz ⇒ 68° @30GHz

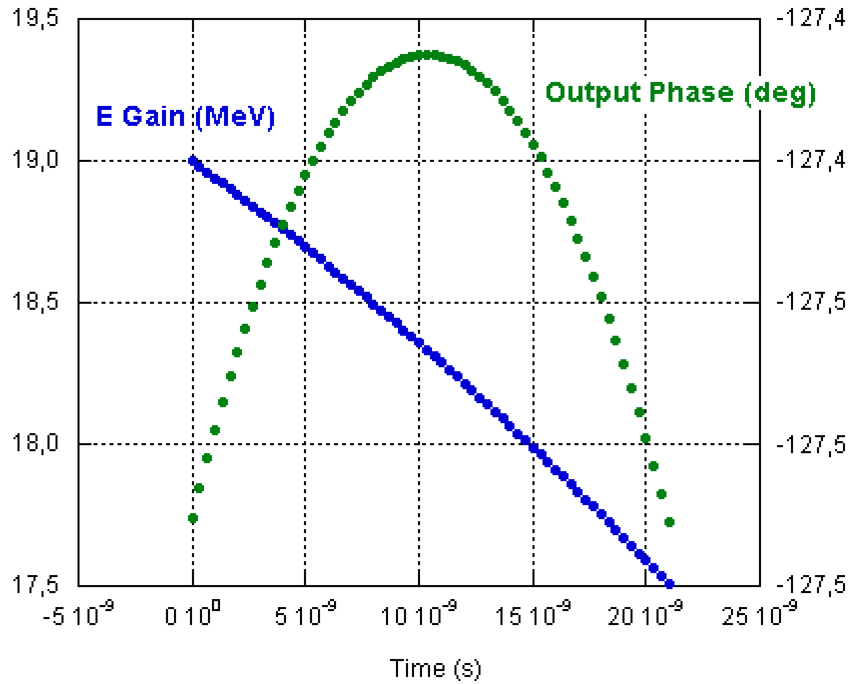
1st compensation method

section detuning to compensate the phase shift ΔF = + 0.789 MHz
extra cooling required ~ 15°

$\Delta\phi_b = \Delta\omega\, T$ = 6° between 1st and last bunch







Energy and Phase deviations :

ΔE = 1.5 MeV $\Delta\phi$ = 0.07° @3GHz $\Rightarrow$ 0.7° @30GHz

2nd compensation method

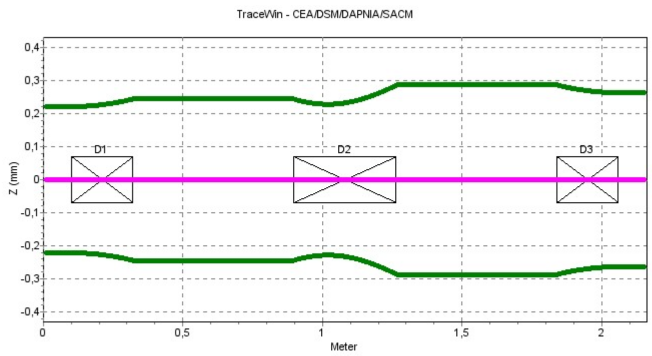
magnetic chicane to compensate the multi-bunch phase-shift without altering the single-bunch characteristics

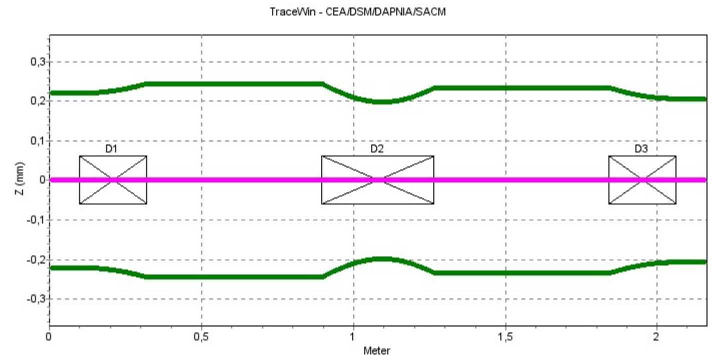
$$\Delta\phi = R_{56}\,\frac{\Delta E}{E}\,\frac{2\pi}{\lambda}$$

for 0.5 nC	~6°	10%	⇒ R_{56} = 0.017 m
for 0.25 nC			⇒ R56 =0.014 m

The compact CTF2 chicane (length ~ 2m) with R_{56} from 6 to 90 mm is a good candidate to perform this compensation

