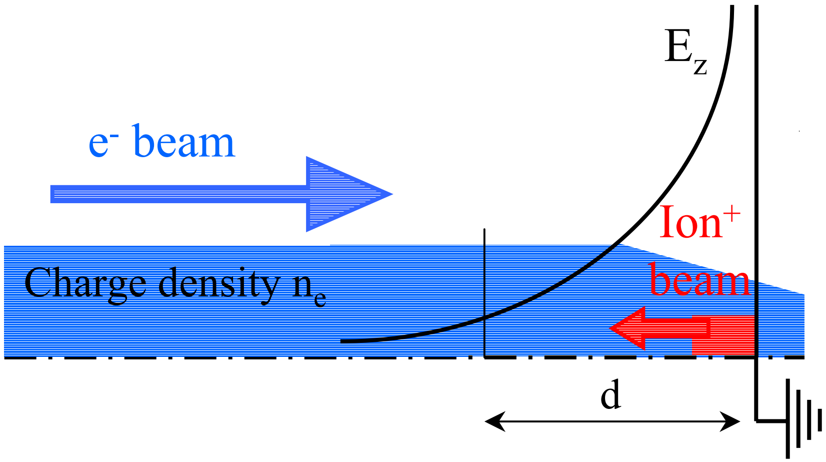
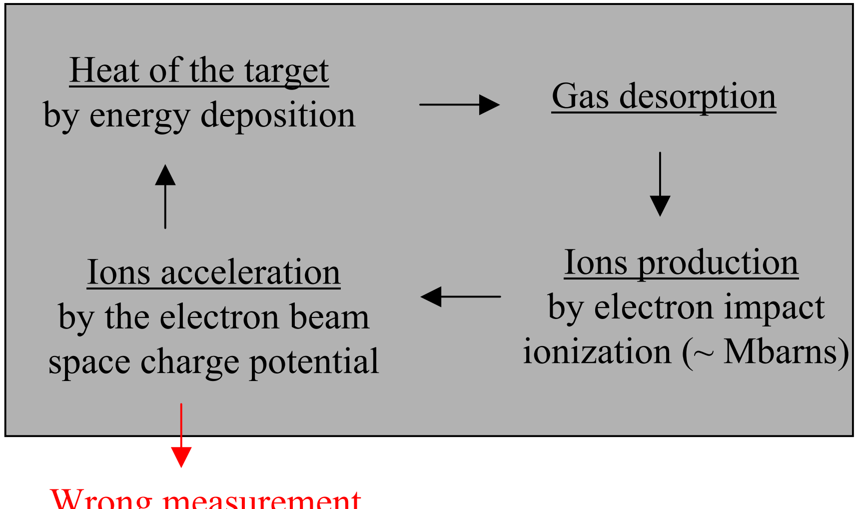
Ion instability on a screen

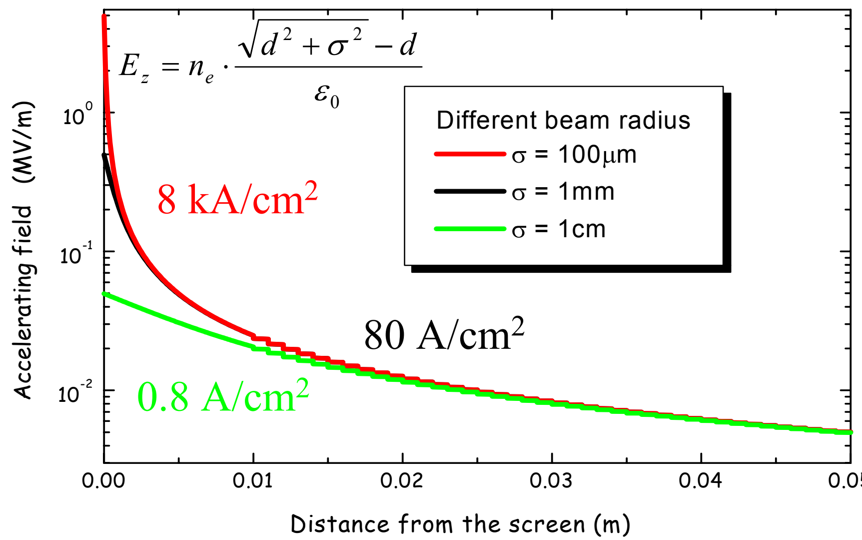
CLIC Drive beam and CTF3 beam

• Design of profile monitors at different location along the linac : 140keV, 20MeV, 50MeV, ..



