Drive Beam Photo-injector Option

for the CTF3 Nominal Phase

- **Motivation**
- **CTF3 Drive Beam Requirements**
- **CTF3 RF gun design**
- **The Laser ⇒ (I. Ross / RAL)**
- **The Photocathode**
- **Cost estimate**
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Motivation

Expected advantages of the photo-injector option compared to the thermionic source :

- The laser time structure can be easily manipulated to produce the best shape $\Rightarrow$ flexibility for studies and for minimizing transient beam-loading in the CLIC main beam
- “Empty“ buckets really empty $\Rightarrow$ reduce losses and the radiation level
- Smaller emittances (transversal and longitudinal) $\Rightarrow$ easier beam transport and bunch length manipulation.
- No low-energy tails at the end of the injector.
- Compactness of injector
- Less expensive

CTF3 Drive Beam Photo-injector Requirements (1)

	Unit	CTF-3
Pulse charge	nC	2.33
Pulse width (FWHH)	ps	10
Peak current	A	240
Number of pulses	-	2310
Distance between pulses	ns	0.667
Charge stability	%	**± 0.1**
Train duration	μs	1.54
Train charge	μC	5.4
Repetition rate	Hz	5
Mean current	mA	0.026
Minimum QE at λ_{laser}	%	**1.5**
Minimum lifetime at QE_{min}	h	**100**
Shots during lifetime	x 10^9	3.9
Photo cathode produced charge	C	10
Mean Laser power at the cathode	W	0.008
Photo-injector Reliability	%	**≥ 95**

BUT

To be taken into account the photo-injector MUST also demonstrate the feasibility for CLIC

- On paper for the laser and with the today technology
  ⇒ This has been done : see CLIC Note 462

- As close as possible of the CLIC working point for the photocathode
  ⇒ This has been done : see CTF3 Note 020

