CLIC drive beam injector design

S. Bettoni, R. Corsini, A. Vivoli

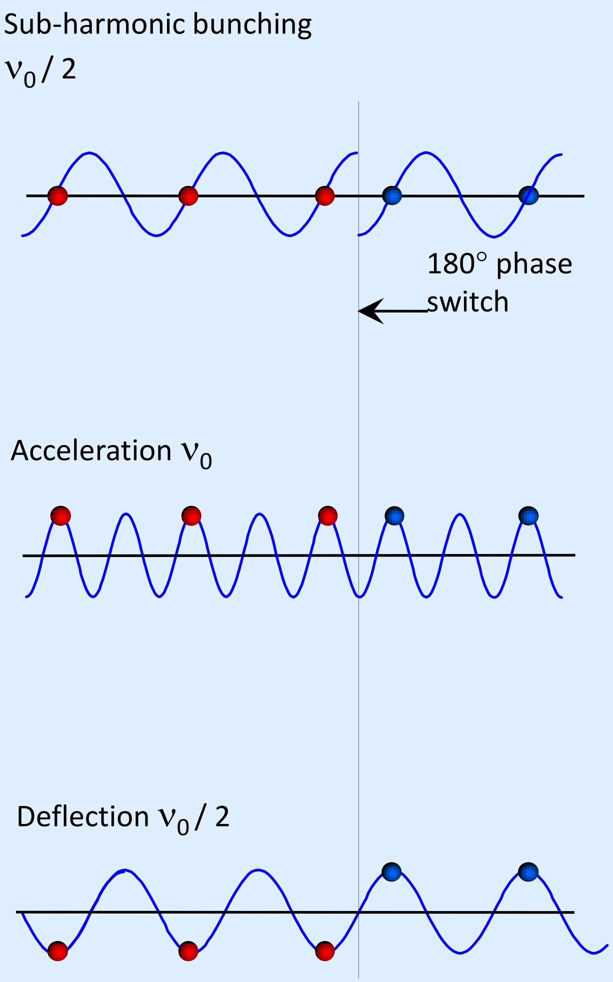
(CERN)

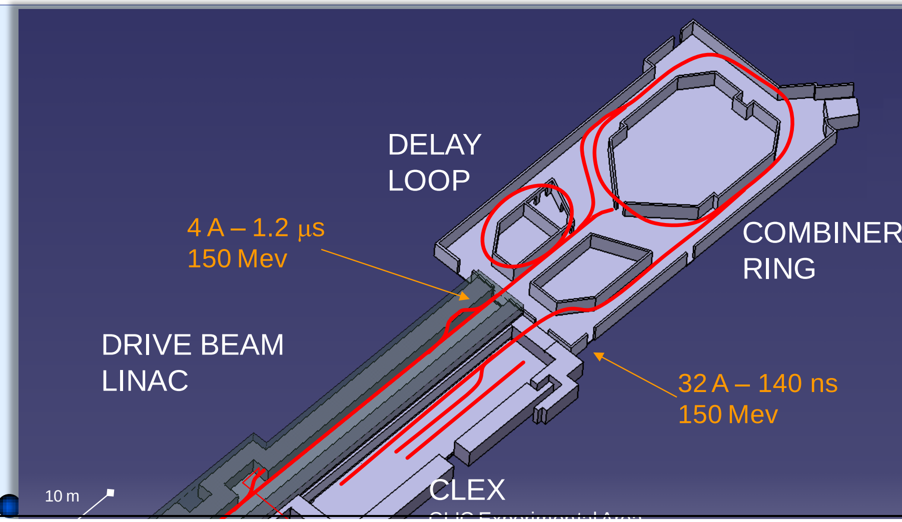
Outline

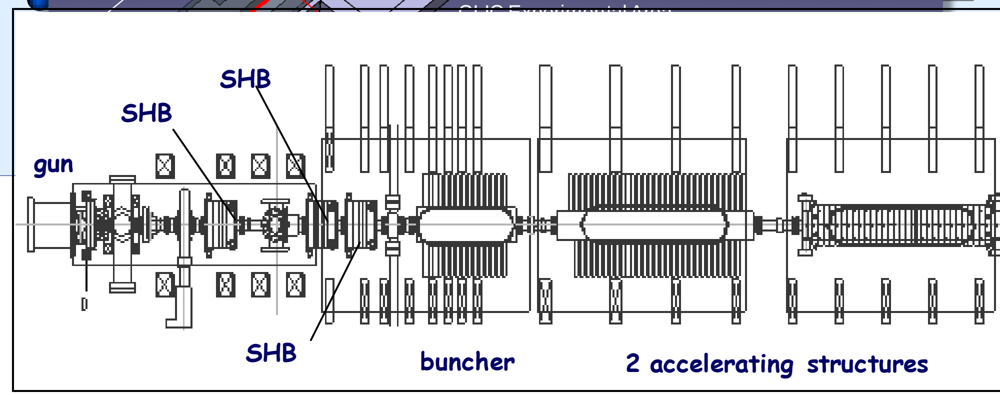
- *CTF3 drive beam injector:*
  - Design, experimental verifications
- *CLIC drive beam injector layout:*
  - Optimization process and criteria
  - Proposed layout
  - Longitudinal and transverse beam dynamics simulations
  - Critical view of the results and possible cures
- *Conclusions & outlook*

Drive beam injector: CTF3 example

Phase coding





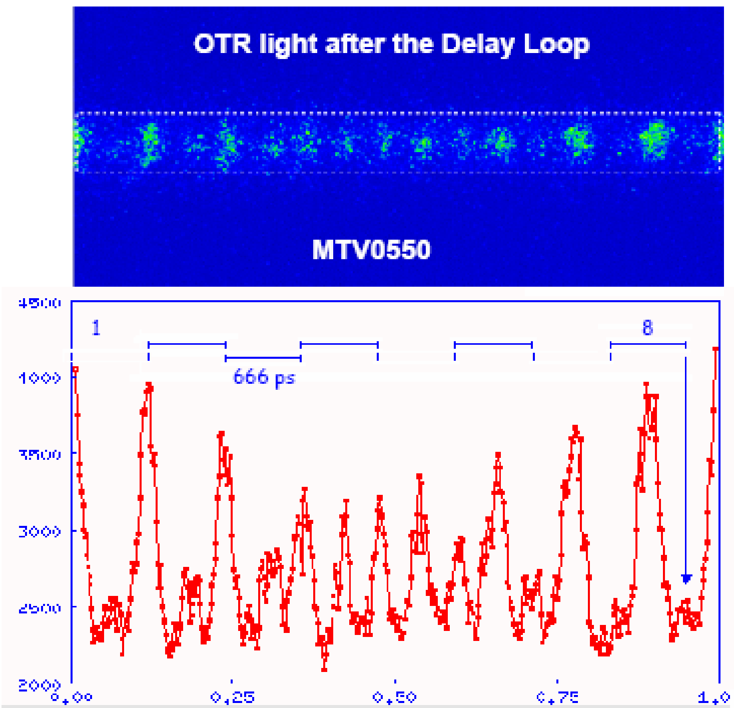


Drive beam injector: CTF3 experience

Key parameters for the SHB system:

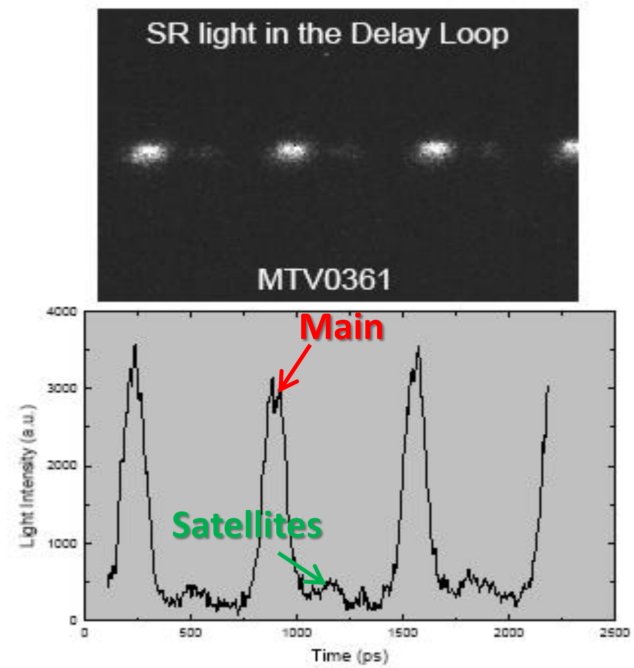
- Time for phase switch < 10 ns
- Satellites (particles captured in 3 GHz RF buckets) population < 7 %

Phase switch:



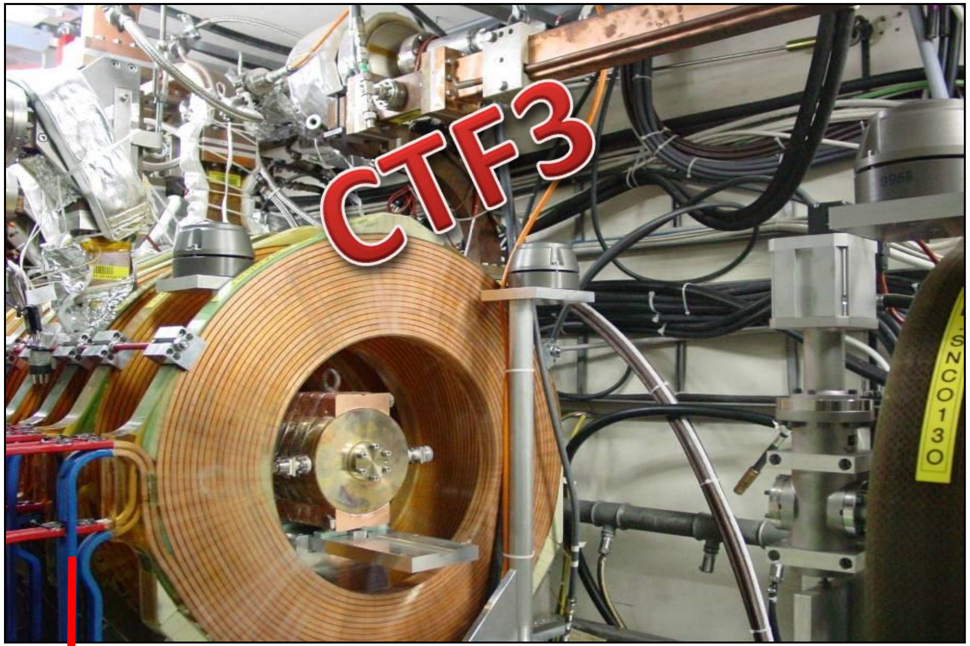
Phase switch within eight 1.5 GHz periods **(<6 ns).**

