

CLIC drive beam injector design

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(CERN)*

Outline

➤ *CTF3 drive beam injector:*

- Design, experimental verifications

➤ *CLIC drive beam injector layout:*

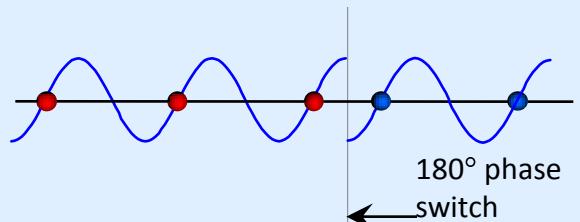
- Optimization process and criteria
- Proposed layout
- Longitudinal and transverse beam dynamics simulations
- Critical view of the results and possible cures

➤ *Conclusions & outlook*

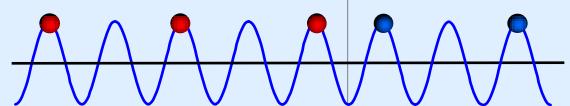
Phase coding

Sub-harmonic bunching

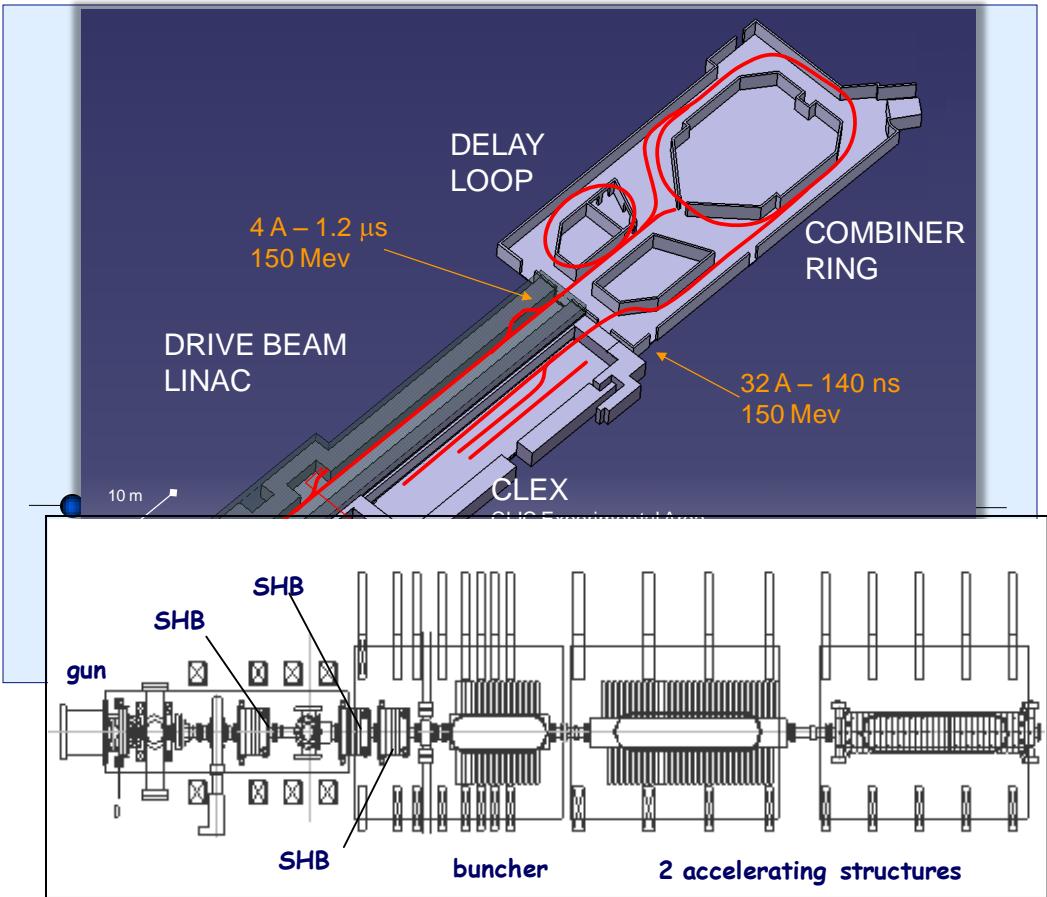
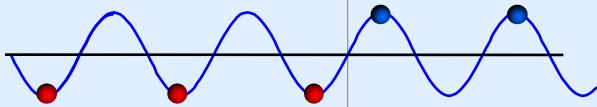
$$v_0 / 2$$



Acceleration v_0



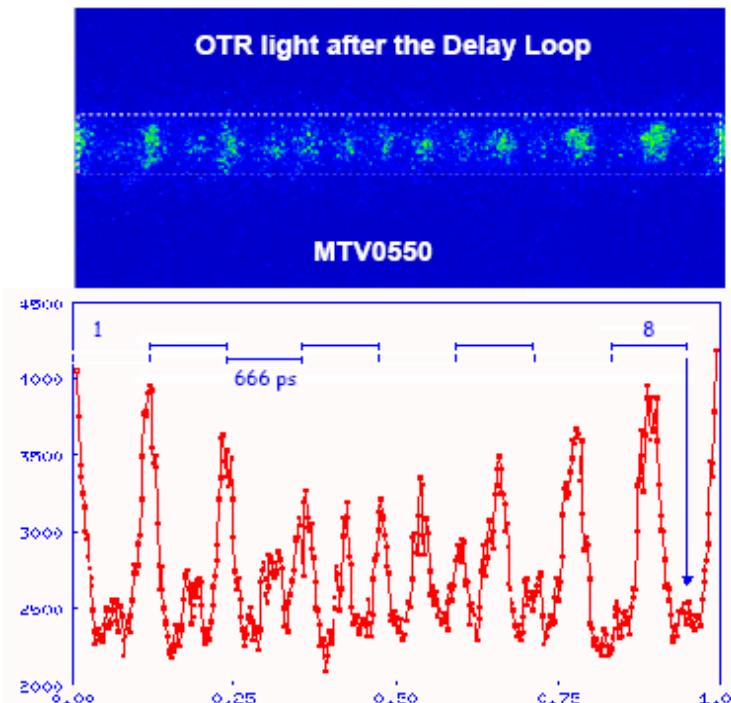
Deflection $v_0 / 2$



Key parameters for the SHB system:

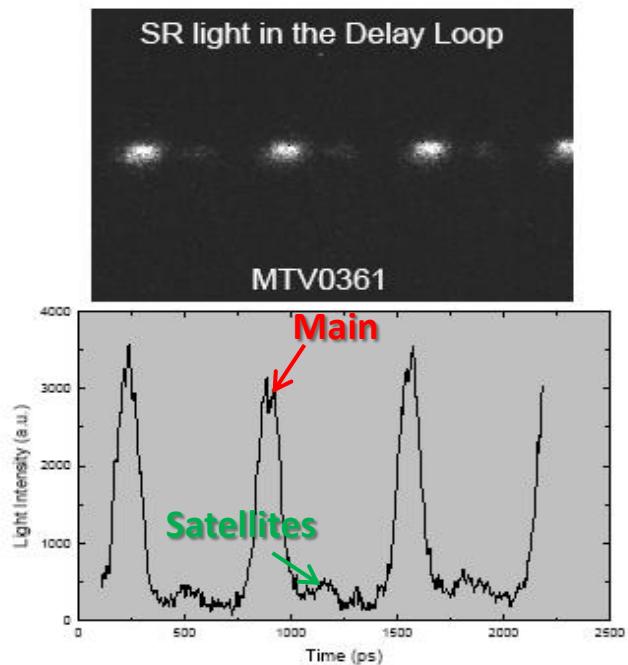
- Time for phase switch < 10 ns
- Satellites (particles captured in 3 GHz RF buckets) population < 7 %

Phase switch:



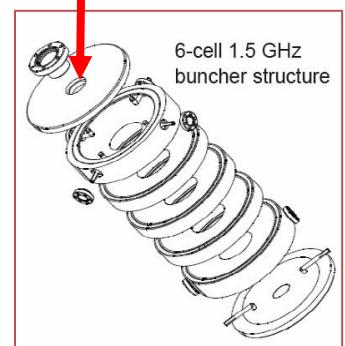
Phase switch within eight 1.5 GHz periods (**<6 ns**).