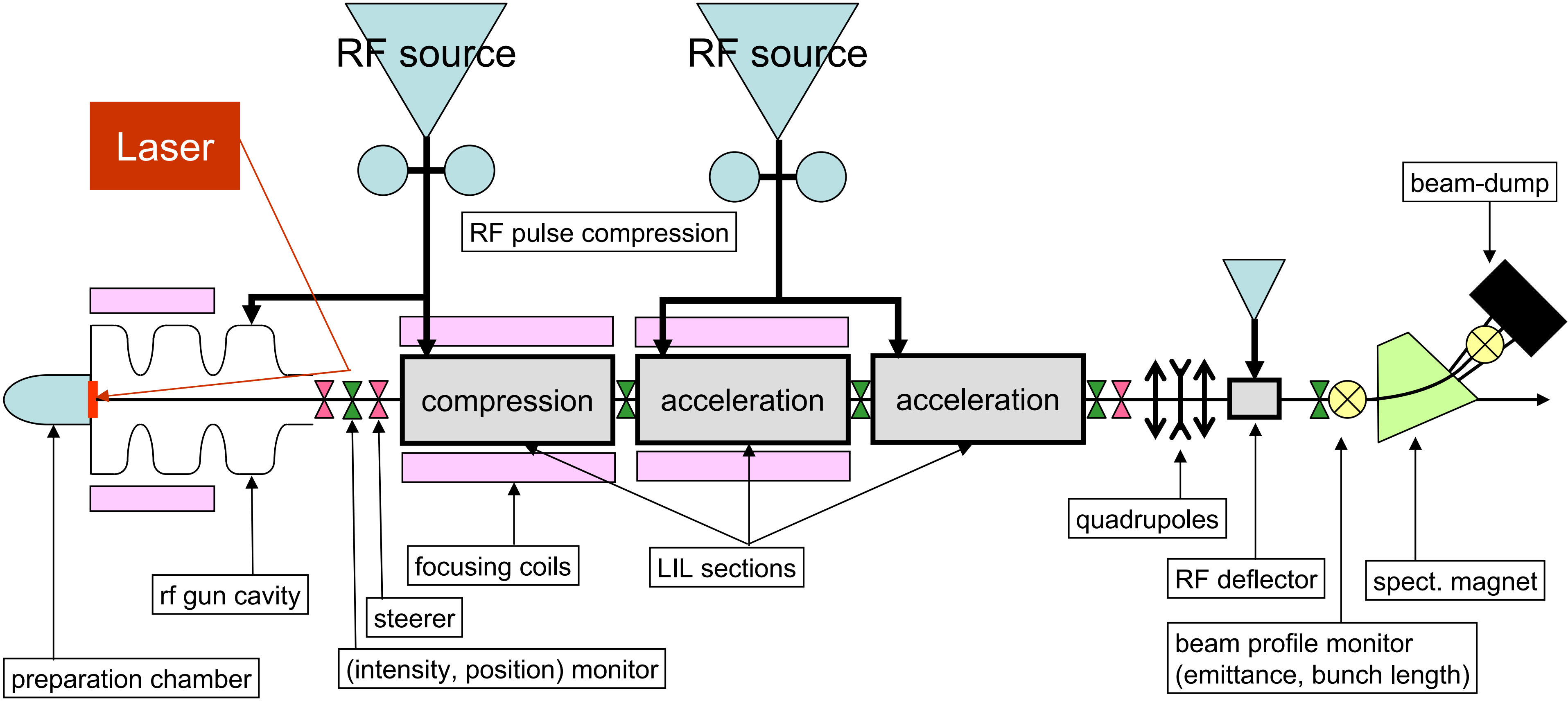
<u>single-bunch</u> : slight increase of the bunchlength
can be canceled by a small correlation term ~ 1.5° RF phase shift





Initial linac scheme

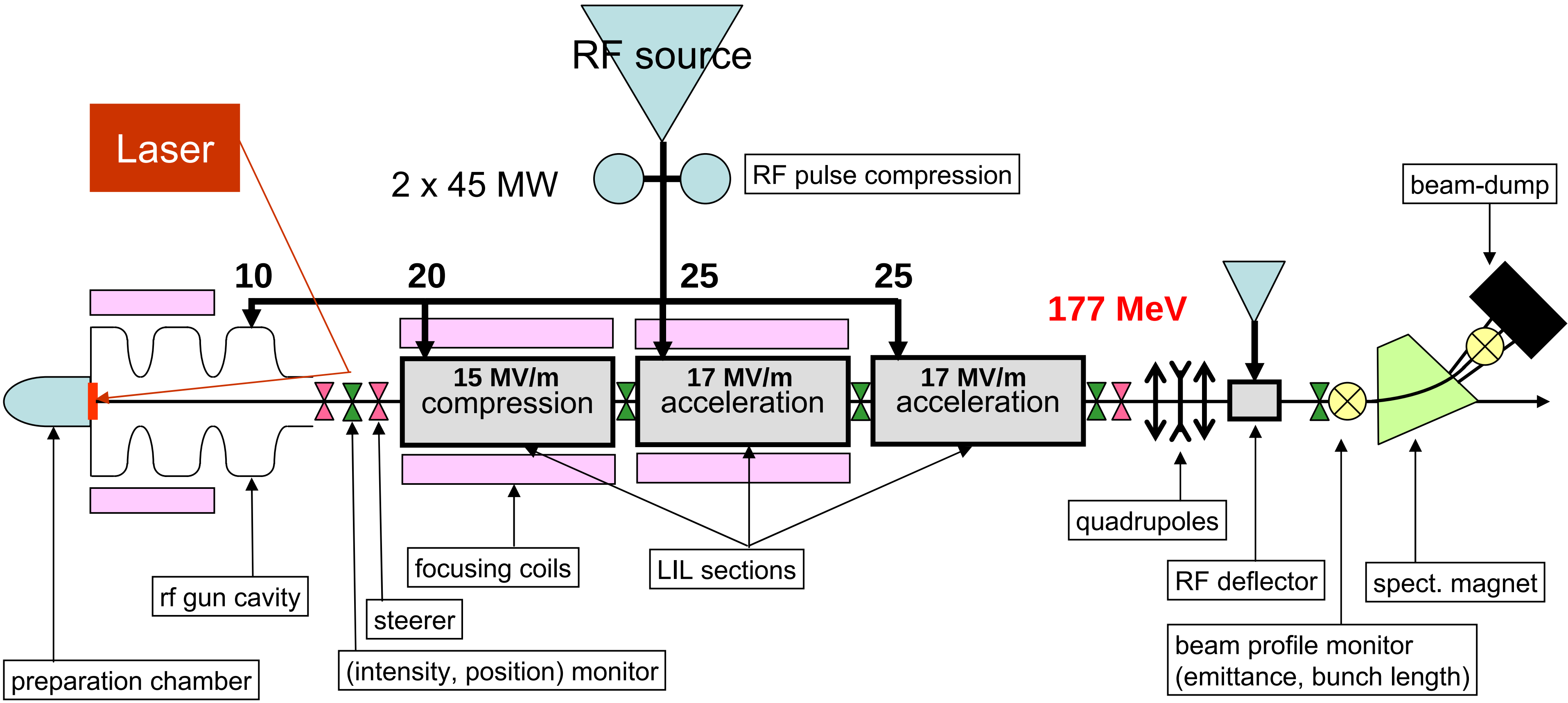
RF photo gun with 0.5 nC bunch charge (Q.E. ~ 1%)
1 compression LIL section + 2 acceleration LIL sections
2 RF sources



