Models of cold doublets and S-band triplet for the FLASH linac

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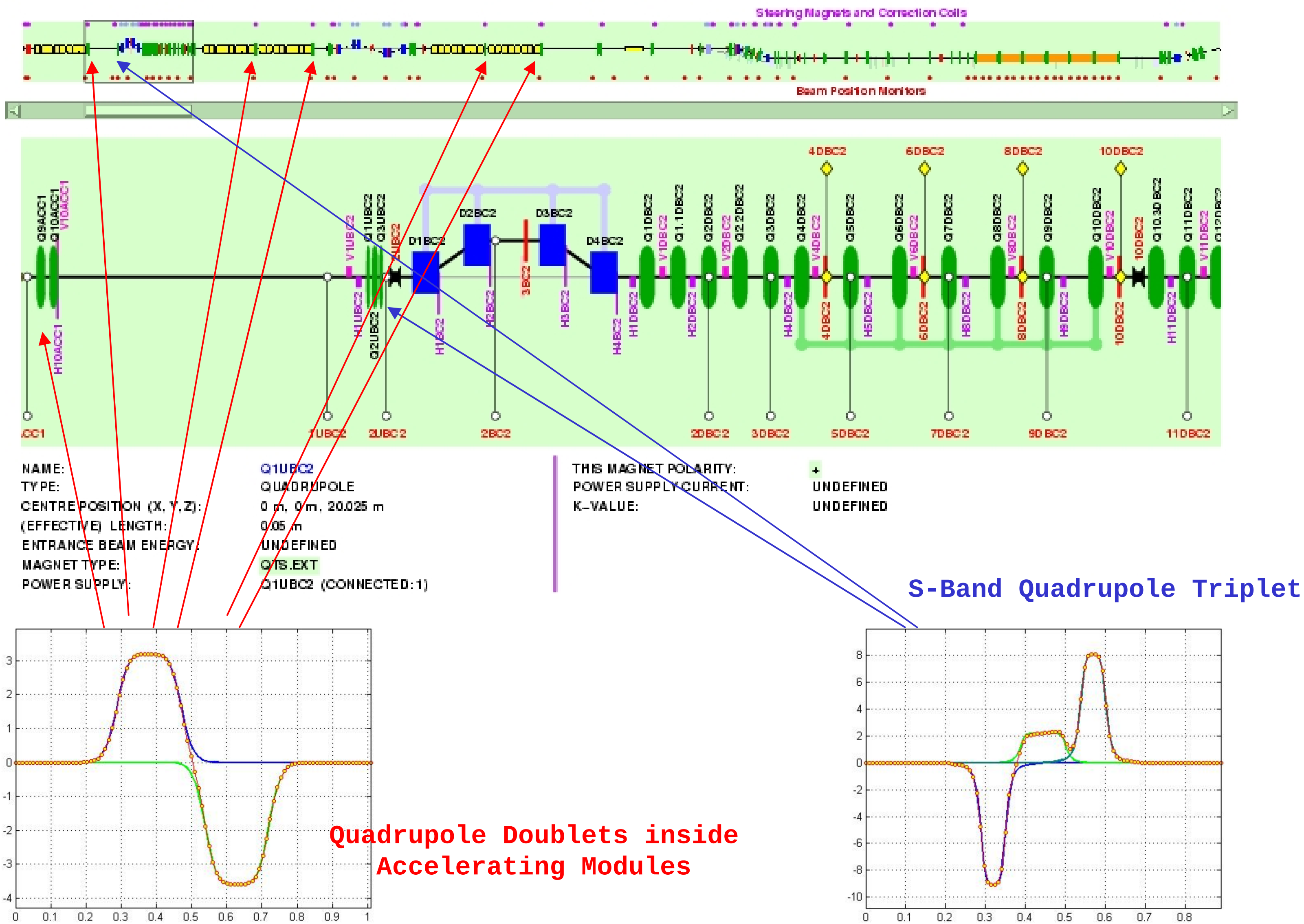
Thanks to M. Marx, Y. Holler and H.-D. Brueck for providing calculations and magnetic measurement data.

Locations of quadrupoles considered



Principal question:

Could the sum field produced by these quadrupoles be represented with "sufficient precision" as a sum of fields of individual quadrupoles (linearity)?

Current answer:

All currently available data (measurements and calculations) support the positive answer on above question, and that makes sense to all following considerations

Data used:

Cold doublet:

- measurements, November 2005,
- measurements by H.-D. Brueck, August 2006
- calculations made by M. Marx, April 2006

S-band triplet:

- measurements made by Y.Holler, 1996 year
- calculations made by M. Marx, November 2006

Steps:

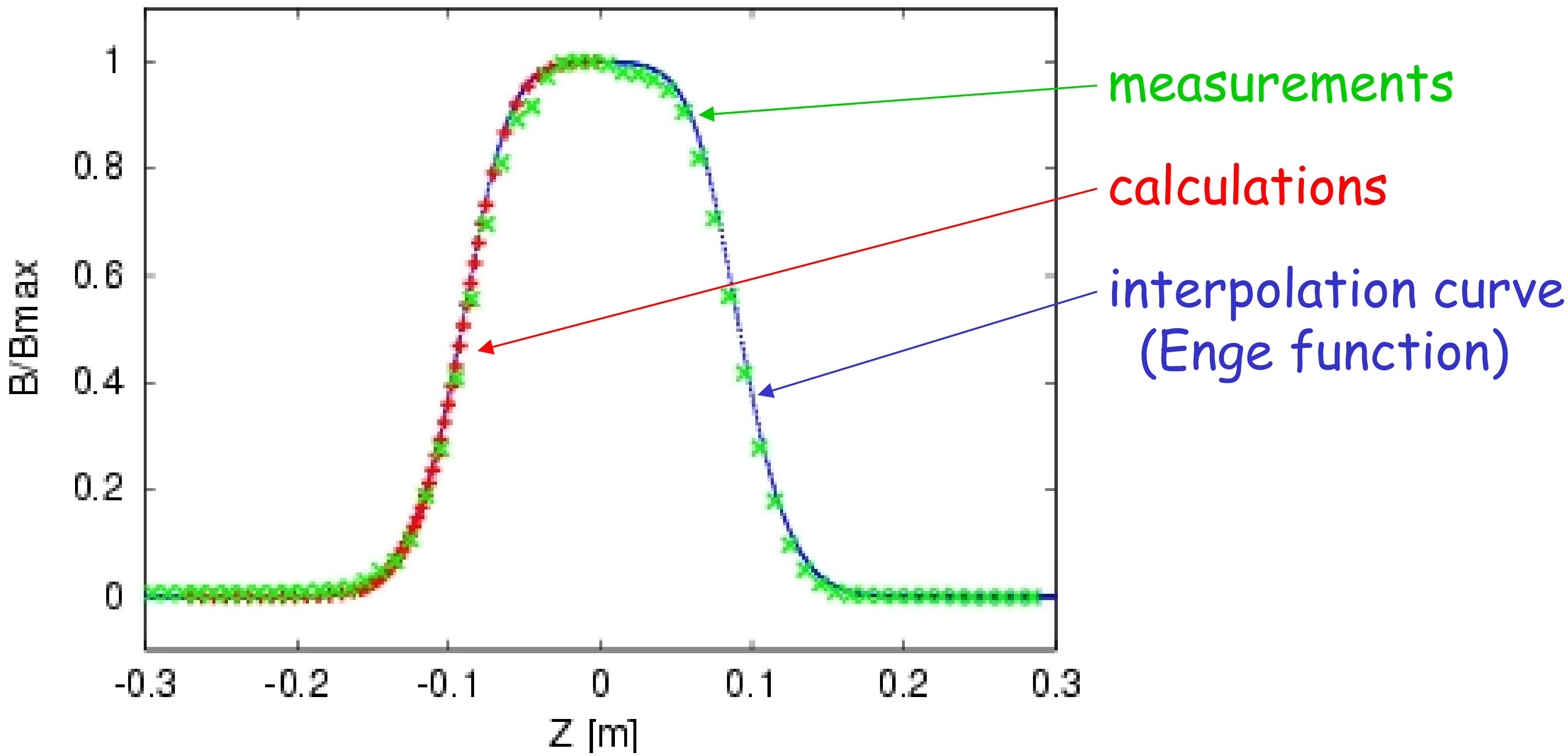
1. Approximation of individual quadrupole field by “even Enge functions” (typical tool in dealing with fringe field problems).