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

- $L_{shb} = 3 * L_{shb}_{CTF3}$ (6 cells)
- $G_{shb} = G_{shb}_{CTF3} / 3$

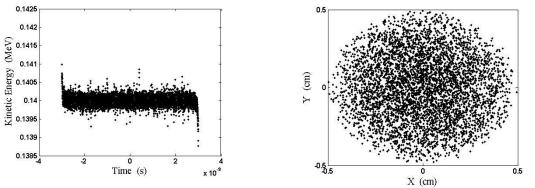
- $L_{shb} = 2/3 * L_{shb}_{CTF3}$ (4 cells)
- $G_{shb} = 3/4 * G_{shb}_{CTF3}$

- $L_{shb} = L_{shb}_{CTF3}$ (2 cells)
- $G_{shb} = G_{shb}_{CTF3}$

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

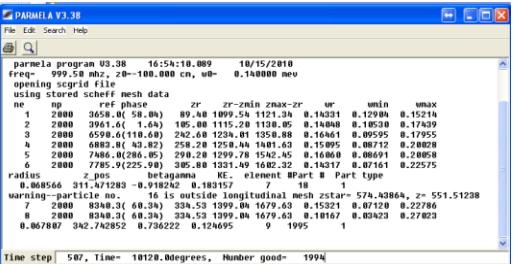


The Matlab driven optimization tool

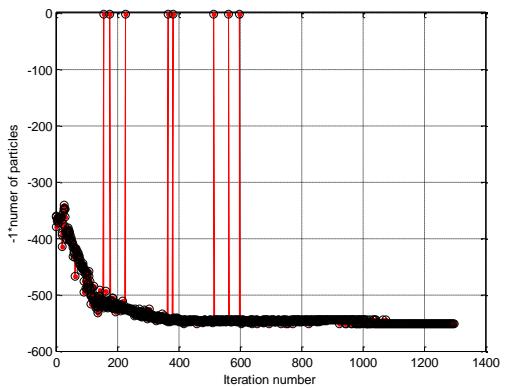


STARTING DISTRIBUTION

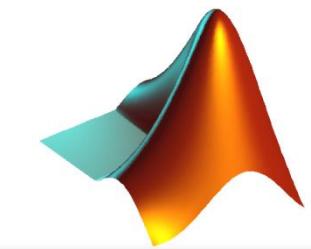
PARMELA FILE INPUT



PARMELA RUN



ANALYSIS OF THE RESULTS

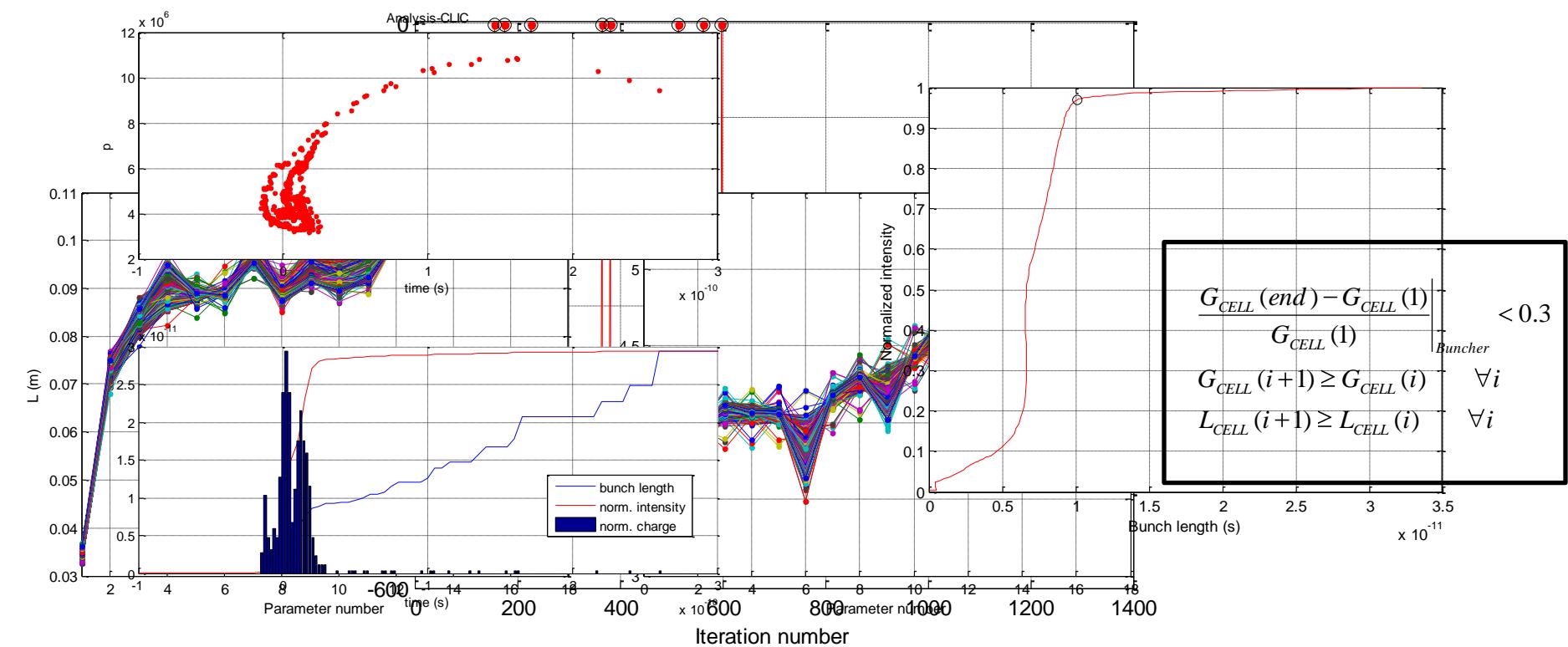


AUTOMATIC MINIMIZATION PROCESS

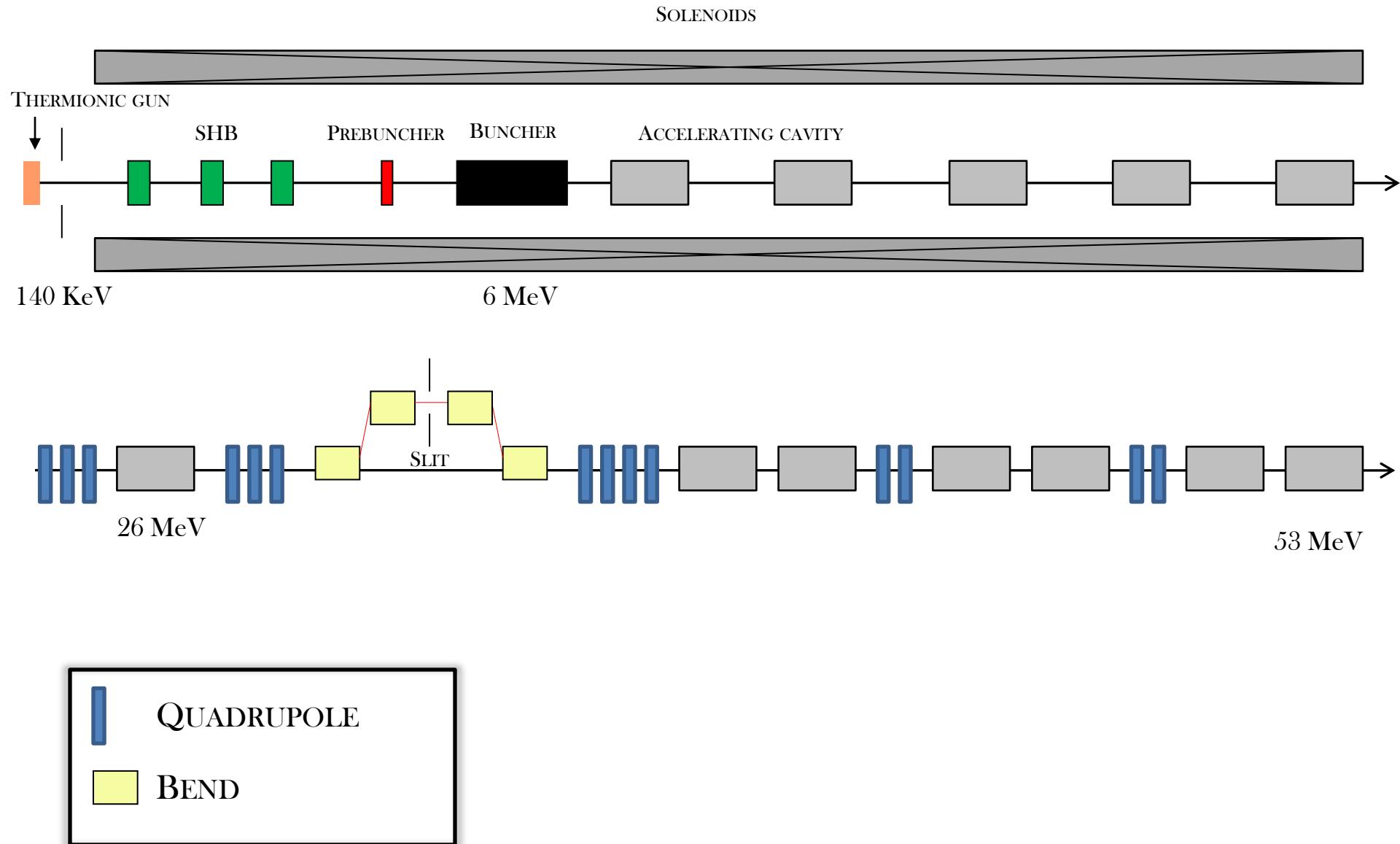
The optimization process: some details

During the optimization:

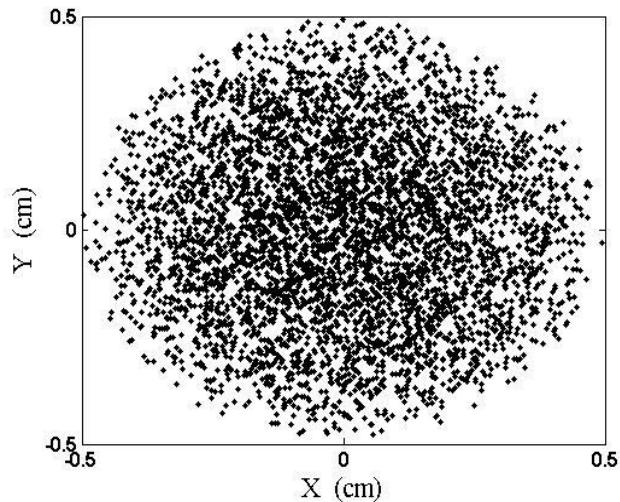
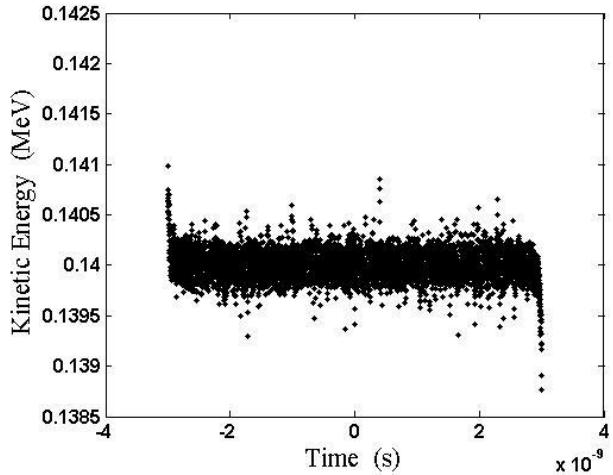
- The code varies the parameters of the system and it does some checks on them
- From the output of Parmela the tool calculates the number of particles in the main of the reference particles cutting the distribution at the target bunch length
- The number of particles in this region is maximized



CLIC drive beam injector layout



Exit of the gun



Energy = 0.140 MeV

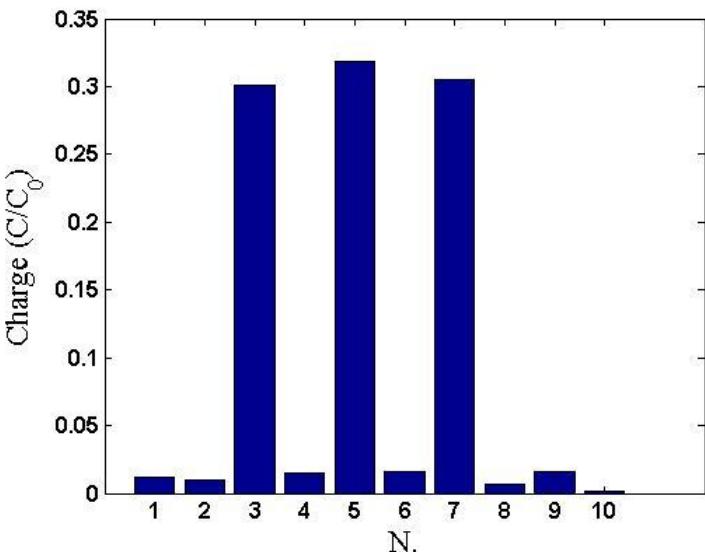
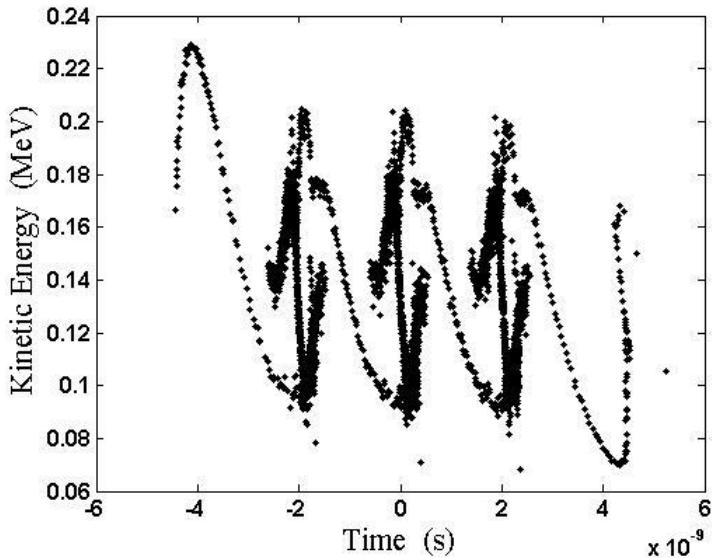
$\sigma_E = 0.00016 \text{ MeV}$

$\Delta T = 6 \text{ ns}$

$\gamma \beta \varepsilon_{x,y} = 3.48 \mu\text{m rad}$

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

SHB system



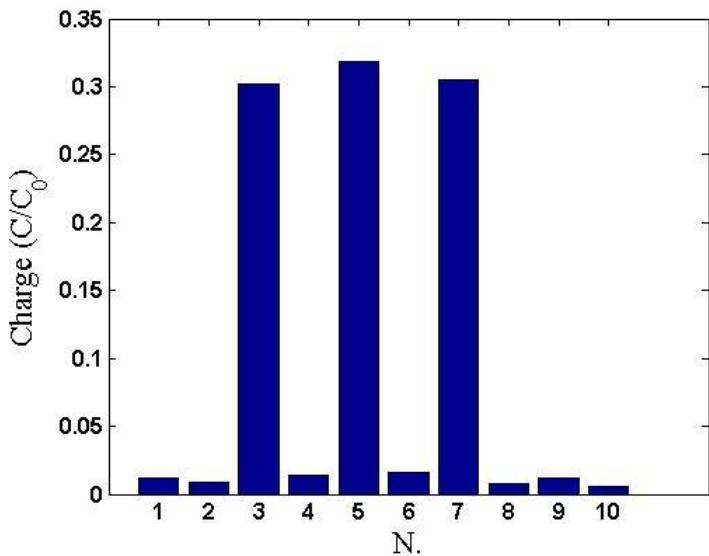
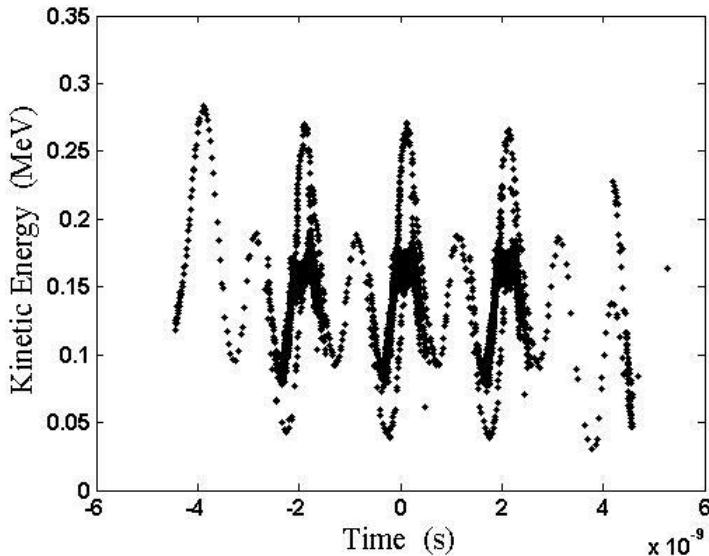
SHB1	Unit	Value
Length	cm	15.6
N. cells		2
Frequency	MHz	499.75
Phase velocity	c	0.93
Voltage	kV	35.0
Aperture radius	cm	4.7

