

- Introduction
 - ✓ SLAC
 - ✓ M5789 (FLNR/JINR)
 - ✓ NSCL #1
 - ✓ NSCL #2
 - ✓ NSCL #3
 - ✓ SHELS (FLNR/JINR)
- Quadrupole effective lengths in LISE++
 - ✓ Effective values in the Optic Setup dialog
- Supplementary: Quad B (1) calibration

TN-63-10
 J. J. Murray
 February, 1963.

EFFECTIVE LENGTH MEASUREMENT FOR

QUADRUPOLE MAGNETS

Coef=1.0

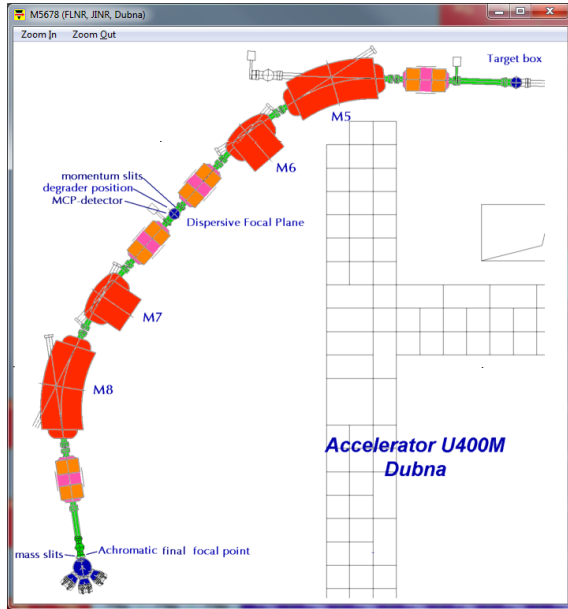
The effective length of a quadrupole magnet can be defined as

$$L_{\text{eff}} = \frac{\int_{-\infty}^{\infty} \frac{\partial B_y}{\partial x} dz}{\left(\frac{\partial B_y}{\partial x} \right)_0} \quad \text{in one plane}$$

To fair approximation the effective length is given by

$$L_{\text{eff}} = l_p + a$$

where l_p is length of the iron poles and a is the apperture radius.



| | 7k30-1500 U400M | 11k-30.600 U400 | 2ML-5-2 | | Limit,A | kG/A | |
|------------------------|------------------------------------|--------------------|----------------|--|---------|------|-------|
| Half-Aperture(cm) | 3.5 | 5.5 | 6.93 | | L1 | 7 | 0.303 |
| Gradient(G/cm) | 1500 | 600 | 262.3456342 | | L2 | 7 | 0.303 |
| Limit(A) | 20 | 17 | 6 | | L0(L2) | 2 | 0.303 |
| Limit from Ap. (kG) | 5.25 | 3.3 | 1.8 | | L3 | 17 | 0.196 |
| Slope(kG/A) | 0.263 | 0.194 | | | L4 | 17 | 0.196 |
| Limit1(A) | 17 | | 2 | | L5 | 17 | 0.309 |
| Slope(kG/A) | 0.309 | | | | L6 | 17 | 0.309 |
| B(Melnikov) | 308.627 | 196.637 | 303.037 | | L7 | 17 | 0.309 |
| | 1.000 | 1.001 | 1.000 | | L8 | 17 | 0.309 |
| | | | | | L9 | 17 | 0.309 |
| | | | | | L10 | 17 | 0.309 |
| | | | | | L11 | 17 | 0.309 |
| Gradient(G/l/cm) | 88.176 | 35.707 | 43.724 | | L12 | 17 | 0.309 |
| Slope(kG/l) Mel'nikov | 0.309 | 0.196 | 0.303 | | L13 | 17 | 0.309 |
| Limit(kG) | 6.2 | 3.3 | 1.8 | | L14 | 17 | 0.309 |
| | | | | | L15 | 17 | 0.309 |
| Length(m) | 0.3 | 0.3 | 0.3 | | L16 | 17 | 0.309 |
| LengthEff(m) | 0.3315 | 0.3495 | 0.3624 | | L17 | 17 | 0.309 |
| LengthEff(m) | Length + 0.9 * HalfAperture | | | | L18 | 17 | 0.309 |
| | | | | | L19 | 17 | 0.309 |
| Limit(A) | 17 | | | | L20 | 17 | 0.309 |
| Limit from Ap. (kG) | 25.5 | | | | L21 | 17 | 0.309 |
| | | | | | L22 | 17 | 0.309 |
| | | Melnikov | | | | | |
| | 2ML-5-2 | 1.833 kG | 7.12A | | | | |
| | | | 6.66A | | | | |
| | | kG/A | A | | | | |
| | | 0.266 | 6.89 | | | | |