2. Determination of effective parameters for hard edge quadrupole models. Two different methods were used.

3. Comparison of “hard edged” and “soft edged” S-band triplet and cold doublet models.

4. Extraction of transfer coefficients between quadrupole gradients and power supply currents.

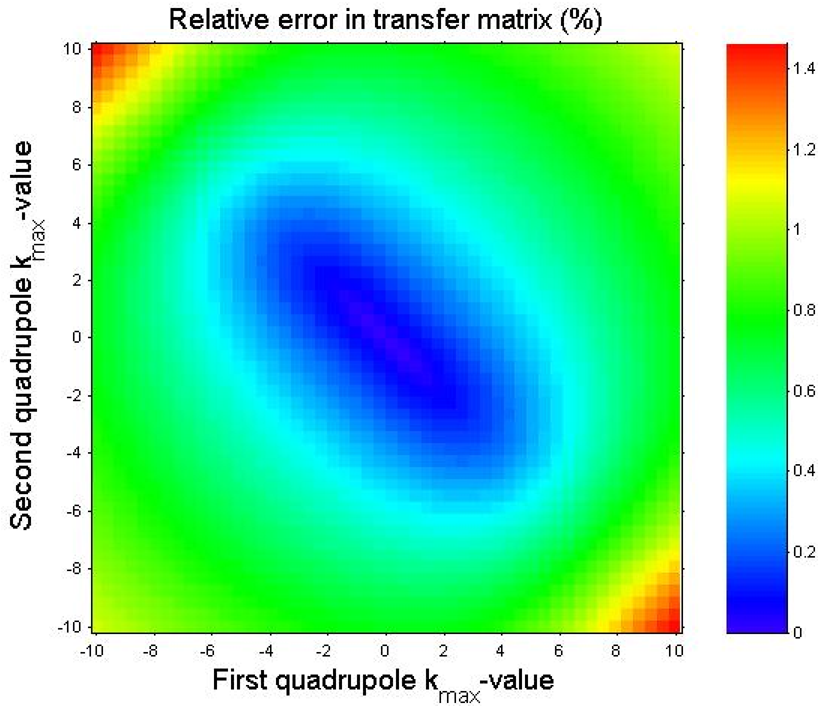
Cold doublet: effective parameters

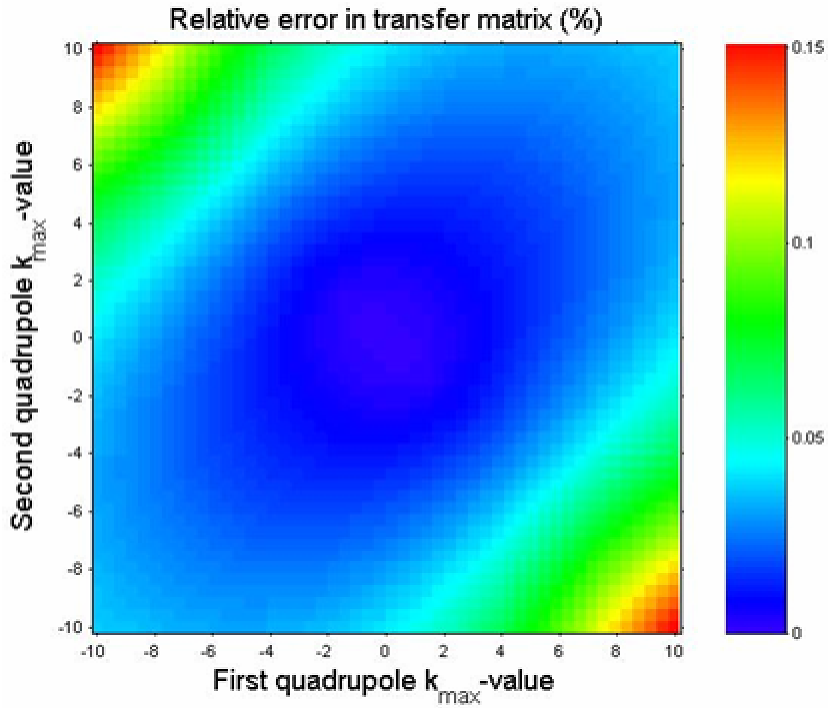


	L_{eff}(mm)	K_{eff}
$\int Bdz \,/\, B_{max}$	≈ 186	1 · k_{max}
Steffen-type approx	≈ 210	≈ 0.888 · k_{max}

Cold Doublet:

comparison of “soft edged” and “hard edged” doublet models





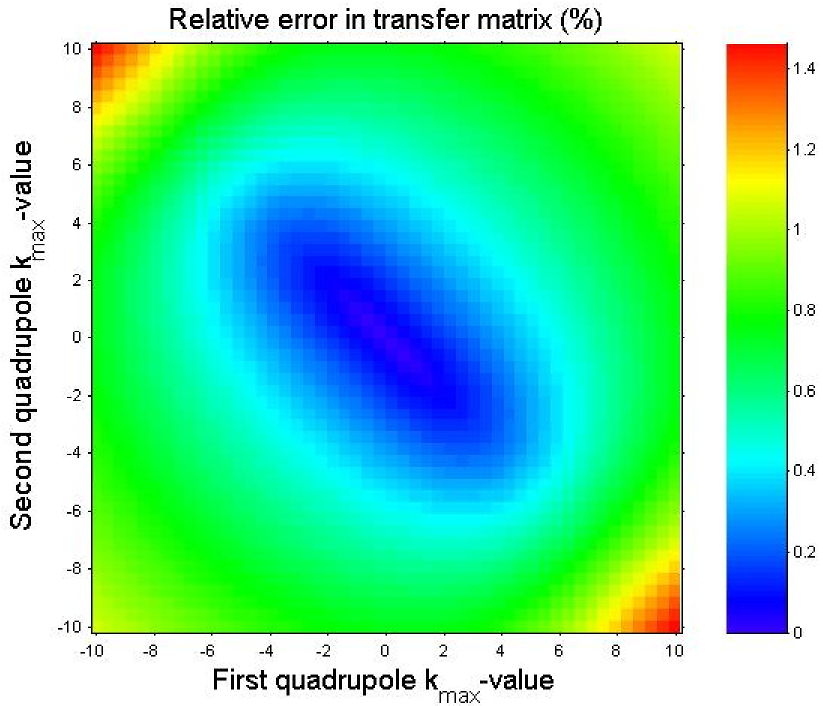
Effective length is defined as a field integral divided by the maximal field value

Effective length is defined as a result of the Steffen-type approximation procedure

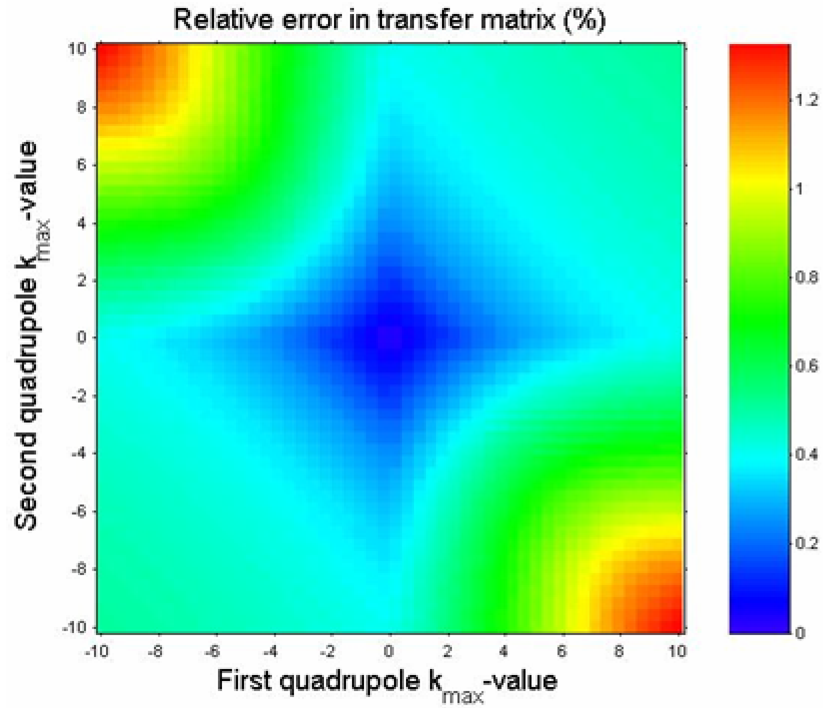
$$\text{relative error} = \frac{|M_{exact} - M_{approx}|}{|M_{exact}|}$$

Cold Doublet:

