Photocathode performance – design requirements

1. **Recap of photocathode studies**
2. **Standard preparation process : DC and RF gun results**
3. **Co-evaporation process : DC and RF gun results**
4. **Photocathode studies inside PHIN – FP6 E.U. program**
5. **CTF3 requirements**
6. **Civil engineering**
7. **Schedule**

Recap of photocathode studies

Since 1991 we tested many sorts of photocathodes :

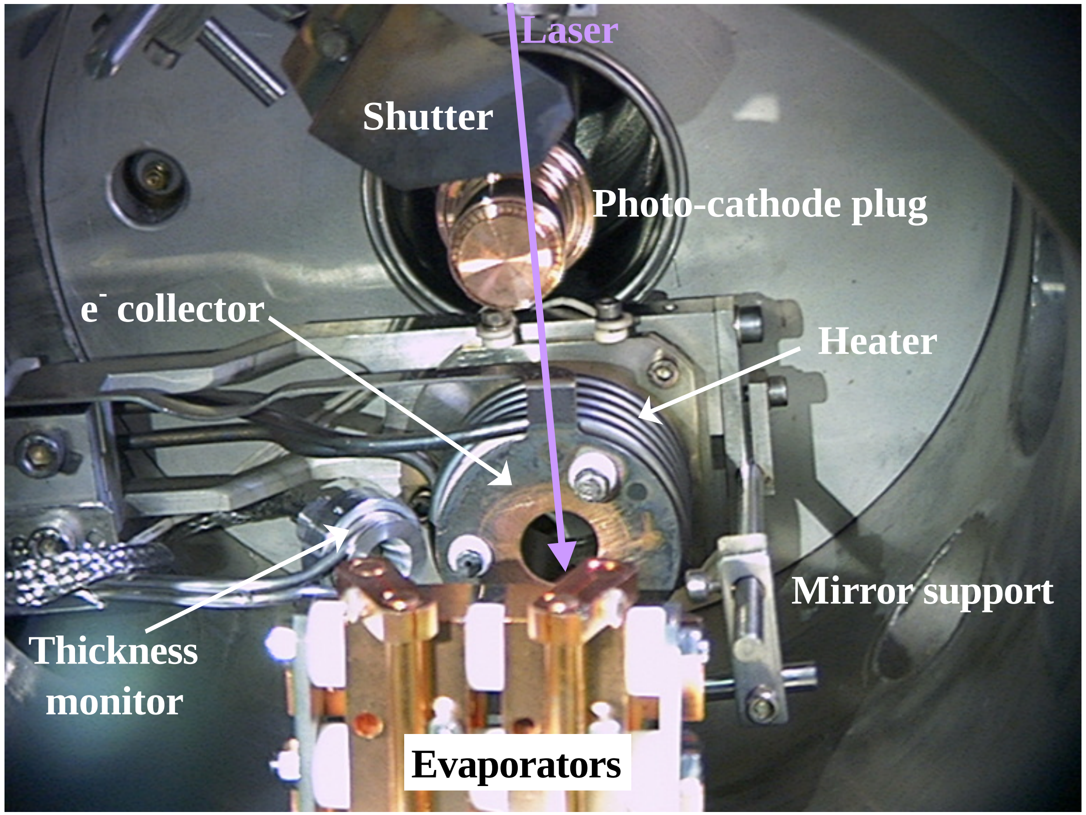
1. **Metallic photocathodes : Al, Au, Cu, Mg, Mo, Sm, Y**
   - QE < 10^{-3} even with special treatment (etching, laser conditioning)
   - QE too low for high charge production : very high powerful laser and / or plasma production at the photocathode. Not suitable for our application
2. **Alkali-antimonide photocathodes : Cs_3Sb, K_2CsSb, K_3Sb**
   - Need ultra high vacuum
   - Good QE at visible light but lifetime too short (few hours) not suitable for our application
3. **Alkali-telluride photocathodes : Cs_2Te, Rb_2Te, RbCsTe, Li_2Te**
   - Need UHV
   - RbCsTe and Rb_2Te : possible rejuvenation after air exposure by heating or etching
   - **Cs_2Te : standard photocathode for our applications** : few % during weeks at high charge and high electric field (up to 120 MV / m)
4. **Other photocathodes : CsI, CsI+Ge, Cs_3As, GaAsO, PLZT, TiO_2**
   - CsI+Ge had been used from 1994 to 2000 in the Probe Beam RF gun because it is air transportable
   - We had no success with the GaAs activation for e-pol. production : preparation chamber not adapted to this application

Photocathodes were deposited on different substrates (Al, Au, Cu, Mg, Mo, Stainless Steel) chemically cleaned and/or cleaned by argon ion bombardment :

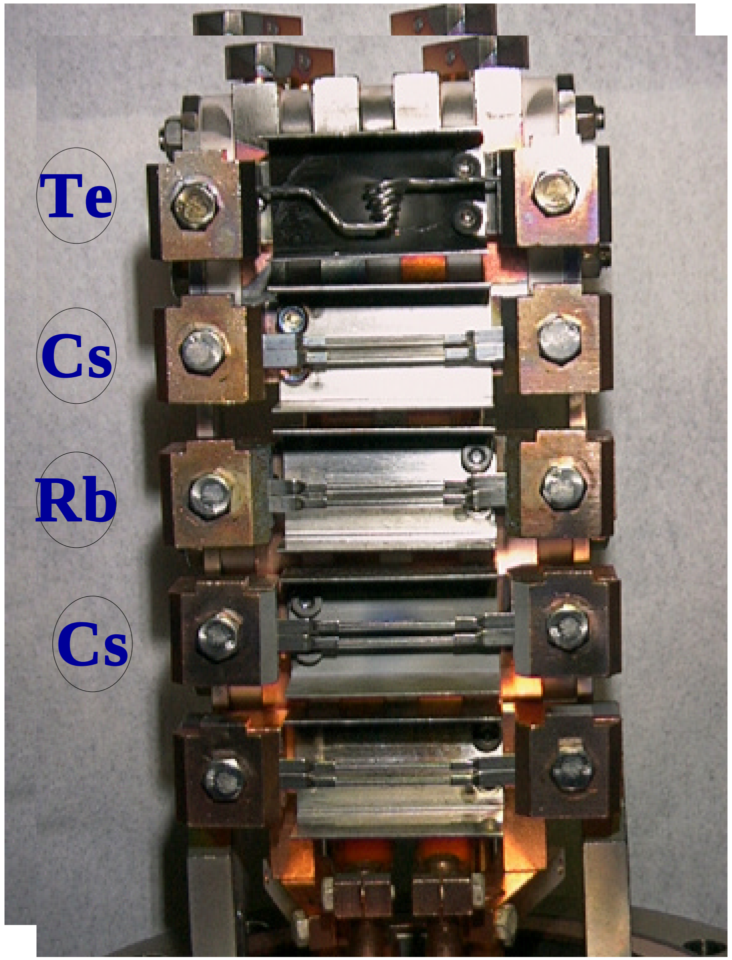
Cu with chemical and etching cleaning with RF conditioning seems to be the best for high electric field.