	Energy (keV)	Current (A)	Pulse length (µs)	Beam size (mm)
CLIC Drive beam	≥ 200	13.8 (8.5)	92	0.1-10
CTF3 Initial	**≥ 140**	**5.4 (3.5)**	**1.54**	**0.1-10**





Ion instability on screen

Simple calculations of the instability

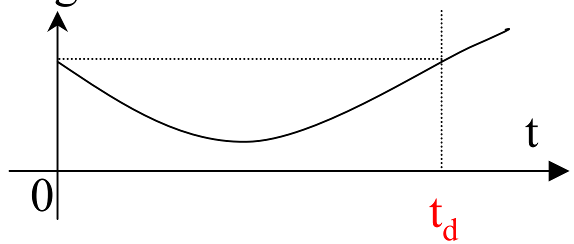
- The electron beam dynamic can be estimated by the following envelope equation

$$\frac{d^2 r}{dz^2} + \frac{\varepsilon^2}{(\beta\gamma)^2 r^3} + \frac{K}{r} = 0$$

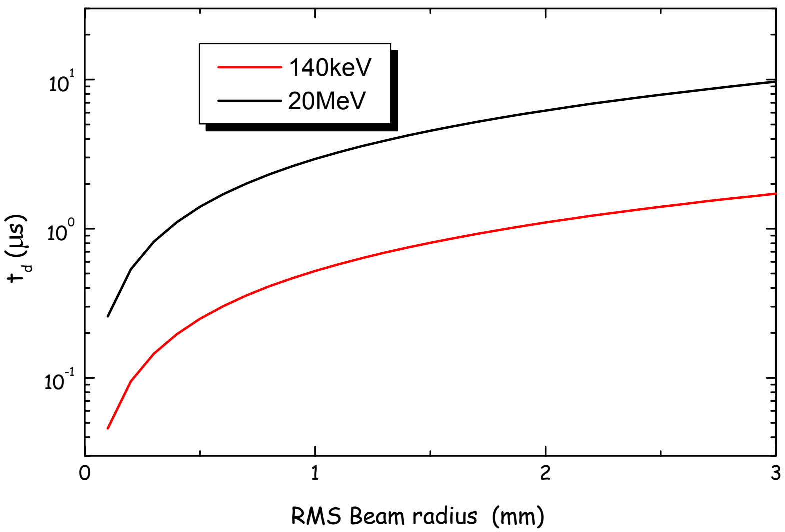
Emittance dependance

Neutralization Factor K

$$K = f(I_e, \beta_e, I_i, \beta_i)$$



Disruption time : $t_d = \sqrt{\dfrac{2\pi}{K\beta_i c}}$

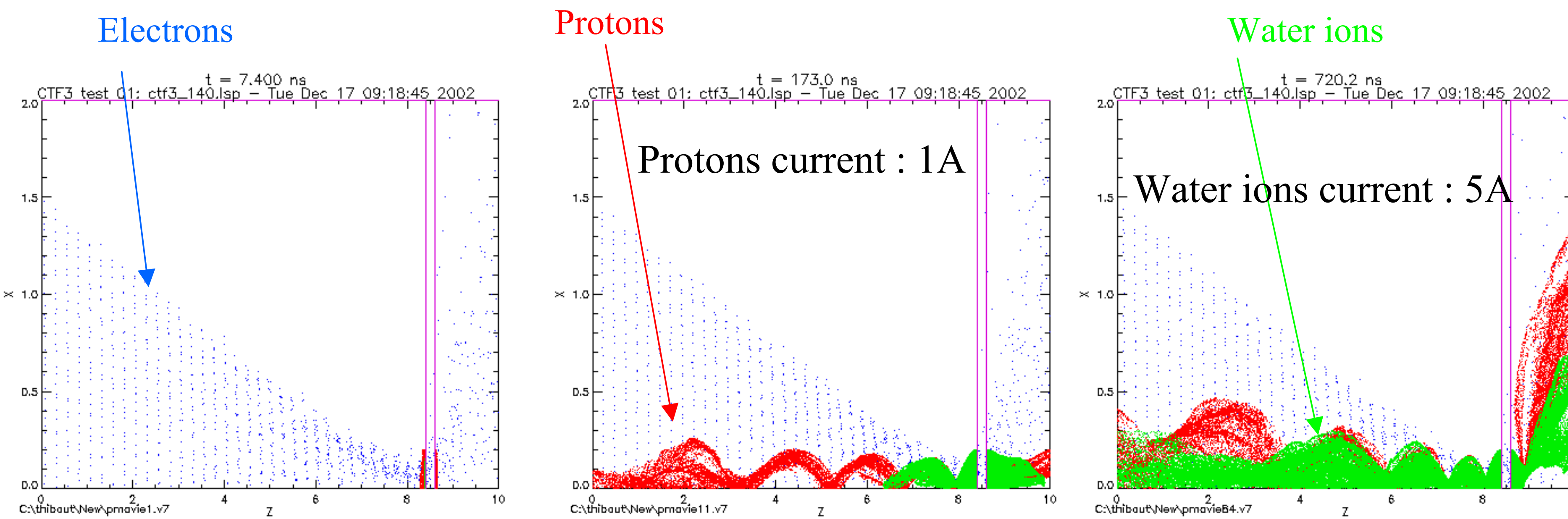


- Instability is present within the beam pulse duration (1µs)
- Much worse at low energy

Ion instability on OTR target

Simulations with the LSP code

- Ions are emitted at t = 0ns

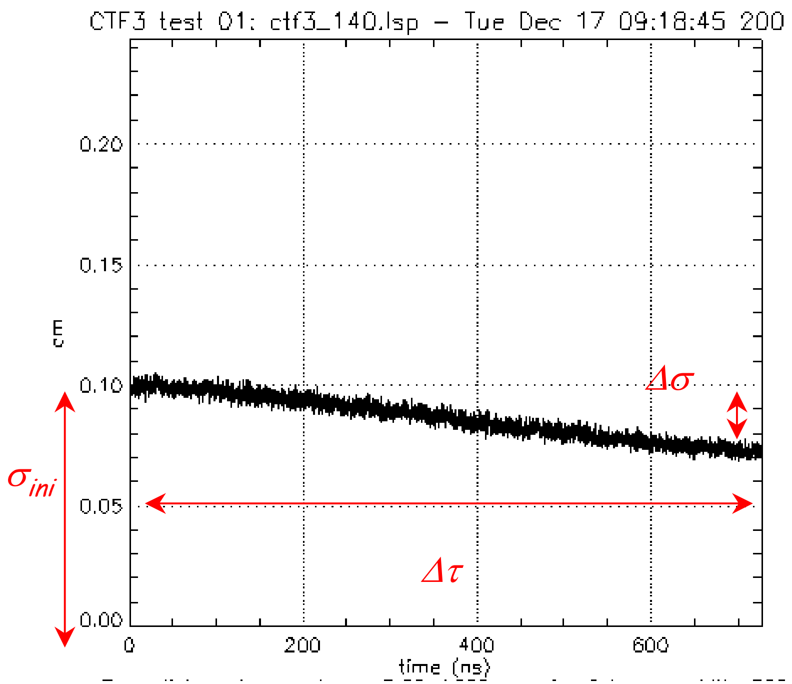


Based on the experimental observations done in the US and in France, two different kind of ions simulated : Protons 9%, OH^+ 91%

Ion instability on OTR target

Simulations with the LSP code

Evolution of the electron beam size at 140keV



σ_{ini}	$\Delta\sigma$	$\Delta\tau$
1mm	30%	800ns
2mm	25%	1μs

- Simulation with LSP show an electron focusing 4 times slower than the theoretical model.

  Probably due to ion beam oscillation which are not taken into account in the simple theory

- At 140keV the beam size is strongly modified

- At 20 MeV the effect becomes negligible (2% over 1μs)

Ion disruption on OTR target

Thermal calculations (1)

ENERGY DEPOSITION:

- Using thin foil to neglect the radiative stopping power in order to minimize the energy deposition
- The 'collision' stopping power only changes from one material to the other less than a *factor 2* *(Be, C, Al, Si, Ti, Mo, W)*

$$\Delta T(r,t) = \frac{1}{c_p \rho}\left[\frac{dE}{dx}\rho e^{-\frac{r^2}{2\sigma^2}} N(t_p, f_o) - k\vec{\nabla}\cdot\vec{\nabla}T\right]\Delta t$$

