CLIC DB injector facility, photo-injector option studies

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➢ **CLIC DB injector**

➢ **Thermionic gun baseline**

➢ **Photo-injector option**

➢ **Conclusions**

Objectives

- **Get started with some CLIC equipment for the drive beam**

- **Develop 1 GHz rf system, klystron, rf structure**

    challenging, long lead time, cost driver

- **Construct high average current particle source**

- **Demonstrate long pulse operation within the stability specification**

- **First part of CLIC 0**

CLIC DB injector specifications

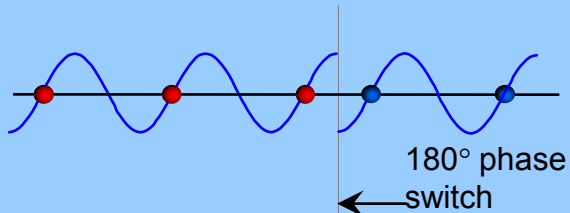| Parameter	Nominal value	Unit
Beam Energy	50	MeV
Pulse Length	**140.3** / 243.7	μs / ns
Beam current	4.2	A
Bunch charge	**8.4**	nC
Number of bunches	70128	
Total charge per pulse	**590**	μC
Bunch spacing	**1.992**	ns
Emittance at 50 MeV	100	mm mrad
Repetition rate	100	Hz
Energy spread at 50 Mev	1	% FWHM
Bunch length at 50 MeV	3	mm rms
Charge variation shot to shot	**0.1**	%
Charge flatness on flat top	**0.1**	%
Allowed satellite charge	< 7	%
Allowed switching time	5	ns

CTF3 example
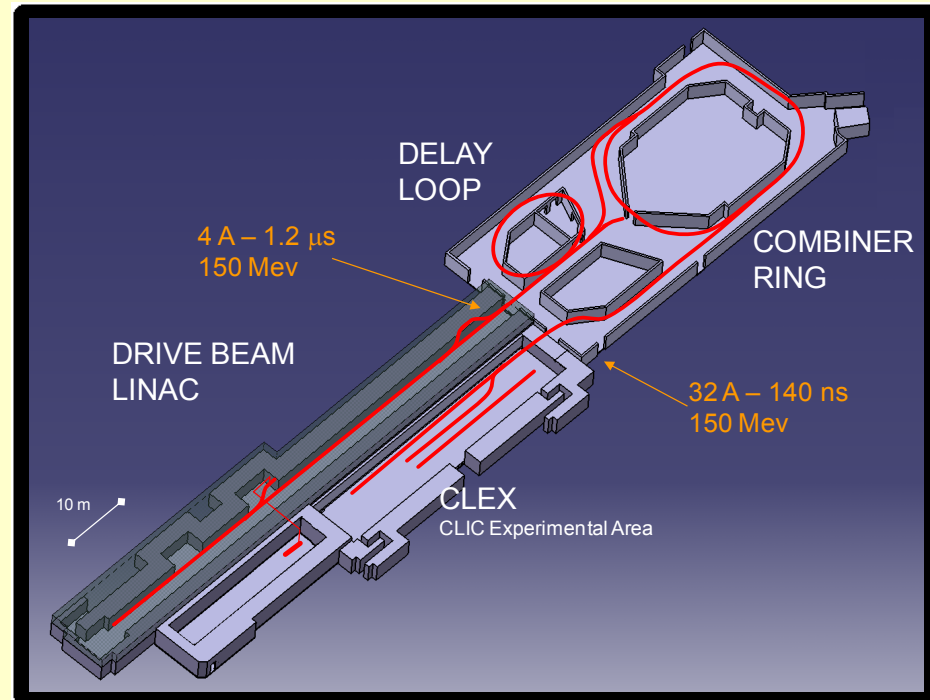## Phase coding by sub-harmonic bunching