"hard edged" doublet model compared with itself

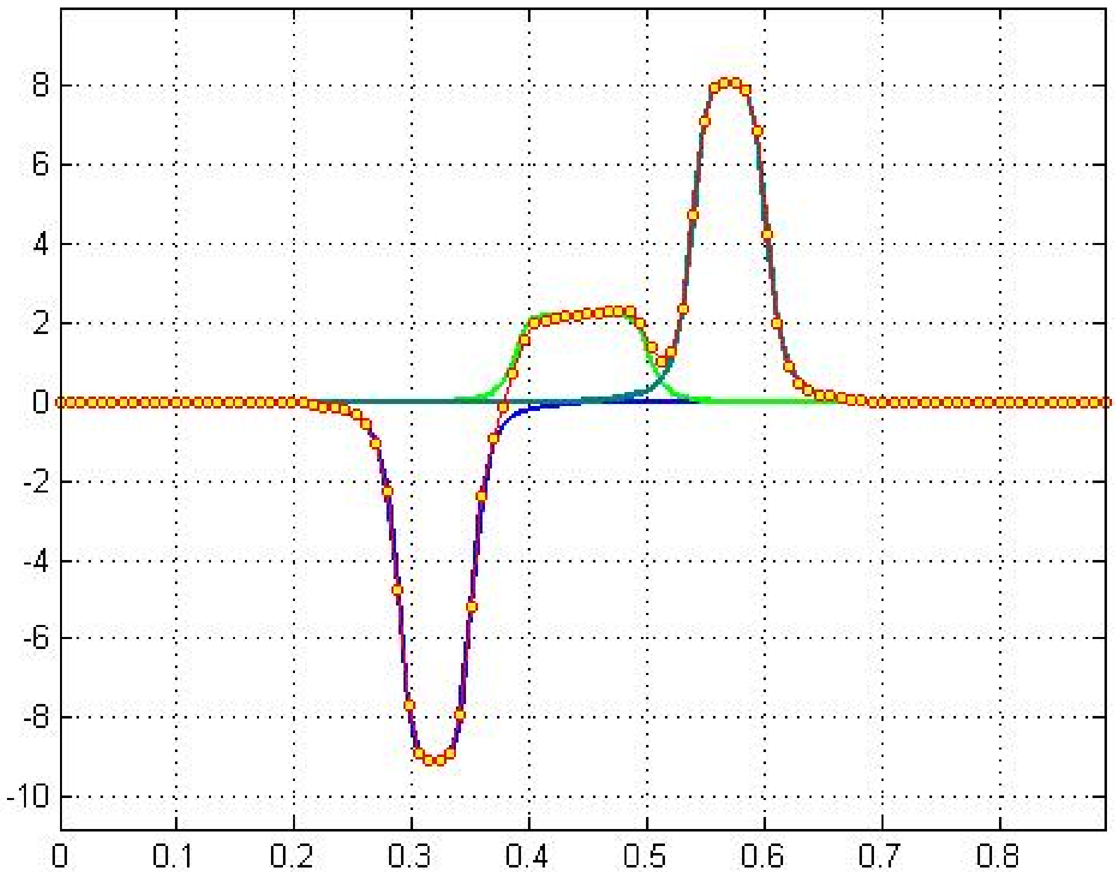


"Soft " and "hard" edged models



"Hard edged" model compared with itself. For the second calculation both k-values where shifted on 0.5% in positive direction

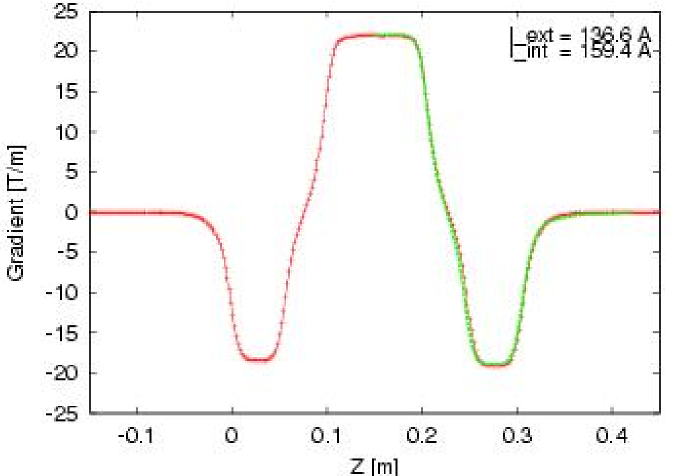
Quadrupole triplet at the BC2 entrance (S-band triplet)

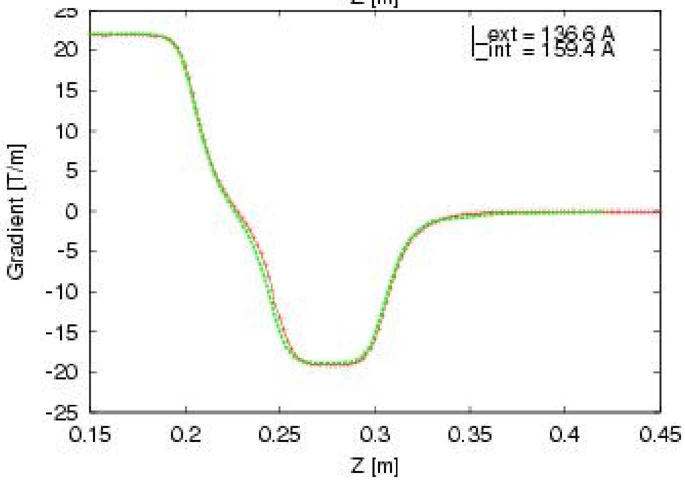


Typical FLASH setting: k(Q1UBC2) ≈ -9.1, k(Q2UBC2) ≈ +2.2, k(Q3UBC2) ≈ +8.1

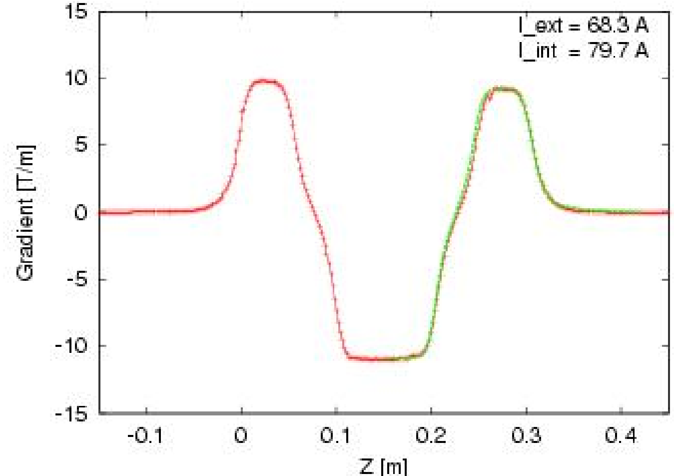
Comparison of measured and calculated data for S-band triplet: Field profiles