Coef=0.9

Courtesy by Mauricio

| Based on drawings | | | | Reference: A. F. Zeller et. al., Adv. Cryo. Eng., Y. 1998, vol. 43, A, pages 245-252. | | | | | | | |
|-------------------|-----------|----------|----------|---|-----|-----------------|----------------------|---------------------|----------------------|------------|-------------------|
| Type | Type ref. | Lyoke[m] | R[m] | type | Qt. | Iron length [m] | Effective length [m] | Pole tip radius [m] | Warm bore radius [m] | Multipoles | Leff= L+ coef * R |
| A | 1 | 0.6500 | 0.132999 | QA | 4 | 0.65 | 0.723 | 0.133 | 0.100 | no | 0.55 |
| B | 2 | 0.3250 | 0.149987 | QB | 12 | 0.325 | 0.400 | 0.150 | 0.100 | yes | 0.50 |
| C | 3 | 0.7151 | 0.149987 | QC | 4 | 0.715 | 0.790 | 0.150 | 0.100 | yes | 0.50 |
| D | 4 | 0.3810 | 0.210033 | QD | 2 | 0.381 | 0.486 | 0.210 | 0.170 | no | 0.50 |
| E | 5 | 0.6250 | 0.149987 | QE | 2 | 0.625 | 0.700 | 0.150 | 0.116 | no | 0.50 |

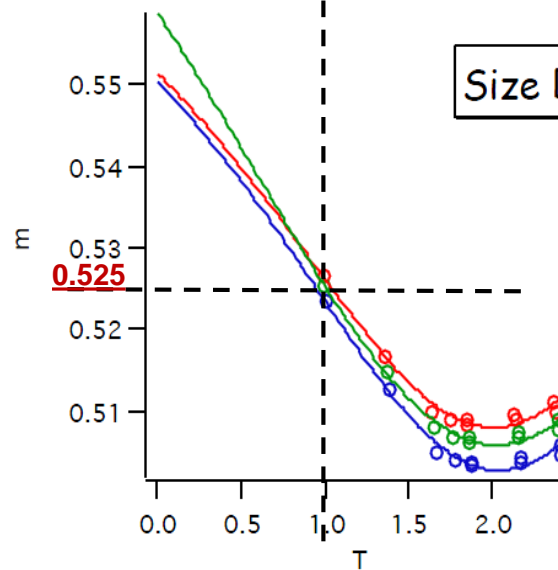
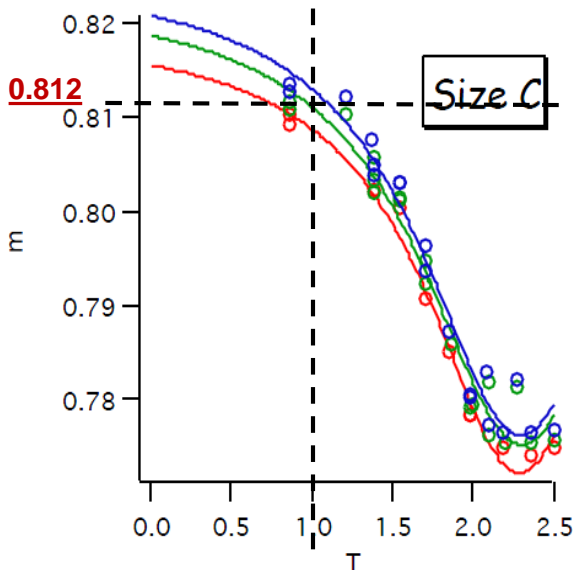
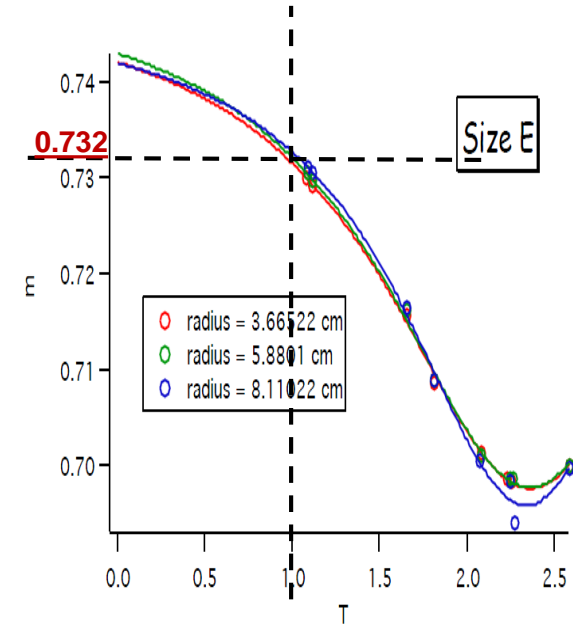
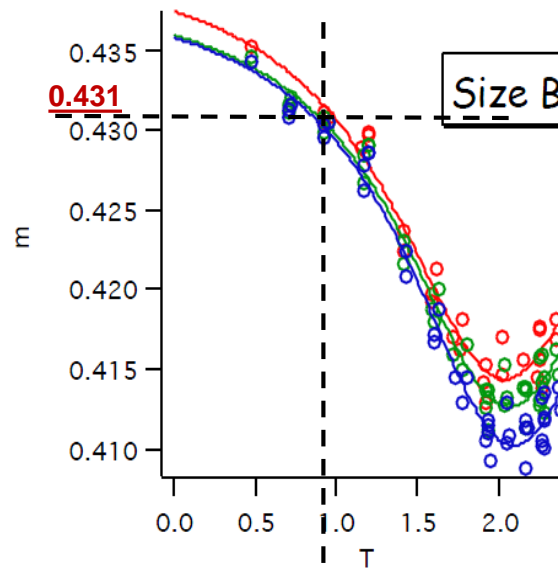
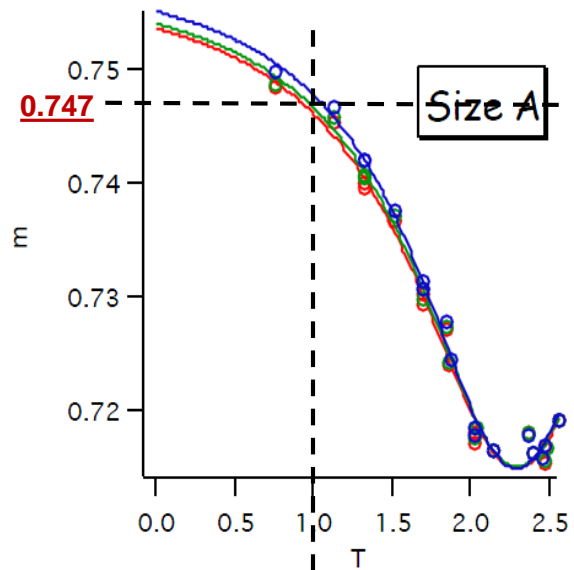
Coef=0.5