Phase coding

Sub-harmonic bunching $\nu_0 / 2$

$180°$ phase switch

Acceleration ν_0

Deflection $\nu_0 / 2$

DELAY LOOP

COMBINER RING

DRIVE BEAM LINAC

4 A – 1.2 μs
150 Mev

32 A – 140 ns
150 Mev

10 m

CLEX
CLIC Experimental Area

gun

SHB

SHB

SHB
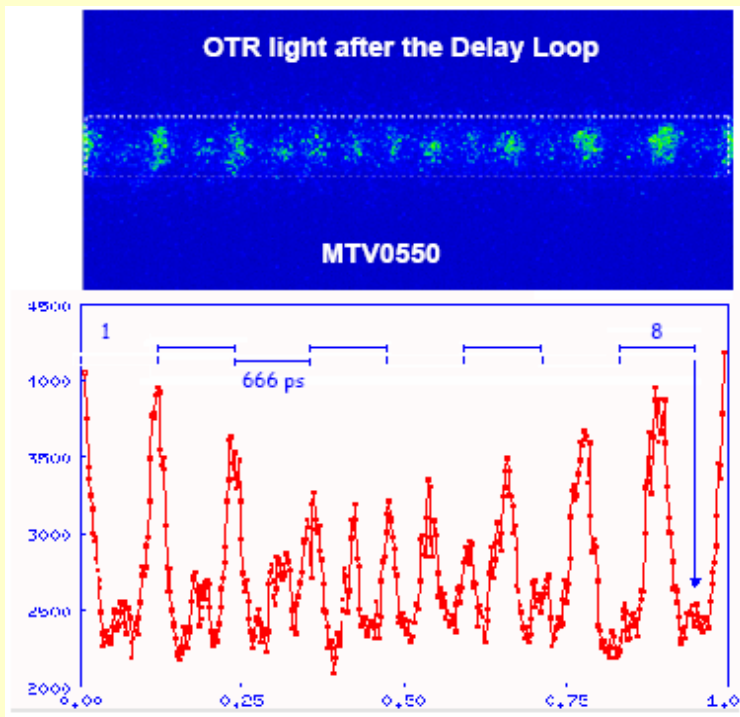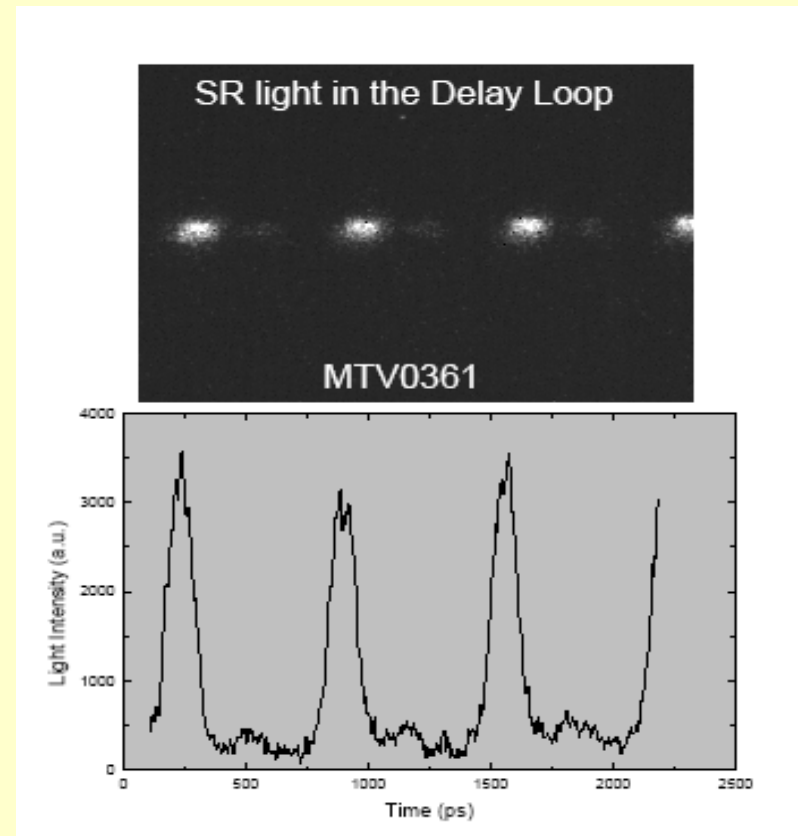
buncher

2 accelerating structures
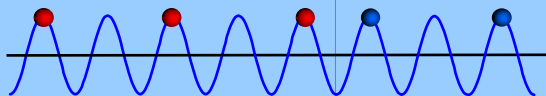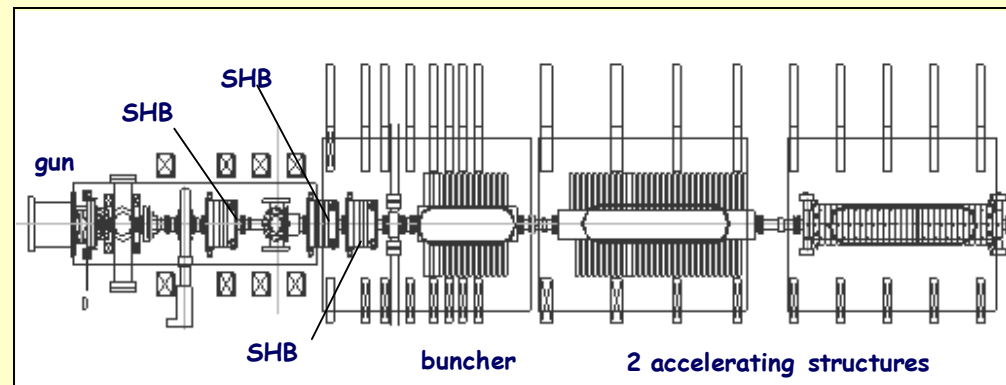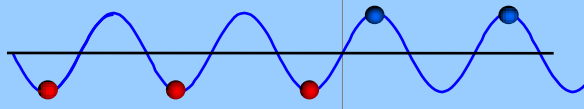
Satellites
High bandwidth buncher and rf source needed

Phase switch:

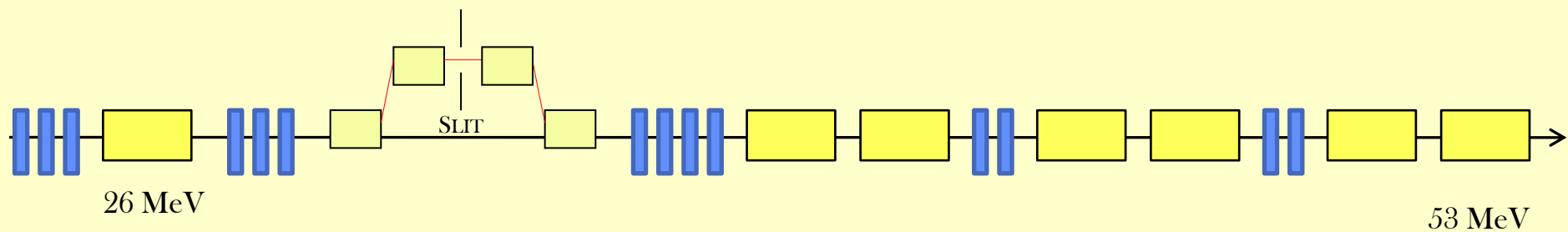Phase switch within eight 1.5 GHz periods **(<6 ns).**