Heating term

Cooling term

- σ : RMS beam size
- $N(n_e, t_p, f_o)$: time evolution of the beam

  n_e : Number of particles, t_p : pulse duration, f_o : repetition rate
- Material properties :

  c_p : Heat capacity , ρ : density , k : thermal conductivity

Material	c_p J/gK	k W/mK	T_{max} °C
Be	**1.825**	**190**	**1287**
C	**0.7**	**140**	**3527**
Al	0.9	235	660
Si	**0.7**	**150**	**1414**
Ti	0.523	22	1668
Mo	0.25	139	2623
W	0.13	170	3422

Need materials with

- High fusion temperature
- High heat capacity c_p
- *High thermal conductivity*

(for graphite ΔT=12% after 1ms)

Good candidate : *Be (poison)*, **Graphite**, *SiC (low reflectivity)*

Ion disruption on OTR target

Possible candidates as screens

- Thermal problem : thin foil of graphite

- Electron photon conversion process: Scintillation or Optical Transition radiation
  - OTR screens :
    - Number of photons proportional to ln(2γ)
    - Light emission cone is 1/γ
    - graphite as a low reflectivity compared to classic OTR screen (27%)

Problem of light intensity at low energy (140keV)

  - Scintillation using a Phosphor deposit of an aluminum foil

Scintillation is

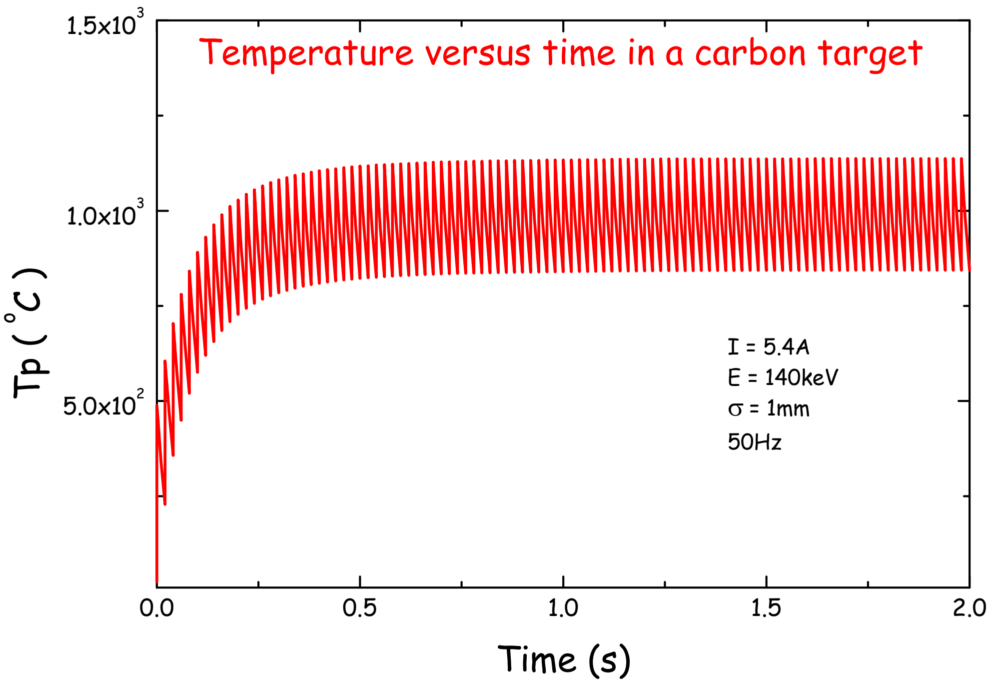
Thermal calculations (2)

Temperature of the screen at 140keV

I = 5.4A , E = 140keV , σ = 1mm				
t_p (µs)	T (°C) @ 10Hz C	Al	T (°C) @ 50Hz C	Al
0.2	103	83	164	132
0.8	272	194	558	421
1.56	440	434	1003	*-731-*

OK

Ions production



I = 5.4A , E = 140keV , σ = 0.7mm				
t_p (µs)	T (°C) @ 10Hz C	Al	T (°C) @ 50Hz C	Al
0.2	165	138	222	188
0.6	352	194	559	469
1.56	706	*-742-*	1334	*-980-*