⇓

The photo-injector should be an option for CTF3 and CLIC

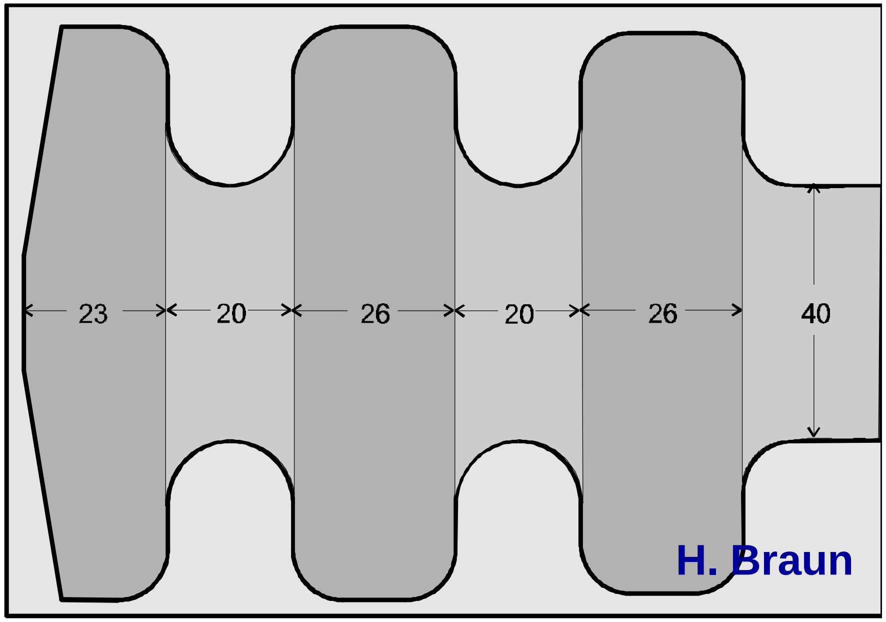
⇓

see CLIC Note 487

CTF3 RF gun design

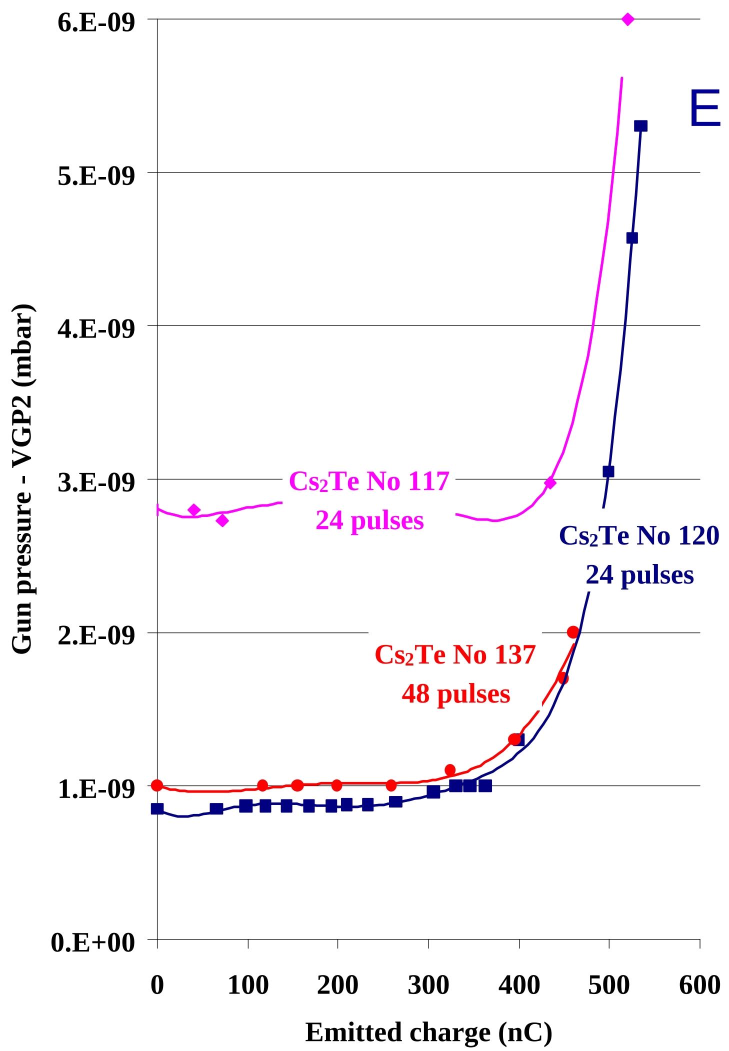
The design for the RF gun is based on the existing CTF 2 drive beam gun