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

CLIC DB injector schematics

SOLENOIDS

THERMIONIC GUN

SHB PREBUNCHER BUNCHER ACCELERATING CAVITY
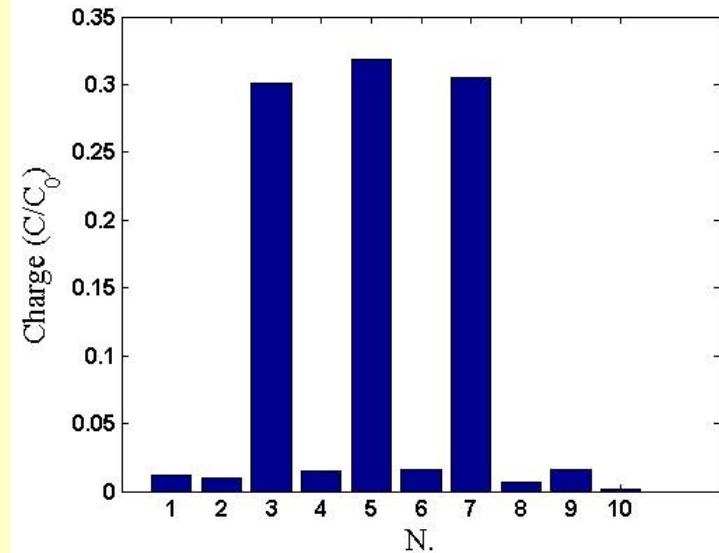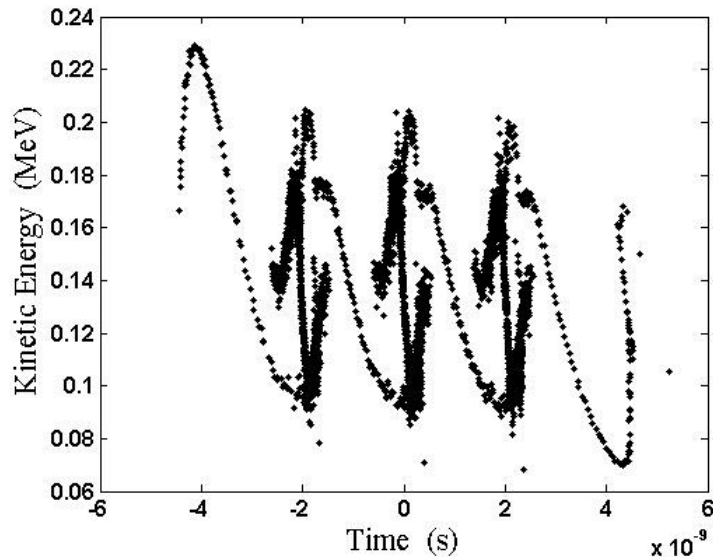
6 MeV

SLIT

26 MeV

53 MeV
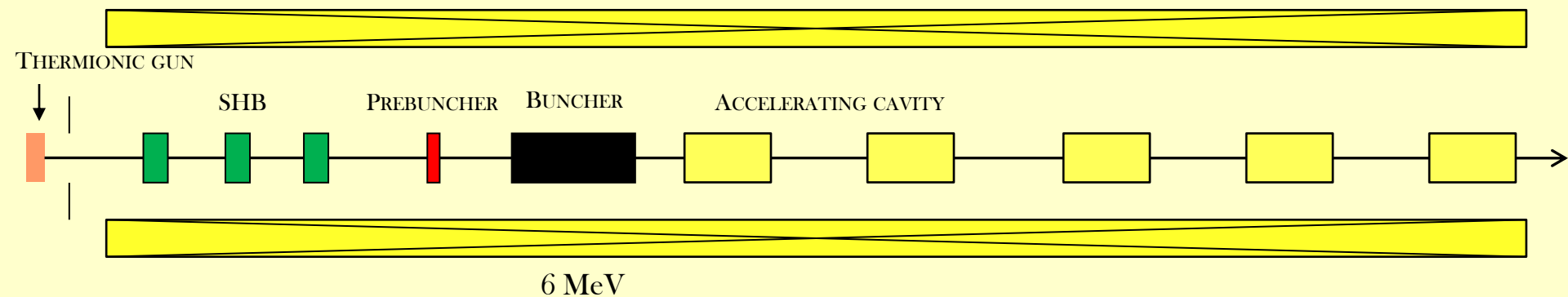
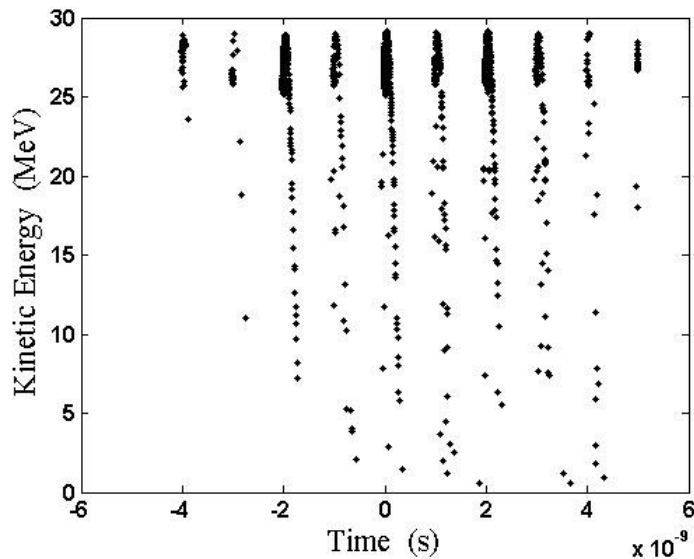**Basically a scaled version of CTF3**