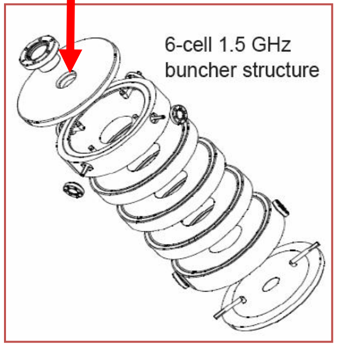
Satellite bunch population:



Satellites bunch population estimated to **~8 %.**

CTF3 first rescaling: the SHB system





Frequency (GHz)	1.49928
Number of cells	6
Iris diameter (mm)	66
Cell length (mm)	26
Input power (kW)	40
Filling time (ns)	10

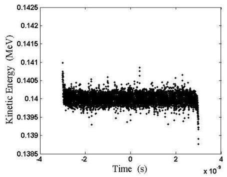
	SHB1	SHB2	SHB3
Phase advance/cell (°)	74.82	70.21	68.23
Phase velocity/c	0.63	0.67	0.69

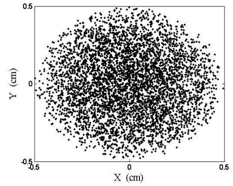
- $Lshb = 3*Lshb_{CTF3}$ (6 cells)
- $Gshb = Gshb_{CTF3}/3$

- $Lshb = 2/3*Lshb_{CTF3}$ (4 cells)
- $Gshb = 3/4*Gshb_{CTF3}$

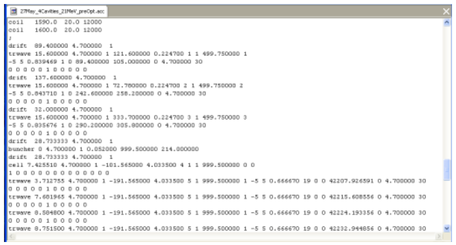
- $Lshb = Lshb_{CTF3}$ (2 cells)
- $Gshb = Gshb_{CTF3}$

The Matlab driven optimization tool

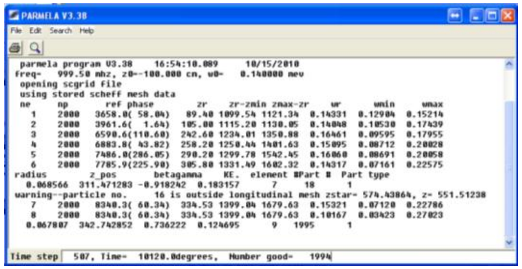




STARTING DISTRIBUTION

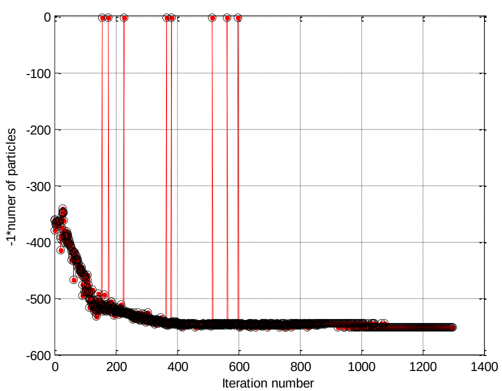


PARMELA FILE INPUT



PARMELA RUN

AUTOMATIC MINIMIZATION PROCESS

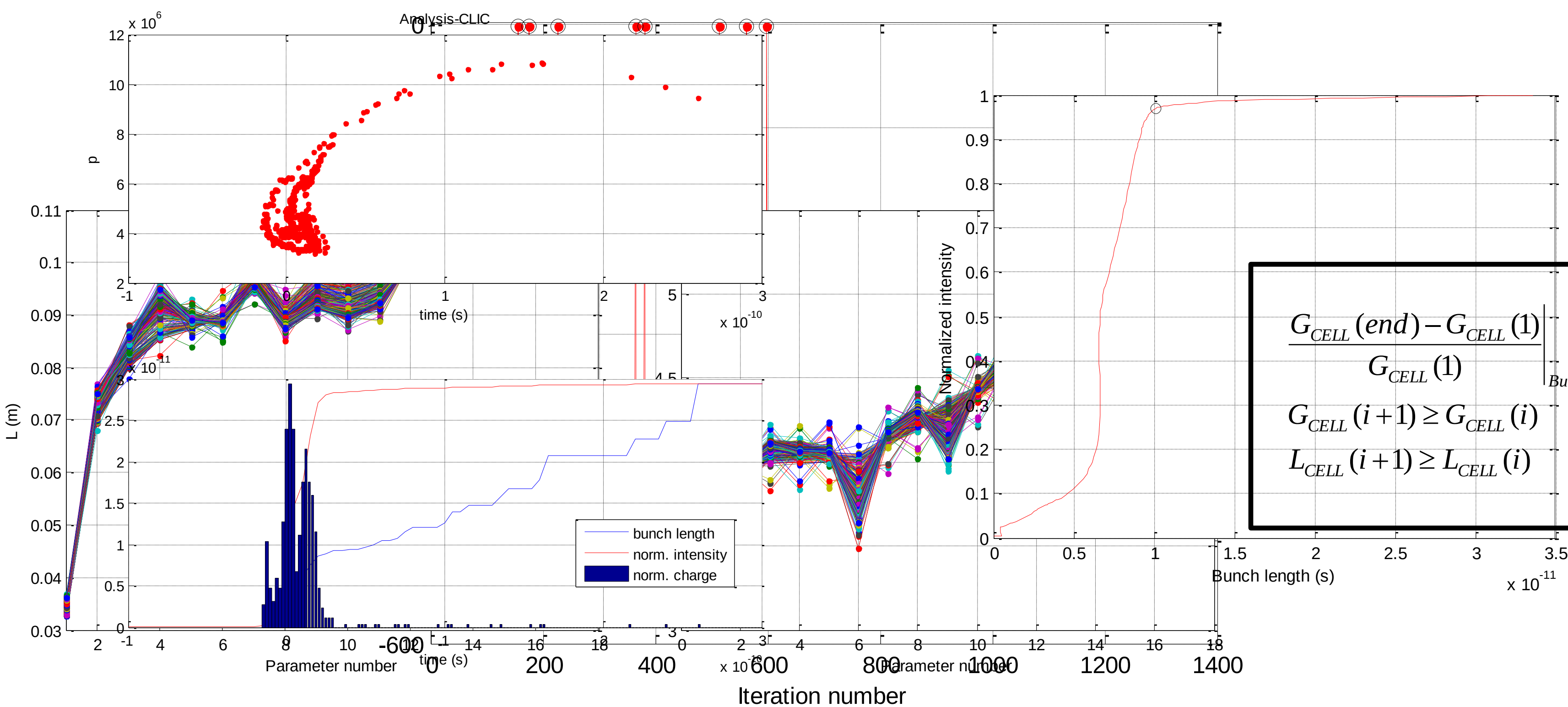


ANALYSIS OF THE RESULTS

The optimization process: some details

During the optimization:

- The code varies the parameters of the system and it does some checks on them
- From the output of Parmela the tool calculates the number of particles in the main of the reference particles cutting the distribution at the target bunch length
- The number of particles in this region is maximized