| 1 | 2 | 3 | 4 | 9 | 5 | 6 | 10 | (Leff-L)/2 | | | | |
|------|-------------|---------------|-----------|----------------|------------|---------------------|------------------|------------|----------|----------|----------|----------|
| COSy | Block name | Kind of Block | Start (m) | Rapp(cm) R(m)* | Length (m) | DriftMode Angle(-)* | L_eff(m) Len(m)* | Quad label | Real L | dL_q/2 | dL_drift | dL/2_sum |
| 1 | tuning | Dipole | 0 | 3.00* | 0 | +0.0 * | 0.00* | Mauricio | 0.23122 | 0.445011 | | |
| 25 | D2 | Dipole | 11.812 | 3.09* | 2.43 | -45.0 * | 2.43* | Mauricio | 0.36529 | 0.594934 | | |
| 26 | S2L5 | z052 | 14.242 | | 0.5424 | D2-T4 | | Scheme | 0.229644 | | | |
| 27 | Q053-4TA | Drift | 14.795 | 15 | 0.5525 | standard | 0.43 | B | 0.6050 | 0.0525 | | |
| 28 | S2L6 | z054 | 15.225 | | 0.1699 | standard | | E | 0.2818 | | 0.1119 | 0.1060 |
| 29 | Q055-4TB | Drift | 15.394 | 15 | 0.732 | multipole | 0.73 | E | 0.6250 | 0.0535 | | 0.0059 |
| 30 | S2L7 | z056 | 16.126 | | 0.1759 | standard | | D | 0.3083 | | 0.1324 | 0.1260 |
| 31 | Q057-4TC | Drift | 16.302 | 21 | 0.526 | multipole | 0.53 | D | 0.3810 | 0.0725 | | 0.0064 |
| 32 | S2L8 | z058 | 16.828 | | 0.6578 | standard | | Mauricio | 0.7303 | | | |
| | | | | | 0.6527 | | | Scheme | 0.259512 | 0.725162 | | |
| 33 | Image2(059) | Drift | 17.486 | | 0 | T4-F2 | | Mauricio | 0.46565 | | | |
| | | | | | | SLITS | | | | | | |

| Based on drawings | | | | Reference: A. F. Zeller et. al., Adv. Cryo. Eng., Y. 1998, vol. 43, A, pages 245-252. | | | | | | | | |
|-------------------|-----------|----------|----------|---|-----|-----------------|----------------------|---------------------|----------------------|------------|--------------------------------|------------------------------|
| Type | Type ref. | Lyoke[m] | R[m] | type | Qt. | Iron length [m] | Effective length [m] | Pole tip radius [m] | Warm bore radius [m] | Multipoles | A1900 TRANSPORT file L_eff [m] | Leff= L+ coef * R Coef [1/m] |
| A | 1 | 0.6500 | 0.132999 | QA | 4 | 0.65 | 0.723 | 0.133 | 0.100 | no | 0.748 | 0.74 |
| B | 2 | 0.3250 | 0.149987 | QB | 12 | 0.325 | 0.400 | 0.150 | 0.100 | yes | 0.43 | 0.70 |
| C | 3 | 0.7151 | 0.149987 | QC | 4 | 0.715 | 0.790 | 0.150 | 0.100 | yes | 0.812 | 0.65 |
| D | 4 | 0.3810 | 0.210033 | QD | 2 | 0.381 | 0.486 | 0.210 | 0.170 | no | 0.526 | 0.69 |
| E | 5 | 0.6250 | 0.149987 | QE | 2 | 0.625 | 0.700 | 0.150 | 0.116 | no | 0.732 | 0.71 |
| | | | | | | | | | | | average | 0.70 |
| | | | | | | | | | | | median | 0.70 |