Simulation results

Longitudinal phase space after sub-harmonic bunching
Same total gap-voltage but fewer cells (2 instead of 6)
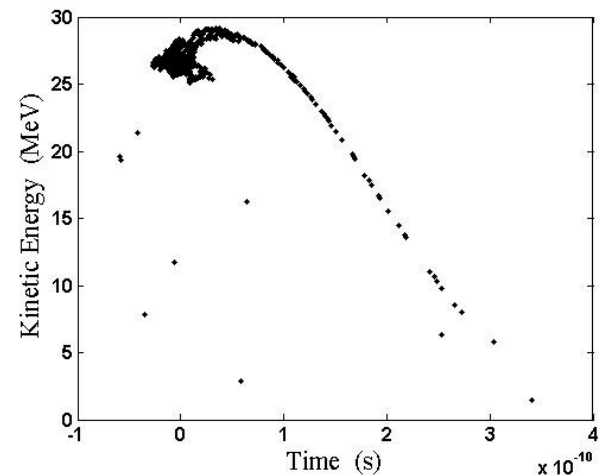**35-39 KV needed**

Simulation results

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

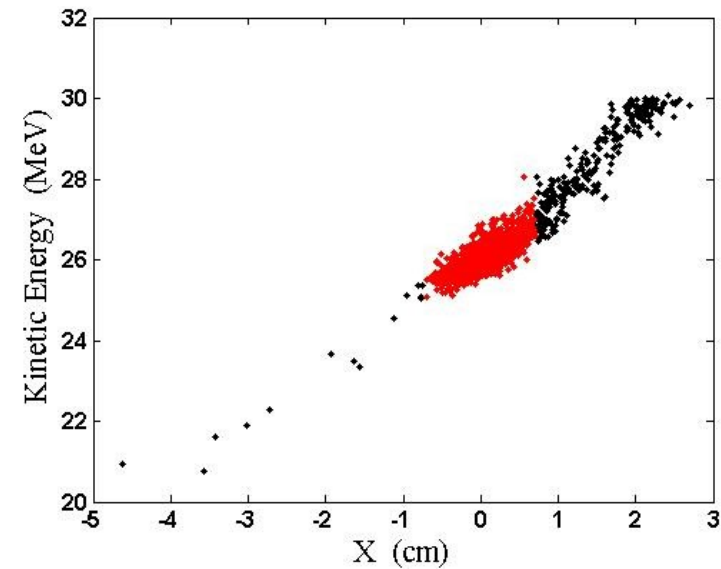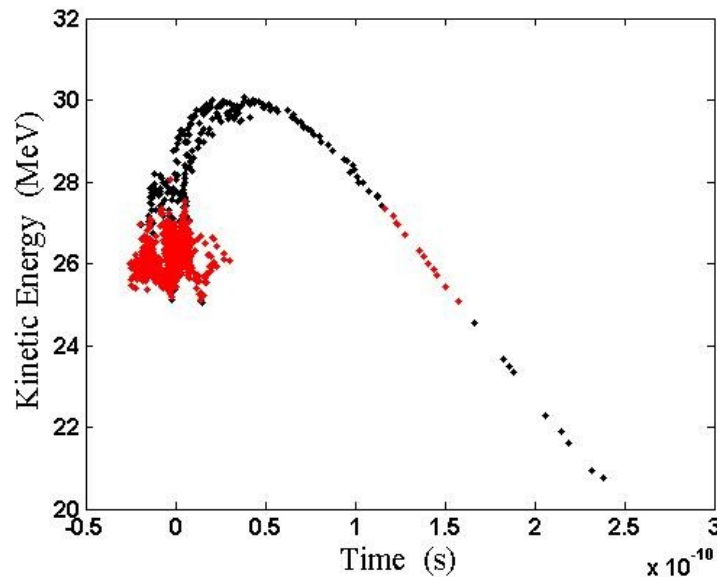**Exit of the solenoids at around 26 MeV, Satellites and tails visible**