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

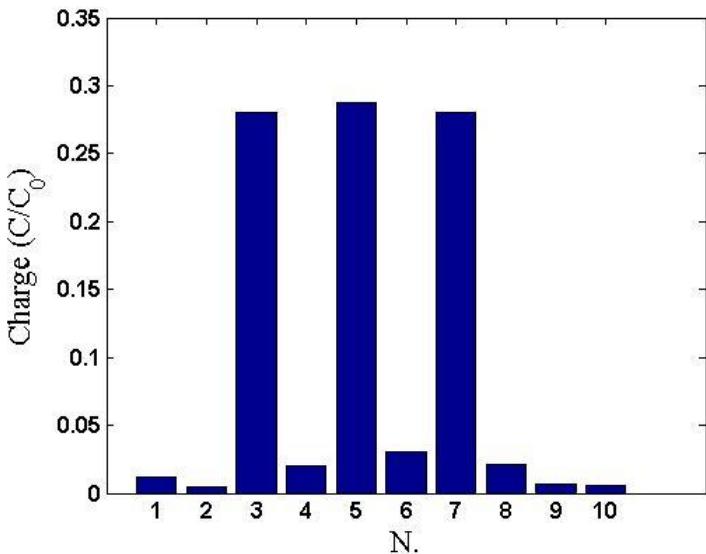
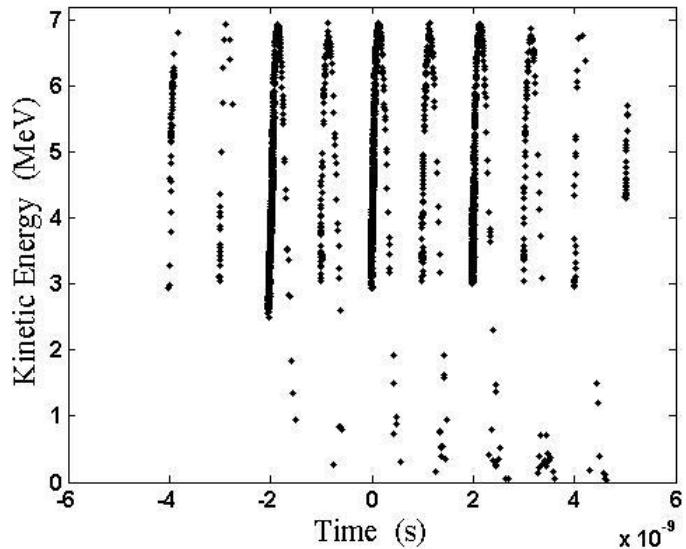
Prebuncher



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

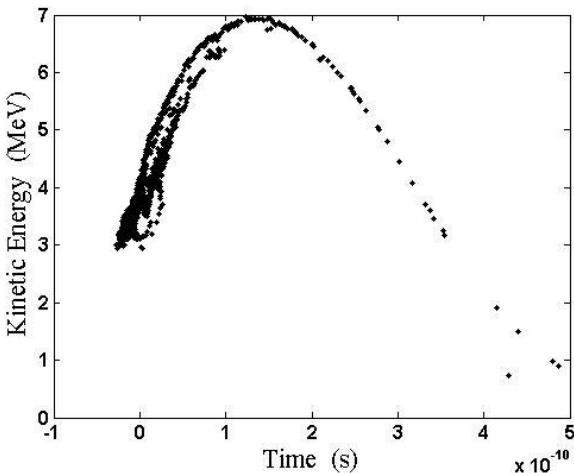
Energy = 0.147 MeV
 σ_E = 0.035 MeV
 ΔT = 9.7 ns
Satellites = 5.5 %

Buncher

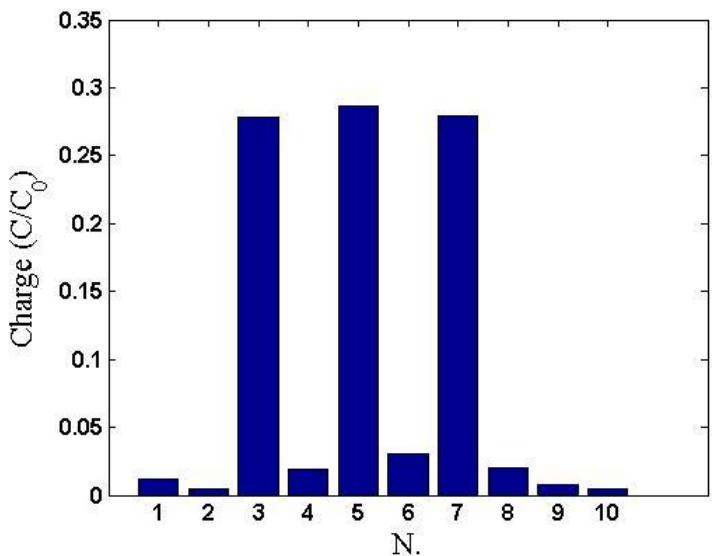
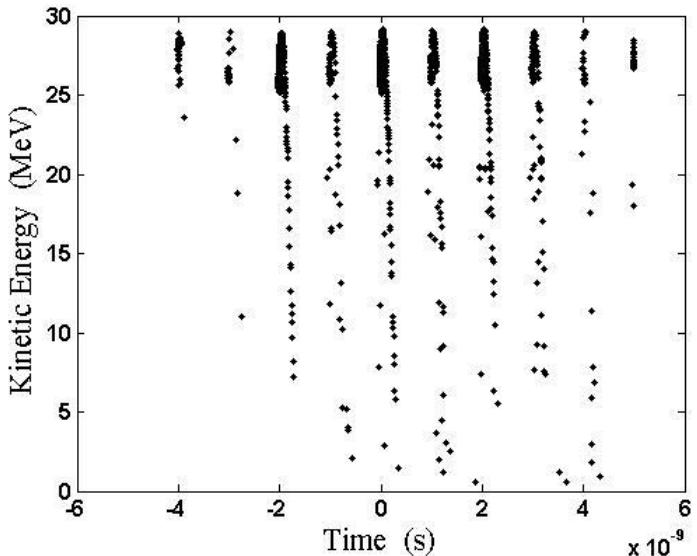


Energy = 4.20 MeV; $\sigma_E = 1.01$ MeV; $\sigma_t = 55.89$ ps.

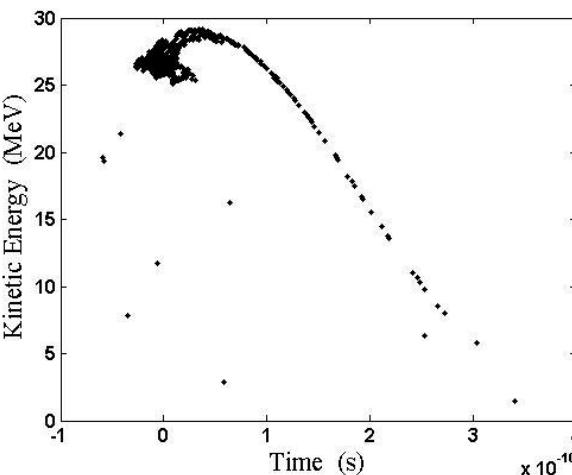
Parameter	Unit	Value
Phase velocity:		
First 12 cells	c	0.68-0.99
Last 6 cells	c	1
Phase advance/cell	π	2/3
Total length	m	1.681
Accelerating field	MV/m	4.2
Beam aperture radius	cm	4.7



Exit of the solenoids ($E \sim 30$ MeV)

