# ATR Magnet Transfer Functions

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## 1. Introduction

In order to establish the correlation between power supply currents and magnet strengths for the ATR magnets, one needs to assign a Transfer Function to each magnet. There are several types of magnets installed in the ATR line and not all of them are measured: typically, a subset in within each magnet group has been measured. For some magnets, direct measurements are not available and in that case data are derived from simulation.
This note describes how magnet data are extracted and processed for the ATR quadrupoles and dipoles and lists the resulting Transfer Function data for every generic group of magnets in the ATR.

## 2. Extraction and processing of measured data

The Transfer Function is defined as:

| | | |
|---|---|---|
| $BL/I$ | [Tm/A] | for a dipole |
| $GL/I$ | [T/A] | for a quadrupole |

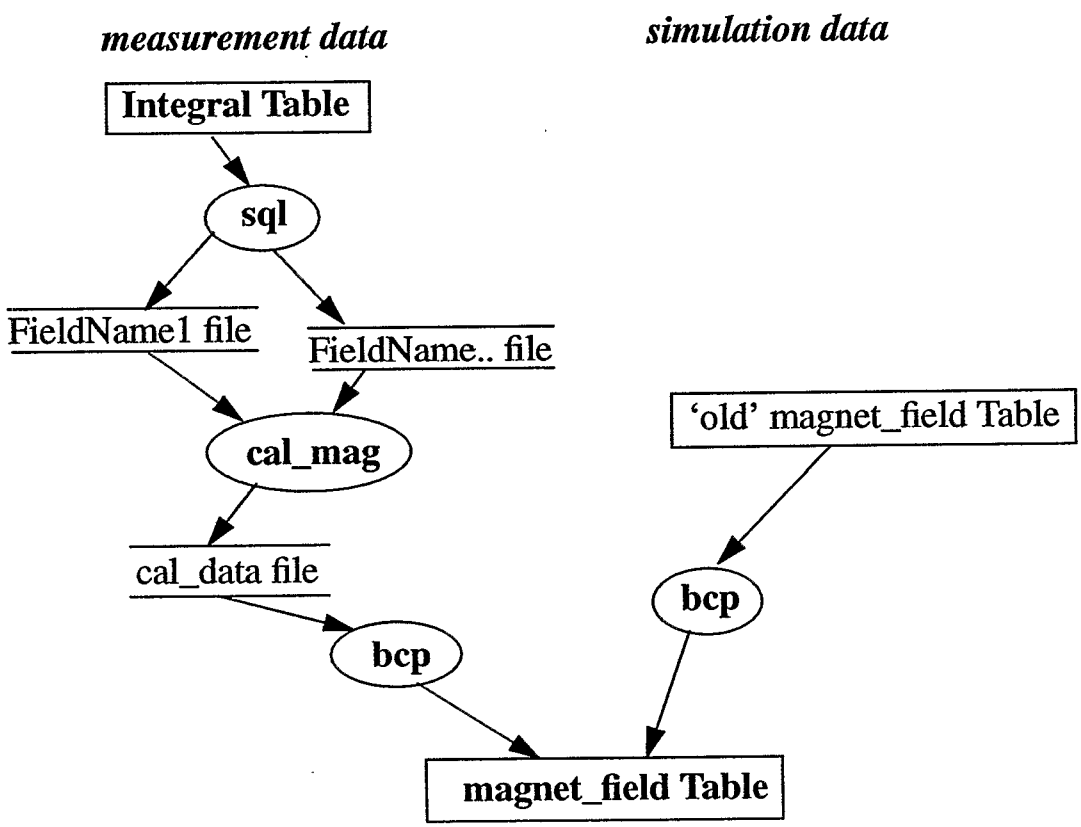
where $B$ and $G$ are the magnetic field and gradient, respectively in Tesla and Tesla/m, $L$ the magnet length in m and $I$ the current in amps. The Transfer Function, ideally constant, is in reality a function of current because of saturation.
We want to assign a Transfer Function to each group of ATR quadrupoles and dipoles that are physically the same. The naming convention for the ATR magnets are recalled in Table 1.
The extraction, filtering and processing of data is summarized by the diagram in Figure 1. The magnetic measurement data are stored in the **Integral Table** in the **atr_cal** database. The magnetic measurement sets are labelled by "Magnet" and the Table stores Transfer Function and multipole data together with specific information about the magnet and the measuring conditions. SQL requests select the right measurement sets for each group of magnet. We selected data sets in the "UP" direction of the hysteresis curve (UpDown field) and with the location of the probe is in the magnet center (RunNum field) for every group of magnets.