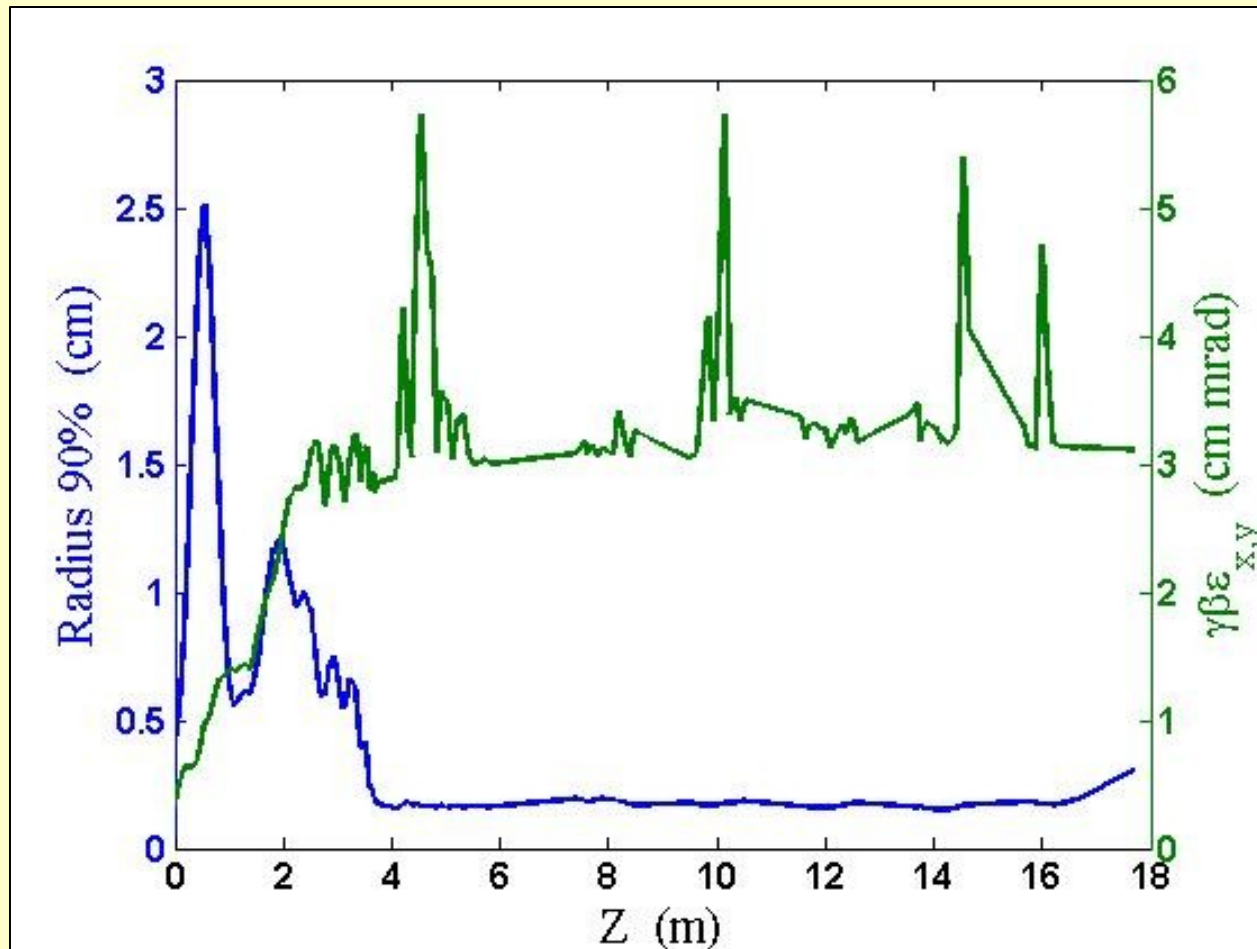# Simulation results

BEFORE THE CHICANE
AFTER THE CHICANE

Longitudinal phase space after the cleaning chicane, 24 % intensity loss at the chicane

Transverse dynamics

Transverse optics after the solenoids at 26 MeV

Simulation results

Parameter	Unit	Simulations	CLIC
Energy	MeV	53.2	
Bunch charge	nC	8.16	8.4
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

- Specifications can be fulfilled
- Some ideas to improve the satellites and total losses
- Beam loading and wake field effects to be studied
- Real rf-design of buncher needed

Thermionic gun

Some simple considerations

CTF3: 1.6 μs, 9.6μC per pulse
1 % droop specs
→7 nF, ~70 J stored energy

CLIC: 140 μs, 700 μC per pulse
0.1 % droop specs
→ 5 μF, ~50 kJ stored energy

CTF3 gun concept might be not scalable for CLIC

Have to investigate a high voltage modulator concept, stability ?
(Max Lab example)

Does a gridded cathode survives this pulse ?