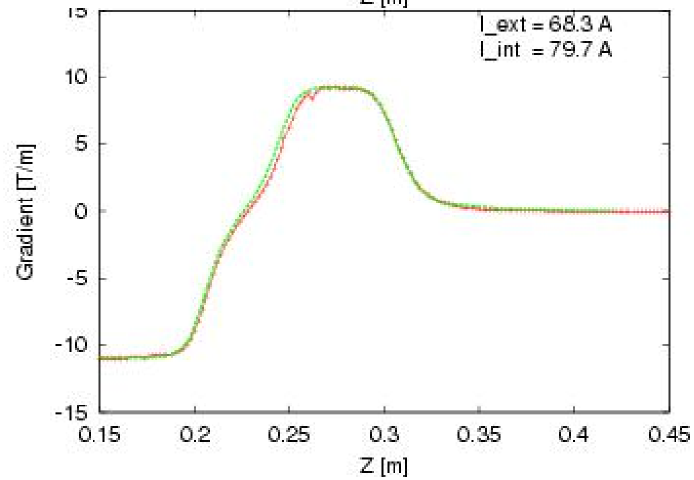
I_ext1=I_ext2=136.6 A, I_int=159.4 A





I_ext1=I_ext2=68.3 A, I_int=79.7 A



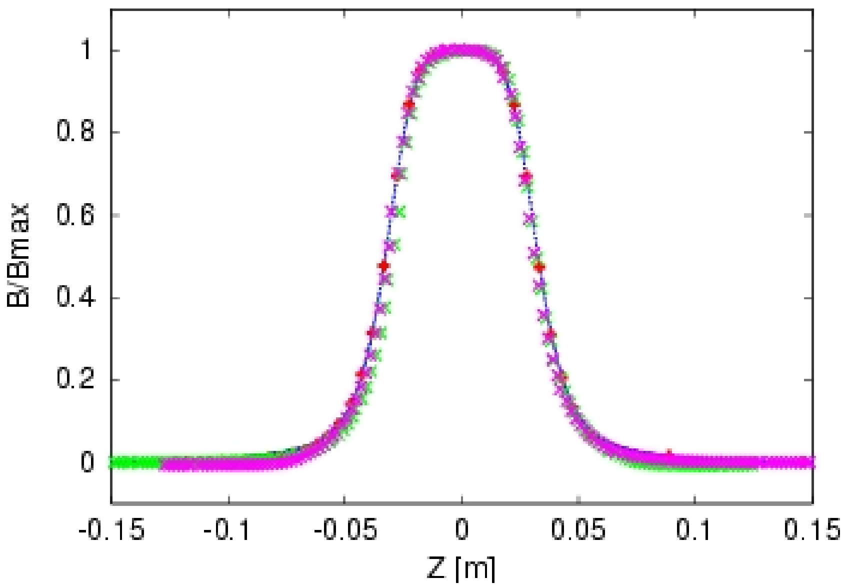


Measured (Y.Holler): red

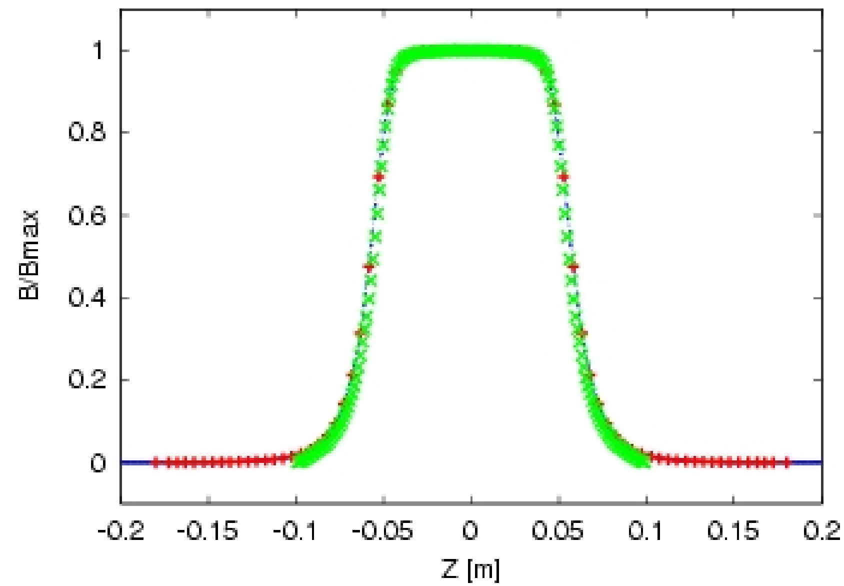
Calculated (M.Marx): green

S-band triplet: effective parameters

External quadrupoles



Internal quadrupole

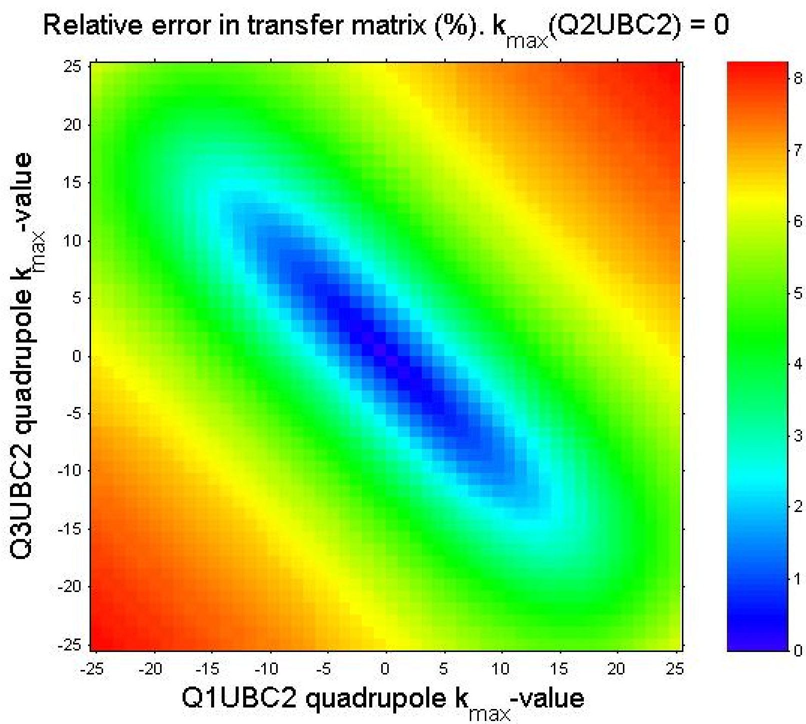