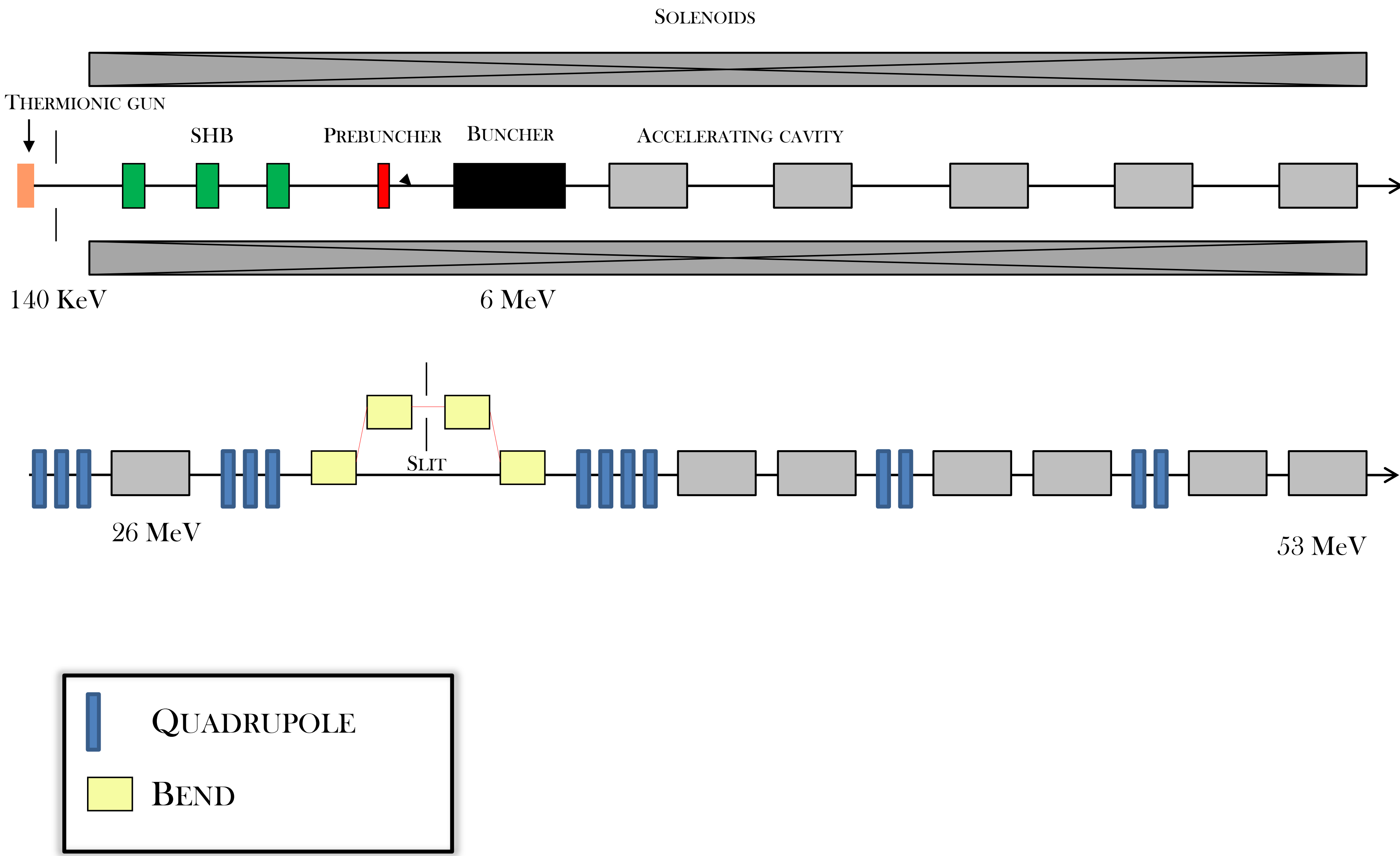


$$\left|\frac{G_{CELL}(end)-G_{CELL}(1)}{G_{CELL}(1)}\right|_{Buncher} < 0.3$$

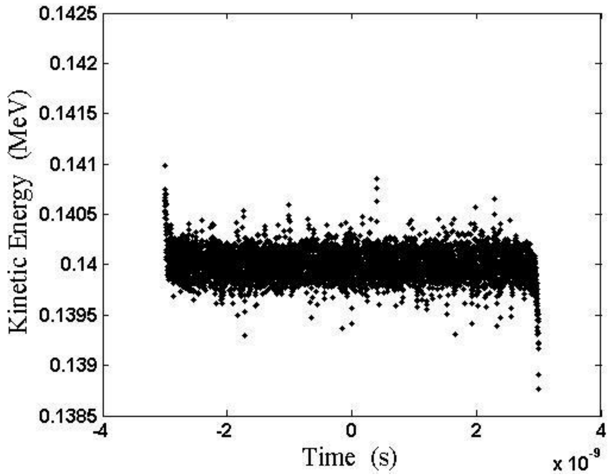
$$G_{CELL}(i+1) \geq G_{CELL}(i) \quad \forall i$$

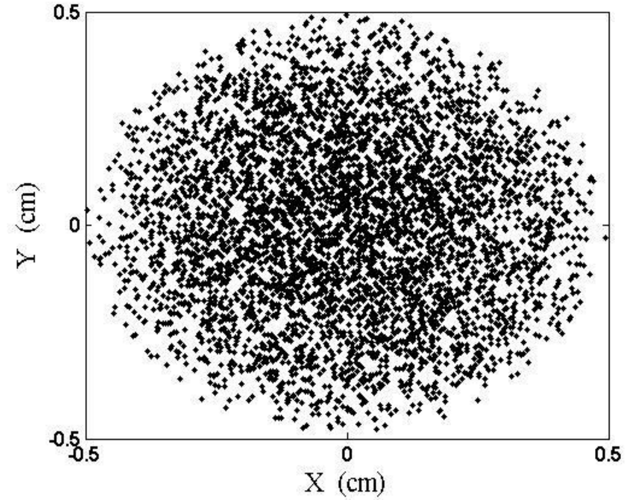
$$L_{CELL}(i+1) \geq L_{CELL}(i) \quad \forall i$$

CLIC drive beam injector layout



Exit of the gun

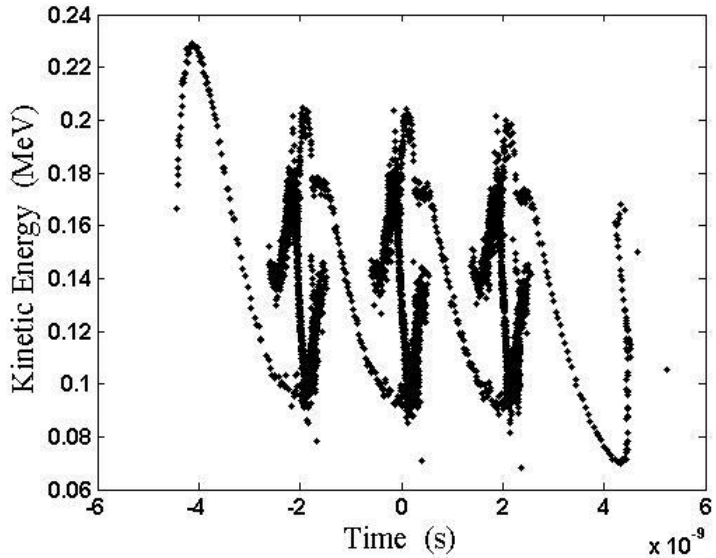


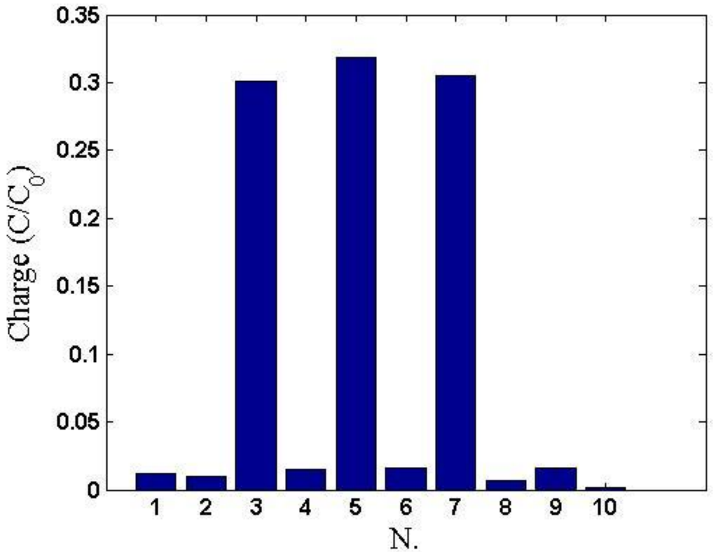


Energy = 0.140 MeV
σ_E= 0.00016 MeV
ΔT= 6 ns
$\gamma\beta\ \varepsilon_{x,y}$= 3.48 μm rad

CLIC parameter	Unit	Value
Pulse duration	μs	140.3
Repetition rate	Hz	50

SHB system





SHB1	Unit	Value
Length	cm	15.6
N. cells		2
Frequency	MHz	499.75
Phase velocity	c	0.93
Voltage	kV	35.0
Aperture radius	cm	4.7

SHB2	Unit	Value
Length	cm	15.6
N. cells		2
Frequency	MHz	499.75
Phase velocity	c	0.61
Voltage	kV	36.5
Aperture radius	cm	4.7

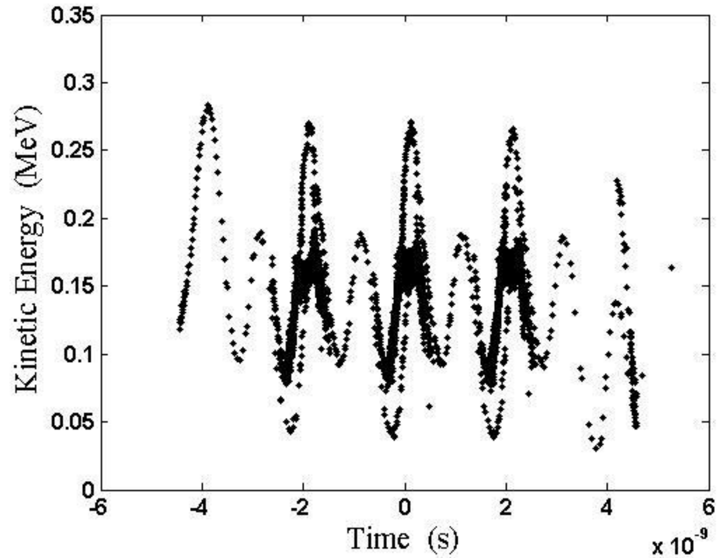
SHB3	Unit	Value
Length	cm	15.6
N. cells		2
Frequency	MHz	499.75
Phase velocity	c	0.73
Voltage	kV	38.8
Aperture radius	cm	4.7