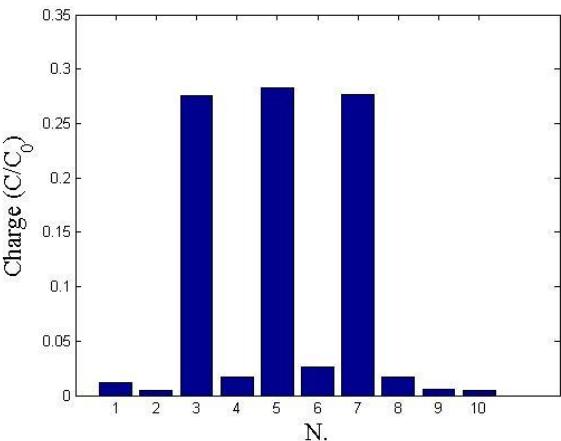
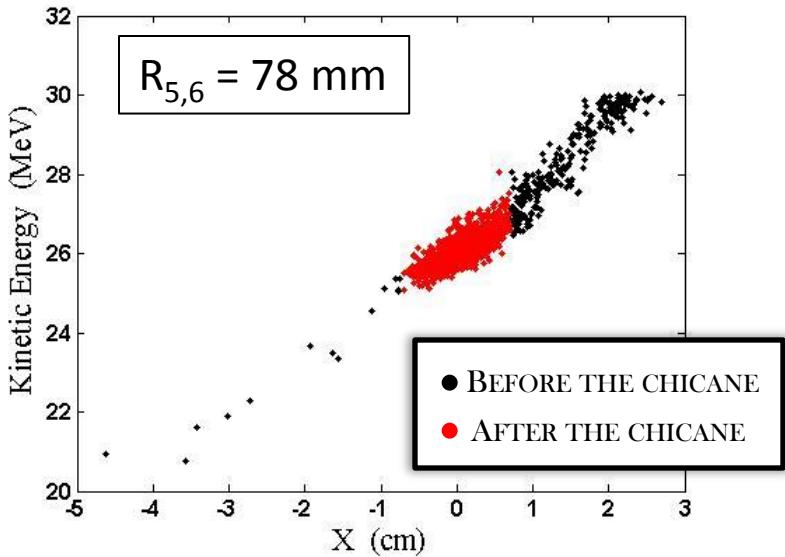
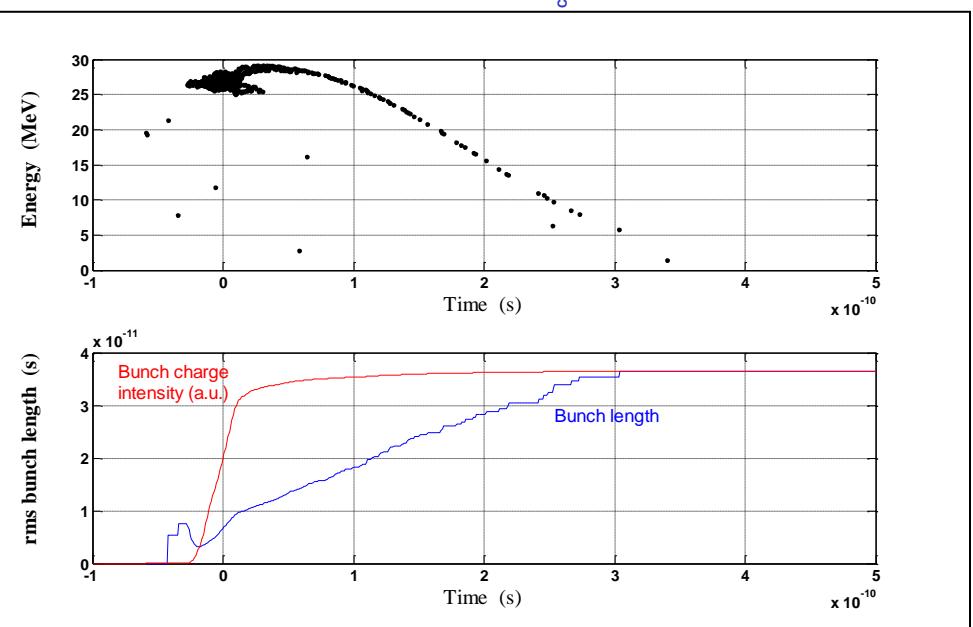
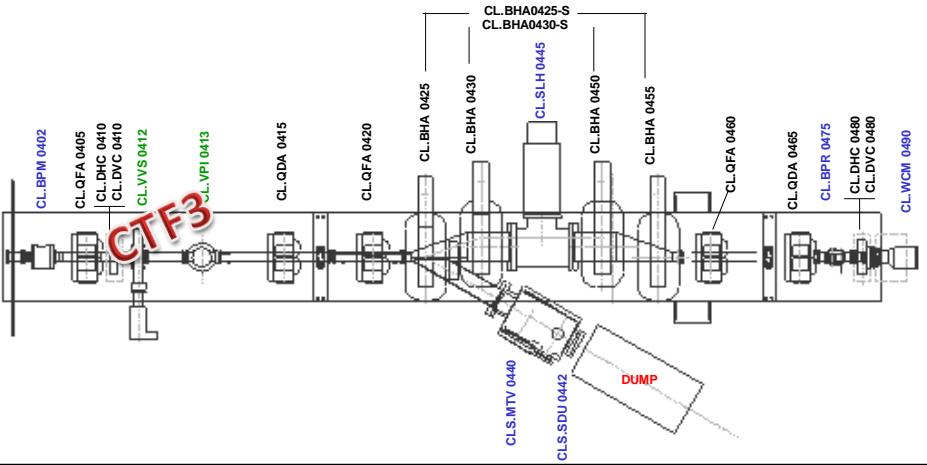


Accelerating cavities parameter	Unit	Value
Phase velocity	c	1
Number of cells		10
Phase advance per cell	π	2/3
Total length	m	0.9998
Voltage	MV	4.8
Beam aperture radius	cm	4.7



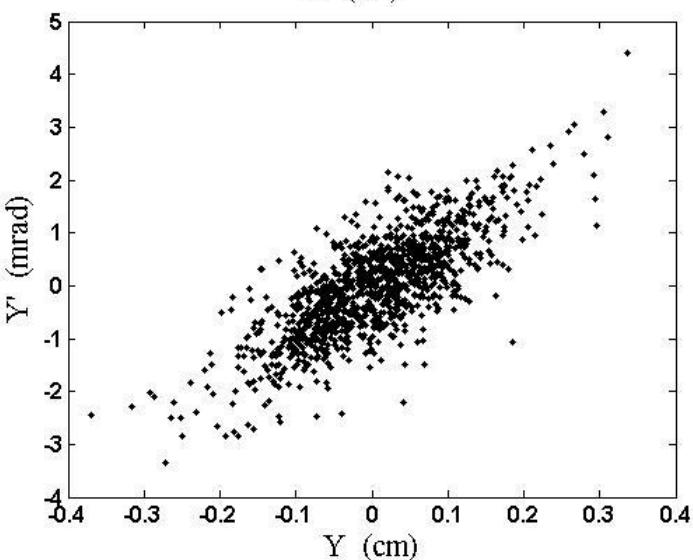
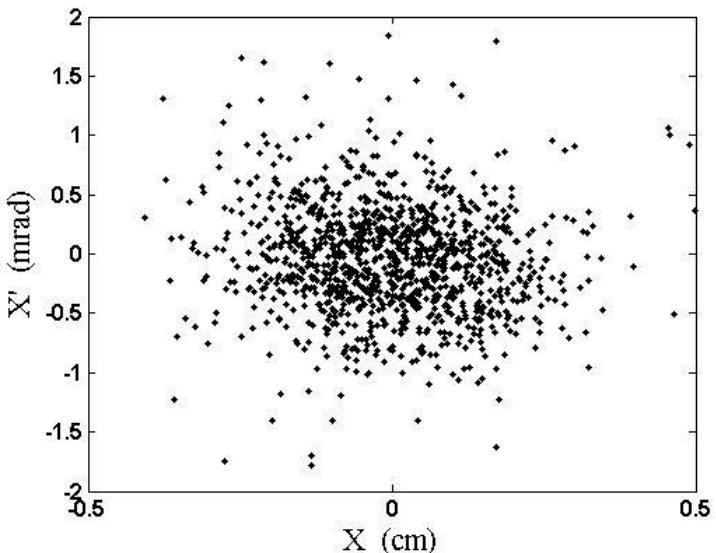
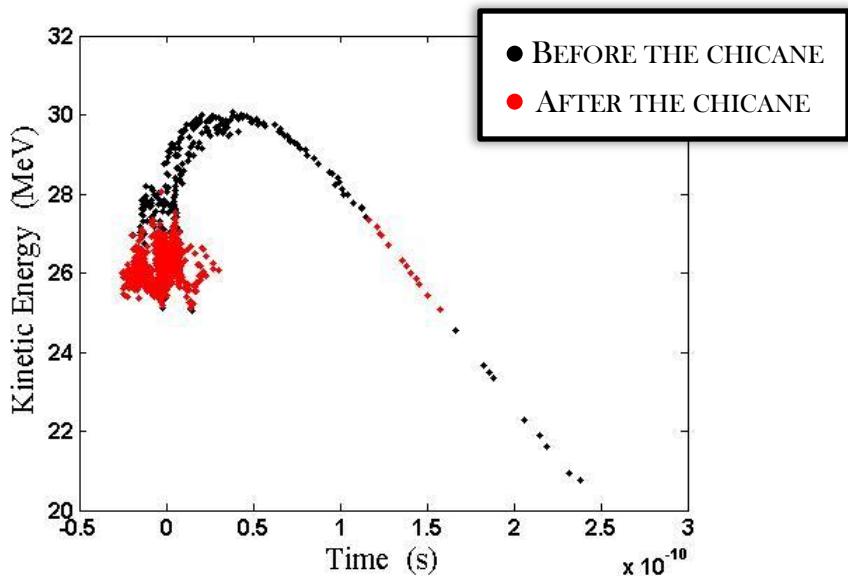
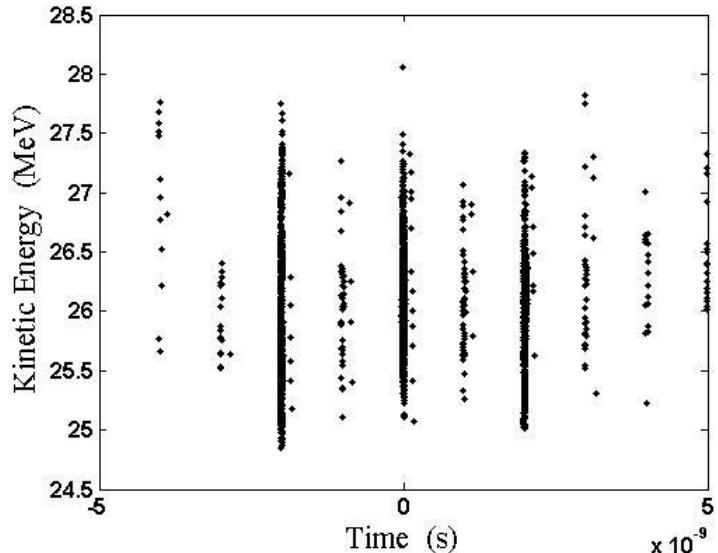
Energy = 26.34 MeV; $\sigma_E = 2.16$ MeV; $\sigma_t = 36.58$ ps.