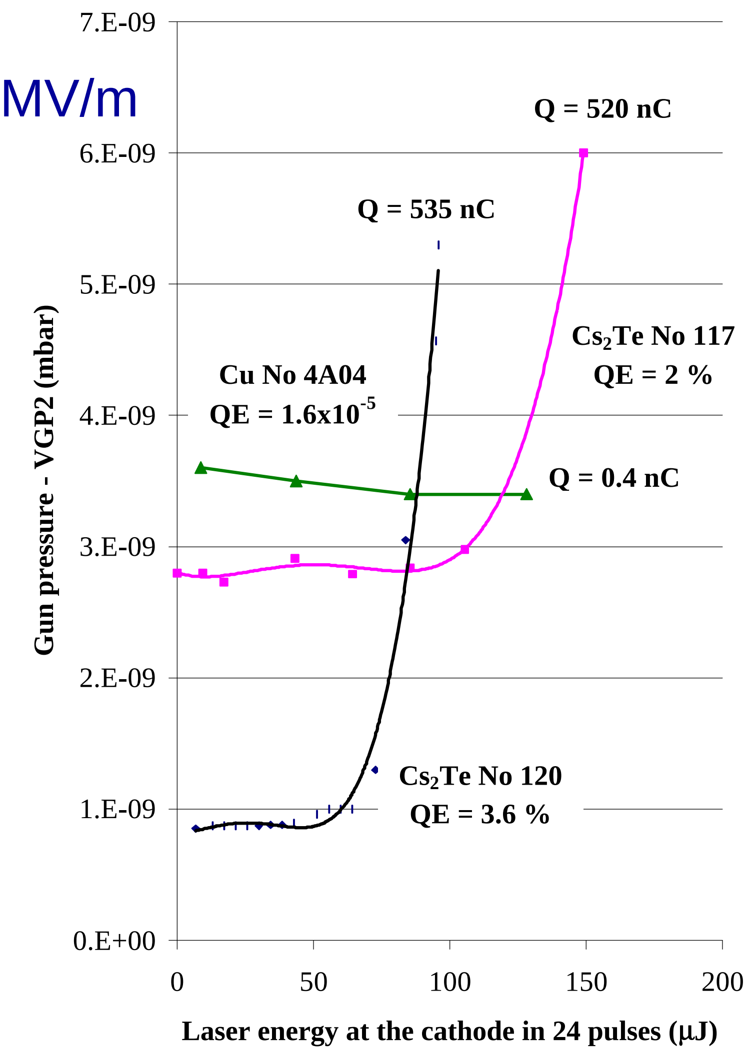
RF frequency	2.99855 GHz
RF power	30 MW
Beam energy	5.6 MeV
Beam current	3.5 A
Peak field on cathode	85 MV/m
Unloaded Q	13000
Coupling factor β	2.9
Delay beam /RF	400 ns