Measured (green and magenta) and calculated (red) data, and interpolation curves (blue, Enge functions)

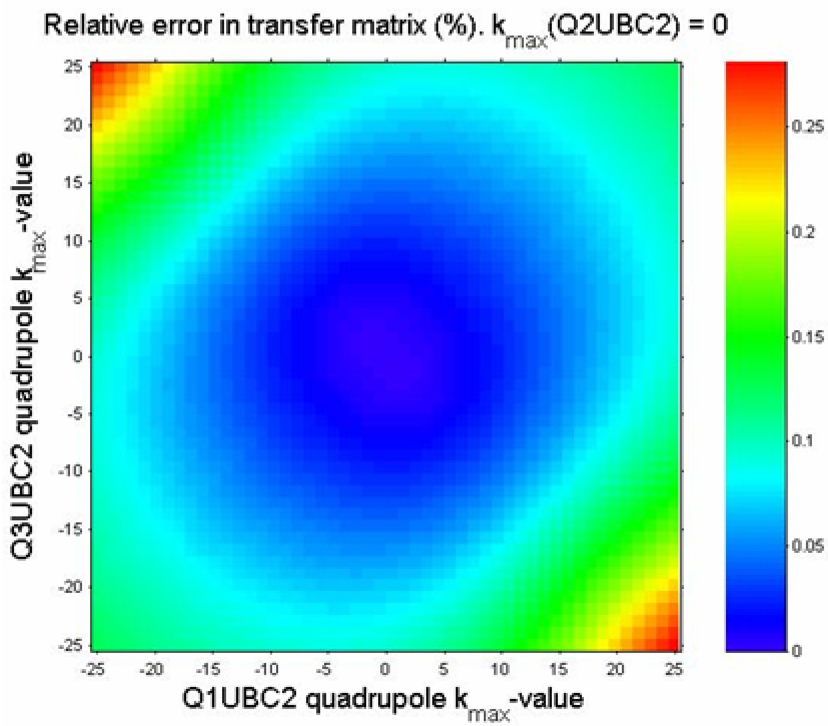
	QTS_EXT		QTS_INT	
	L_{eff}(mm)	k_{eff}	L_{eff}(mm)	k_{eff}
$\int Bdz/B_{max}$	≈ 70	$1 \cdot k_{max}$	≈ 120	$1 \cdot k_{max}$
Steffen-type approx	≈ 93	≈ $0.759 \cdot k_{max}$	≈ 131	≈ $0.914 \cdot k_{max}$

Triplet:

comparison of "soft edged" and "hard edged" triplet models



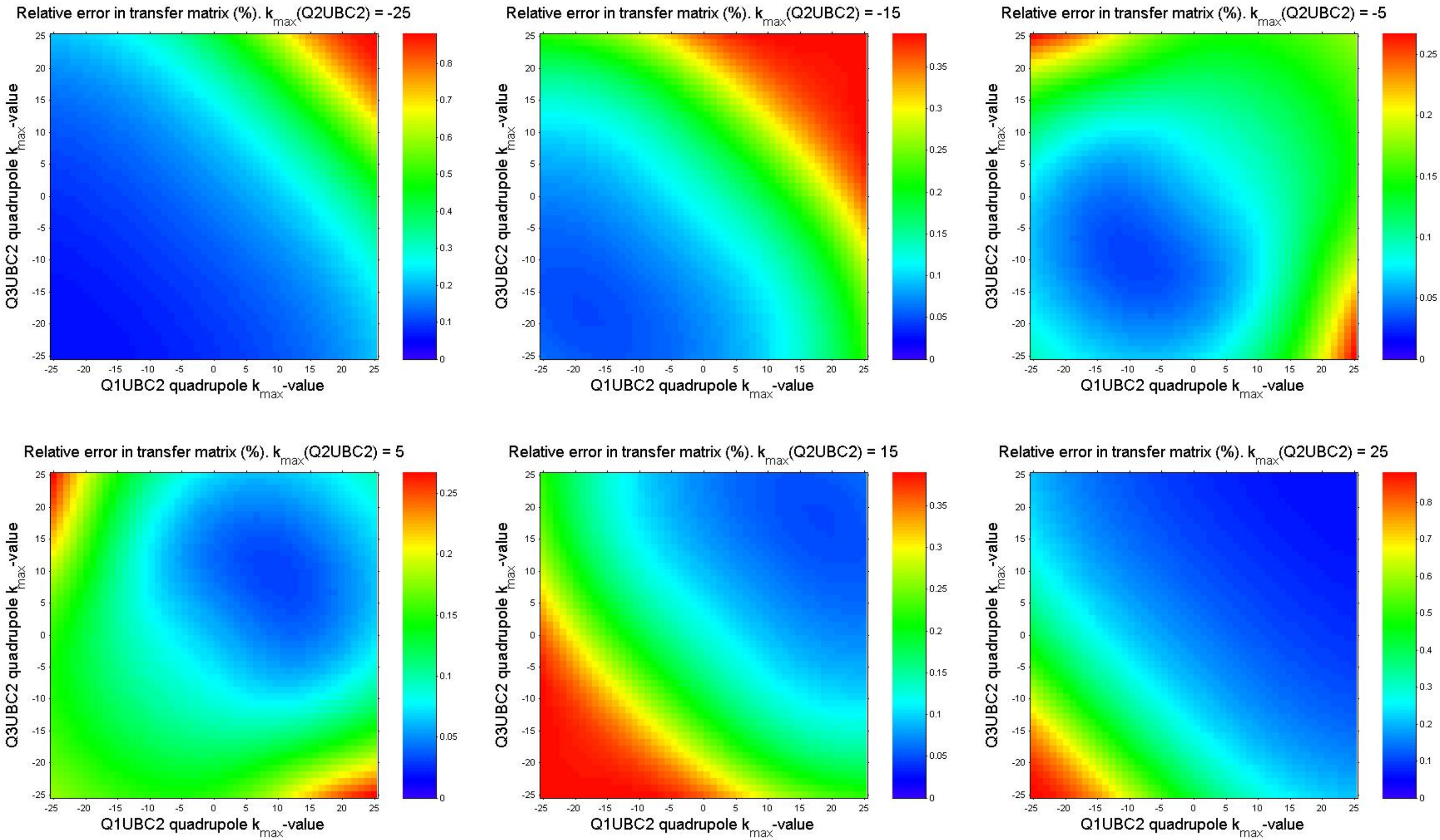
Effective length is defined as a field integral divided by the maximal field value



Effective length is defined as a result of the Steffen-type approximation procedure

$$\text{relative error} = \frac{|M_{exact} - M_{approx}|}{|M_{exact}|}$$

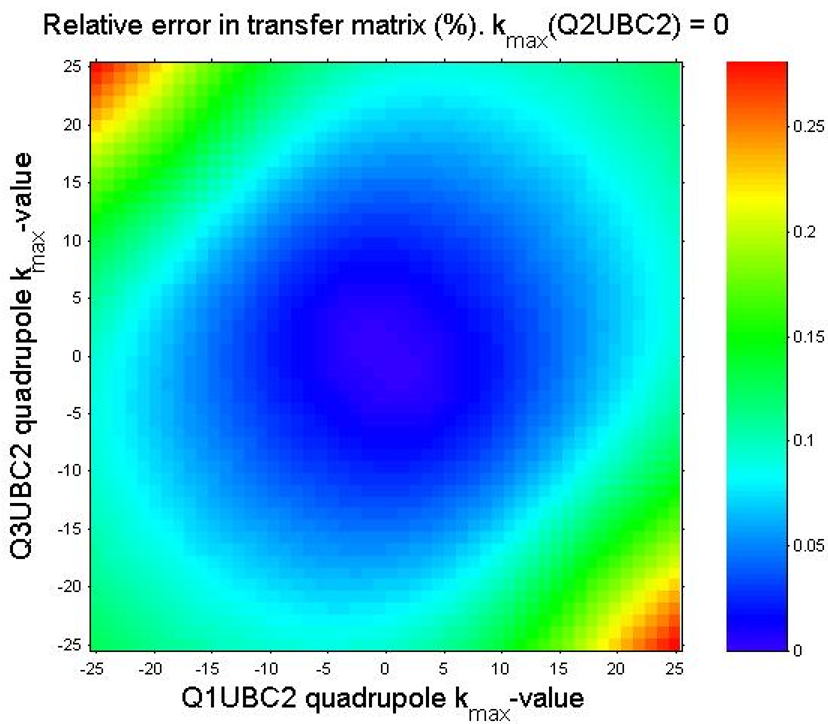
Triplet: effective length is defined as a result of the Steffen-type approximation procedure



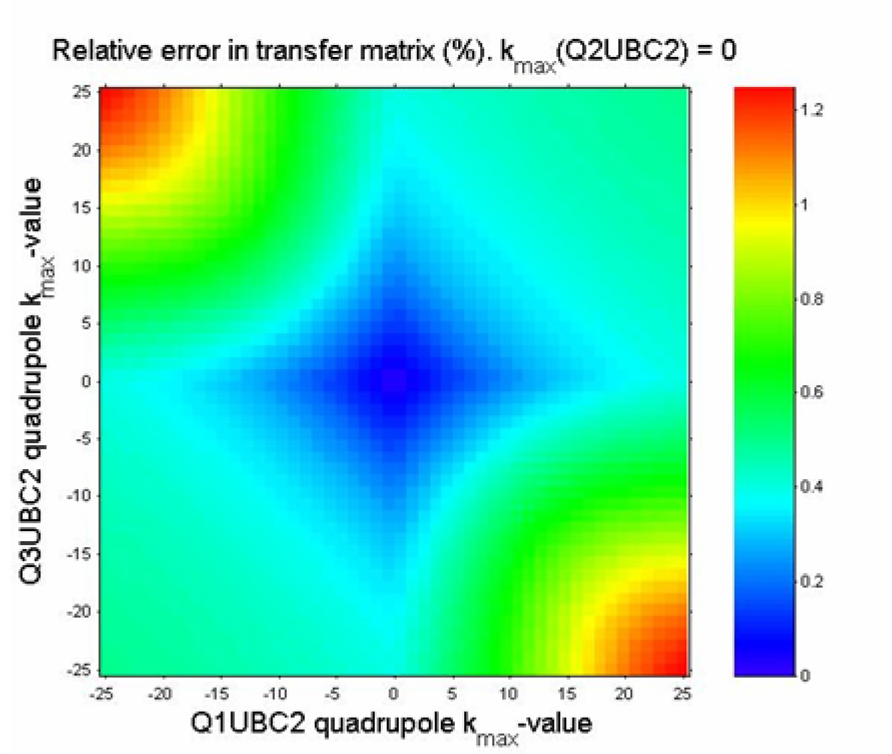
In all range of k-values scan an error is below 1%

