Processing view-screen data to determine emittance

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1 Introduction

Beam sizes observed on the ELBT view-screens over several days: Oct 26 to Nov 1 have been processed to estimate the emittance. For this, a common initial-beam was fitted to the above data using `TRANSOPTR`.

The emittance value found is $\sim$ 13 mm.mrad (normalized). For the fit to work, it was found necessary to assume a non-zero correlation at the cathode: $r_{12}^{20\mathrm{eV}} \approx$ -0.9 ($\alpha^{20\mathrm{eV}} \approx$ 2.5).

2 `TRANSOPTR` procedure

In the `TRANSOPTR` code, given an initial beam represented by its phase space projections, the sigma matrix (beam envelopes) is computed with space charge included and propagated along the beam-line, in this case ELBT.

Also initial-beam ellipses and emittances can be fitted in a least square sense. This is achieved by inserting (within `TSYSTEM`) the single passage through the beam-line into the body if a loop over N measurements. Each measurement corresponds to a fixed focusing setup (strengths of 3 solenoids) and produces two numbers (X,Y) – beam sizes observed at the single active view screen. A table is then prepared, N lines long, similar to Table 1 below. The table is read by an external Fortran routine called within `TSYSTEM` immediately before the loop, while a common block passes its content.

It seems convenient to not reset initial z within the loop, in which case the N propagated envelopes appear on a single plot as this is shown on Figure 1 (a fictions beam-line, N-times longer than ELBT). This particular plot uses the data of `Data Oct 26` with N=10 and the fit point being set at gun exit.

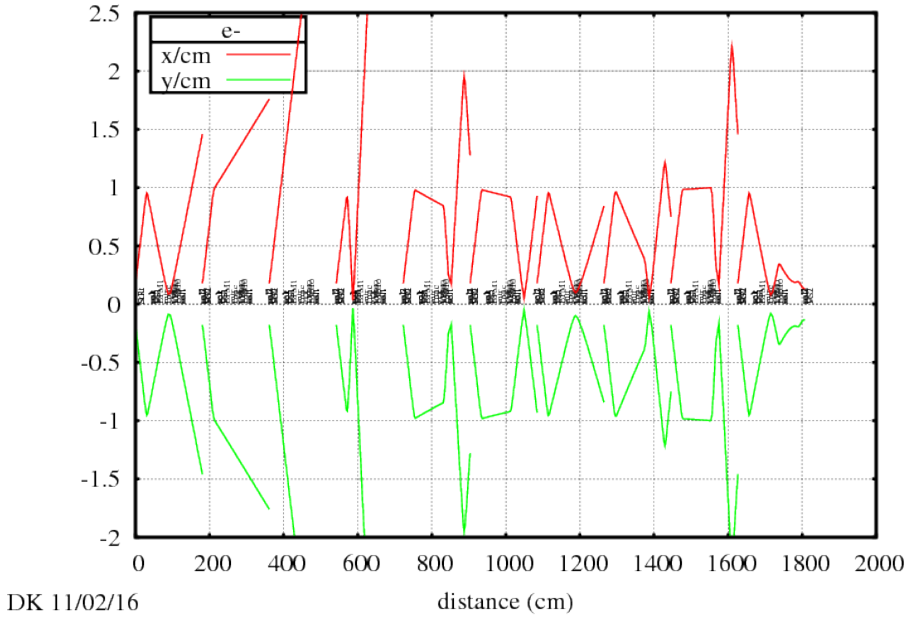

Figure 1: N=10 envelopes joined in a single beam line, N-times longer than ELBT. All cases have the same fitted initials.

3 Measurement data

3.1 `Data Oct 26`

EGUNSOL	ELBTSOL1	ELBTSOL2	EGUNVS1	ELBTVS0	ELBTVS1	weight
2.7	0	0	–	.2	–	10
1.9	0	0	–	2.7	–	10
0.	0	0	2.8	–	–	10
4.05	0	0	0.06	–	–	10
2.19	3.8	3.24	–	–	2.12	0
2.151	2.517	0	–	–	1.95	10
2.6	2.55	0	–	–	1.7	10
2.41	3.8	3.24	–	.98	–	10
2.11	3.8	3.24	–	1.98	–	10
2.71	3.8	3.24	–	.1	–	10

Table 1: `Data Oct 26` (no processing). Solenoid currents in A (first three columns) and measured full beam-sizes at a single active view screen in cm. Equal weight 10 is used in OPTR for all data. One data (No 5) is discarded (weight zero).