**Table 1: Naming Convention for ATR magnets.**

| Name | Use | Examples |
|---|---|---|
| LatticeName | lattice files | uq1, ud3, wq2, xd28, yq6 |
| SiteWideName | device unique name | uq1, ud3, wq2, xd28, yq6 |
| SerialName | hardware serial name | ATRQSS015, ATRSWM01 |
| DeviceName | identifies magnet type | q, d |
| GenericName | identifies group of magnets | C-defocus, SLAC730 |
| FieldName | identifies group of magnets | typeCL, SLAC730 |
| Magnet | name for measurement data | RDXCL5, QSS015, RDXBL1 |

The selected data are then processed by **cal_mag**, a code which calculates for each group of magnets averages and standard deviations of the current, Transfer Functions and multipole data. The results are then rewritten and copied (**bcp**) into the **magnet_field Table** in the **atr_gddb** database.

**Figure 1. Diagram of data extraction and processing.**



For the magnets that do not have measurement data, simulation data are entered. Table 2 summarizes what kind of data are currently stored in the magnet_field table.

**Table 2: Summary of ATR magnet data.**

| FieldName | Magnet Count | Measured Magnet Count | type of data | Device Name | SiteWideName of magnets |
|---|---|---|---|---|---|
| typeAfat | 2 | 1 | raw | d | ud1 ud2 |
| typeCL | 12 | 7 | ave | d | ud3 ud4 ud5 ud6 wd1 wd2 wd3 wd4 wd5 wd6 wd7 wd8 |
| typeBL | 50 | 12 | ave | d | xd1 yd1 xd3-->xd26 yd3-->yd26 |
| typeBS | 10 | 2 | ave | d | xd2 yd2 xd27 yd27 xd28 yd28 xd29 yd29 xd30 yd30 |
| typeAthin | 2 | 1 | raw | d | xd31 yd31 |
| N3Q36 | 2 | 1 | raw | q | uq1 uq2 |
| 4Q26.5 | 8 | 4 | ave | q | uq3 uq9 uq10 wq2 xq1 yq1 xq2 yq2 |
| SLAC1000 | 8 | 9 | ave | q | uq4 uq5 uq7 uq8 xq5 yq5 xq6 yq6 |
| SLAC730 | 13 | 15 | ave | q | uq6 uq11 uq12 uq13 wq1 wq3 wq4 wq5 wq6 xq3 yq3 xq4 yq4 |
| wpitch | 2 | 0 | sim | p | wp1 wp2 |
| swm | 1 | 0 | sim | swm | xswm (yswm) |
| lambpitch | 2 | 0 | sim | p | xp1 yp1 |
| lamb | 2 | 1 (3) | ave | lamb | xlamb ylamb |

FieldName describes the generic group of magnets, DeviceName labels the magnet type (note: typeCL, typeBL and typeBS are *combined function* magnets). MagnetCount tells how many magnets of that particular group are installed in the ATR line, and their SiteWideName are also listed. MeasuredMagnetCount tells how many of them have been measured. (note: existence of magnet spares causes the latter Count for some entries to be larger than the former). Data are of type "**ave**" if obtained by averaging measured data sets, "**sim**" if derived by simulation or "**raw**" if only 1 magnet in the group was measured.
(for the Lambertson the average was taken over 3 sets of measurements of the same magnet).
Although not explicitly showed here, the magnet_field Table contains also simulation data for the trim dipoles.

## 3. ATR dipoles and quadrupoles Transfer Functions

The following set of plots show the processed Transfer Function data as a function of current for the magnet groups (labelled by FieldName).
Transfer Function data are expressed in Tesla m/Amp for the dipoles and Tesla/Amp for the quadrupoles.