Cleaning chicane

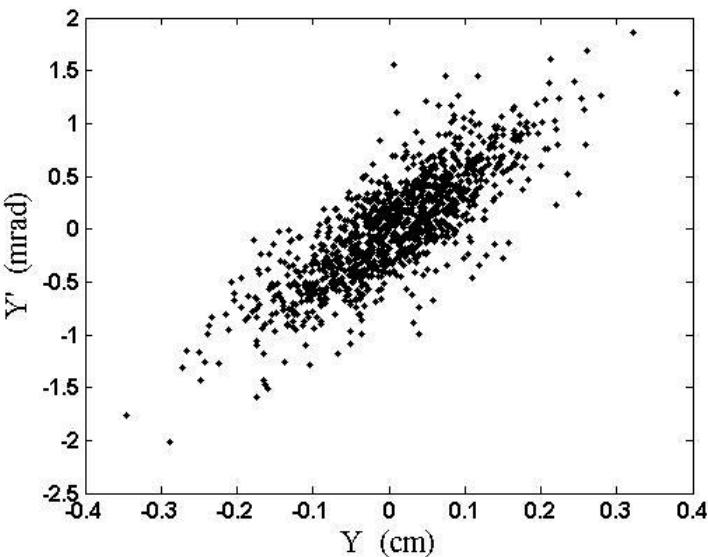
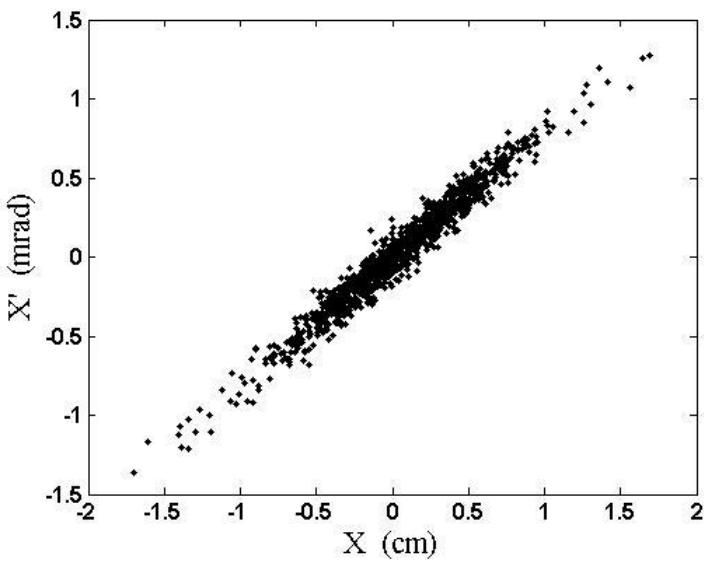
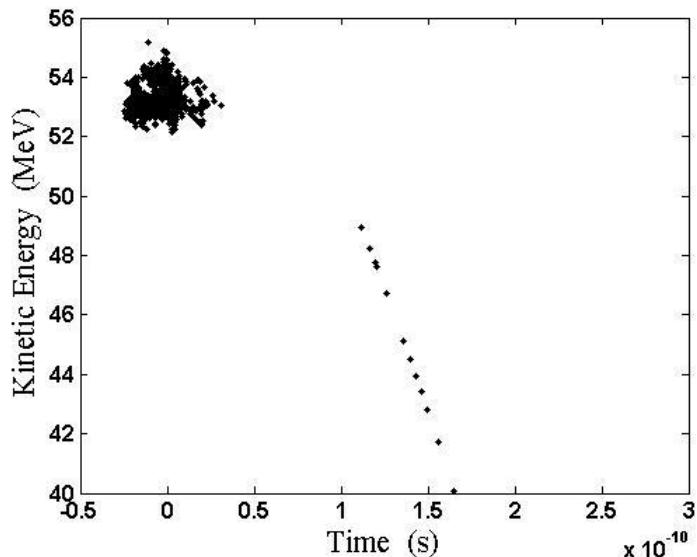
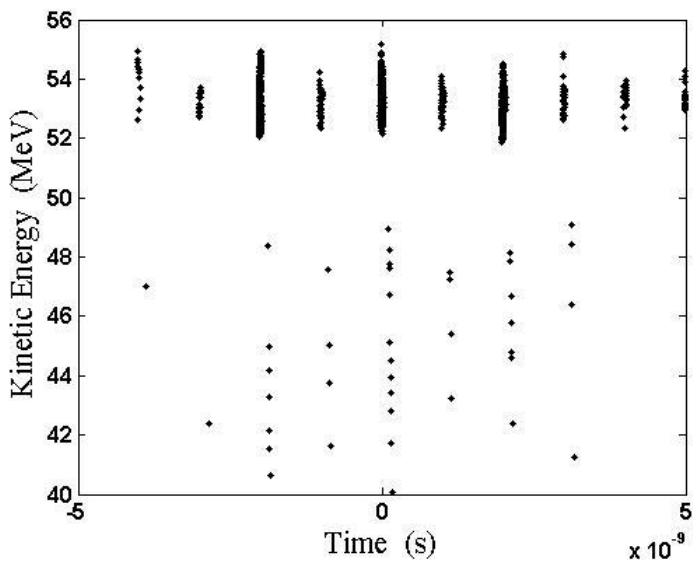


Bend length = 15 cm; Bend angle = 14.32 deg; Reference E = 26 MeV; Slit aperture = 7 mm;
Intensity decrease = 24%.