Slight De-Rating

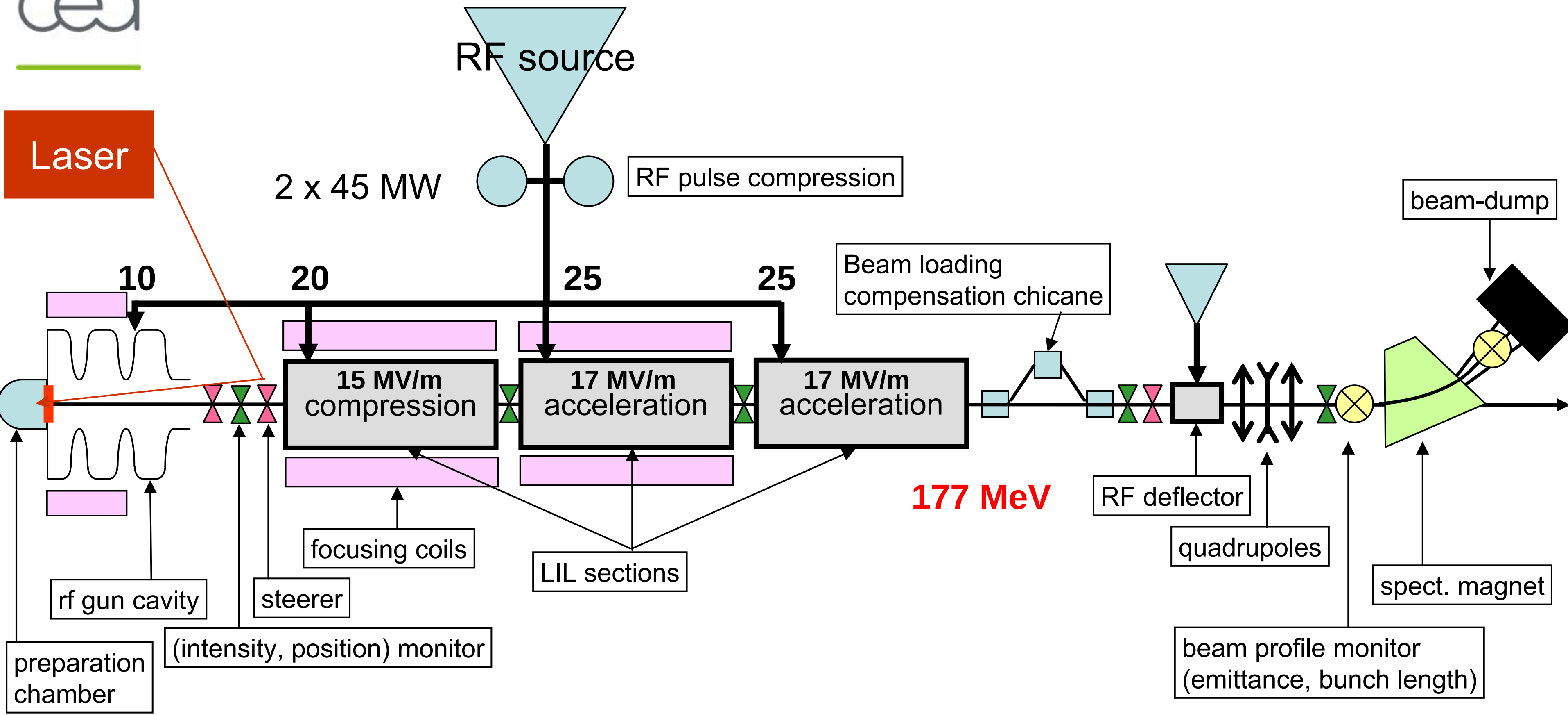
while keeping the main objective main changes :

- in-situ photocathode prep chamber ⇒ Q.E. degraded ⇒ Q_b ~ 0.25 nC
- 1 single RF source