Special attention should be paid to the vacuum pumping speed

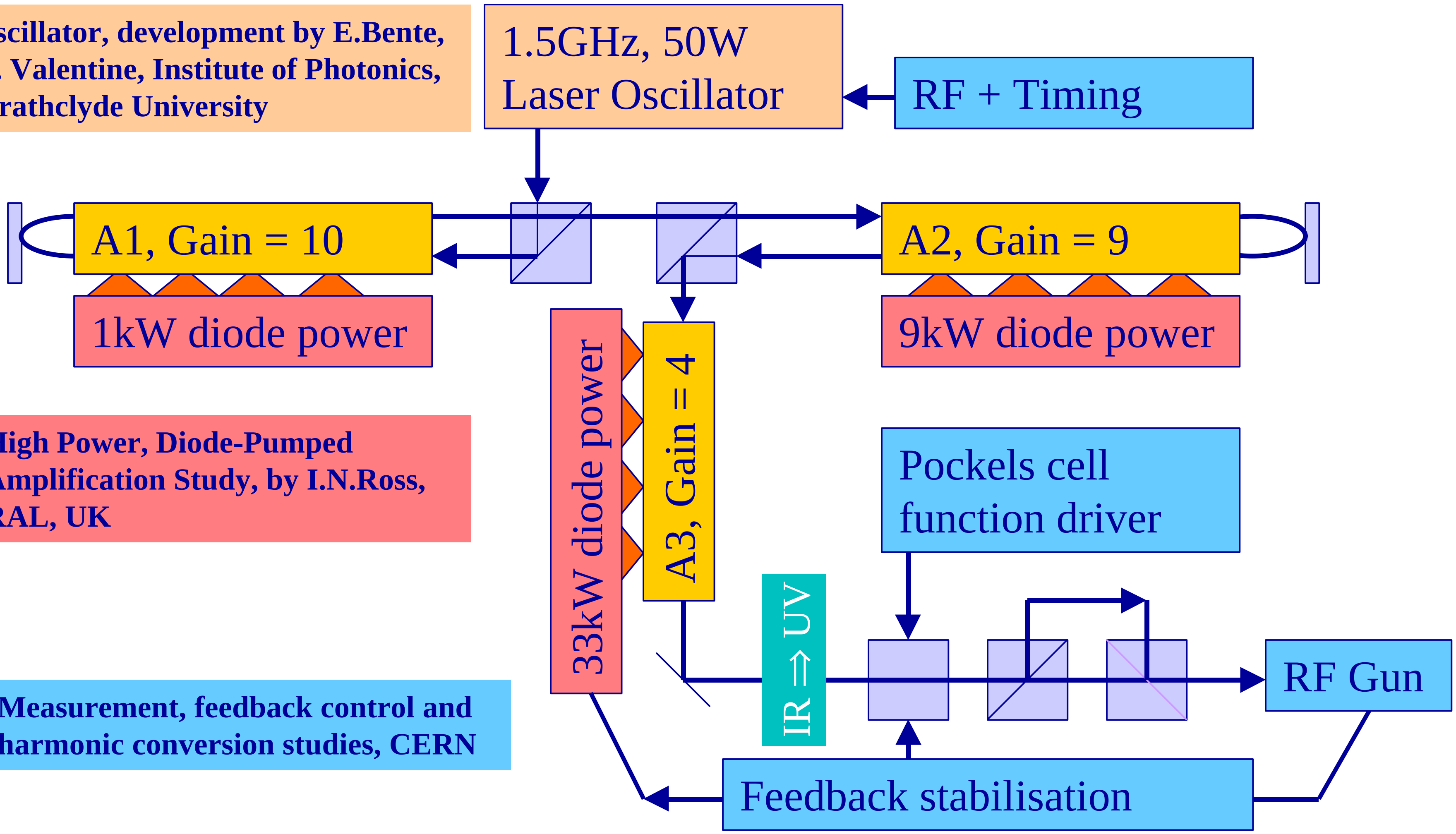
CTF-2 Drive Beam : RF Gun Desorption ?