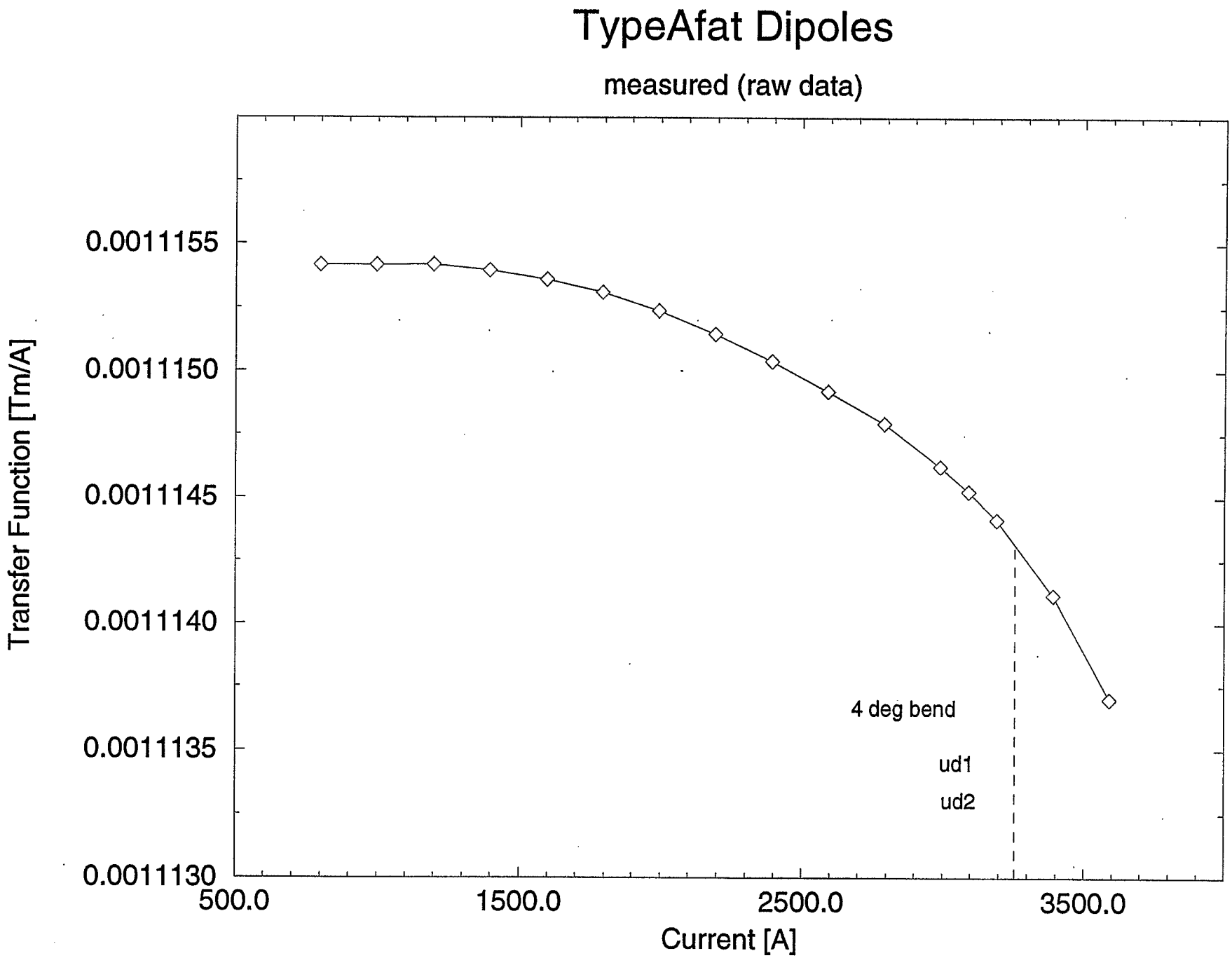
The dashed lines on the plots mark the magnet operating currents in the ATR optics for $Au^{77}$ ions at $\gamma$=12.6. In the case of dipoles there is generally 1 line, with the only exception being the typeCL dipoles: as seen in Table 2, they are used both for the 8 degrees bend in the U line and for the 20 degrees bend in the W line. In the case of quadrupoles, the dashed lines correspond to individually powered magnets.