Coef=0.7

Courtesy by Daniel



| A1900 TRANSPORT file | | |
|----------------------|-----------------|---------------|
| Type | Iron length [m] | L_{eff} [m] |
| A | 0.65 | 0.748 |
| B | 0.325 | 0.43 |
| C | 0.715 | 0.812 |
| D | 0.381 | 0.526 |
| E | 0.625 | 0.732 |

It looks like the Effective lengths at 1 T were used in the TRANSPORT file

Courtesy by A.Popeko

Used in simulations:

LQ = 310; {Length of quadrupole iron in mm}

LQeff = 380; {Effective length of quadrupole in mm}

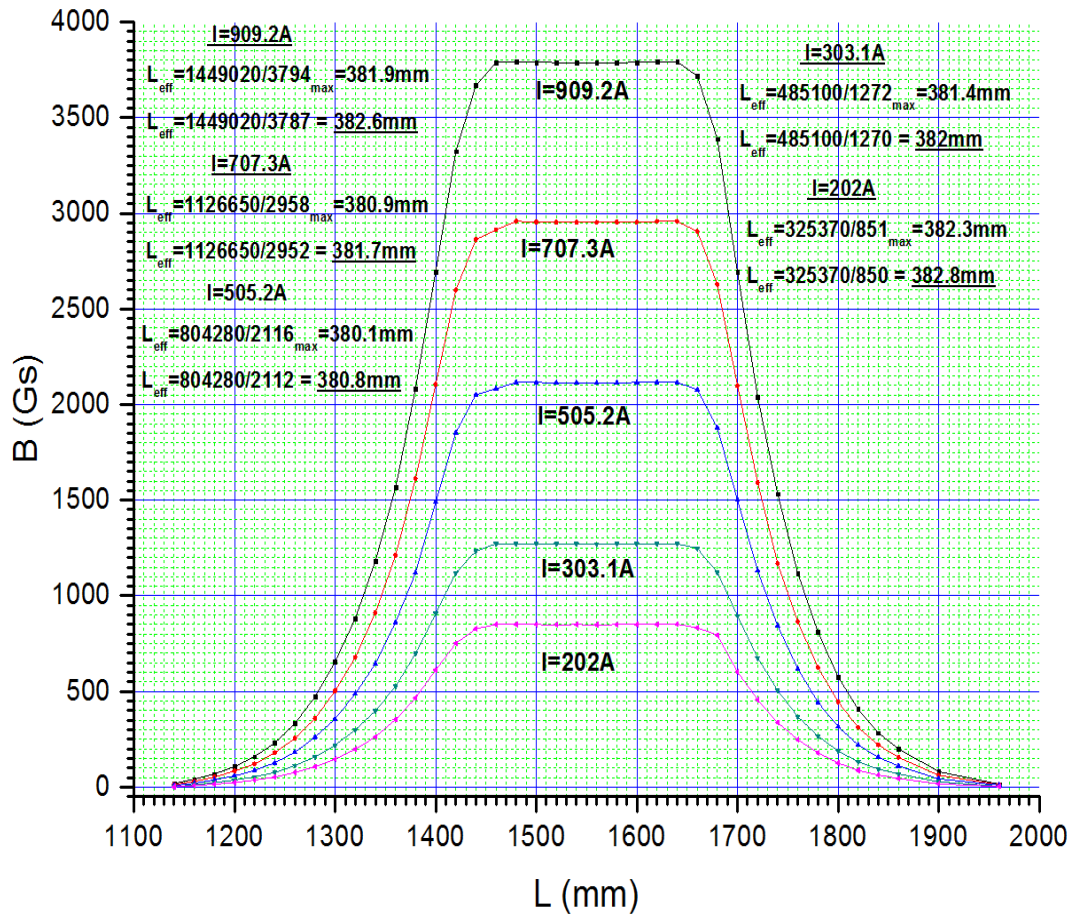
~~coef~~

~~0.778~~

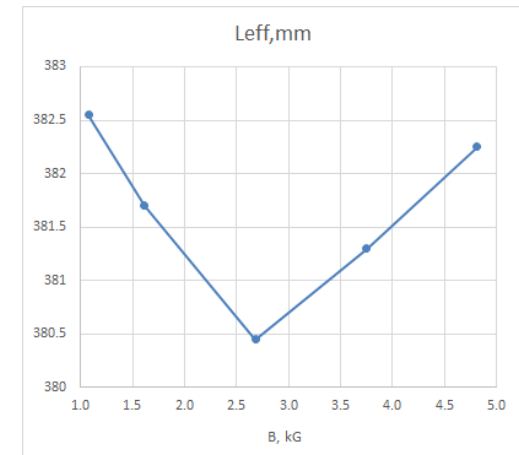
Coef=0.7

6 identical quads

Q1 (pole 4) effective length on R rel.=0



| I | B, kG | Leff,mm |
|---------|---------|---------|
| 202 | 1.08 | 382.55 |
| 303 | 1.615 | 381.7 |
| 505 | 2.68368 | 380.45 |
| 707 | 3.7504 | 381.3 |
| 909 | 4.8124 | 382.25 |
| average | | 381.65 |