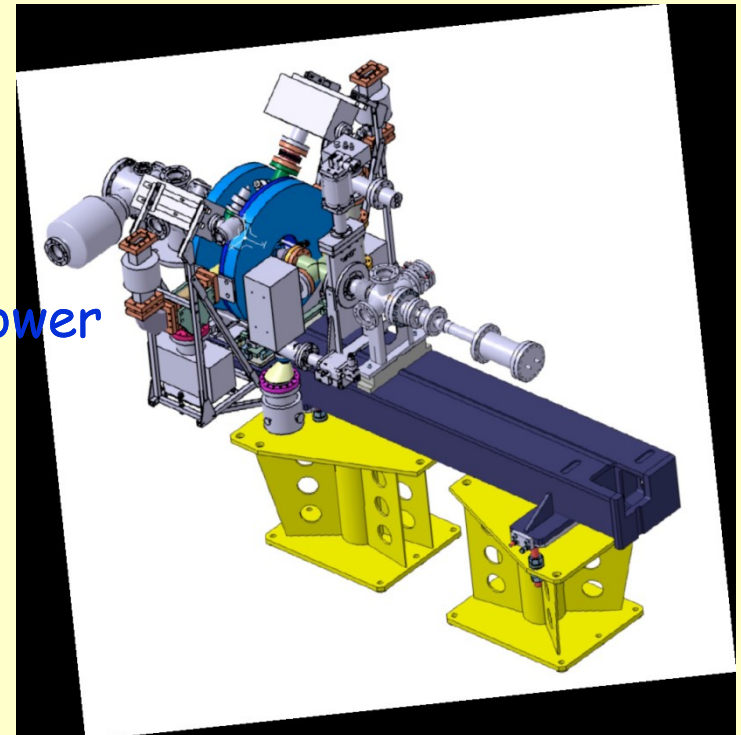→ Most likely new gun design needed

Photo injector option

Advantages

- No satellites or tails, phase coding on the laser side
- No or less bunching needed, possibly better emittance
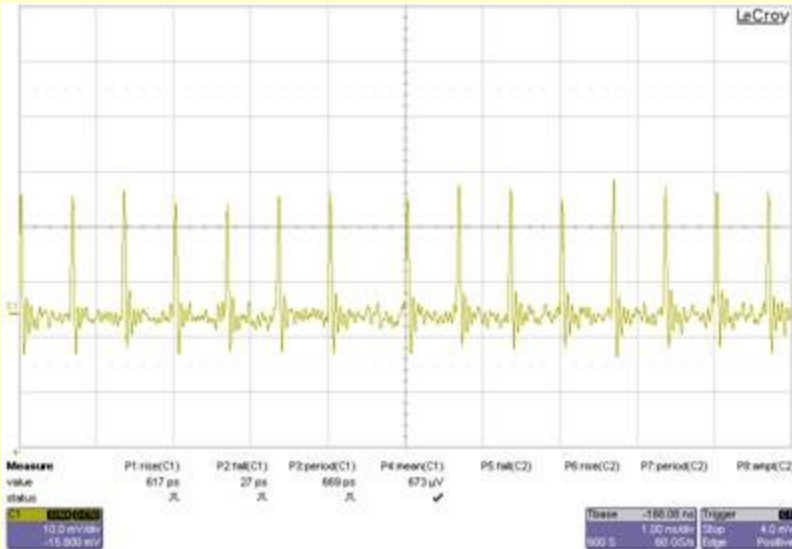- Flexible time structure

Concerns

- Cathode lifetime
- Challenging laser, peak and average power
- Intensity stability
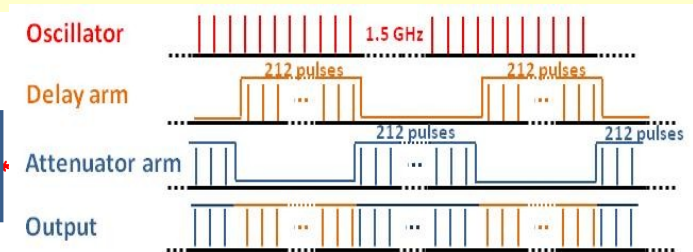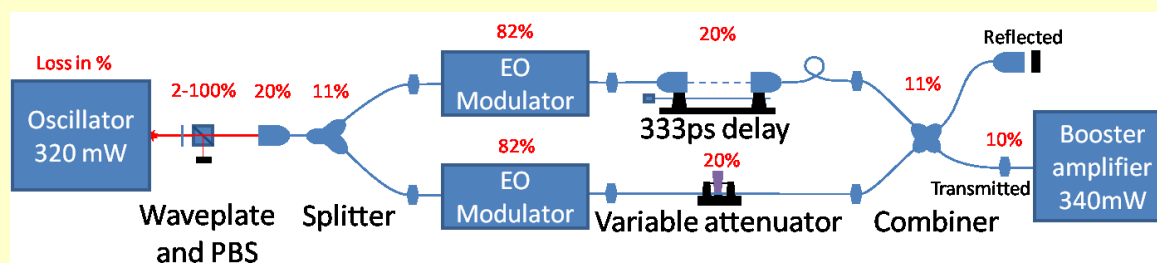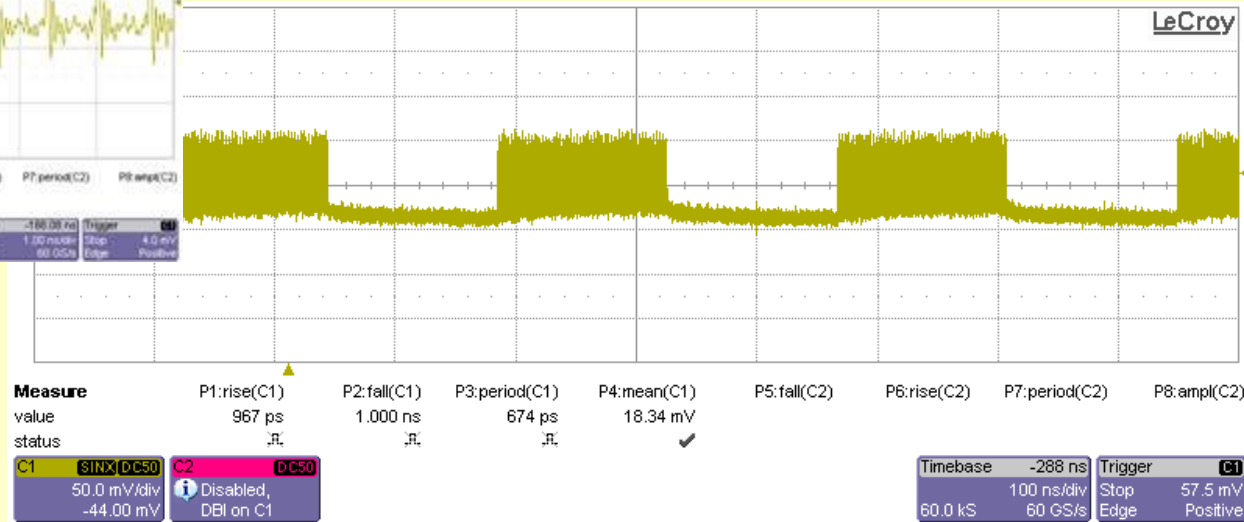- Maintenance and operation