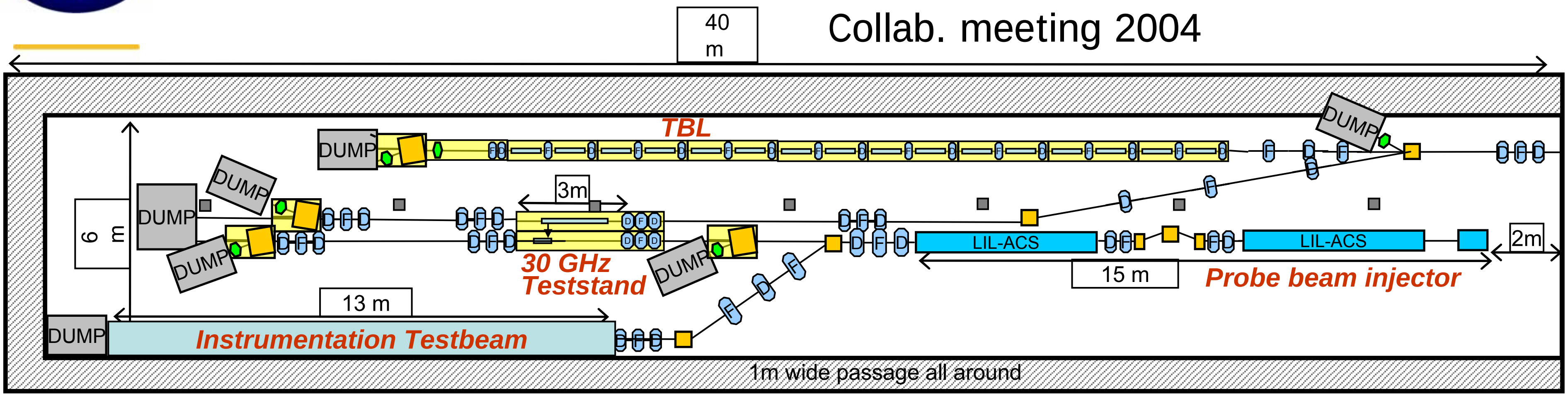
with magnetic chicane

reference scheme

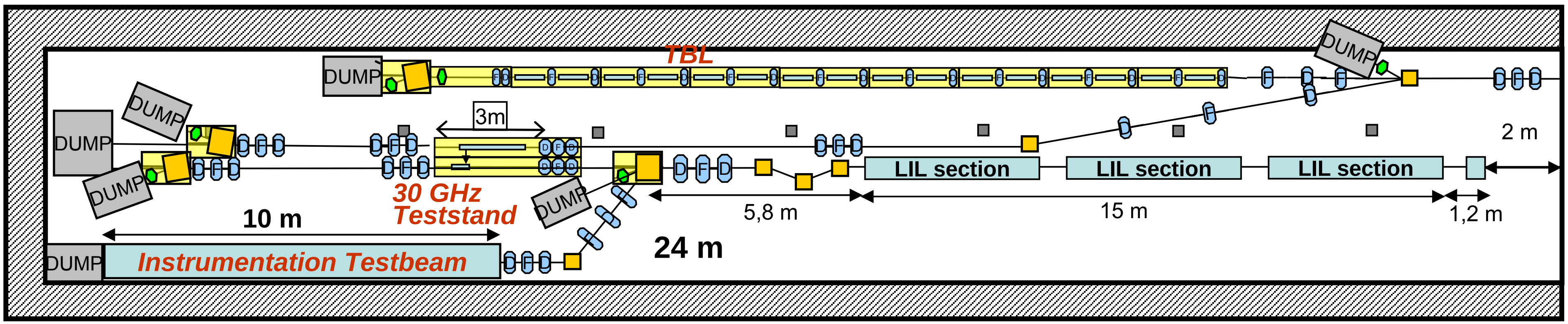


Lay-out in CLEX

Collab. meeting 2004



3 LIL sections + « multibunch » chicane



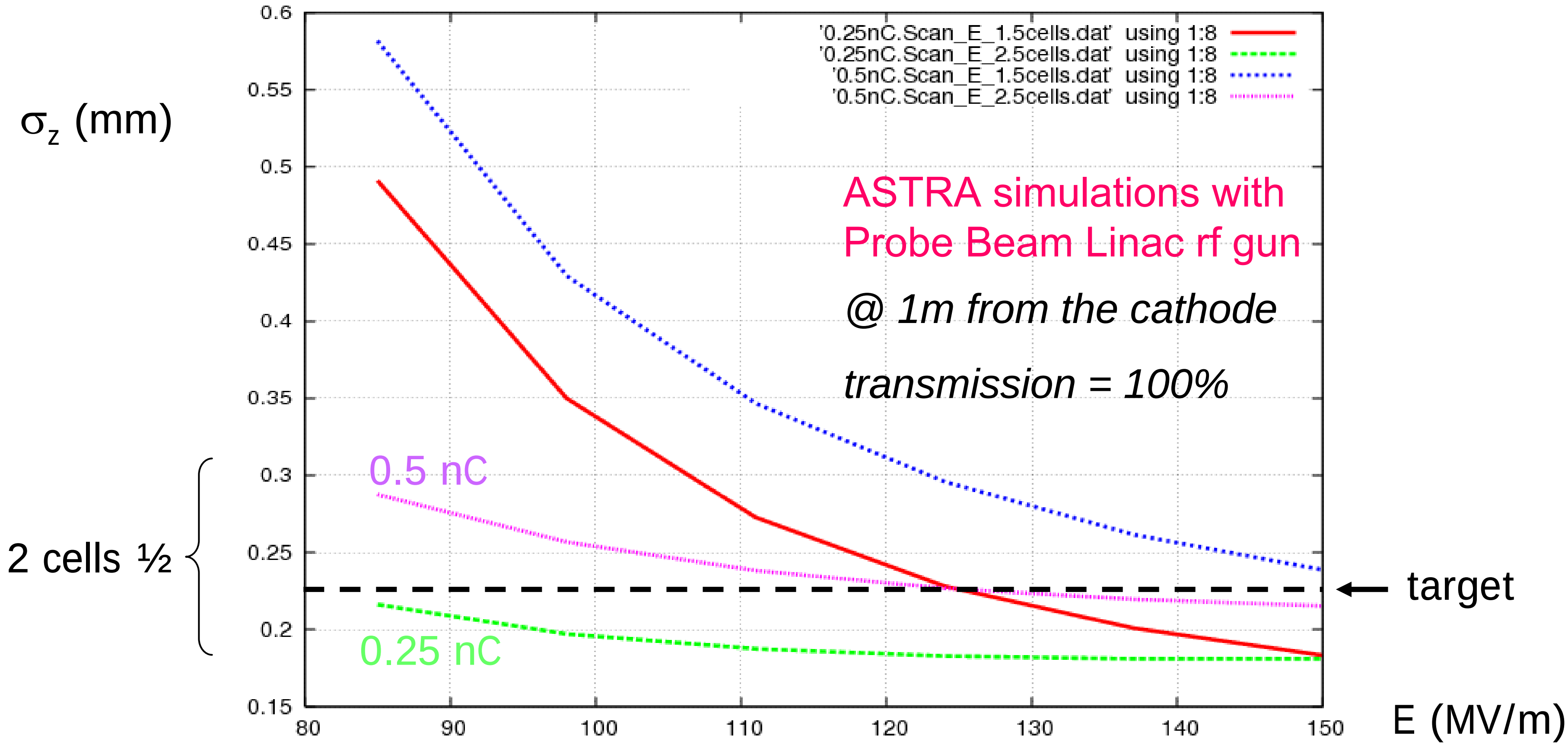
total length ~24 m from left wall

⇒ 2-branch dipole, Instrumentation Test Beam ~10 m

Alternative scheme to save space

Theoretically & experimentally, it has been shown that for low charge <1 nC **bunch