Courtesy by A.Popeko

Used in simulations:

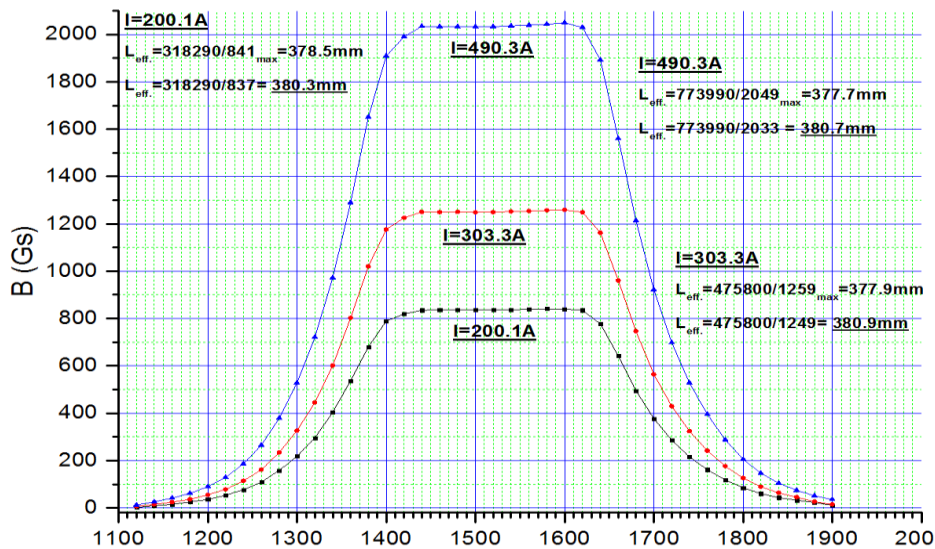
LQ = 310; {Length of quadrupole iron in mm}