Energy = 0.138 MeV

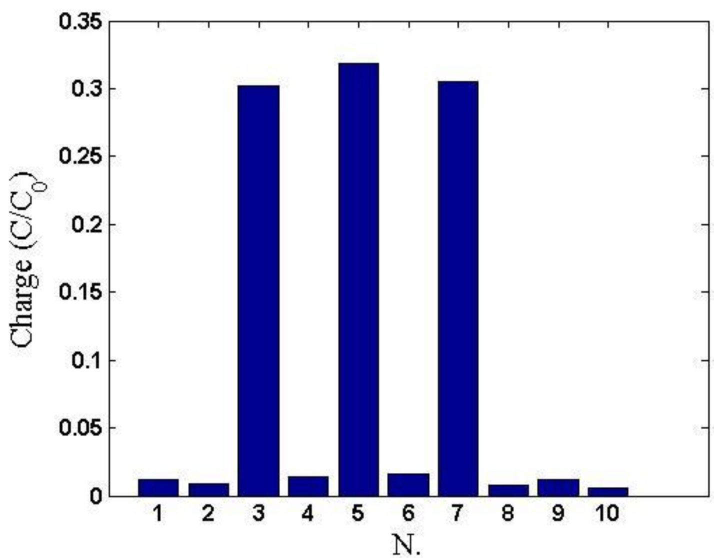
σ_E= 0.029 MeV

ΔT= 9.68 ns

Prebuncher

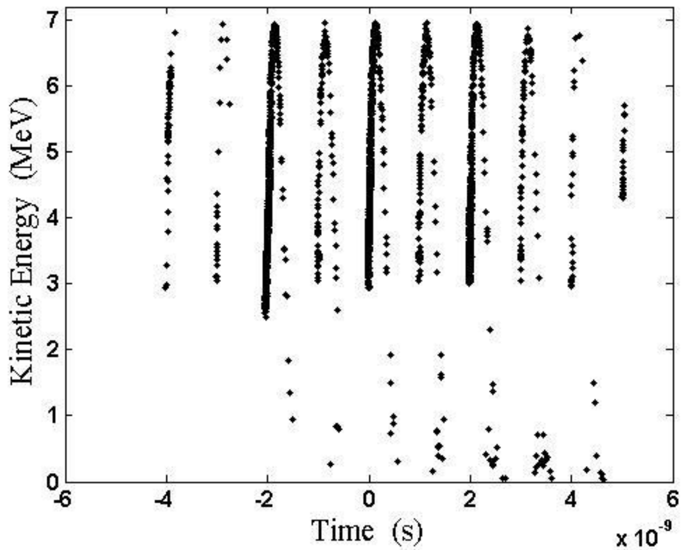


Parameter	Unit	Value
Length	cm	6
Number of cells		1
Frequency	MHz	999.5
Accelerating gradient	MV/m	1.2
Aperture radius	cm	4.7

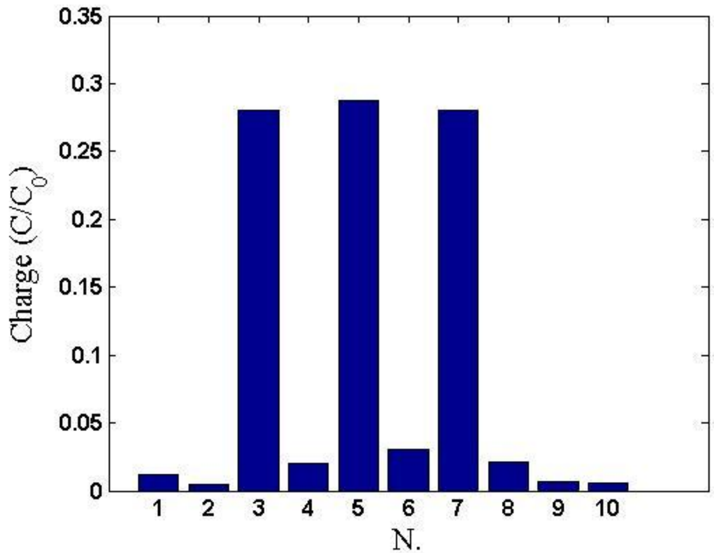


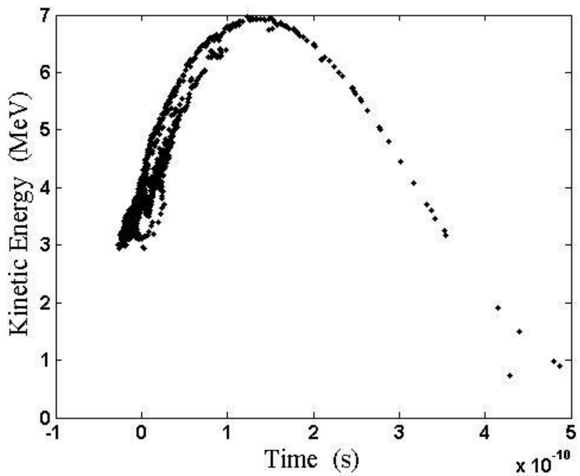
Energy = 0.147 MeV
σ_E= 0.035 MeV
ΔT= 9.7 ns
Satellites= 5.5 %

Buncher



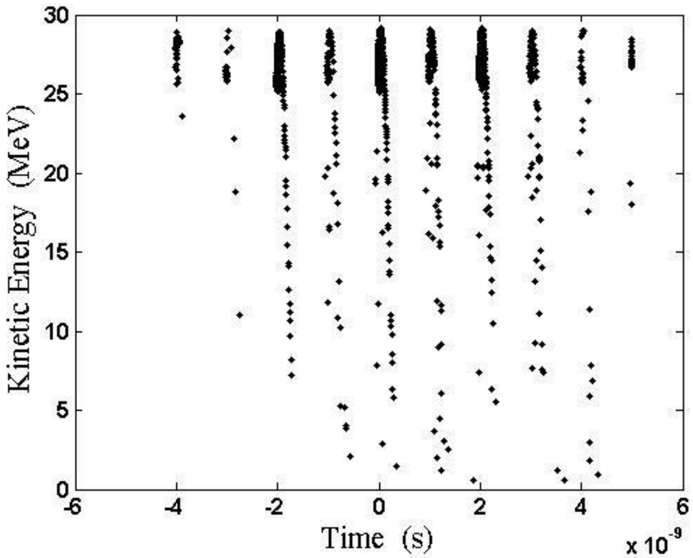
Parameter	Unit	Value
Phase velocity:		
First 12 cells	c	0.68-0.99
Last 6 cells	c	1
Phase advance/cell	π	2/3
Total length	m	1.681
Accelerating field	MV/m	4.2
Beam aperture radius	cm	4.7



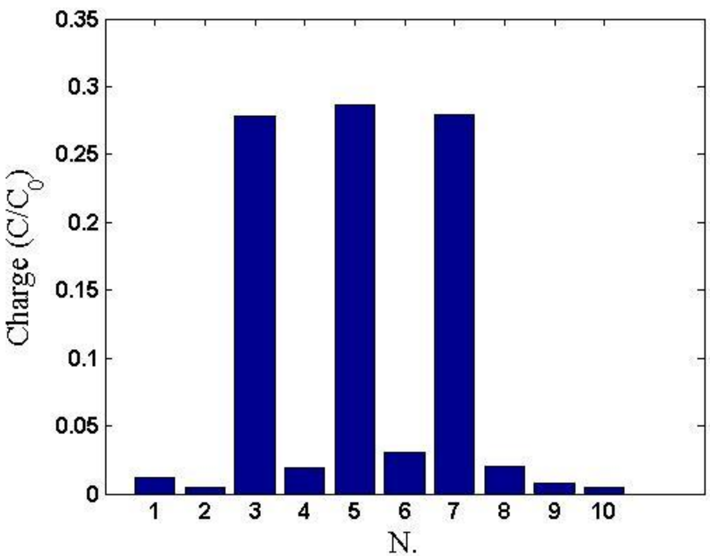


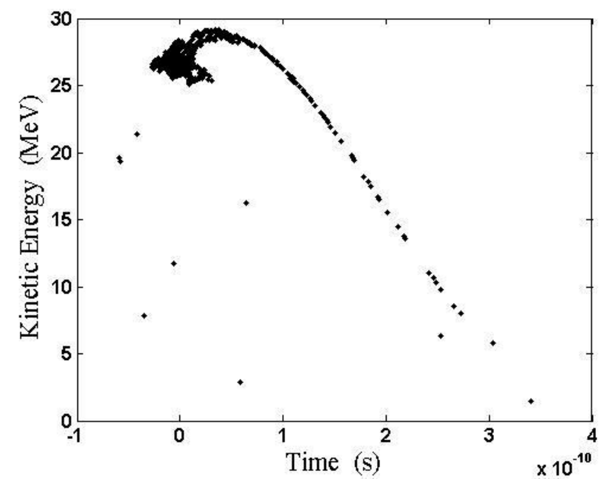
Energy = 4.20 MeV; σ_E= 1.01 MeV; σ_t= 55.89 ps.