Standard evaporation process

Inside the preparation chamber



Evaporators



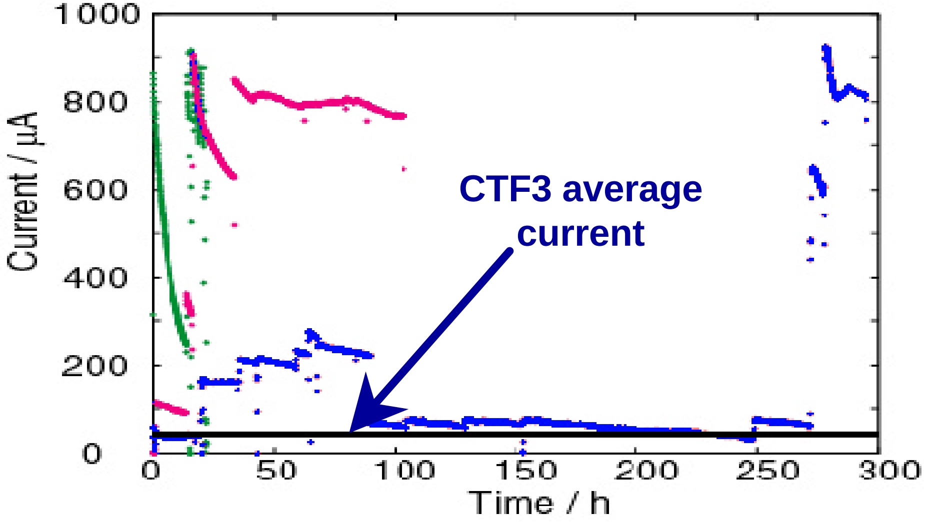
Cs-Te photocathode :

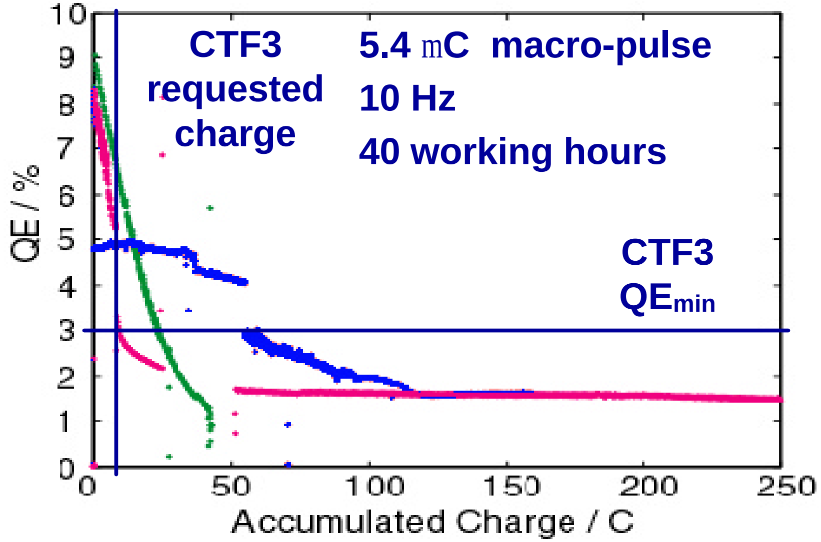
About 15 nm of Cs over 10 nm of Te

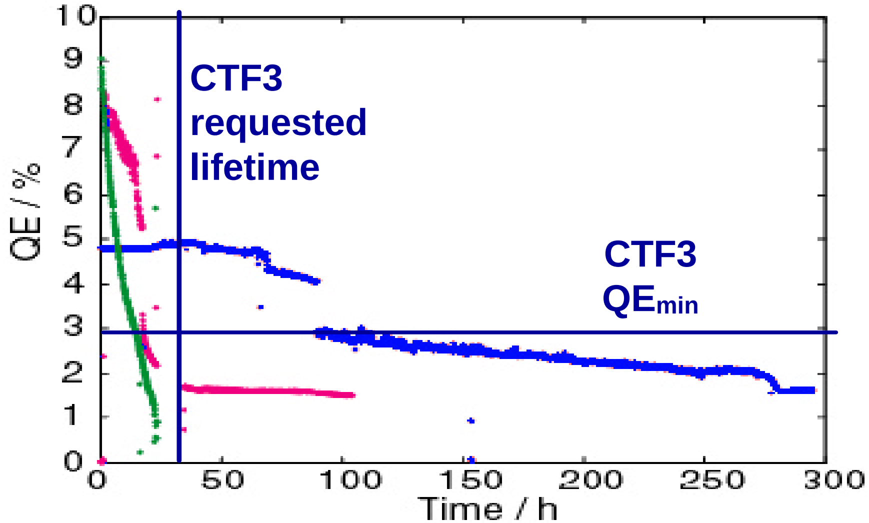
Deposited at room temperature

Standard evaporation process : High charge test (mC)

Cs_2Te photo-cathodes tested in the DC gun @ 9 MV/m
Up to 300mW UV on the cathode ; 100 ns pulse length, 10 A, 1kHz Rep.Rate