LQeff = 380; {Effective length of quadrupole in mm}

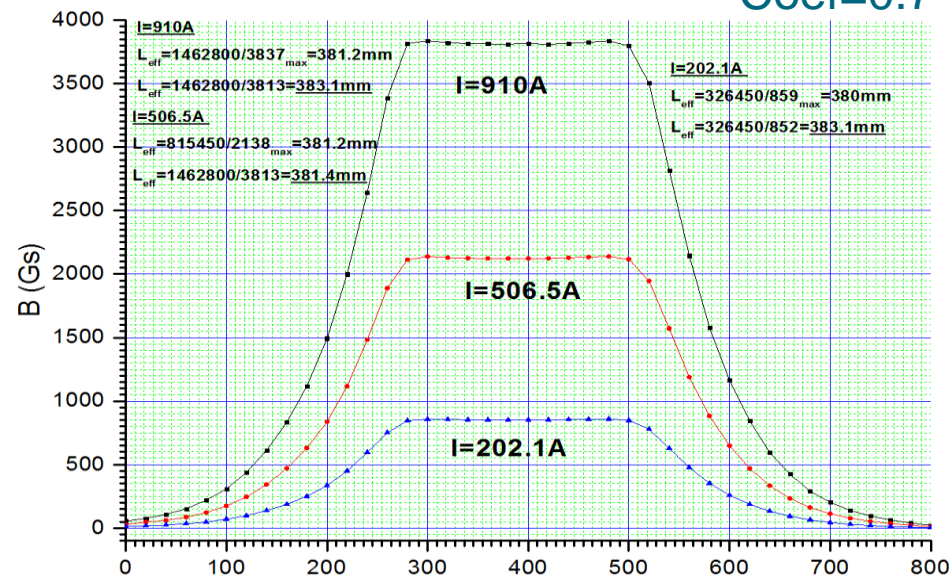
~~coef~~
0.778

Coef=0.7

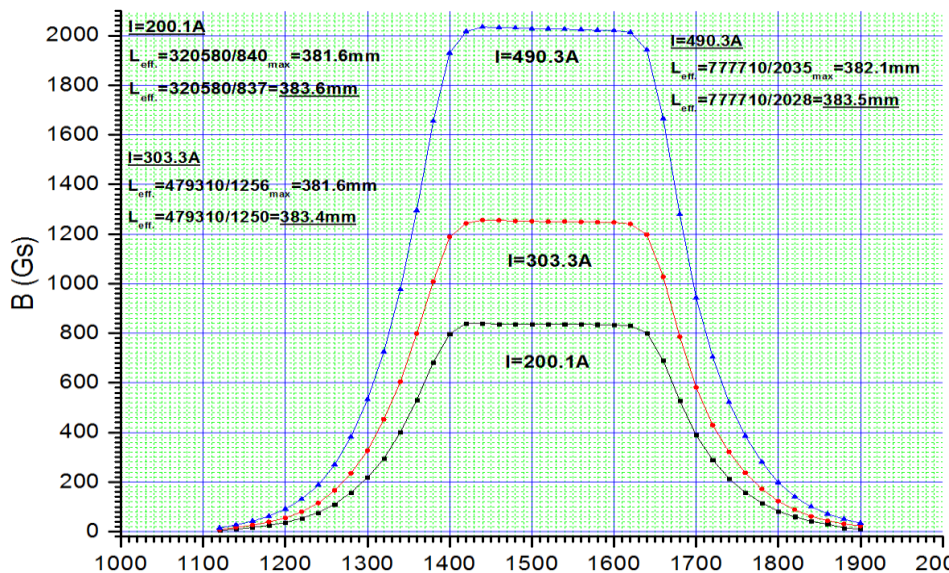
Q6 (pole4) eff. length



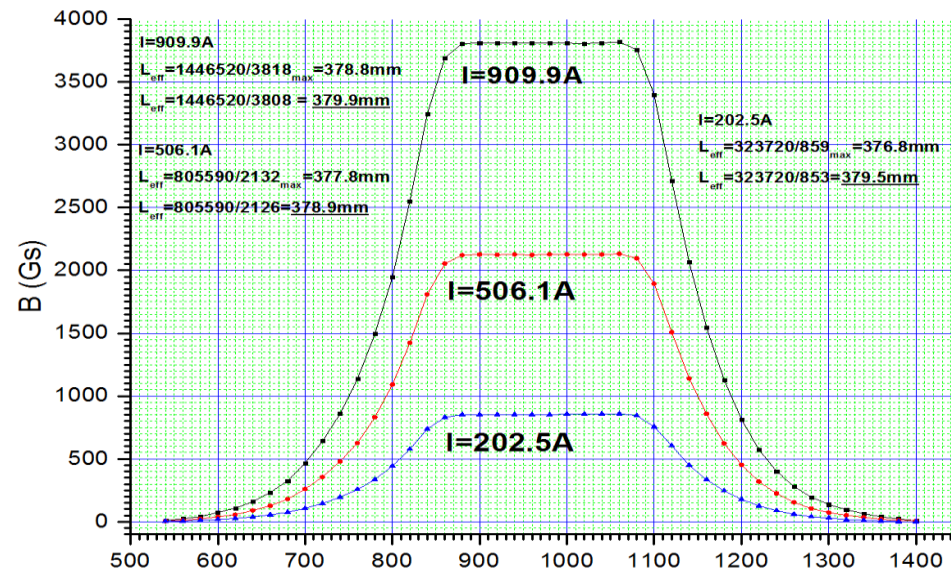
Q3 (pole 3) effective length



Q6(pole3) eff. length



Q2 (pole3) effective length



Multipole: Quad 1

Magnetic Multipole Settings

| | | | |
|---|------------|-----------|----|
| | QUADrupole | SEXTopole | |
| L_eff (effective length) mode: <Calc> [c=0.78] | 0.38 | | m |
| B (field at pole tip) | 4.51378 | 0 | kG |
| Radius (half-aperture) | 9 | 9 | cm |

Multipole fixed Brho-value corresponding to the setting fragment: 0.74779 Tm

Calculate 2nd order matrix elements
 Allow remote matrices recalculation

+852.06 A

if Brho-value has been changed then

no actions
 recalculate automatically B (fields), keep the matrix [Recommended]
 recalculate automatically the matrix, keep B (fields)

Block settings, Information

Block length: 0.31 m
 Current (Real) Brho-value for the setting fragment: 0.74779 Tm
 Setting fragment: 255Rf20+

Quad 1 : multipole effective length

Note:
 Effective length is used for optical matrix calculation, Block length is used for time-of-flight calculations

Equal to Block Length (L)
 Set manually by user
 Calculated : $L_{eff} = L + a \cdot coef$

where
 "L": block (physical) length [m]
 "a": half-aperture [m]