After the cleaning chicane



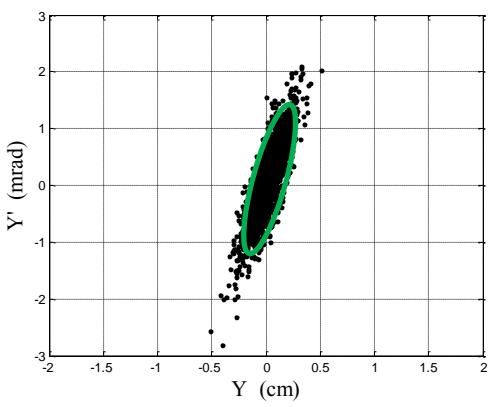
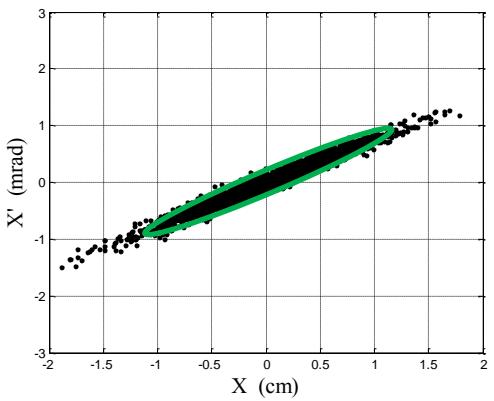
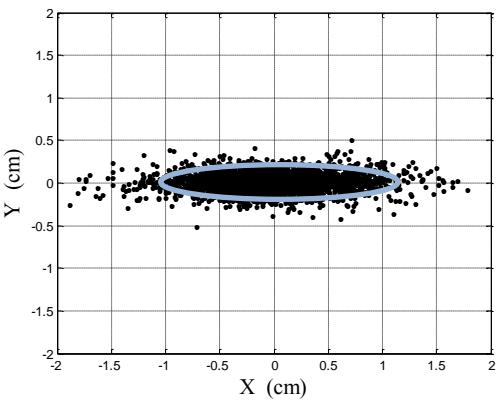
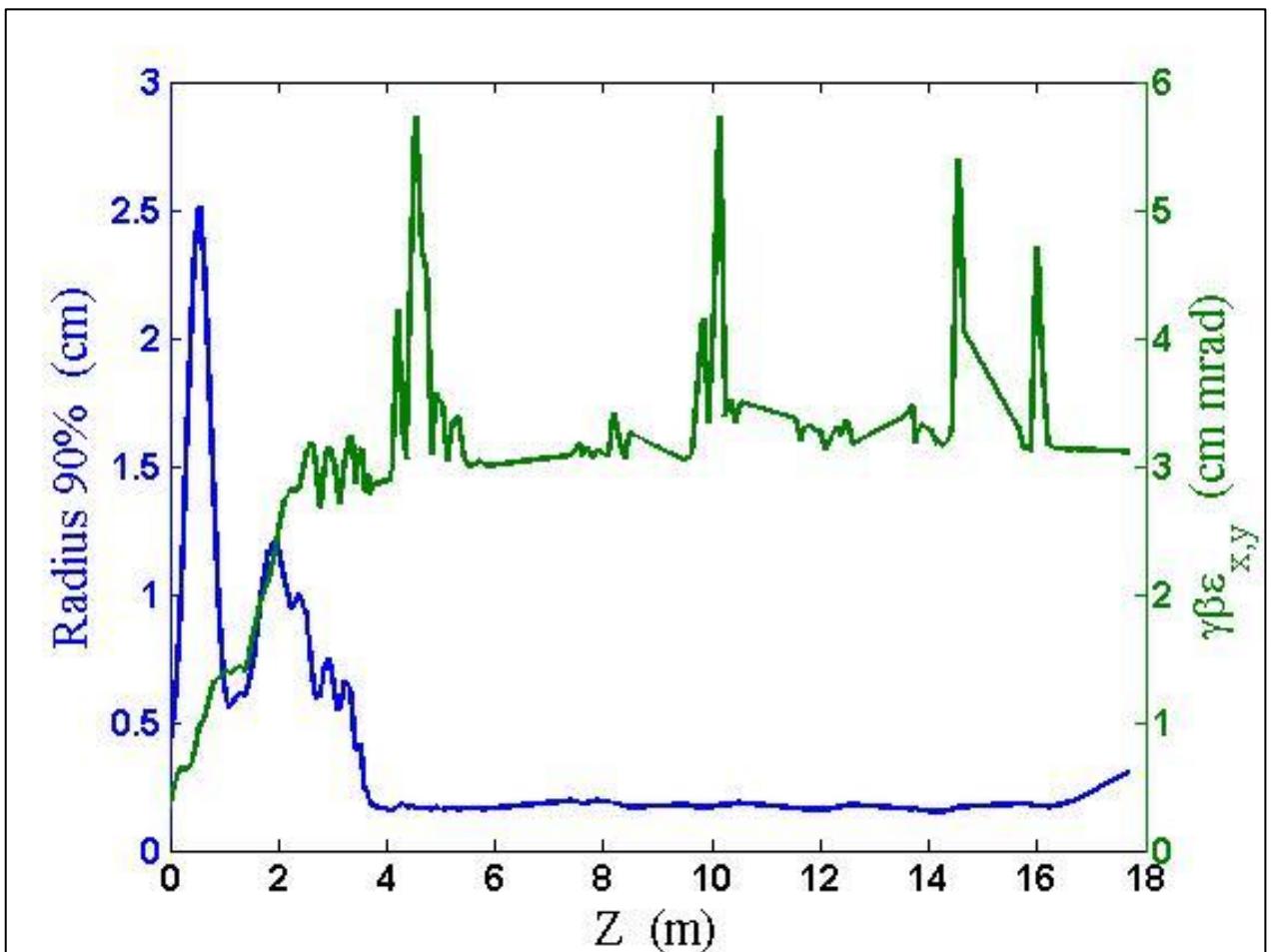
Energy = 26.07 MeV; $\sigma_E = 0.40$ MeV; $\sigma_t = 17.14$ ps.

Injector exit ($E \sim 50$ MeV)

Energy = 53.25 MeV; $\sigma_E = 0.45$ MeV; $\sigma_t = 9.45$ ps.

$\gamma\beta\varepsilon_x = 32.92$ $\mu\text{m rad}$; $\gamma\beta\varepsilon_y = 28.73$ $\mu\text{m rad}$.

CLIC drive beam injector: transverse dynamics



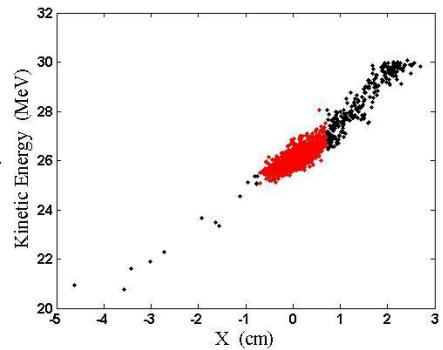
Parameter	Unit	Simulations	CLIC
Energy	MeV	53.2	
Bunch charge	nC	8.16	≥ 8
Bunch length (rms)	mm	2.83	3 (@ 50 MeV)
Energy spread (rms)	MeV	0.45 (@53 MeV)	< 0.50 (@ 50 MeV)
Horizontal normalized emittance (rms)	$\mu\text{m rad}$	32.9	≤ 100
Vertical normalized emittance (rms)	$\mu\text{m rad}$	28.7	≤ 100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

CLIC requests fulfilled

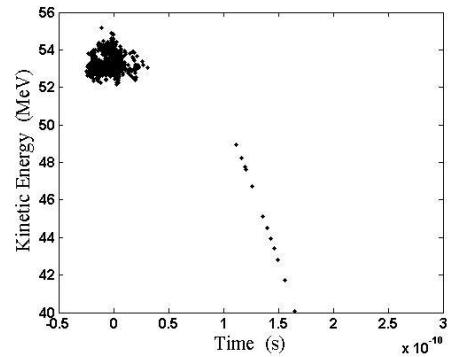
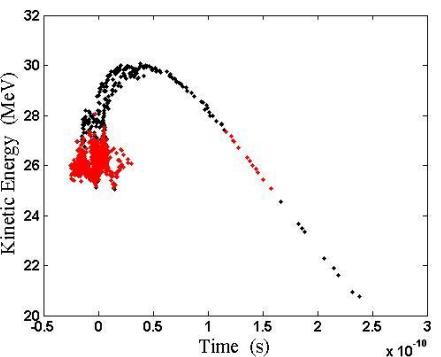
CLIC drive beam injector design: a critical view

More optimizations still ongoing:

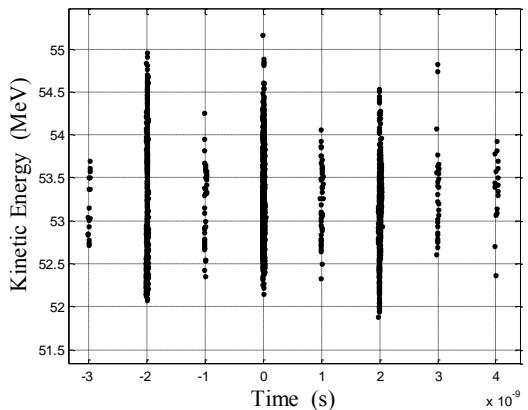
- Intensity decrease at the chicane = 24% (close to CTF3 20%)



- Additional chicane needed
(power???)



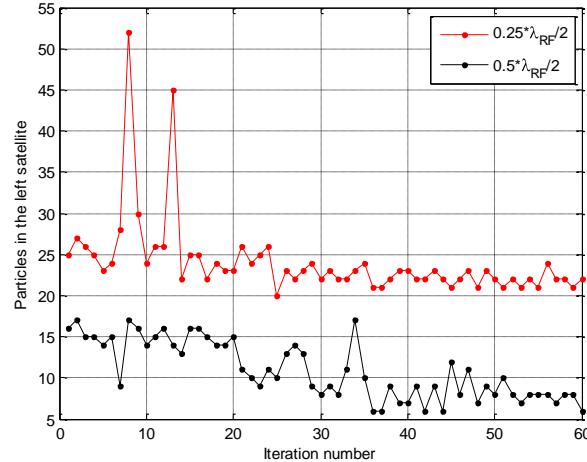
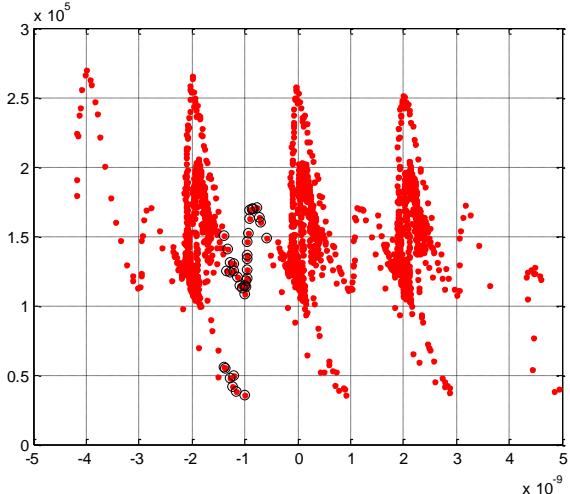
- Satellites population = 4%