Collaboration RAL, Strathclyde University and CERN

Oscillator, development by E.Bente, G. Valentine, Institute of Photonics, Strathclyde University



High Power, Diode-Pumped Amplification Study, by I.N.Ross, RAL, UK

Measurement, feedback control and harmonic conversion studies, CERN

S.Hutchins 2001

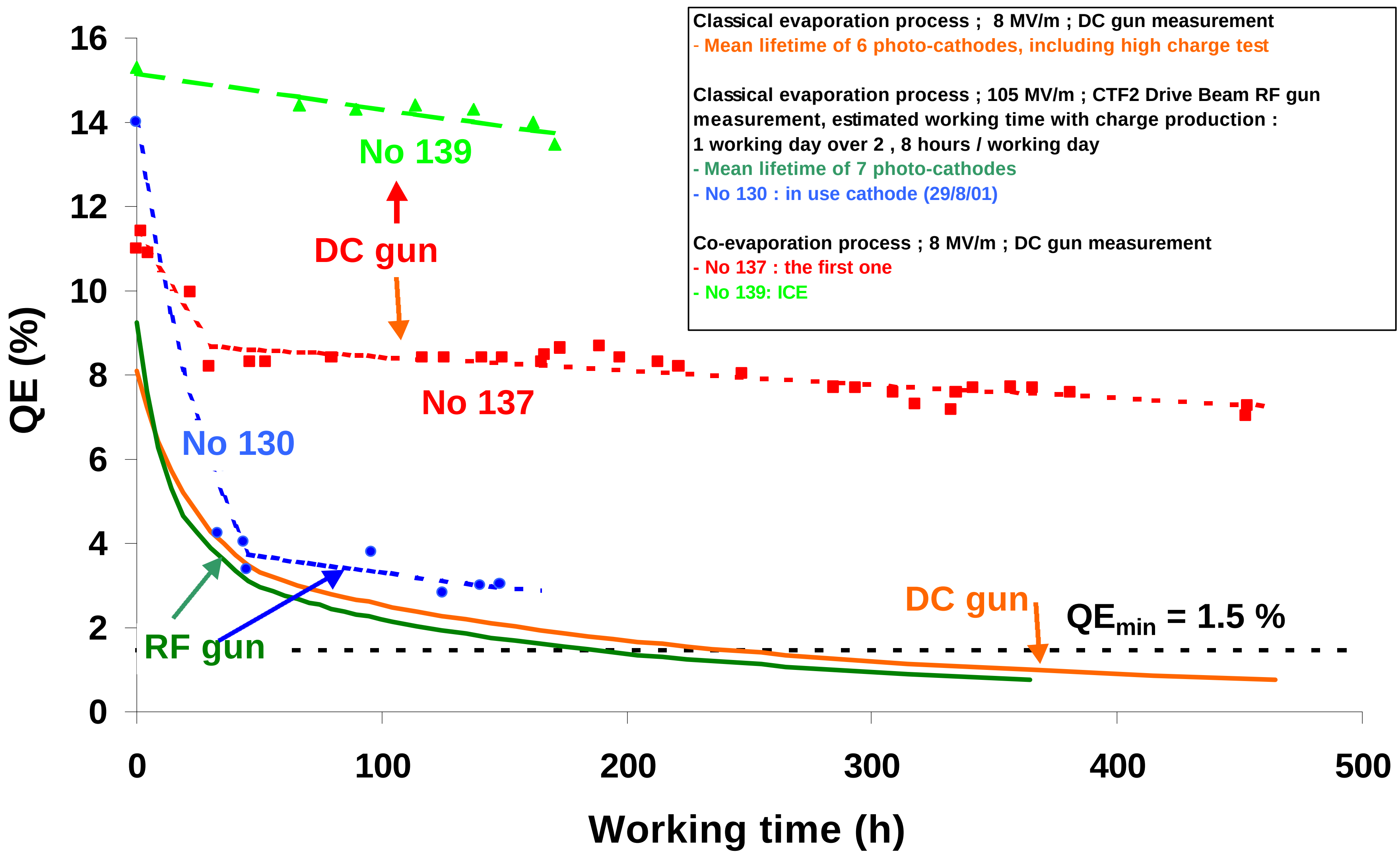
Cs_2Te Photocathode properties

Performances obtained at CTF or during the High Q test :

- **Working wavelength < 270 nm**
- **Maximum electric field : at least 125 MV/m**
- **Fast response time : < few ps (measurement limited by instrumentation)**
- **Low dark current : similar to copper**
- **High peak current : up to 10 kA**
- **Macro-pulse charge : 750 nC in 48 pulses, spacing 333 ps**
- **High mean current : at least 1 mA - 1μC at 1 kHz - (limited by laser power and HV power supply)**
- **Mean current density : 21 mA/cm^2**
- **Resistance to laser damage: at least 6 W/cm^2 @ 262 nm**

- **Lifetime : QE > 1.5 % during 460 h @ 750 μA, 1.4×10^{-9} mbar at 8 MV/m in the DC gun**

Cs_2Te Photocathode lifetime



Laser Parameter List (preliminary)

MO + PA	Wavelength	1047 nm (Nd :YLF)	
	Pulse width (FWHH)	≤ 10 ps	
	Pulse train duration	> 100 µs	
	Repetition rate	5 Hz (100 Hz)	
	Timing jitter	± 1 ps	
MO	Frequency	375 – 750 – 1500 MHz	
	Output energy / pulse	133 – 66 – 33 nJ	
	Output power in the pulse train	**50 W**	
Power Amplifier	Distance between pulses	0.667 ns	
	Amplitude stability	± 0.1 % (with feedback)	
	Wavelength on the photocathode	262 nm	
	Total efficiency from IR_{out} to $UV_{cathode}$	**3.6 %**	
	Included safe margin trans. (operation + material)	50 %	
	Charge / bunch	2.33 nC	
	Photocathode QE	1.5 %	4.5 %
	UV energy at the cathode / pulse	0.75 µJ	0.25 µJ
	Output IR energy / pulse	21 µJ	7 µJ
	Output IR energy / train	3.15 J	1.05 J
	Pulse train mean power	31.5 kW	10.5 kW
	Extracted output power / optical pumping power	0.66	
	Optical pumping power	47.7 kW	**16 kW**

Cost estimate

Preliminary cost estimate :

- **Material (without infrastructures and spares) : 0.5 - 1 MCHF**
  - Laser : 500 kCHF with QE ~ 4.5 %
  - Photocathodes : 20 kCHF
  - RF gun : 100 kCHF

- **Exploitation :**
  - material (with spares) : 70 kCHF / year
  - manpower : 1 man-year / year

Possible schedule

- **Till the end of 2002 : More tests**
  - Experiments to demonstrate the reliability of the laser as close as possible of the CTF3 conditions (PILOT)
  - Photocathode lifetime at high QE in the CTF2 and RF gun desorption study
- **End of 2002 : final decision on the CTF3 source**

If the photo-injector is selected

- **Spring 2003 :** Main parts will be ordered
- **18 months** will be necessary to build all parts of the photo-injector
- **Mid 2004 :** Laser-room and infrastructures should be ready to start the laser assembly
- **Autumn 2004 :** Laser starting-up - the RF gun will be ready
- **Winter 2004-2005 :** RF gun installation with the RF network - starting-up and commissioning of the photo-injector
- **Spring 2005 : Operational production of electron beam in CTF3**