compression can take place in a photocathode rf gun** when rf gun phase → -90° (zero crossing)

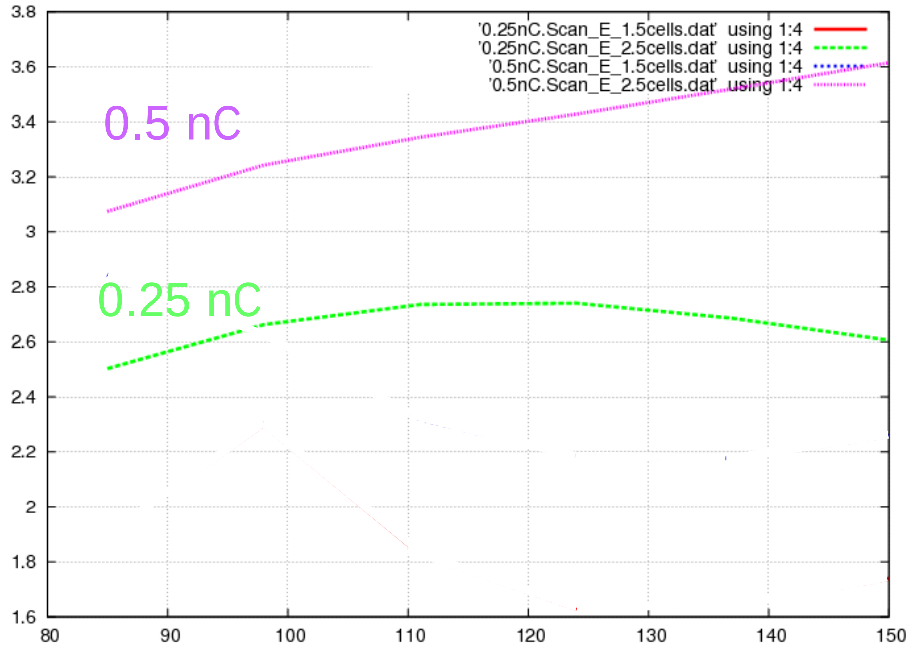
"Experimental observation of high-brigthness microbunching in a photocathode rf e gun" X.J. Wang, X. Qiu, I. Ben-Zvi PRE, vol.54 (oct. 1996)



RF gun compression option

ε_x (μm.rad)

transverse emittance is OK



Conclusion :

to further decrease the bunchlength down to 225 μm at 0.5 nC

⇒ increase field (85 → 120 MV/m)