Phase coding

Principle just demonstrated, to be tested with beam in the following weeks
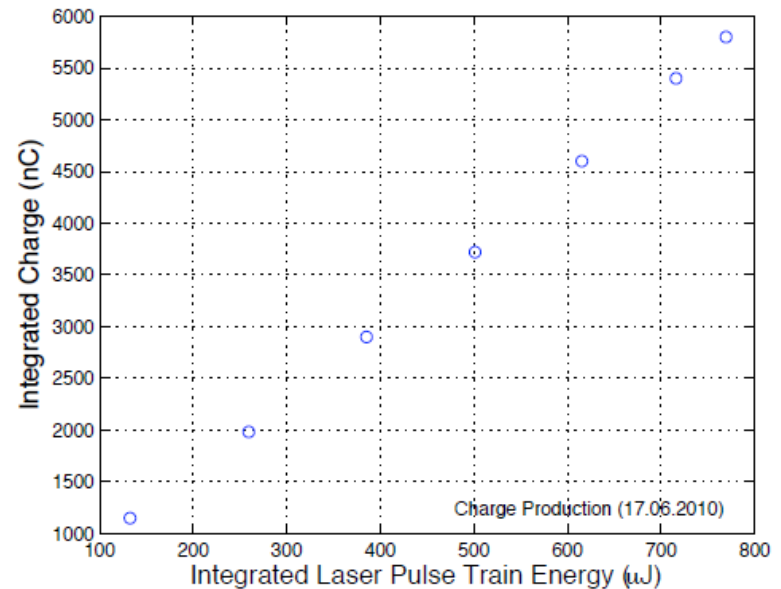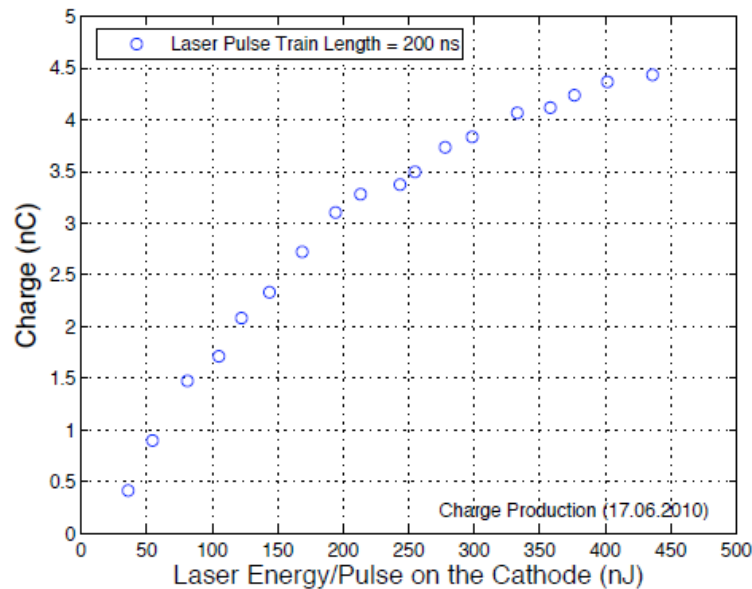
Charge production

Showed in CTF2 already the bunch charge needed (> 10 nC)
Total charge test performed in the cathode lab (> 1 mC)
460 h with 1.5% QE have been shown in excellent vacuum
Combination of those together has not yet been demonstrated
Cathode lifetime under this rough conditions is a big concern
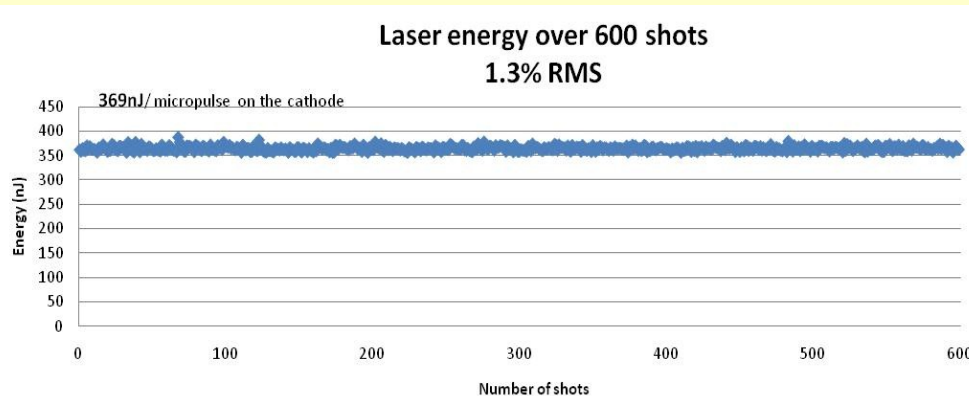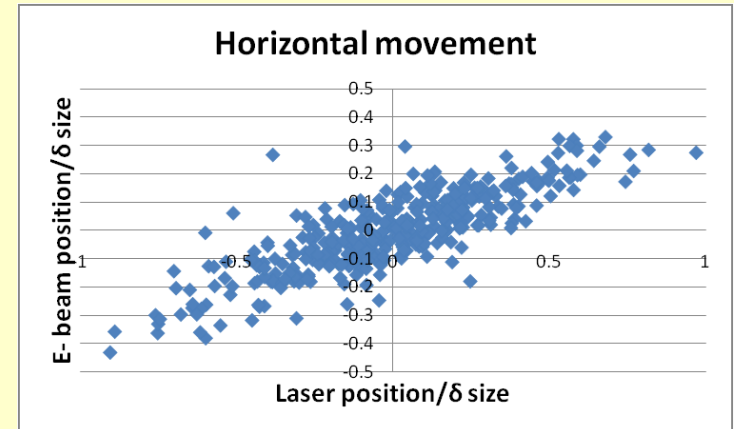

Charge production with PHIN

Stability

In laser room

Macrop	IR	Green	UV
RMS stability	0.23%	0.8%	1.3%

Nonlinear conversion increases noise and causes amplitude variations along the train

In PHIN

Laser RMS	Current RMS	Train length(ns)	
1.3% RMS	0.8% RMS	1250	best
2.6%	2.4%	1300	worst