J_{max} = 21 mA/cm²

F_{max} = 6 W/cm² @ 266 nm

Up to QE_{min} = 3 % Cs_2Te photo-cathodes fulfill CTF3 specifications

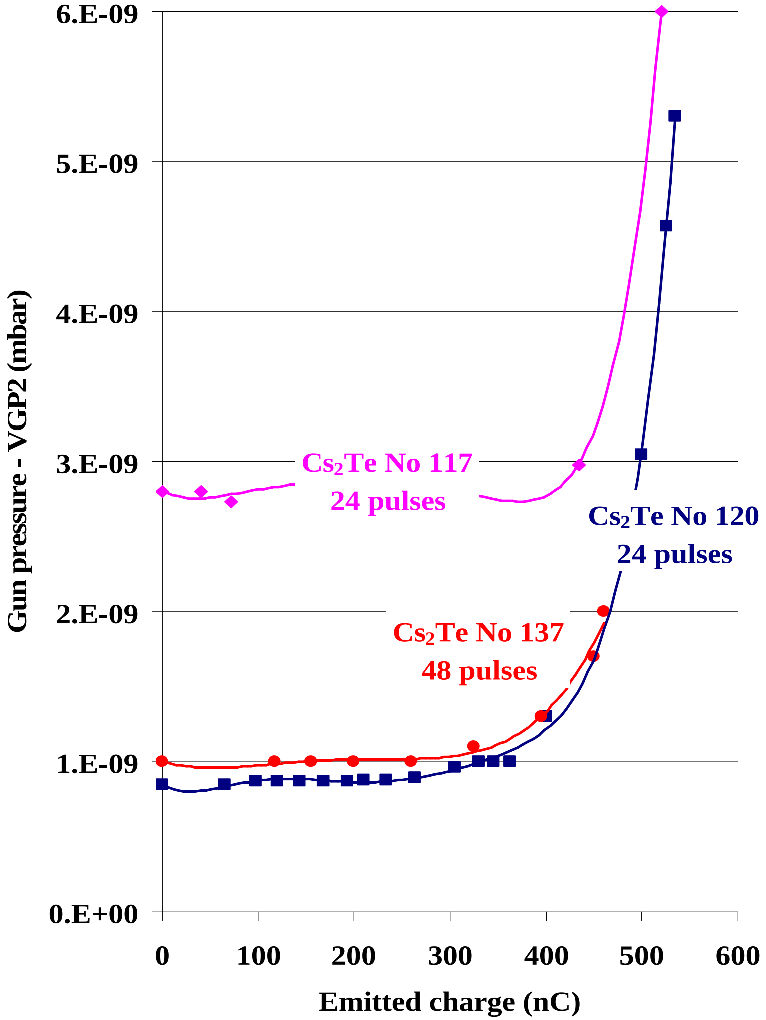
Standard evaporation process : Cs_2Te typical results

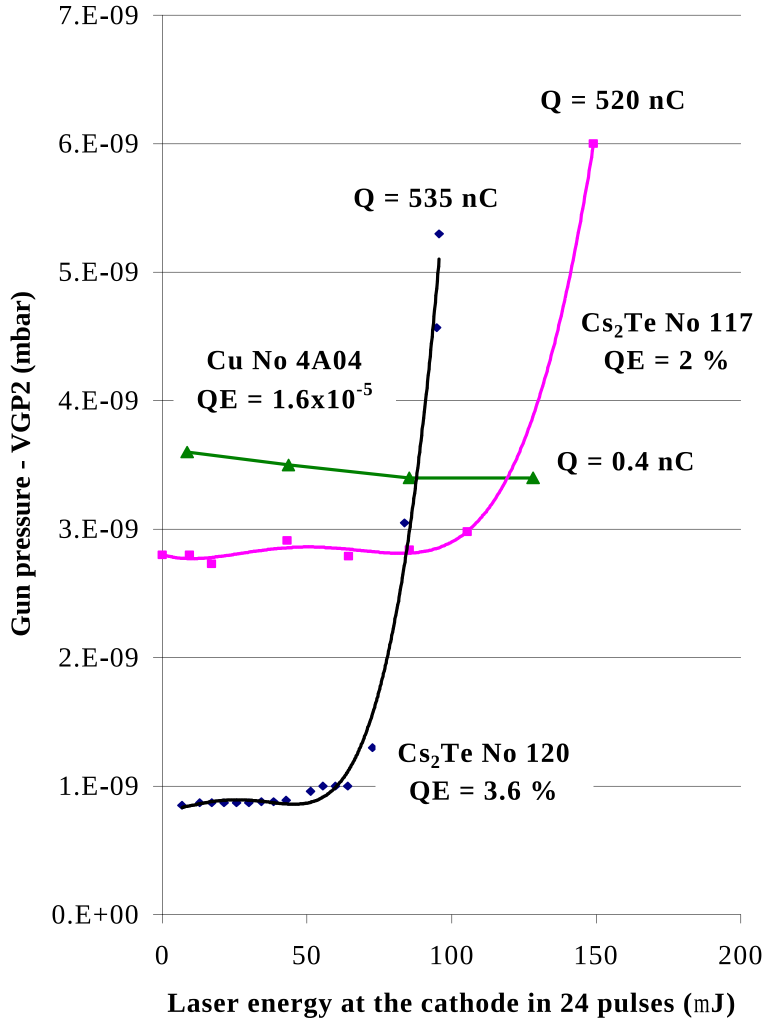
Standard evaporation process means : evaporation of an alkaline layer over a tellurium layer on different substratum

Typical results with Cs_2Te	DC gun	RF gun
Nom. electric field	8 MV/m	100 MV/m
Peak current	20 A	Few kA
Pulse width (FWHM)	6 ns	10 ps
Mean current	1 mA	8 mA
Best substratum	Au	Cu – Au (?)
Starting QE	4% £ QE £ 15%	2% £ QE £ 8%
Typical lifetime with QE > 1.5 %	Few months (extrapolated)	Few weeks
Working vacuum pressure	10^{-10} mbar	1 – 5 x10^{-9} mbar
Storage vacuum pressure	few 10^{-11} mbar	10^{-10} mbar