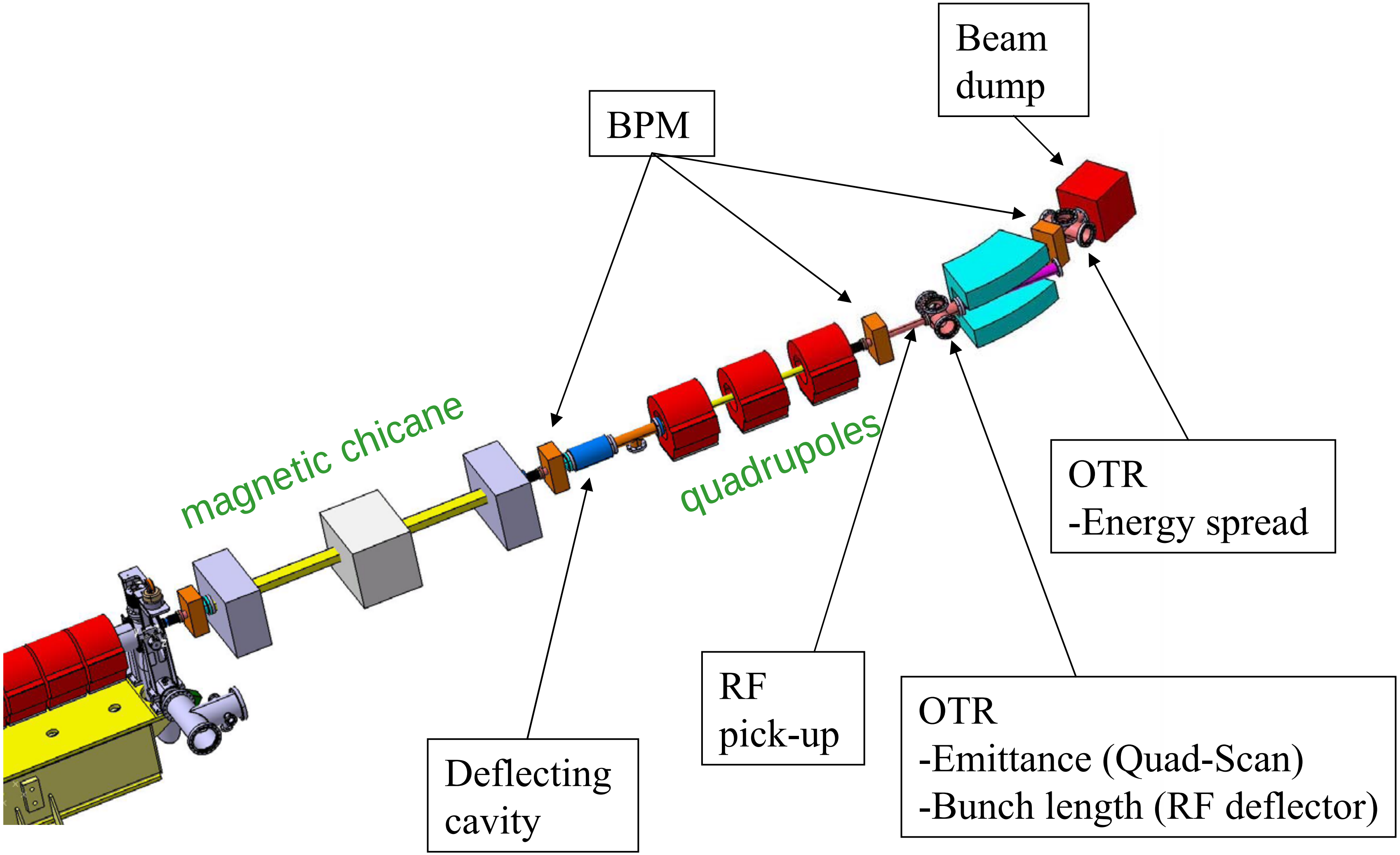
⇒ and/or go closer to zero-crossing but transmission < 100%

the rf gun compression option can save

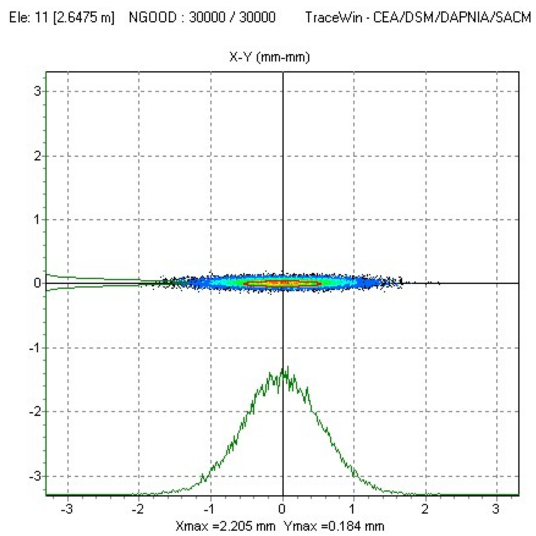
1 LIL section and magnetic chicane ~ 7 m

it is worth checking carefully ...