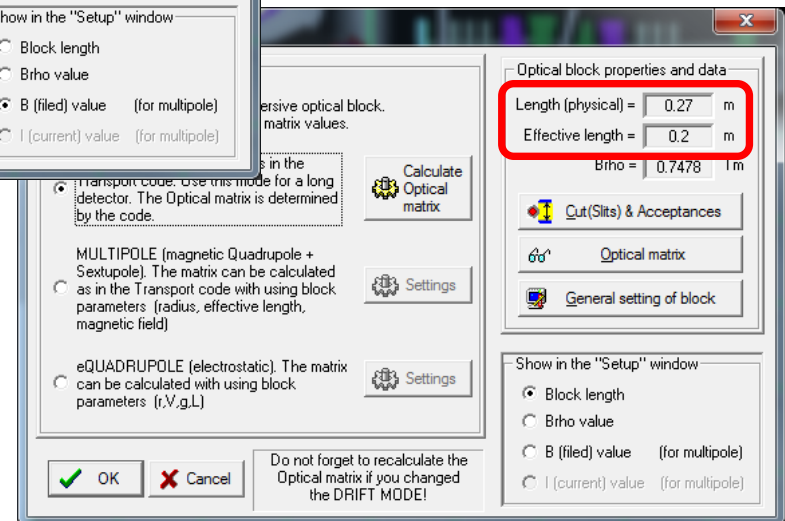
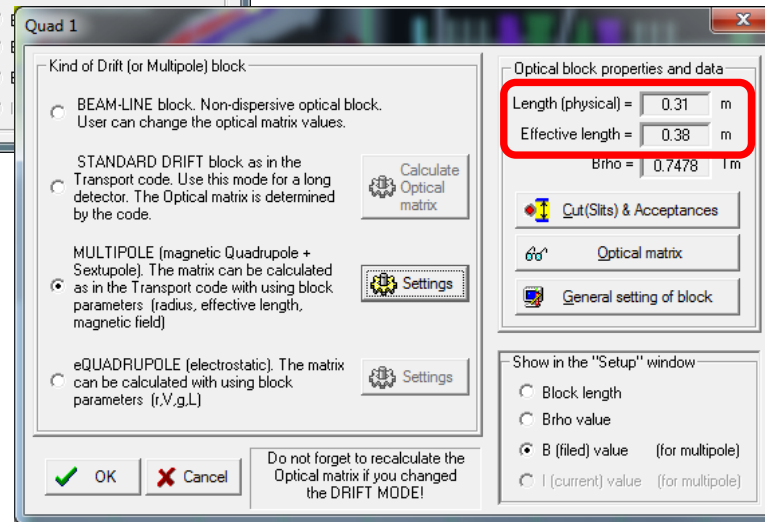
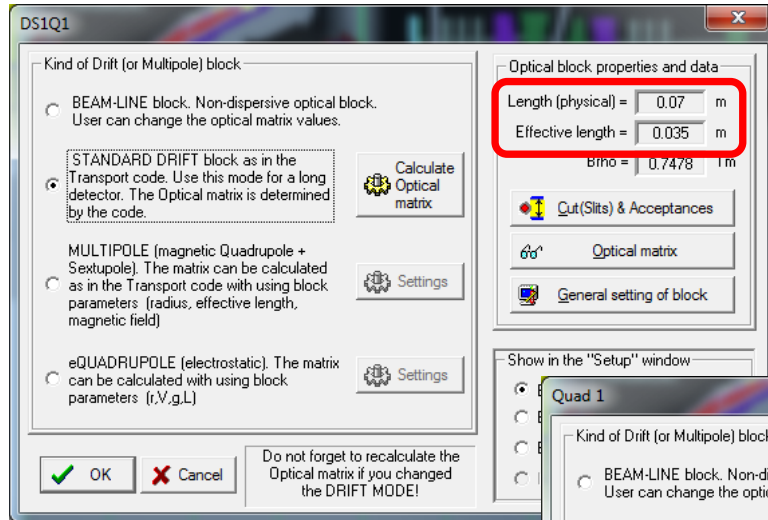
coef = 0.7778
 recommended vaule is 0.7

Neighbour blocks have to be drifts. Their effective lengths will be recalculated in order to compensate this effective quad length.

Obtained from calibration file $L_{eff} = f(B)$
 Will be done soon

A1900 extended configurations will be rebuilt soon
 Using Effective quad lengths

Drift + Quad + Drift



- ❑ Quads with calculated effective lengths should be surrounded by non-zero length drifts
- ❑ LISE++ checks for drift blocks existence and for their new positive effective length values