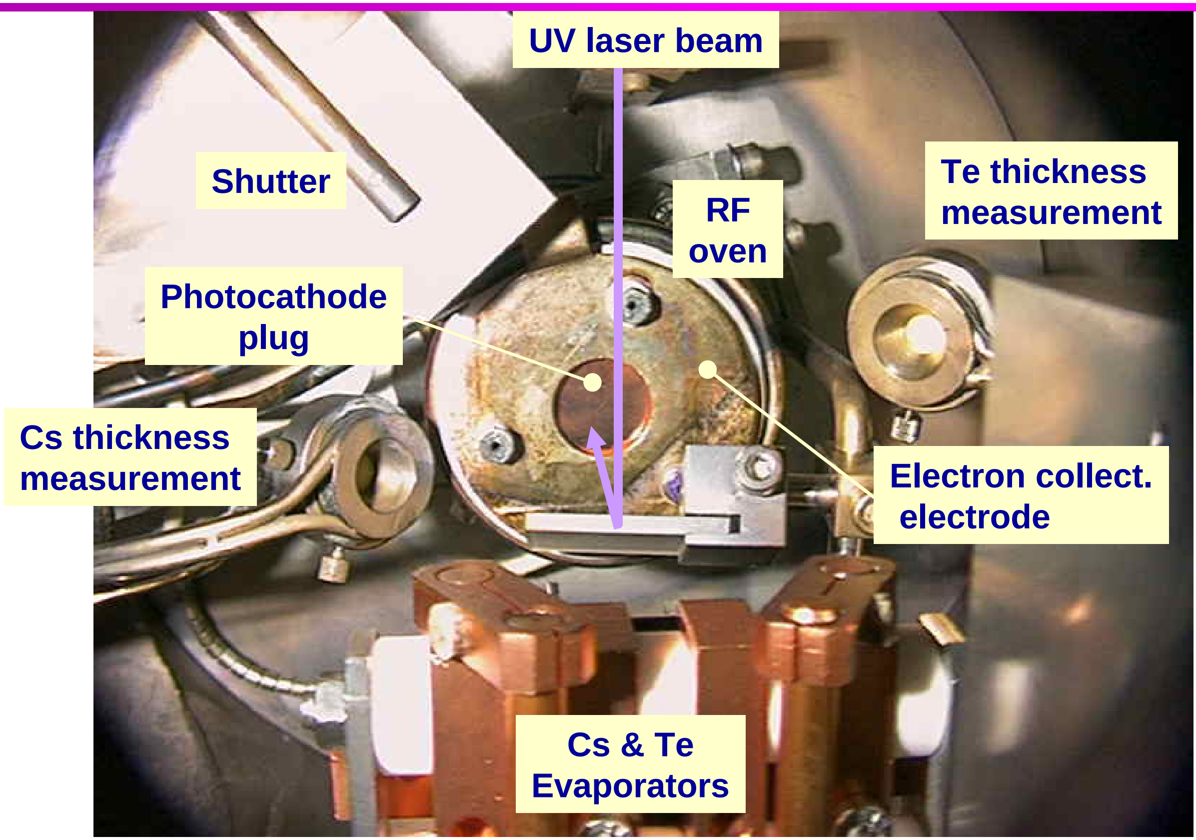
CTF2 RF gun desorption

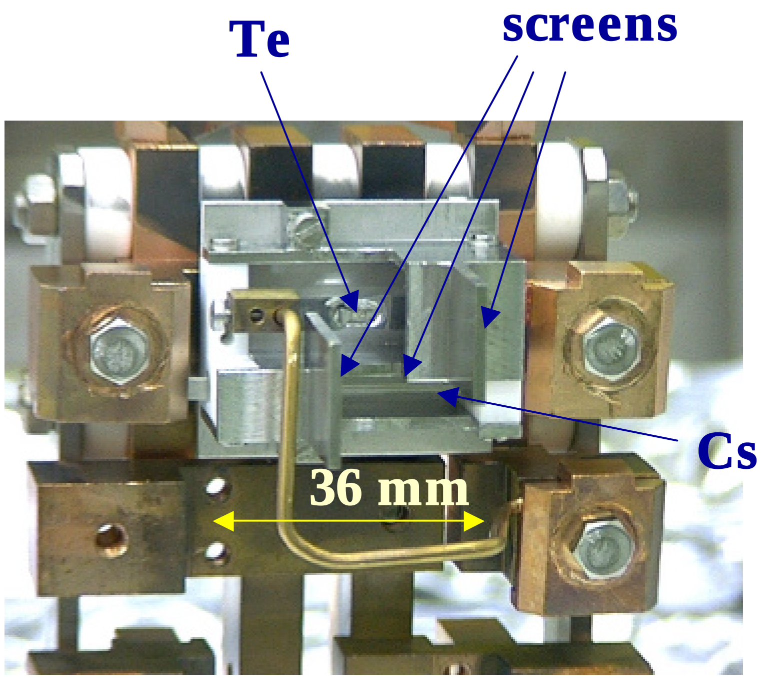
E = 105 MV/m





Co-evaporation process





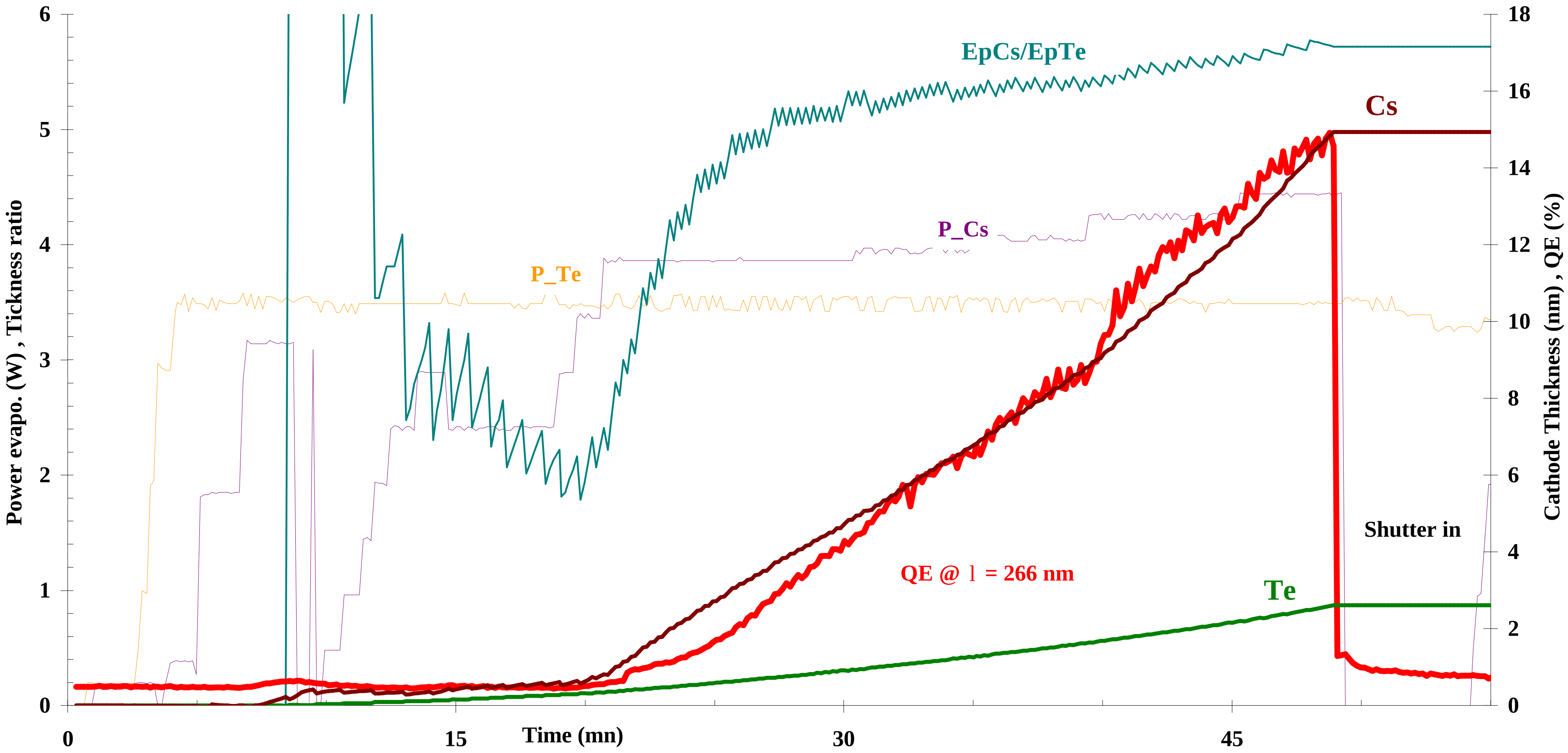
Evaporation at room temperature

	Tellurium	Cesium	
Thickness	1.3 - 11	3.9 - 49	nm
Evaporation rate	0.1 – 0.5	0.5 - 2	nm/mn

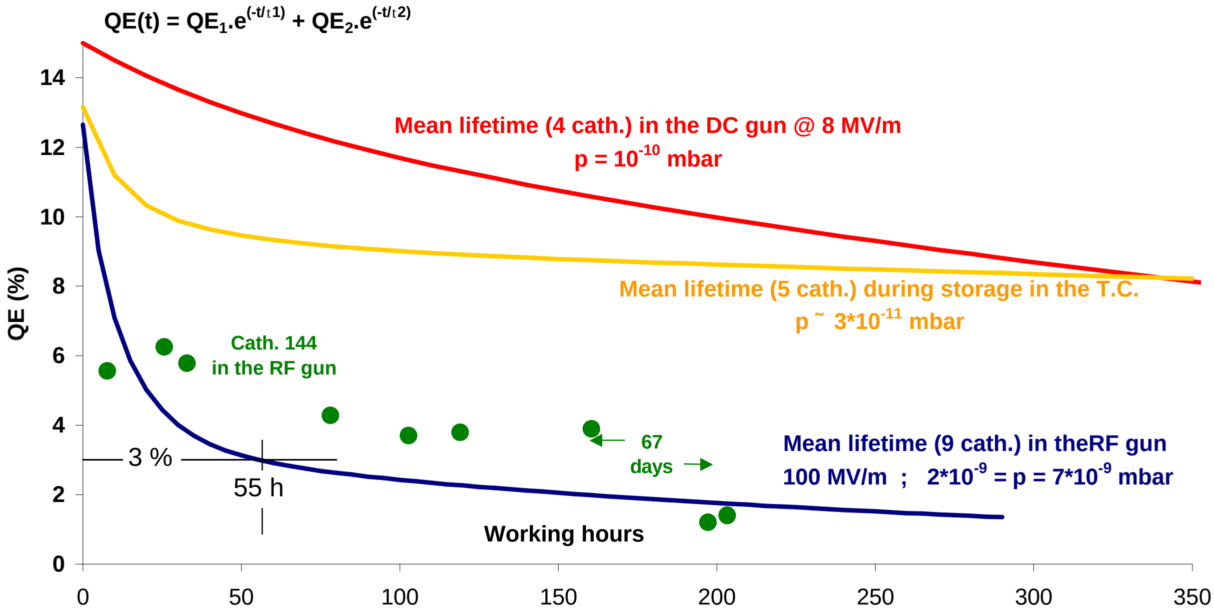
20 cath.	QE(%)	Cs/Te
Min	8.2	4
Average	14.9	5.1 (6.6 exp.)
Max	22.5	7.2

Co-evaporation process : photocathode preparation

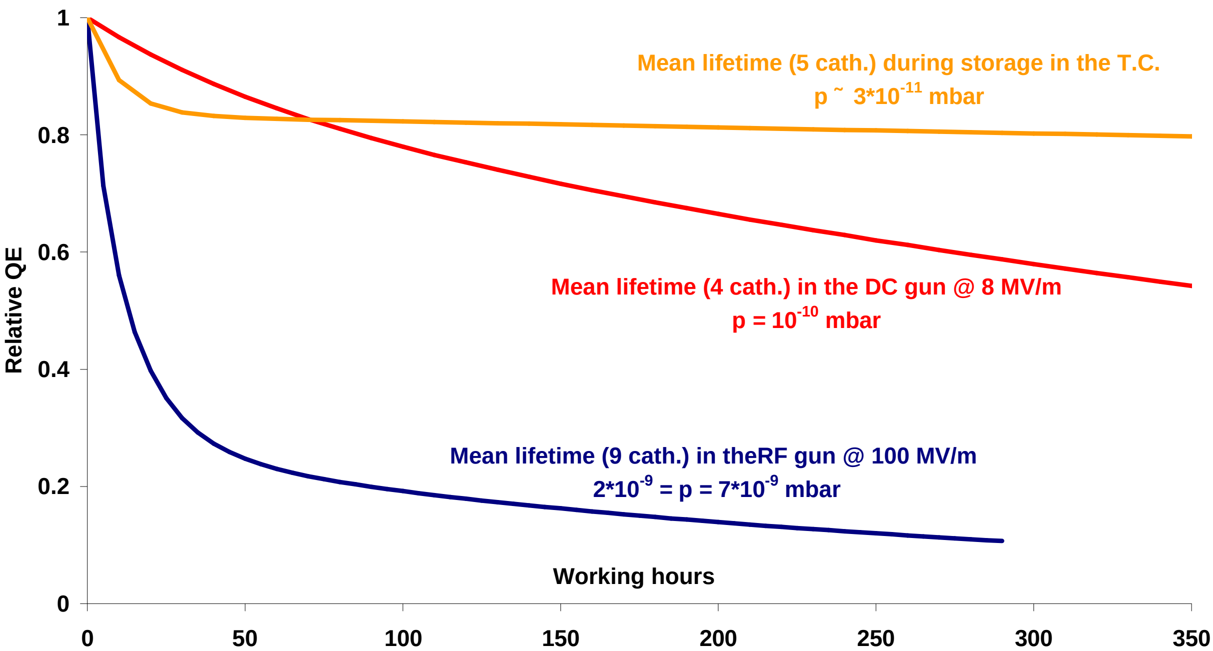
Evaporation of the photo-cathode No 155 : Cs2Te Co-evaporation process
plug 4A01   19/11/2002



Co-evaporation process : cath. lifetime



QE = f (t)	QE_1 %	τ_1 (h)	QE_2 %	τ_2 (h)
Transport carrier	3.85	18.9	9.17	3311
DC gun	2.24	65.9	12.74	779.5
RF gun	9.2	14	3.4	315



Co-evaporation process : dark current measurements

Measurements in the RF gun @ 100 MV/m ; RF pulse duration : 1.5 ms

Standard conditioning process:
Slow increase of the klystron output power by minimizing breakdowns, until 18MW nominal power, corresponding to 100 MV/m. After more than 10 minutes without breakdown, the cathode is considered as conditioned.