Diagnostics Beam Line

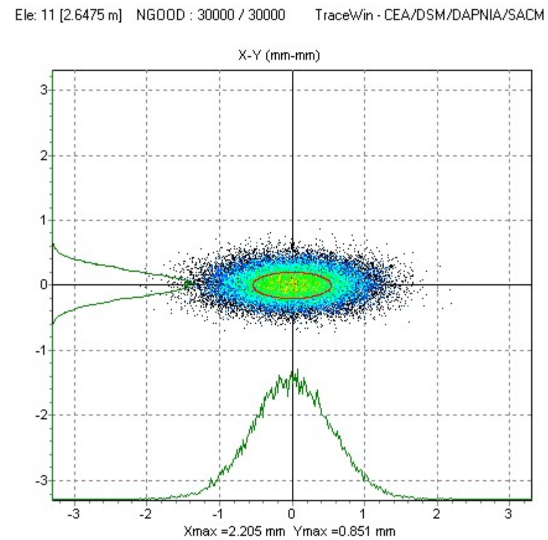


Bunch length measurement



Cavity OFF

$\sigma_{y\ OFF} = 0.04$ mm



Cavity ON

$\sigma_{y\ ON} = 0.20$ mm

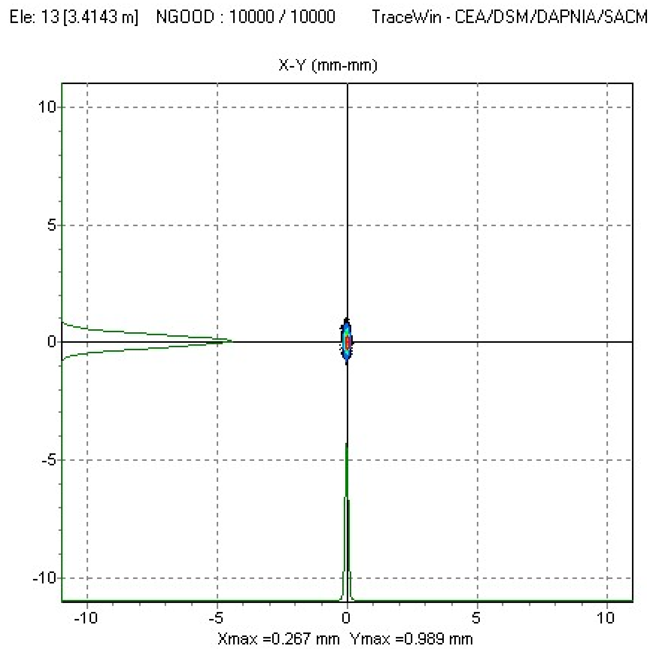
- Vertical deflection at zero crossing
- Input power 7 MW→ U=1.55 MV/m
- Beam energy E=177 MeV
- Bunch Length σ_z=0.225 mm (rms)
- R_{12} = 1.6 m (from cavity to screen)

$$\sigma_{BL} = \sqrt{\sigma_{ON}^2 - \sigma_{OFF}^2} = 0.197mm$$

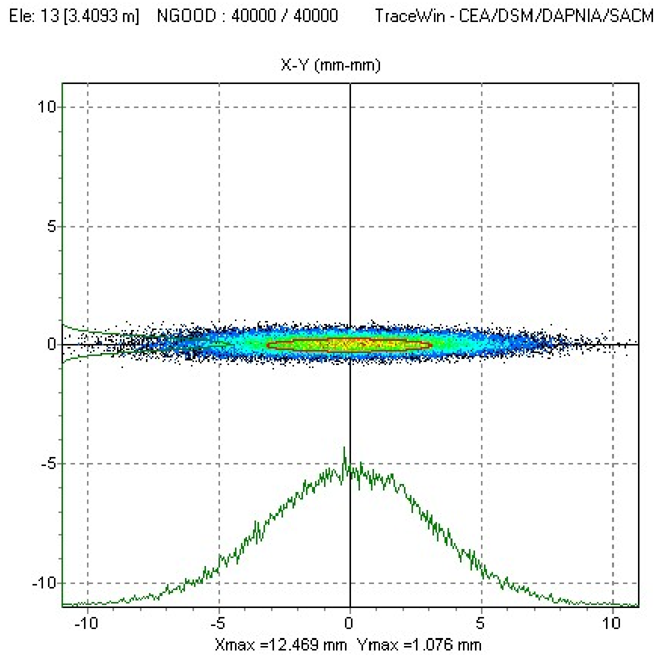
$$\sigma_{BL} = R_{12} \cdot \frac{U}{E} 2\pi \frac{\sigma_z}{\lambda} \longrightarrow \sigma_z = 0.223mm$$

RF deflector
powered by a klystron of DB Linac

Energy spread measurement



β - emittance

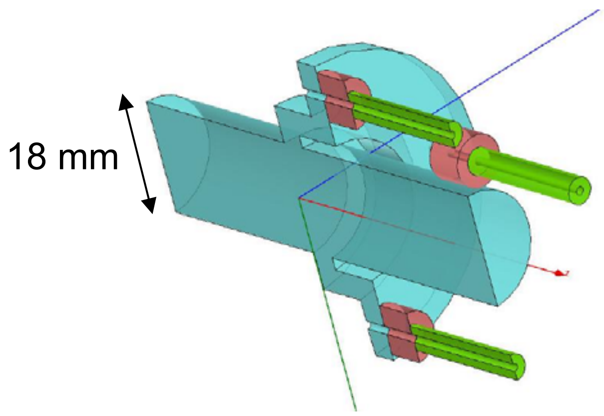


with energy spread $\sigma_E/E = 1\%$

- assuming spectrometer $\alpha \approx 30°$, $\rho \approx 1$ m
- synchrotron light on the OTR $\Rightarrow$ C-foil shielding (as proved on CT line)
- Time resolution with bandwidth > 250 MHz requires new ADC cards

Specifications : single bunch & multi-bunch operation (1-64 @ 3 GHz) 0.5 nC

- reentrant cavity original design from *R. Bossard (CERN)*
- proposed and developed for TTF (*M. Luong, C. Simon - DAPNIA)*