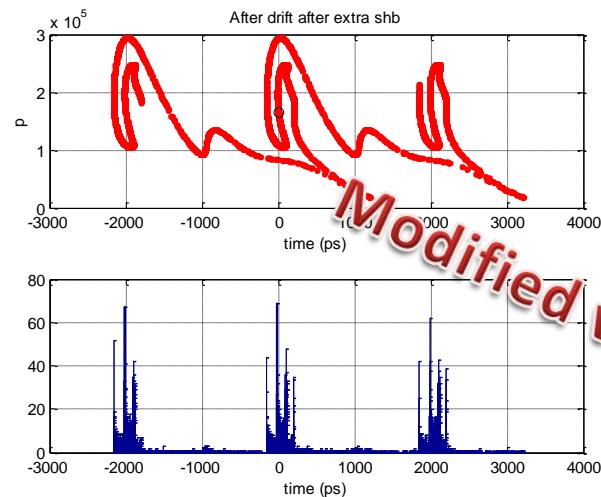
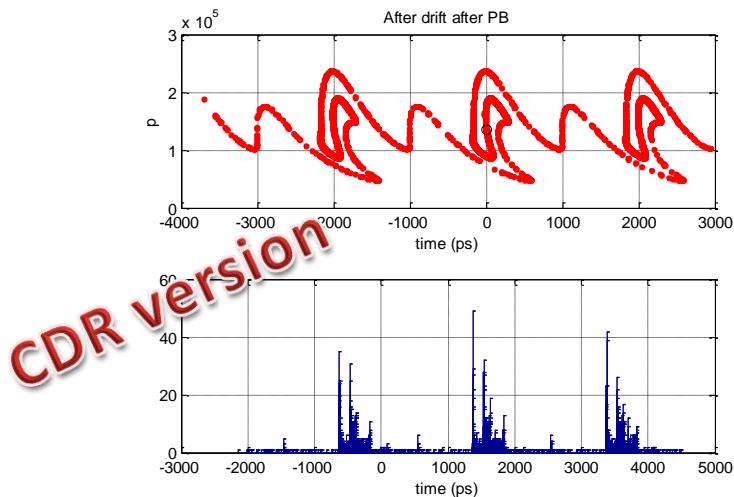
Satellites minimization: possible cures

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

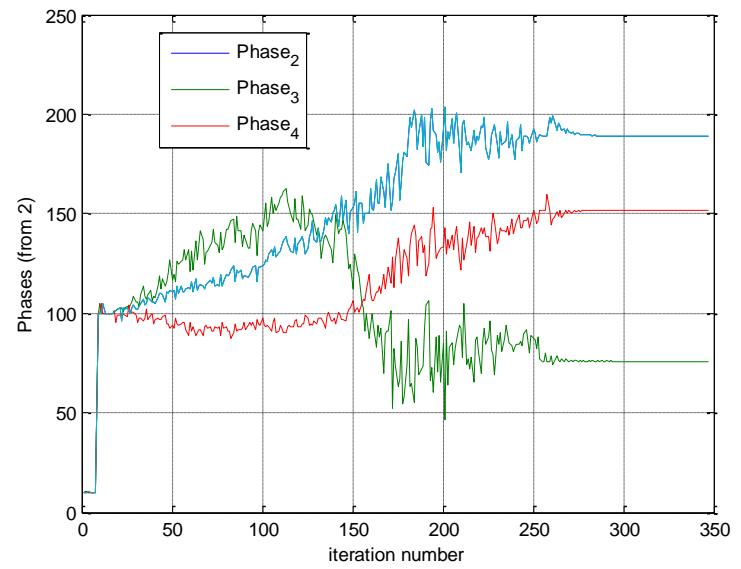
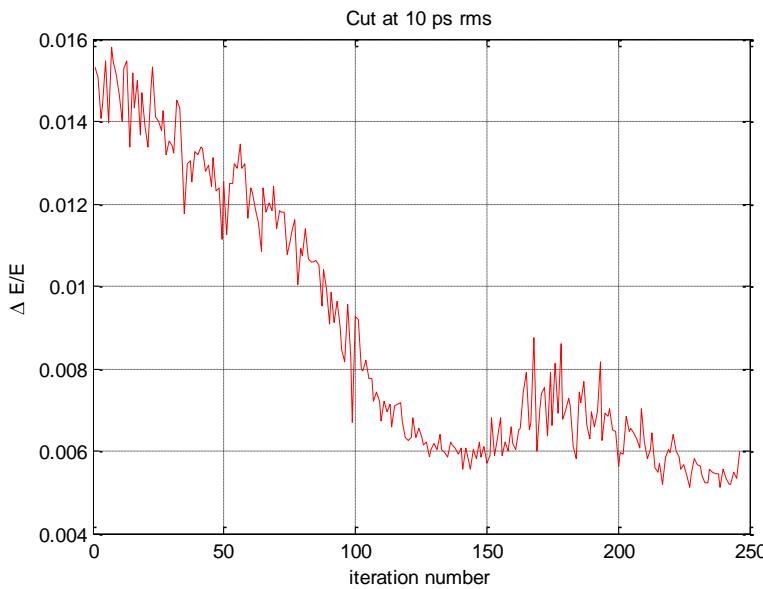


Re-optimization using as a figure of merit the energy spread at a fixed bunch length and optimization of the accelerating cavities:



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

- 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 08:00 - 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) (CICO)

- 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')

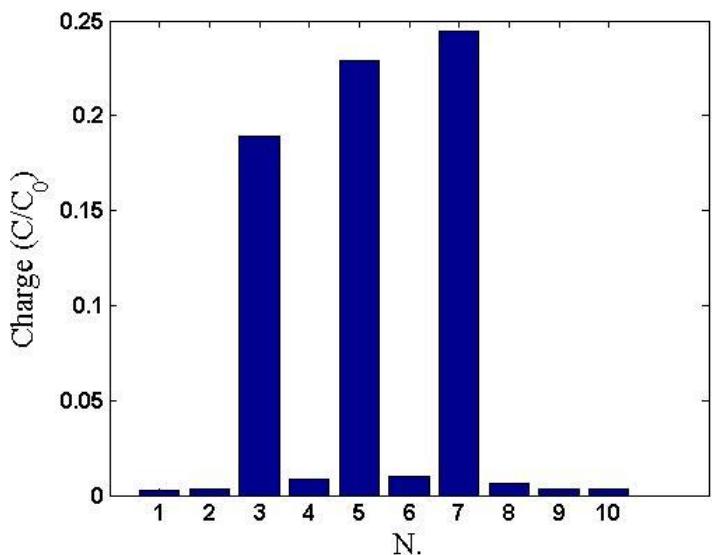
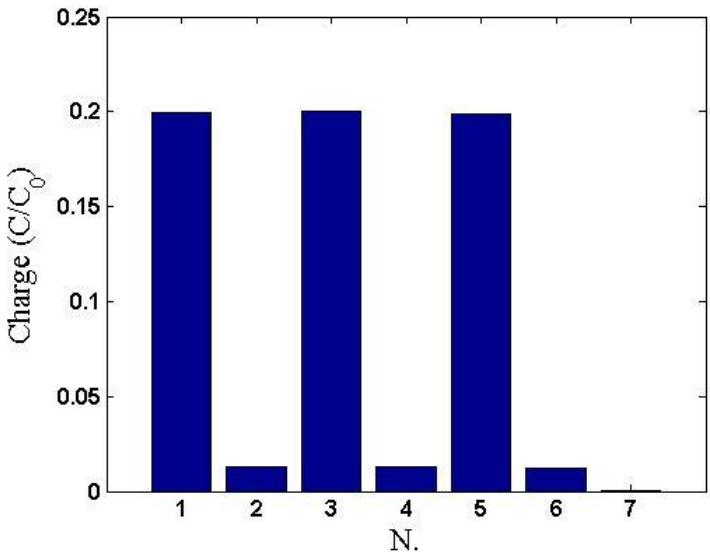
16:00->18:30 ECFA Parallel: Cosmology (Convener: Marco Battaglia (*CERN and UCSC*) , Marco Cirelli (*CERN and CNRS IPhT Saclay*) , Geraldine Servant (*CERN*)) (Room 23 - floor "0")

- 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