	Fresh Cs_2Te photo-cath.	Used Cs_2Te photo-cath	Chemically cleaned copper plug	ICE cleaned copper plug	ICE cleaned used Cs_2Te photo-cath.
f (eV)	3.5	4.1	4.6	4.6	4.6
b From - to	76 - 60	86 - 65	104 - 70	94 - 49	102 - 100
Eq.Radius (nm)	27 - 80	45 - 173	38 - 269	55 - 2616	31 - 37
I_{mean} (mA) at 100MV/m	7.3 – 6.6	6.5	5.2 – 4.8	4.3 – 3.8	3.2

ICE : Argon ion bombardment at $5x10^{-2}$ mbar eq. N_2

Photocathode studies inside PHIN – FP6 E.U. program

- **Reproducibility of alkali-telluride photocathodes produced by co-evaporation**
  - Thickness measurement
  - Product quality
  - Cleanliness of the substratum
  - Evaporation rate
- **Study of alkali-antimonide photocathodes produced by co-evaporation**
  - Cs_3Sb, K_3Sb, Na_2Sb+K, Na_2Sb+Cs, Na_2Sb+K(Cs)
  - Photocathode properties at $\lambda = 532$ nm
- **Comparison between telluride and antimonide cathodes for the CTF3 specifications**
- **Proposal from other labs**