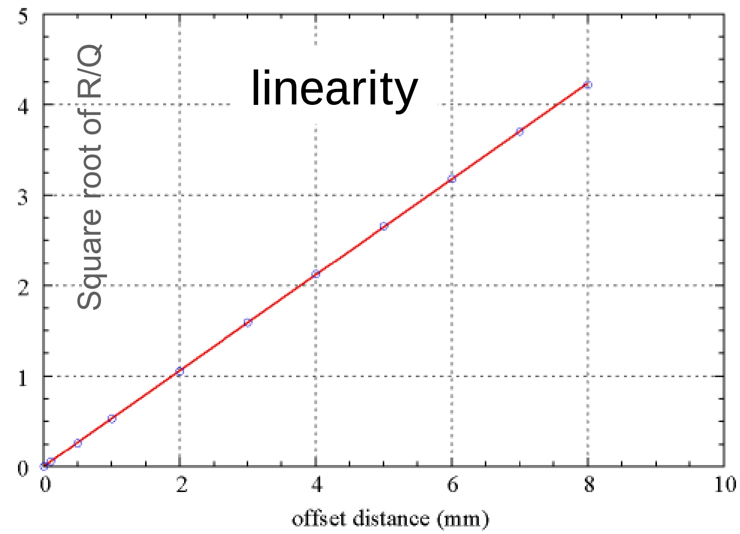
HFSS model
blue : vacuum
red : alumina
green : PTFE

new design for CALIFES:

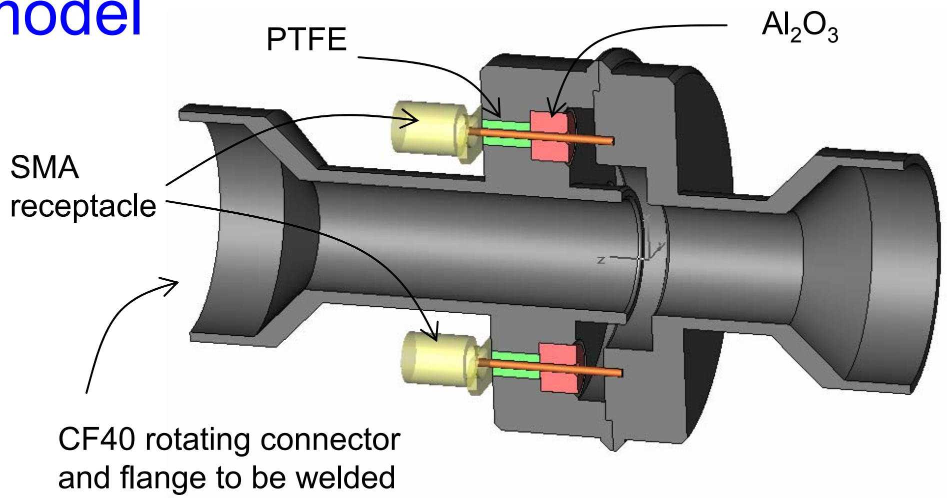
- higher dipole frequency with larger frequency separation between monopole and dipole modes
- low exposition of coupling loops to electric fields

mode	F (GHz)	Q	R/Q
monopole	3.85	24	22.3 (on axis)
dipole	5.94	43	1.1 (at 2 mm)

dipole mode : will be tuned to 5.996 GHz for resonant operation with 64 bunches



Mechanical model



Electronics

- 180° hybrid coupler
- direct detection for sum signal
- synchronous detection for delta signal

Summary

- good linearity and resolution ~ 10 μm
- should not be expensive (standard electronics)

1st Conclusion

2005 : definition of the probe beam linac

$\Rightarrow$ to freeze the architecture before Christmas !!!

2006 : specifications setting up, fabrication of components

additional human ressources expected beginning of 2006

2007 : installation in CLEX building assumed ready end of 2006

2008 : start of commissioning

Last Conclusion

THERE **IZNOGOUD** PROBE BEAM … WITHOUT **CALIFES** !!!

Time schedule

N°	Nom de la tâche
1	**CTF3 / Probe Beam Lianc**
2	**Conception générale**
3	Calculs préliminaires
4	Simulations avec canon RF
5	Calculs optique faisceau
6	**Photo-injecteur**
7	Optimisation canon HF
8	Etude méca cavité canon RF
9	réalisation cavité + test
10	Etudes système laser
11	montage sur site
12	test sur banc
13	**Systèmes RF**
14	Modulateurs : specs
15	Modulateurs : fabrication
16	Klystron - auxiliaires - BOC
17	installation sources
18	Distribution RF : specs
19	Distribution RF : fabrication
20	Bas niveau RF : CdC
21	Bas niveau : fabrication
22	câblage-montage
23	**Diagnostics**
24	**Mesureurs position**
25	faisabilité - simulations
26	électronique : CdC, sous-traitance, test
27	mécanique : CdC, sous-traitance
28	**Mesureur émittance (OTR)**
29	définition expérience
30	étude mécanique
31	traitement d'image
32	**Mesureur longueur de paquet**
33	définition expérience
34	cavité déflectrice
35	mécanique
36	source RF
37	**Alimentations**
38	CdC et sous-traitance
39	**Systèmes Vide**
40	Etude vide
41	appro - montage
42	**Contrôle-Commande**
43	supervision
44	automates (soft)
45	**Implantation - Intégration**
46	Etude
47	Intégration (2 projeteurs)
48	Réal mécanique
49	**Electrotechnique : baies et câblage**
50	Pré-étude, CdC, suivi de réal
51	câblage sur site
52	**Montage sur site**
53	Installation composants
54	**Commissioning**
55	Essais et faisceau