Horizontal movement

Laser energy over 600 shots 1.3% RMS

369nJ/micropulse on the cathode

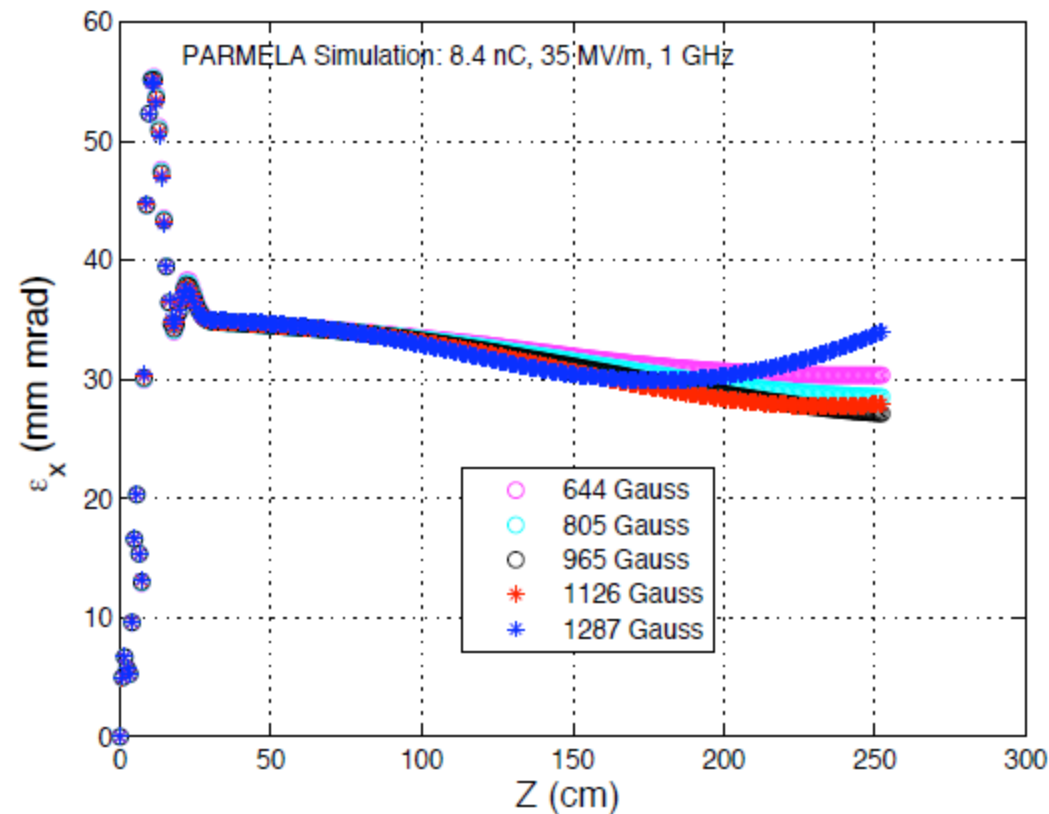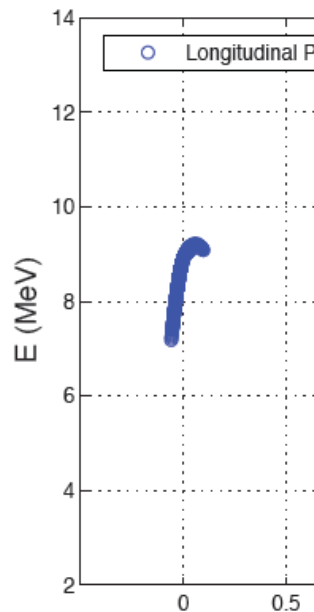**Beam stability seems almost entirely determined by laser stability**
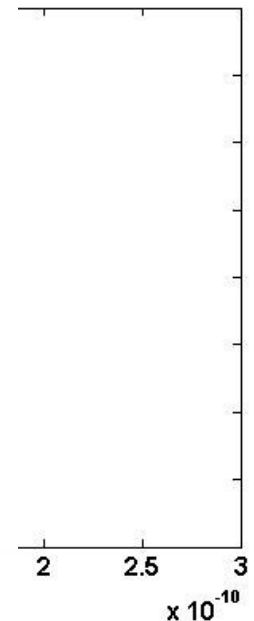
We need 0.1% RMS stability

Beam dynamics simulations

Using scaled version of PHIN gun, 1 GHz
Concerns: Power, cooling and vacuum

Comparison
simulation results

Parameter	RF Gun	Thermionic Gun	CLIC Drive Beam
RF Frequency (GHz)	1	1	1
Gradient (MV/m)	35	-	-
Charge / Bunch (nC)	8.4	8.16	8.4
Beam Size (1σ) , σ_x (mm)	4.3	-	-
Laser Spot Size (1σ), σ_L (mm)	2	-	-
Normalized Emittance, $\epsilon_{x,n}$ $(mm\,mrad)$	27.1	32.9	< 100
Beam Energy (MeV)	8.8	53.2	2730
Bunch Length, σ_z (ps)	18	9.43	$10 - 3.33$
RMS Energy Spread, $\Delta E\,(KeV)$ / (%)	297 / 3.37 (8.8 MeV)	450 / 0.84 (50 MeV)	$\leq 1\%$ (50 MeV)
Satellite Bunches (%)	0	4.9	as less as possible

Research program
Photo injector option

- Continue working with PHIN set up,
  study increased bunch charge and cathode lifetime issues

- Laser Intensity feedback

- Try to generate CLIC-like laser pulses to study
  average power and train stability issues

- Eventually design and realize 1 GHz rf-gun

- Full system test (1 GHz rf system needed)

- Some work on alternative (green) cathodes

Conclusions

- Conceptual designs for both injector options exist, more detailed technical design has to start

- Will continue following up the photo injector option

- Try to design test facility which allows to test both

- Have to start with thermionic gun and 1 GHz system as soon as possible !