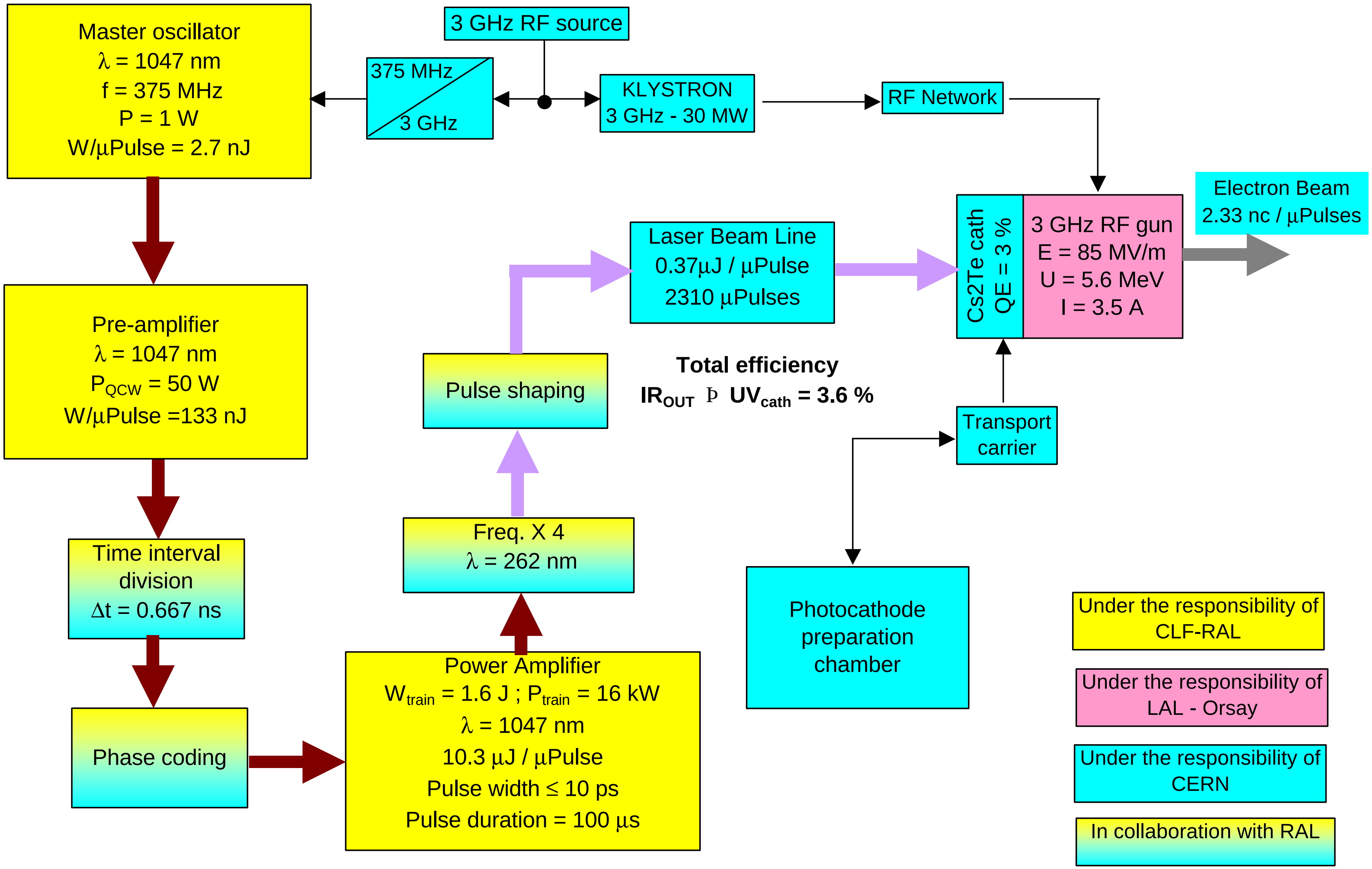
CTF3 photo-injector specifications

			NOMINAL	OPTIONAL		Unit
	Pulse train duration (1)		1.548			µs
	Pulse train charge (1)		5434			nC
	Average current in the pulse train		3.51			A
	Number of bunches in the sub-pulse		212	106	53	
	Odd/even sub-pulse width (FWHH)		140.735			ns
	Number of bunches in the pulse train (1-2)		**2332**	1166	583	
e- beam	Charge / bunch		2.33	3	5	nC
	Distance between bunches		**0.667**	1.334	2.668	ns
	Bunch width (FWHH)		10	10	10	ps
	ε_T normalized	≤	25			π.mm.mrad
	$\Delta p/p$	≤	2			% rms
	charge stability	≤	0.25			% rms
	Repetition rate		**1 - 50**			**Hz**
	Mean current @ 50 Hz		271.68			mA
	RF frequency		2.99855			GHz
	RF power	≤	30			MW
RF gun	Beam energy	≥	5			MeV
	Beam current		3.51			A
	Vaccum pressure @ nominal charge	≤	**2×10^{-10}**			**mbar**
Photo-cathode	**Cs2Te : QE**	3	**3**	**3**	**3**	**%**
	Wavelength	<	270	270	270	nm
	Lifetime	3	40			working hours
	UV energy / bunch @ the cathode		0.368	0.473	0.789	µJ
	Beam radius - min @ the cathode		1	1.4	2	mm
	Beam radius - max @ the cathode		2	2.8	4	mm
	Energy stability @ the cathode (rms)	≤	0.25			% rms
Laser beam conv. and transport	Pointing stability	±	0.5			mm
	Odd/even sub-pulse width (FWHH)		140.74			ns
	Odd-even sub-pulse rise/fall time (10%-90%)		2 - 30			ns - ajustable
	IR-UV conversion efficiency		0.15			
	Safe margin		0.5			
	Laser beam transport transm.		0.7			
	Pulse shaping and coding transm.		0.7			
	UV cath. energy / Output IR energy		**0.037**	**0.037**	**0.037**	
	Output IR energy / bunch	≥	10	13	21	µJ
	Bunch width (FWHH)	≤	10	10	10	ps
Output Laser	Wavelength		1047			nm
	Repetition rate		1 - 50			Hz
	Timing jitter	≤	1			ps rms

(1) **With starting bunches**

(2) **The photo-injector must be able to produce only one electron pulse**

CTF3 requirements : photo-injector synoptic



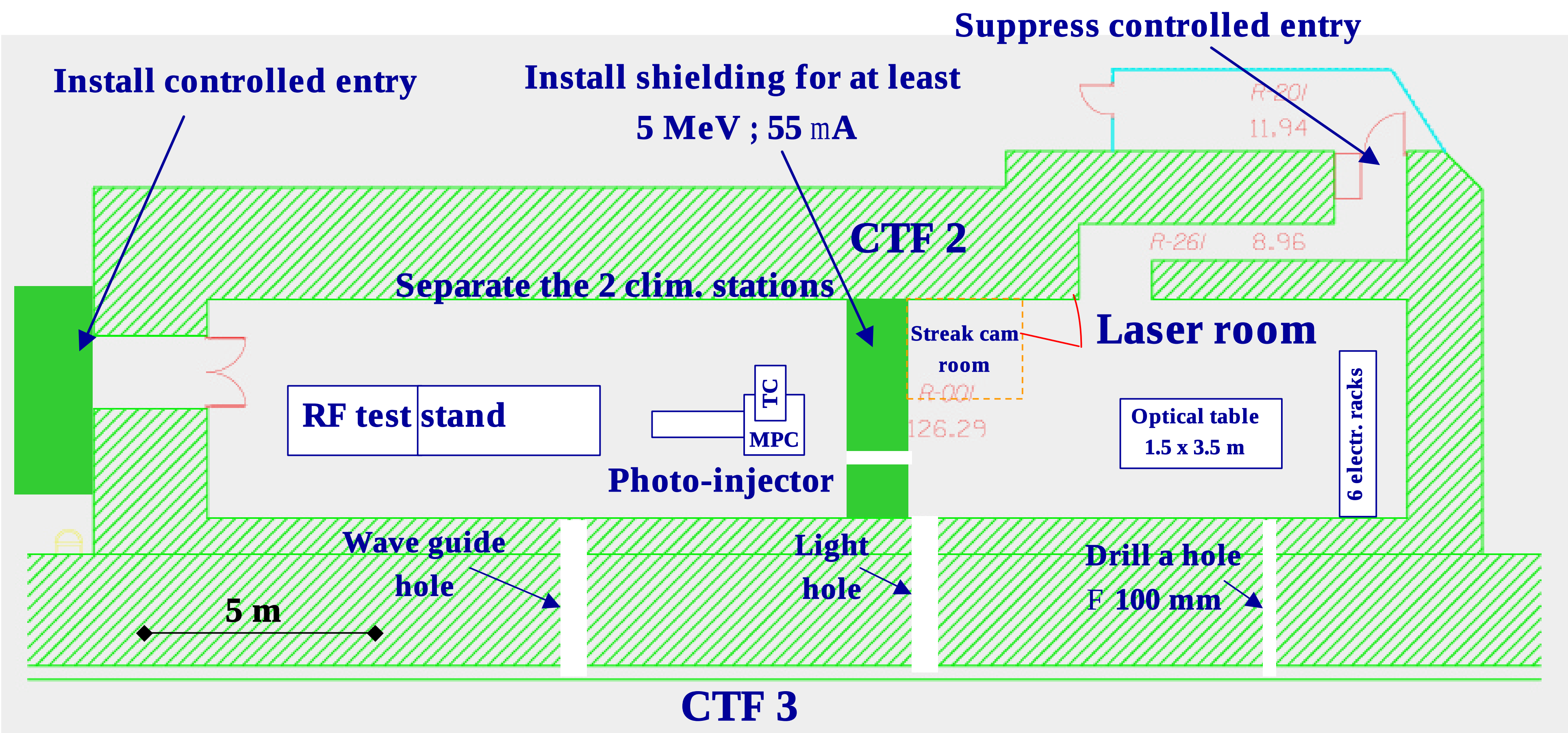
CTF3 Requirements

- Photocathodes with a QE ≥ 3 % during at least 40 working hours
- A photocathode production to guarantee a continuous run of at least 6 months

For that we have to do :

- A complete maintenance of the preparation chamber and of the transport carrier (for CTF2 and CTF3 thermoionic gun area installation)
- Adapt the RF gun transfer chamber (MPC) to the new gun and to the new sites (we assume the same photocathode plug)
- Re-use and / or develop an automatic RF conditioning process
- Pursue photocathode studies mainly to increase the lifetime, the reproducibility, and to fulfill the CLIC requirements
- Design and built new transport carrier and / or MPC for installation in the CTF3 linac area (not scheduled)