Triplet:

“hard edged” triplet model compared with itself



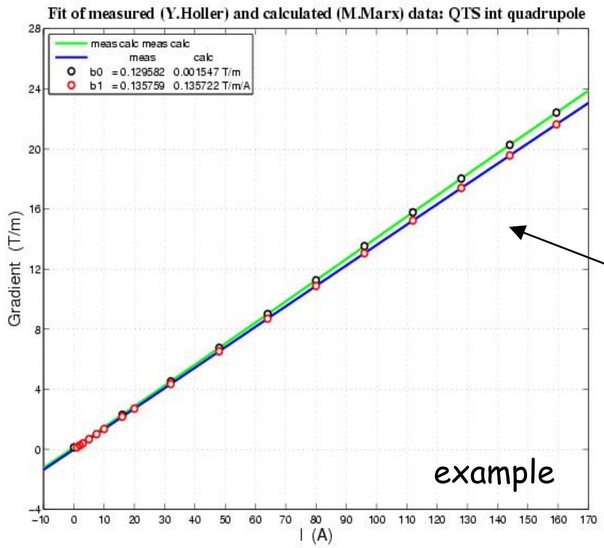
“Soft ” and “hard” edged models



“Hard edged” model compared with itself. For the second calculation both k-values where shifted on 0.5% in positive direction

Transfer between quadrupole gradients and power supply currents

Fit by cubic polynomial: $G = a_0 + a_1 \cdot I + a_2 \cdot I^2 + a_3 \cdot I^3$



S-band triplet: a1

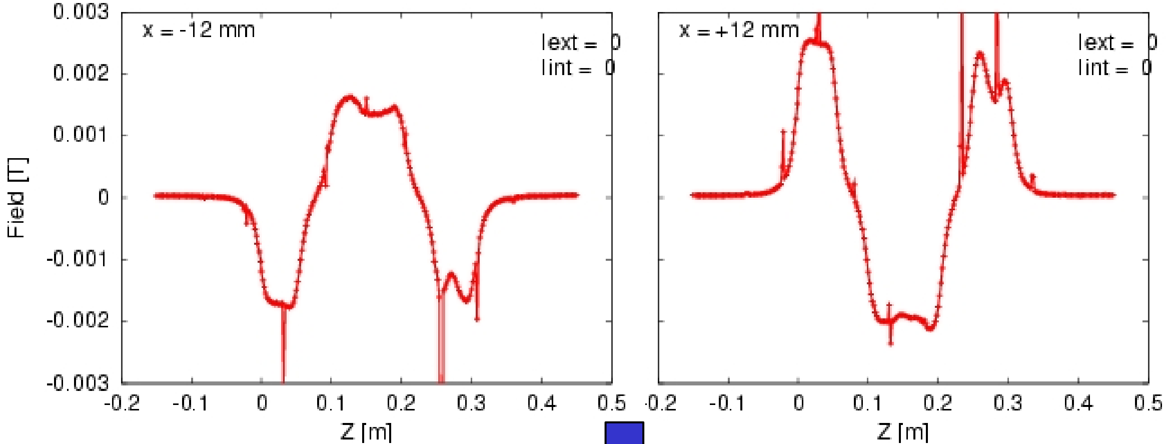
FLASH: a1 = 0.14 - currently in usage

	meas	calc	
QTS_int	0.13576	0.13572	0.03%
QTS_ext	0.13778	0.13539	1.7%

a1 = 0.1356 can be used (3% with r. to 0.14)

Measurement of excitation curve has been done for QTS_ext_1 at x_m = 12 mm, for which the measured value of remnant field is larger than for QTS_ext_2.

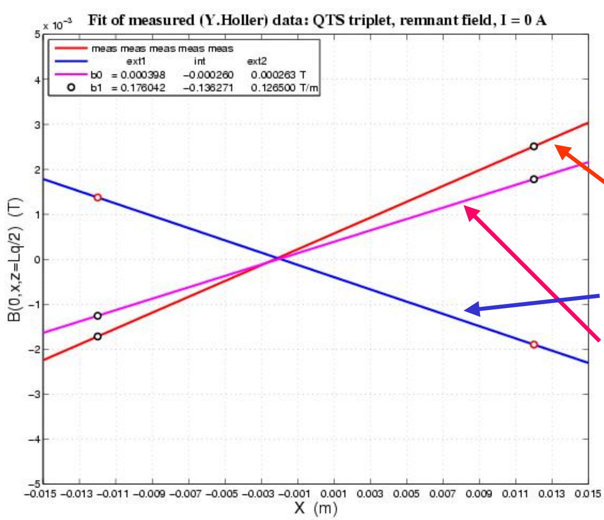
S-band triplet: a0 (remnant field)



Measurements:

I_ext1: 0, 136, 0
I_int: 0, 0, 159
I_ext2: 0, 136, 0
x_m = -12, +12 mm

B_ext1(+12) > B_ext2(±12)



FLASH: a0 = 0.12 currently used

	I	fit	I	fit	I	fit
QTS_ext1	0	0.176	136.6	-	0	0.174
QTS_int	0	0.136	0	0.122	159.4	-
QTS_ext2	0	0.127	136.6	-	0	0.120

The end !