Exit of the solenoids (E~30 MeV)



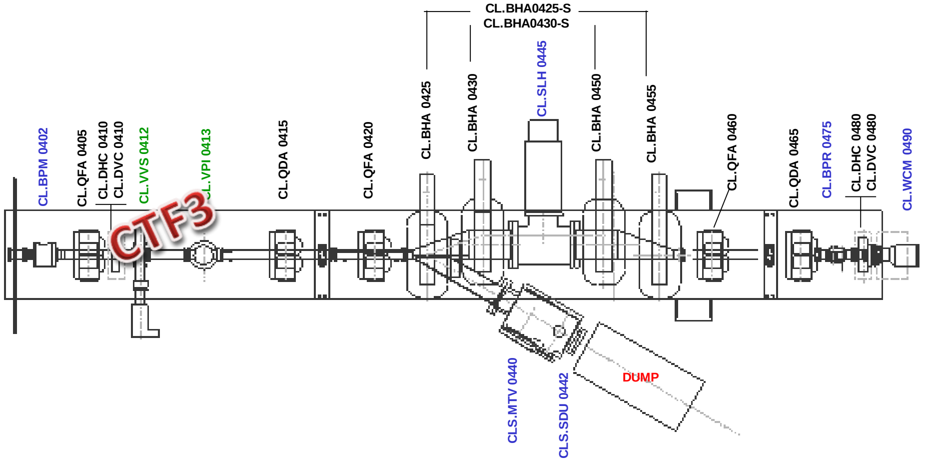
Accelerating cavities parameter	Unit	Value
Phase velocity	c	1
Number of cells		10
Phase advance per cell	π	2/3
Total length	m	0.9998
Voltage	MV	4.8
Beam aperture radius	cm	4.7

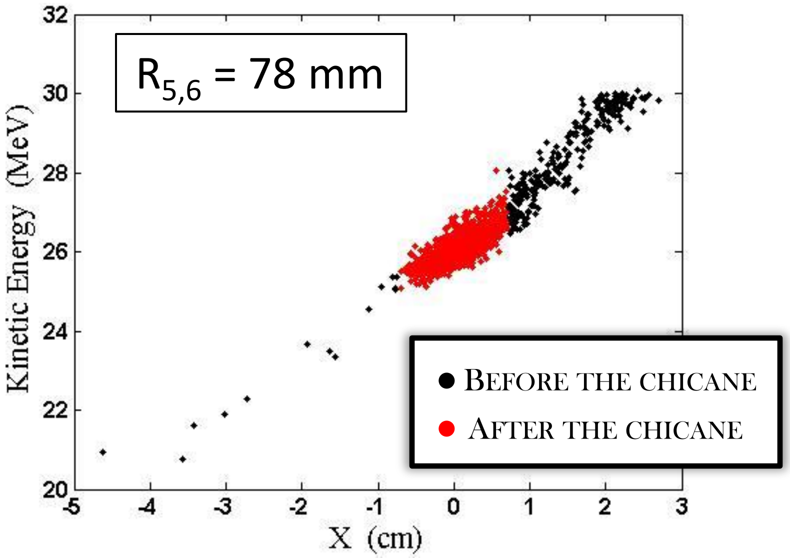


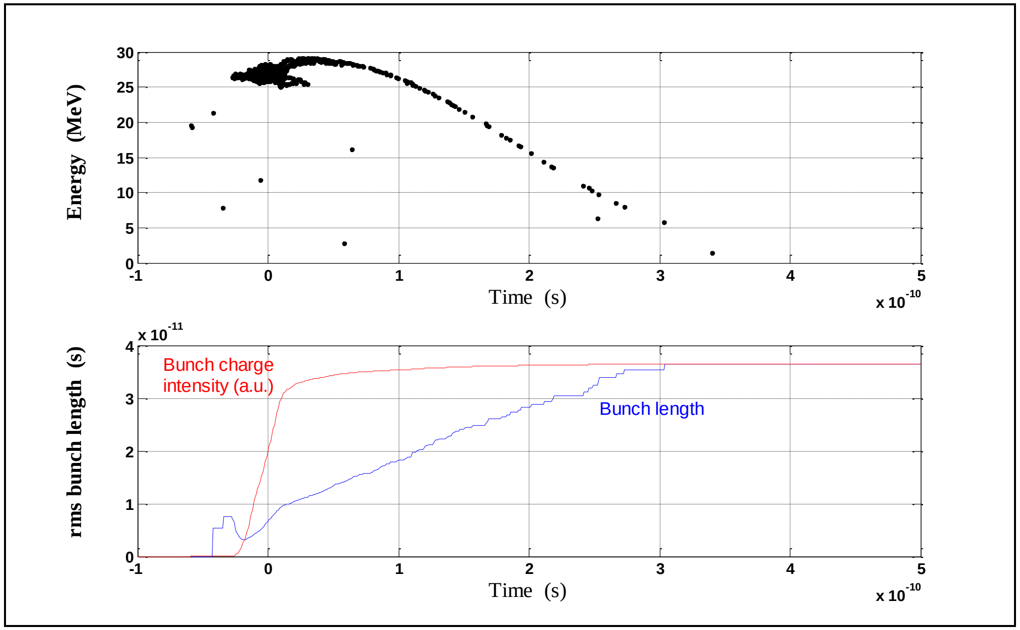


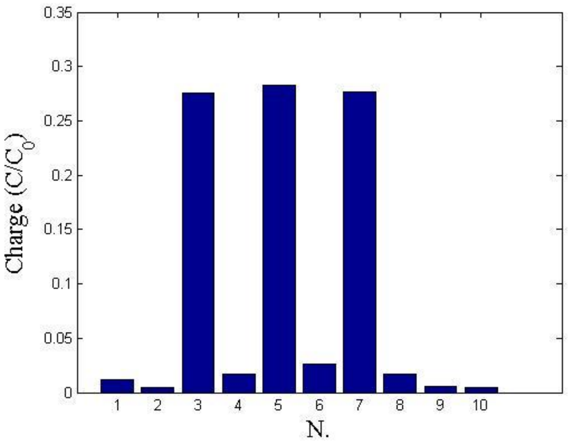
Energy = 26.34 MeV; σ_E= 2.16 MeV; σ_t= 36.58 ps.

Cleaning chicane



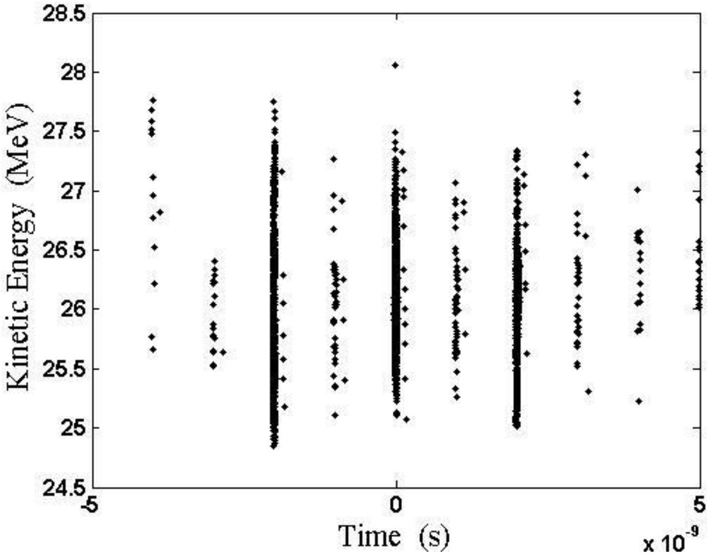


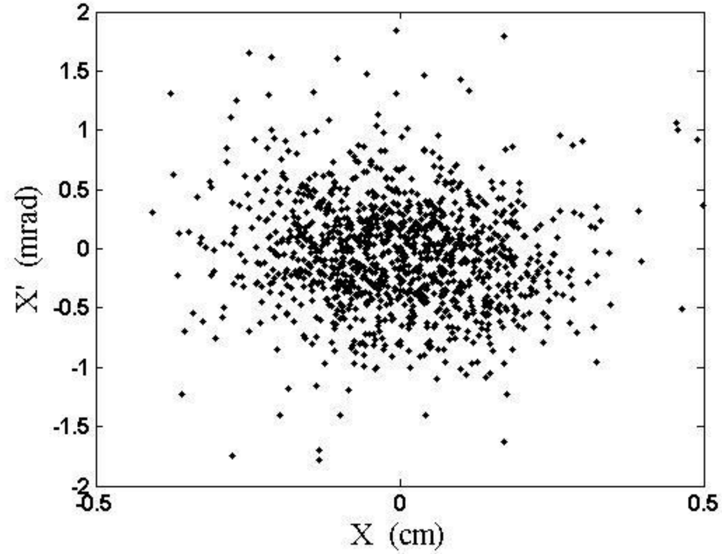


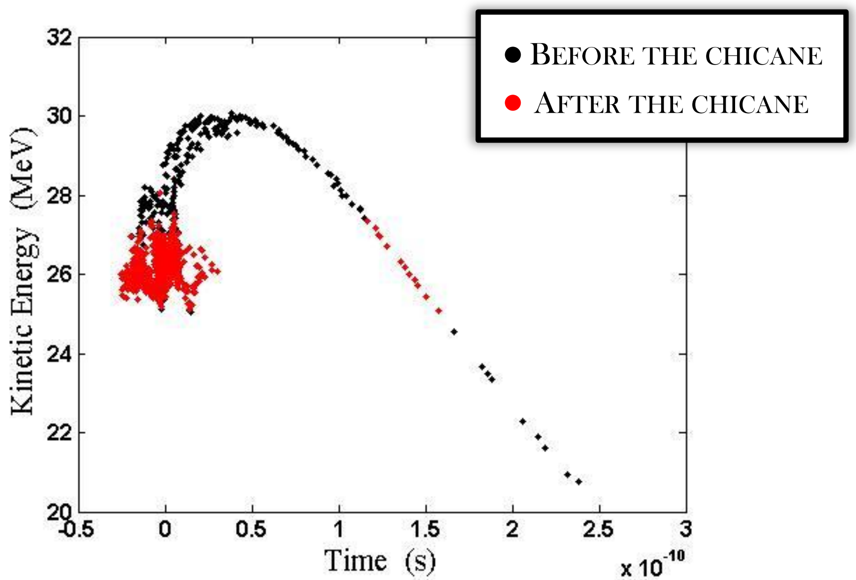


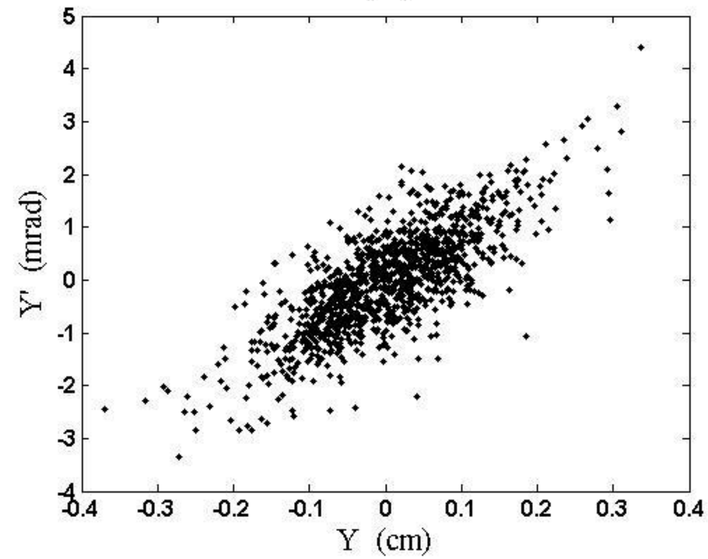
Bend length = 15 cm; Bend angle = 14.32 deg; Reference E = 26 MeV; Slit aperture = 7 mm; Intensity decrease = 24%.