Civil engineering : Photo-Injector in the CTF2



Setup for test and commissioning

Civil engineering : Photo-Injector in the CTF3

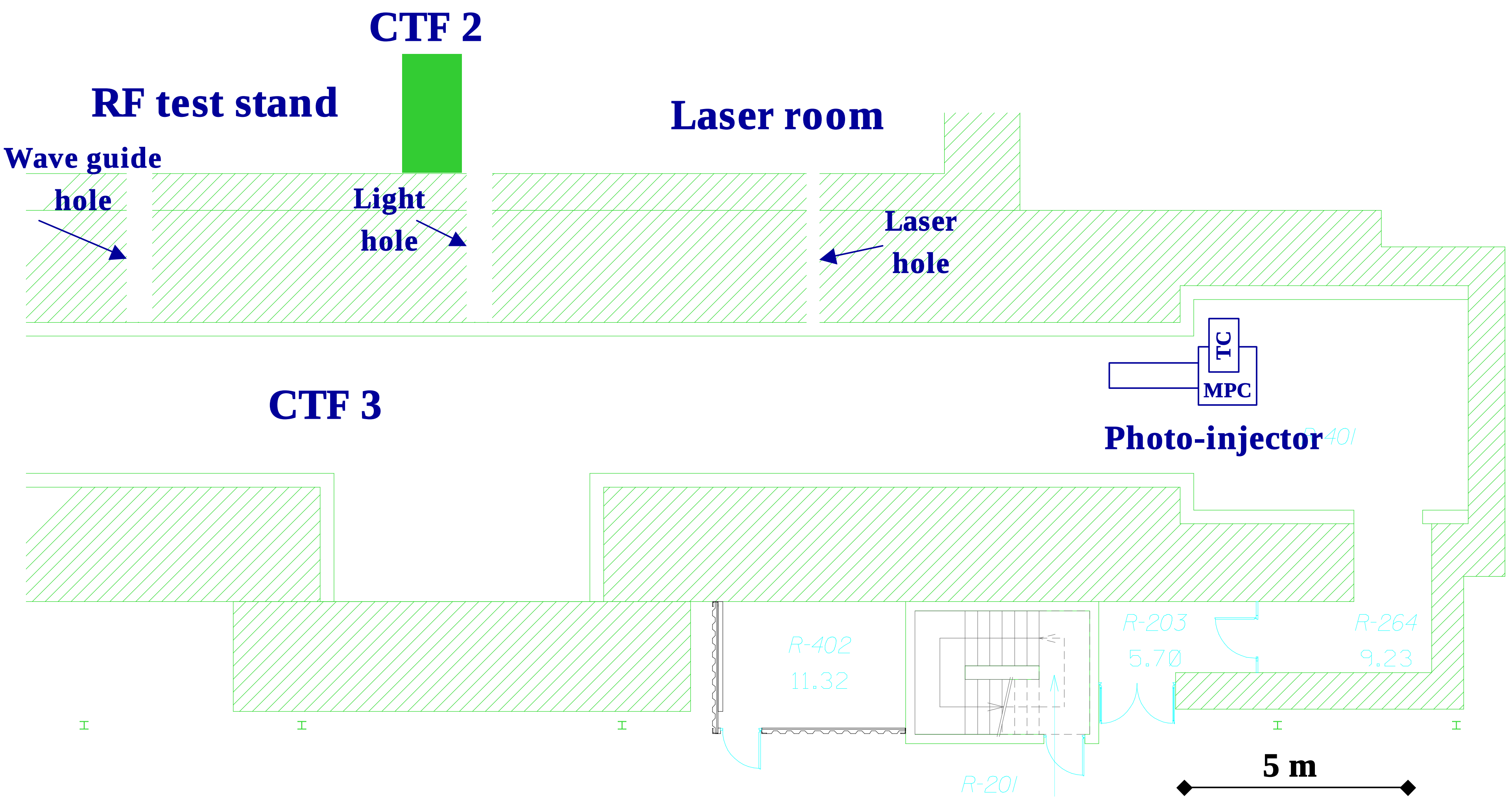
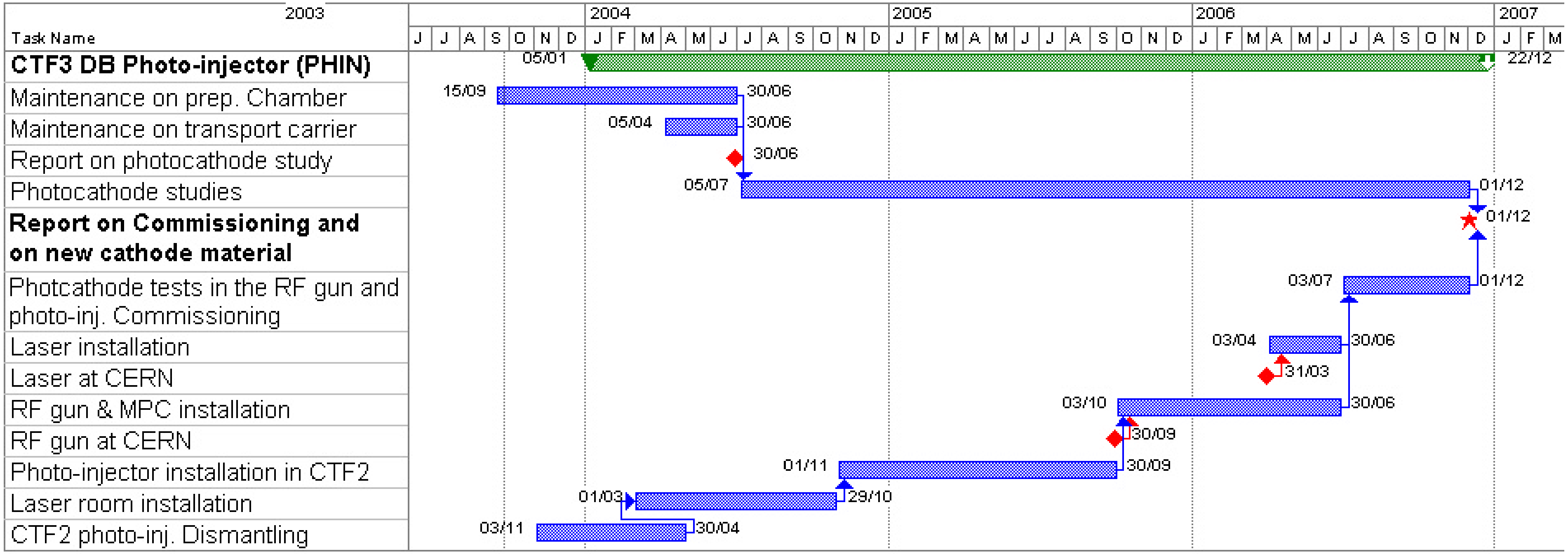


Photo-injector as the CTF3 source

Schedule inside the PHIN – FP6 – E.U. program

Realization of the photo-injector option in two steps :

- **Operational photo-injector in the CTF2 in the end of 2006**



- **Operational photo-injector in the CTF3 in the middle of 2007**
  - **Installation during the shut-down 2006-2007**
  - **Commissioning spring 2007**