3.2 `Data Nov 1`

EGUNSOL	ELBTSOL1	ELBTSOL2	EGUNVS1	ELBTVS0	ELBTVS1	weight
0.	0	0	2.93	–	–	10
2.71	0	0	1.49	–	–	10
3.48	0	0	0.63	–	–	10
3.69	0	0	0.39	–	–	10
1.91	0	0	–	2.63	–	10
2.19	0	0	–	1.77	–	10
2.67	0	0	–	0.15	–	10

Table 2: `Data Nov 1` (no processing) at 1 mA. No data discarded.

4 Fit of `Data Oct 26` and `Data Nov 1` together

Fits were performed at both the gun exit (all three ellipse parameters unknown), or at the cathode (initial size known), the latter case however adding some uncertainty, as it involves usage of approximate electric field in the cathode region (on-axis component only). The results (available, but not included in this note) were nearly identical indicating that our Gun-field model is in fact adequate enough.

In Tables `Data Oct 26` and `Data Nov 1` the beam is round at the screens.

If fitting at the gun exit, 300 KeV (12 cm from cathode), and assuming uncoupled ellipses, there are three unknown parameters, the two Twiss plus emittance: $\alpha^{300}, \beta^{300}$ and ϵ^{300}. These were found to be a little too many [1].

If fitting is done at the cathode, energy 20 eV assumed, one can reduce the number of unknowns to two (chosen are $\alpha^{20\text{eV}}$ and $\beta^{20\text{eV}}$) by adding a constraint: initial size $X = 4$ mm (cathode radius).

Also at cathode one could set a constraint for zero-correlation $\alpha^{20\text{eV}} = 0$, however *this did not work*. Getting a good fit turned out possible only when a non-zero r_{12} was allowed.

The `Data Oct 26` and `Data Nov 1` are joined, so that N=16.

The following table together with Figure 2 present the results from a fit at cathode.

A summary of the fitting:

Vary: $\alpha^{20\text{eV}}$ and $\epsilon^{20\text{eV}}$

Constraint: ini. $X = 0.4$ cm

Result: $\epsilon^{20\text{eV}} = 0.15\ \pi$ cm.rad $\Rightarrow \epsilon^{300\ \text{KeV}} = 10.8\ \pi$ mm mrad

$\alpha^{20\text{eV}} = 2.5 \quad \Rightarrow$
ini. $X' = 1.03$

$r_{12}^{20\text{eV}} = \mathbf{-0.93}$

$\alpha^{300} = -4.1$
$\beta^{300} = 26.7\ cm$

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[1] unless we combine with the results from the Allison scans available both at 85 KeV and at 300 KeV, but this was not done.

On Fig. 2, measured beam sizes (green) are seen to agree with predicted by `TRANSOPTR` values (red) to within a fraction of a millimeter.

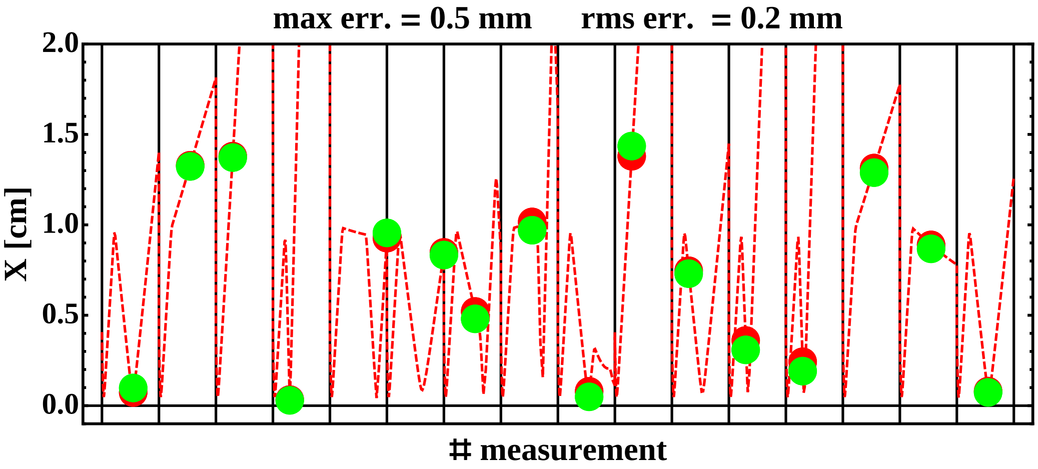

Figure 2: **Green dots:** measured beam sizes at the three view screens (for 16 solenoid settings, Tables 1 and 2) used to fit an initial beam at cathode. **Dashed red:** the 16 envelopes resulting from propagation of the resultant fitted initial beam. **Red dots:** propagated-envelope values at the view screens.