After the cleaning chicane



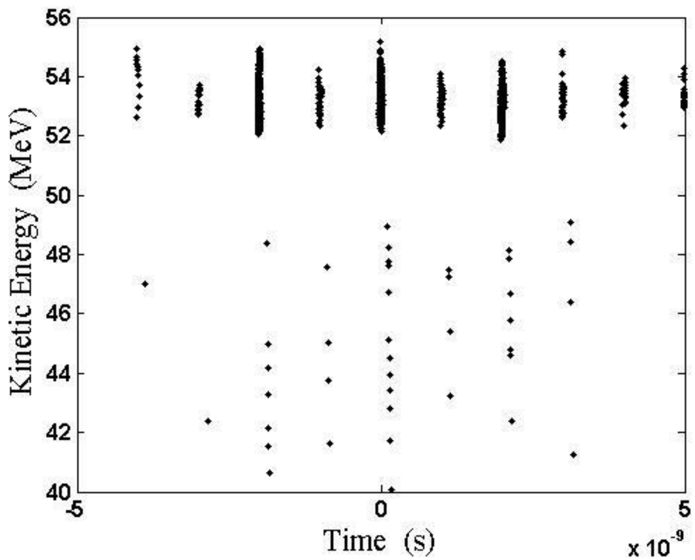


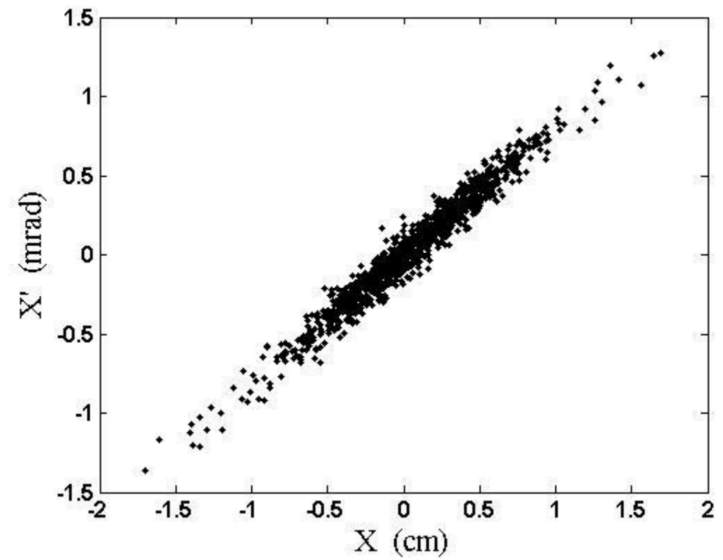


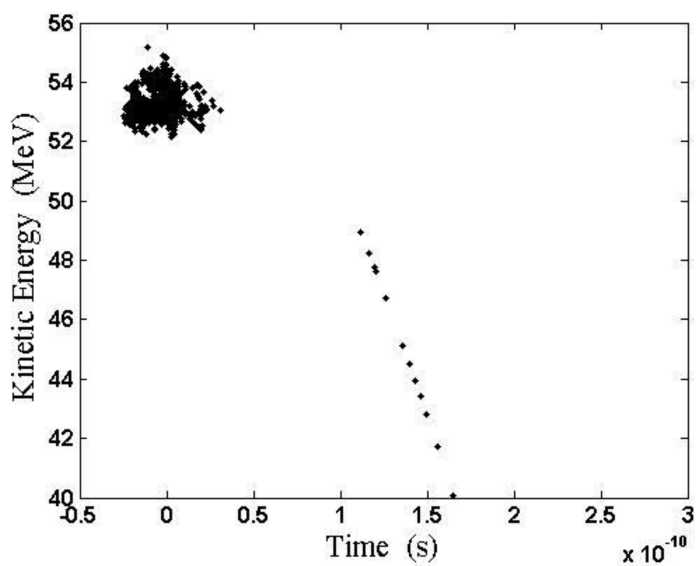


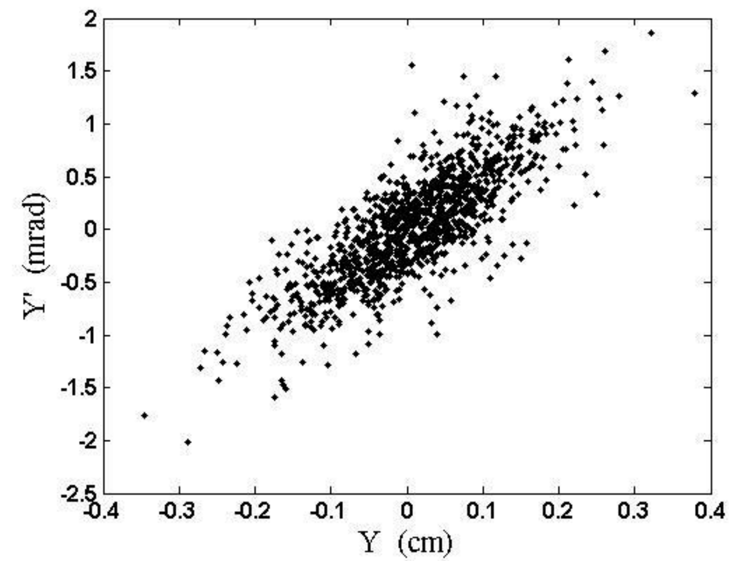
Energy = 26.07 MeV; σ_E= 0.40 MeV; σ_t= 17.14 ps.

Injector exit (E~50 MeV)