Ion disruption on OTR target

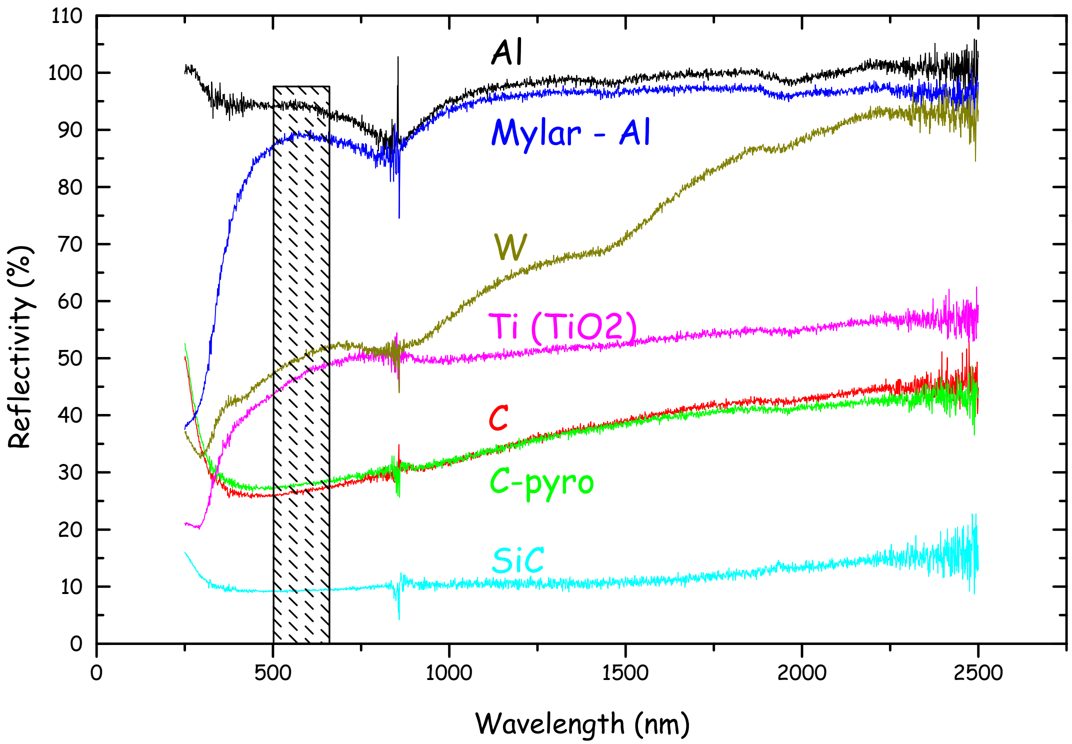
Thermal calculations (3)

Temperature of the screen at 360MeV

I = 3.5A , E = 360MeV , t_p =1.56µs				
σ (mm)	T (°C) @ 10Hz C	Al	T (°C) @ 50Hz C	Al
0.25	1730	*-1650-*	2250	-
0.5	-	*-680-*	-	-
0.6	-	510	-	*-650-*

- **Thin OTR foil in Graphite is ok for the CTF3 beam**
- **We have to find a new alternative for the CLIC DRIVE BEAM**

Material	Al	Al-Mylar	W	Ti	C 1	C 2	SiC
R (%) at 500nm	94	87	47	44	27	26	9.2
R (%) at 600nm	94	89	51	48	28	27	9.5



Conclusions

•For CTF3 this ion instability will affect the use of beam profile monitor for the low energy beam

•Polarizing the screen itself is not possible since the beam space charge field is really strong (MeV/m)

- Is there any possibility to suppress this effect by :
  - direct beam conditioning
  - surface and material treatment
  - specific vacuum technology
  - ……..

After the discussion

•Target on a floating mass, auto-polarization ?

•Dedicated heating system of the screen. Not foreseen yet

•Looking for a other experimental facilities to understand the phenomenon : electron microscope,….

•Use of Bore carbide suggested

• Perspectives for first test on CTF3 in may:
  - •Outgasing test of the foreseen material
  - •High temperature treatment of the screen (up to 1500 degree).
  - •Possible use of getter material
  - •Conditioning and heating the target with the beam itself
  - •Possible use of laser surface cleaning (penetration ~ nm)