The char "c" denotes **calculated** value

Quadrupoles and dipoles fast editing

| Block | Given Name | Start(m) | Length(m) | B0(kG) | Br(Tm)corr/*r... | DriftM/*An... | Rapp(cm)*R... | L_eff(m)*L_dip(m) | 2 nd order | CalcMatr/*Z-Q | AngAcc.Apps.Slits | COSY_link | SE |
|--------|------------|----------|-----------|---------|------------------|---------------|---------------|-------------------|------------|---------------|-------------------|-----------|----|
| Dipole | tuning | 0.000 | 0.0001 | -2.4926 | * 0.7478 | * 0.0 | * 3.0000 | * 0.0001 | no | * 84 | -- -- | - | S |
| S | Drift | DTS1 | 0.000 | 0.3500 | | standard | | | | | -- HV -- | - | e |
| S | Drift | slits 1 | 0.350 | 0.0000 | | SLITS | | | | | -- HV -- | - | e |
| S | Drift | DS1Q1 | 0.350 | 0.0700 | | standard | | c_0.0350 | | | -- HV -- | - | e |
| Q | Drift | Quad 1 | 0.420 | 0.3100 | +4.5138 | 0.7478 | QUAD | 9.0000 | c_0.3800 | yes | 1 | -- HV -- | e |
| S | Drift | dqiqk | 0.730 | 0.2700 | | standard | | c_0.2000 | | | -- HV -- | - | e |
| Q | Drift | Quad 2 | 1.000 | 0.3100 | -4.1172 | 0.7478 | QUAD | 9.0000 | c_0.3800 | no | 1 | -- HV -- | e |
| S | Drift | dqiqk | 1.310 | 0.2700 | | standard | | c_0.2000 | | | -- HV -- | - | e |
| Q | Drift | Quad 3 | 1.580 | 0.3100 | +2.0125 | 0.7478 | QUAD | 9.0000 | c_0.3800 | yes | 1 | -- HV -- | e |
| S | Drift | dq3c1 | 1.890 | 0.5515 | | standard | | c_0.5165 | | | -- HV -- | - | e |
| E | ElecDip | C1 | 2.442 | 0.6592 | | | | | | * 84 | -- HV HV | - | E |
| S | Drift | dc1d1 | 3.101 | 0.4229 | | standard | | | | | -- HV -- | - | e |
| D | Dipole | D22_1 | 3.524 | 0.6230 | +4.6256 | * 0.7478 | * 22.1 | * 1.6166 | * 0.6230 | yes | * 84 | -- -- | E |
| S | Drift | dd1sv | 4.147 | 0.3054 | | standard | | | | | -- HV -- | - | e |
| S | Drift | slits SV | 4.452 | 0.0000 | | SLITS | | | | | -- H- | - | e |
| S | Drift | dsvd2 | 4.452 | 0.3054 | | standard | | | | | -- HV -- | - | e |
| D | Dipole | D22_2 | 4.757 | 0.6230 | -4.6256 | * 0.7478 | * -22.1 | * 1.6166 | * 0.6230 | yes | * 84 | -- -- | E |
| S | Drift | dd2c2 | 5.380 | 0.4229 | | standard | | | | | -- HV -- | - | e |
| E | ElecDip | C2 | 5.803 | 0.6592 | | | | | | * 84 | -- HV HV | - | E |
| S | Drift | dc2q4 | 6.463 | 0.5515 | | standard | | c_0.5165 | | | -- HV -- | - | e |
| Q | Drift | Quad 4 | 7.014 | 0.3100 | +0.6284 | 0.7478 | QUAD | 9.0000 | c_0.3800 | yes | 1 | -- HV -- | e |
| S | Drift | dqiqk | 7.324 | 0.2700 | | standard | | c_0.2000 | | | -- HV -- | - | e |

Selected block: Dispersive (Dipole) | Block Length (m): 0.0001 | Selected Block Edit | Multipole Edit | Cuts (Acceptances) | Optical Matrix

Angular acceptance (mrad): Horizontal ± [] Use [] | Vertical ± [] Use [] | Shape: Rectangle [] Ellipse [x]

Inside Aperture (mm): X = min [-50] max [50] Use [] | Y = min [-50] max [50] Use [] | Shape: Rectangle [] Ellipse [x]

Slits (mm) after this BLOCK: X = min [] max [] Use [] | Y = min [] max [] Use [] | Shape: Rectangle [x] Ellipse []

1-st order Matrix Elements: Plot [] | View [] | Quit [] | Help []

Multipole: Quad 1

Magnetic Multipole Settings

QUADrupole SEXTupole

L_{eff} (effective length) mode: <Calc> [c=0.78] 0.38 m

B (field at pole tip) 4.51378 0 kG

Radius (half-aperture) 9 9 cm

Multipole fixed Brho-value corresponding to the setting fragment 0.74779 Tm

Fix current value

Calculate 2nd order matrix elements

Allow remote matrices recalculation

B(I) calibration

+852.06 A

if Brho-value has been changed then

no actions

recalculate automatically B (fields), keep the matrix [Recommended]

recalculate automatically the matrix, keep B (fields)

Block settings, Information

Block length 0.31 m

Current (Real) Brho-value for the setting fragment 0.74779 Tm

Setting fragment 255Rf20+

Recalculate B(field) for the fragment current Brho

Calculate Optical matrix OK

Edit optical matrix Cancel

Quad 1: quadrupole filed calibration

B 4.5138 kG

I 852.064 A

Calibration file

Accept value & Exit Quit

Calibration file

Open file View file Clear

Q1.cal

Columns = 2 OK Cancel

Rows = 21

Note

The calibration file is in ASCII format. The first line contains 2 integer values describing the structure of the file:

1. Number of columns (either 2 or 3)
2. Number of rows (calibrated points)

The next lines are the calibration data. The Columns can be separated by a Space, a Comma or a Tabulation. User can put comments after the data.

1st column: the Current (I) required
 2nd : Magnetic field (B read) from NMR required
 3rd : set Magnetic filed (B set) optional