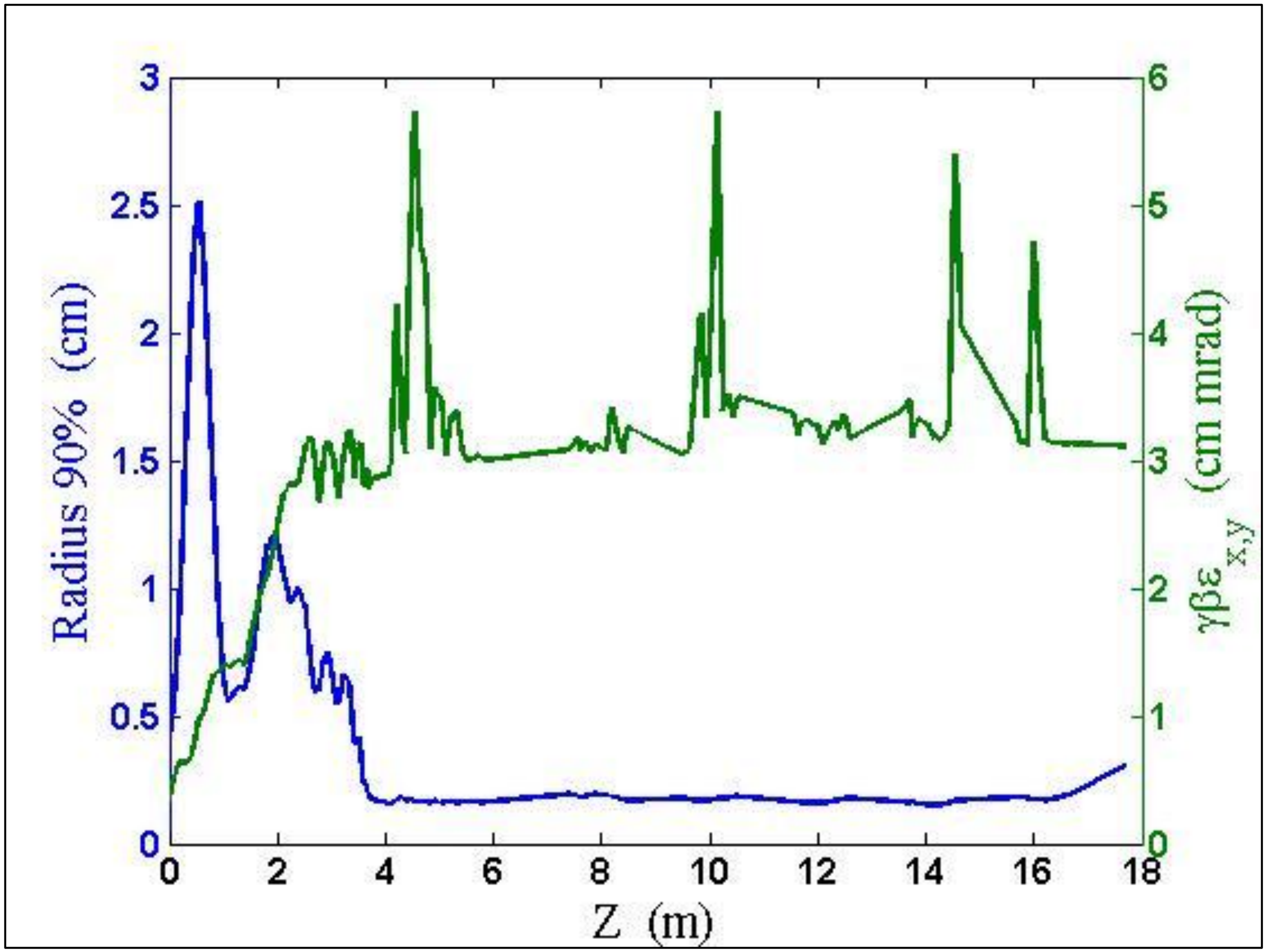


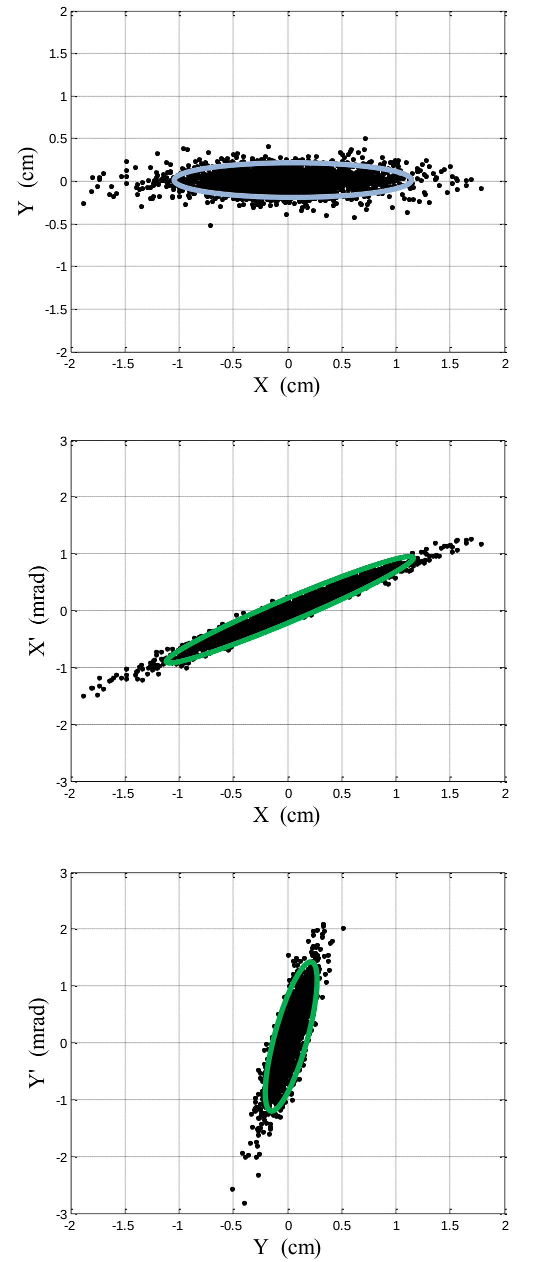


Energy = 53.25 MeV; σ_E= 0.45 MeV; σ_t= 9.45 ps.

$\gamma\beta\varepsilon_x$= 32.92 μm rad; $\gamma\beta\varepsilon_y$= 28.73 μm rad.

CLIC drive beam injector: transverse dynamics





CLIC requests and simulation results

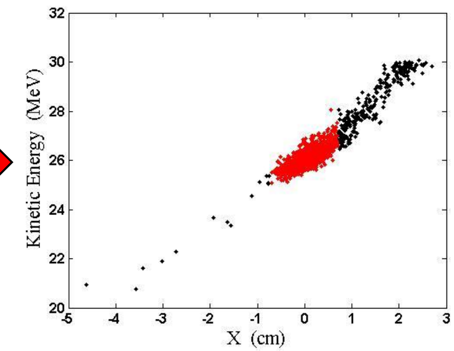
Parameter	Unit	Simulations	CLIC
Energy	MeV	53.2	
Bunch charge	nC	8.16	≥ 8
Bunch length (rms)	mm	2.83	3 (@ 50 MeV)
Energy spread (rms)	MeV	0.45 (@53 MeV)	< 0.50 (@ 50 MeV)
Horizontal normalized emittance (rms)	µm rad	32.9	≤ 100
Vertical normalized emittance (rms)	µm rad	28.7	≤ 100
Satellites population	%	4.9	As less as possible

CLIC requets fulfilled

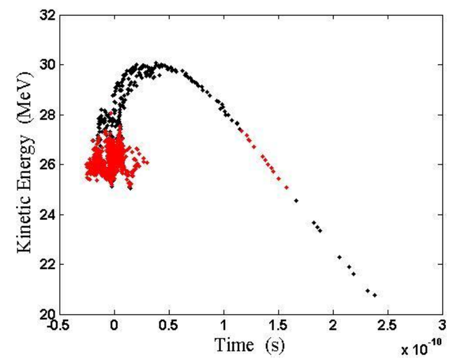
CLIC drive beam injector design: a critical view

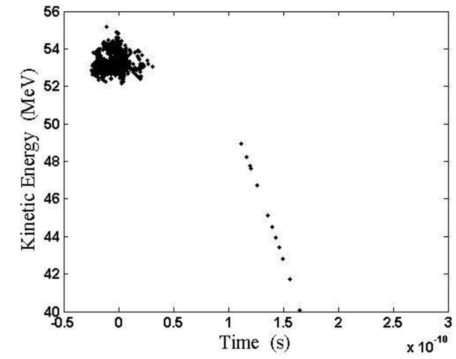
More optimizations still ongoing:

- Intensity decrease at the chicane = 24% (close to CTF3 20%)

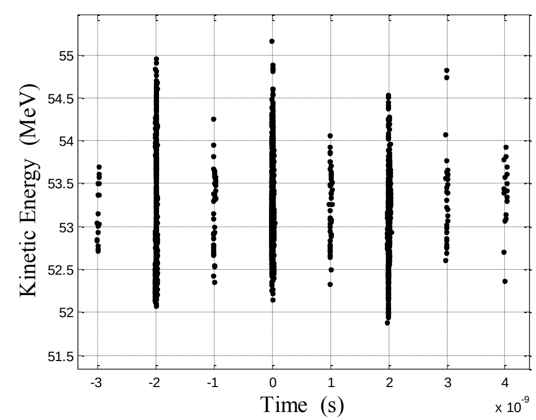


- Additional chicane needed
  (power???)





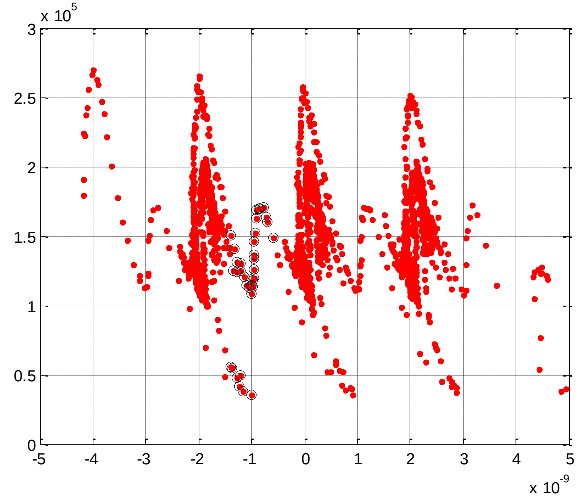
- Satellites population = 4%

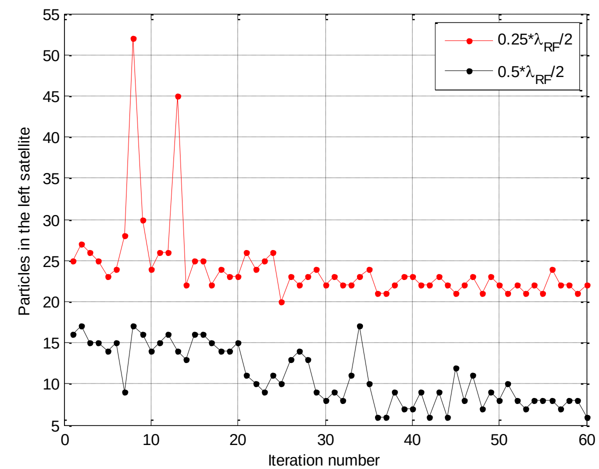


Satellites minimization: possible cures

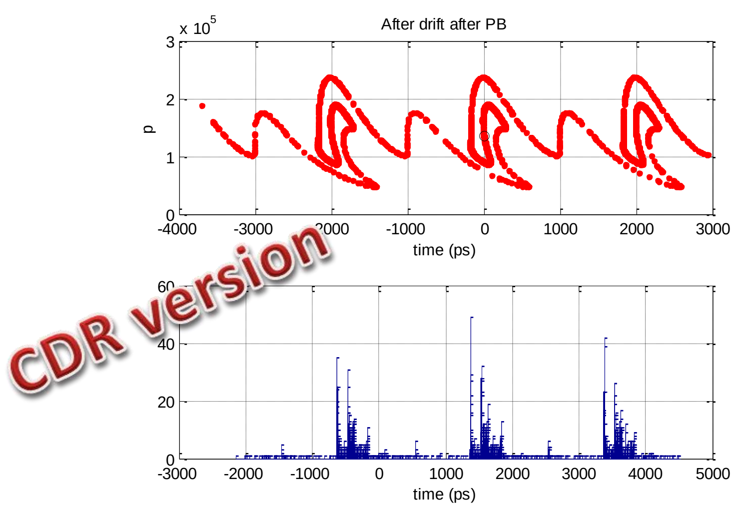
Identified two approaches to minimize the satellites content:

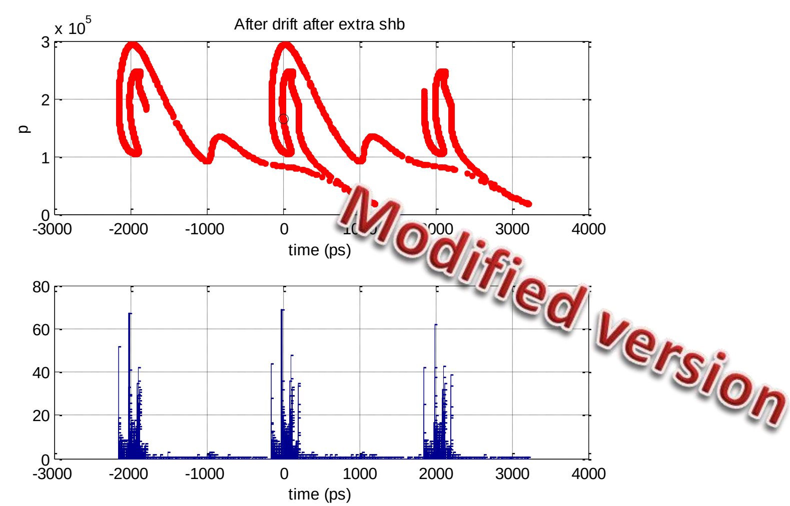
- Minimize the number of particles in the time interval of the satellites





- Use an additional SHB to shift the energy of the satellites





Starting from an idea by P. Urschütz (presently at Siemens)

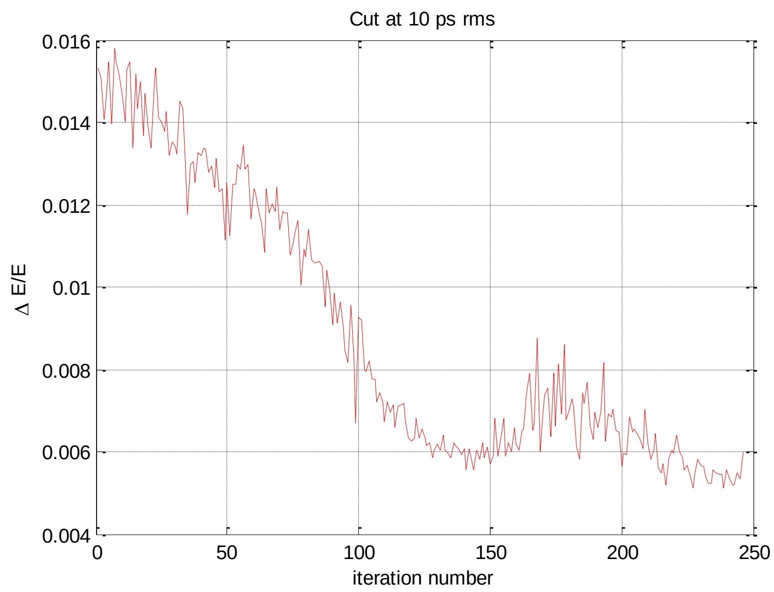
Efficiency: an alternative solution

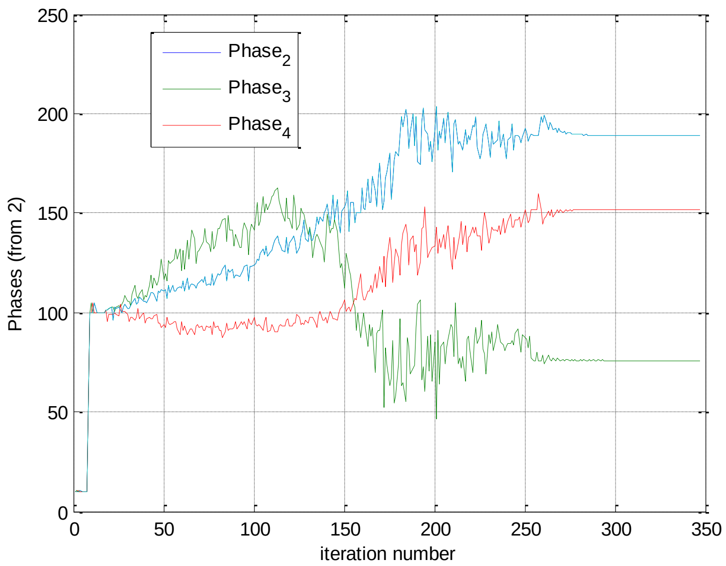
Re-optimization using as a figure of merit the energy spread at a fixed bunch length and optimization of the accelerating cavities:

→ Particles in a more confined E-t region

- Intensity decrease at the chicane = 19% (24%)
- Total losses from the start = 22% (30%)
- Particles to be lost in the additional chicane reduced

  by a factor 2





Conclusions

- A design of the CLIC drive beam injector based on a **thermionic gun** has been studied
- Parmela simulations verified that the challenging **CLIC requests can be fulfilled** (longitudinal & transverse)
- Identified some **possible improvements** (beam losses, satellites content) and optimization already ongoing
- **Further studies** (beam loading compensation, wakefields effects and beam stability) to be done
- Proper **RF design** of the elements to be done

If you don't have other questions …

14:36 Realization and Test of the Engineering Prototype of the CALICE Tile HCal (18') — Mark Terwort (*ILC*)

14:54 Calibration issues for the CALICE 1m3 AHCAL prototype (18') — Jaroslav Zalesak (*Institute of Physics, Academy of Sciences*

15:12 The Fastest Calorimeter (18') (Slides)

14:00->*15:30* **ECFA Parallel : Forward Region** (Room 16 floor "-1")

14:00 NOTE: Forward Region Contributions have been integrated into the CALO (Wednesday at 08: 11:00) Sessions (01')

14:00->*15:30* **IDAG** (Room 8 - floor "2")

15:30 coffee break (30')

16:00->*18:00* **Accelerator session: WG 3 (Main linac and superconducting RF)** (CICC

16:00 Re-entrant shape cavity (20') (Slides)

16:20 Seamless cavity at FNAL (20') (Slides)

16:40 New studies of niobium material (20')

17:00 Atomic Layer Deposition (20')

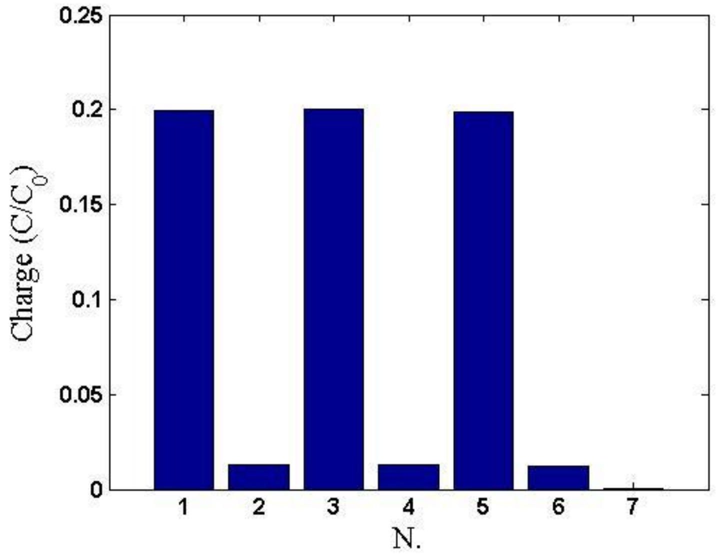
17:20 New material cavity (20')

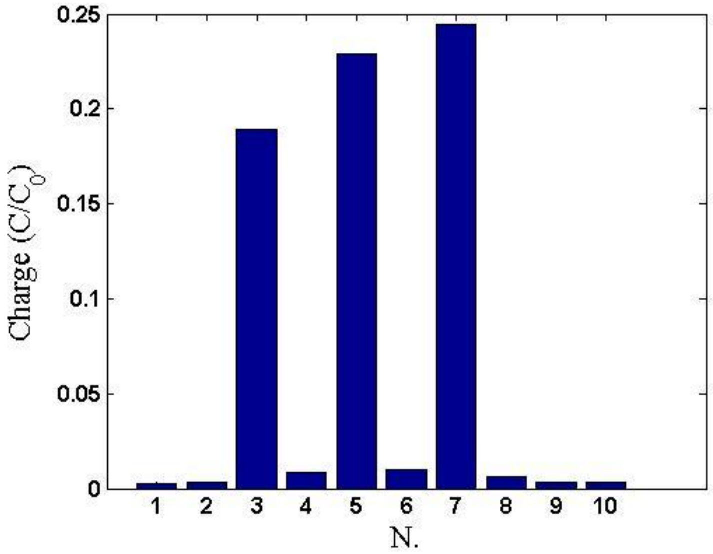
16:00->*18:30* **ECFA Parallel: Cosmology** (Convener: Marco Battaglia (*CERN and UCSC*) , Marco Cirelli (*CERN and CNRS IPhT Saclay*) , Geraldine Servant (*CERN*)) (Room 23 - floor "0")

16:00	On long-lived staus (30') (webex information)	Alejandro Ibarra (*TUM Munich*)
16:30	Probing Dark Matter at the LHC (30')	Alex Tapper (*Imperial College, London*)
17:00	On probes of Hidden forces and dark sectors at e+e- colliders (30')	Brian Batell (*Perimeter Institute*)
17:30	On Sneutrino dark matter (30')	Genevieve Belanger (*LAPTH*)
18:00	On SUSY dark matter (30')	Pearl Sandik (*U Texas*)

Spare slide: space charge

Without space charge





With space charge