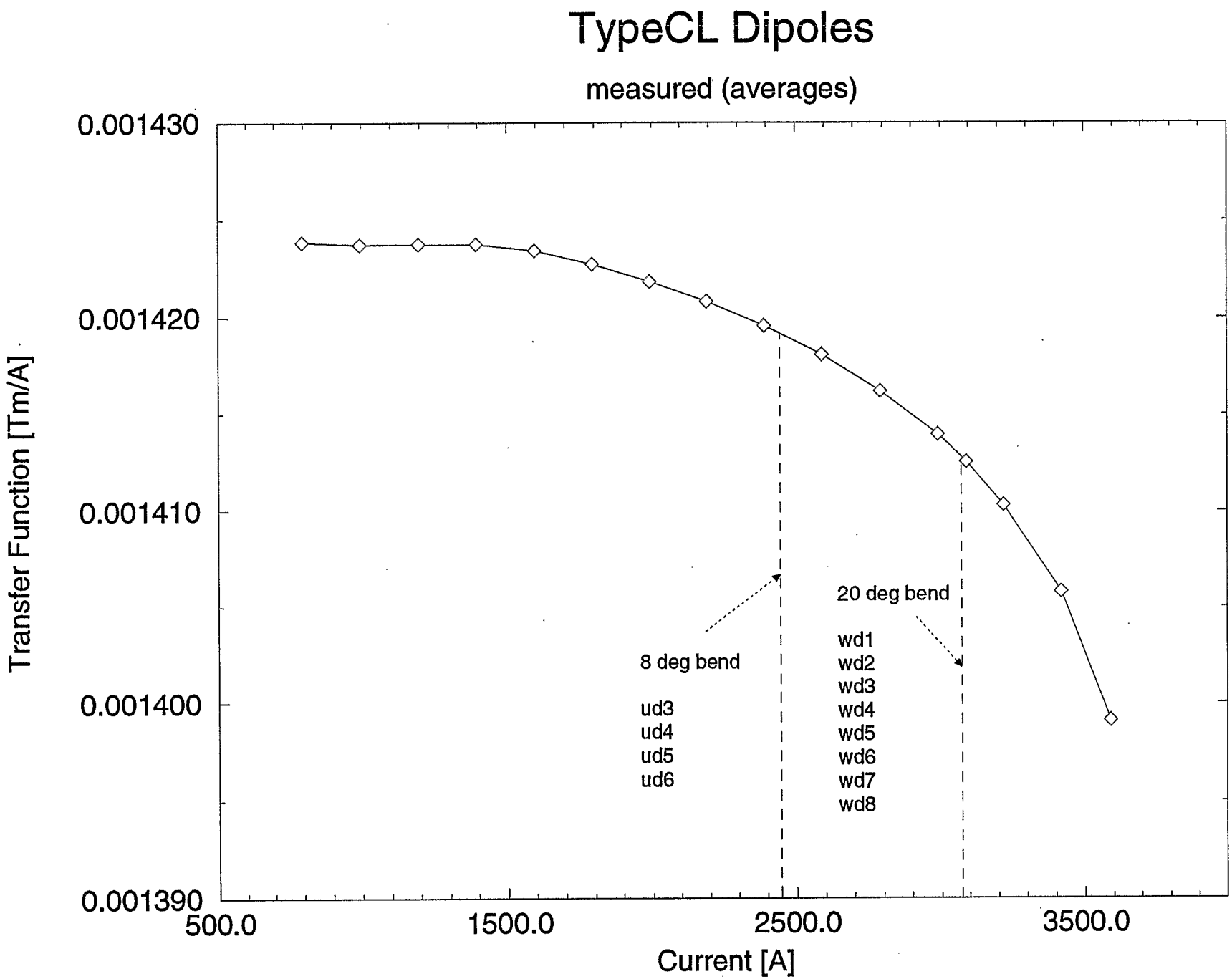
## 4. Correlation between ATR Magnet strength and PS current

The actual correlation between current in the power supplies and magnet strength is established by the Magnet application program[1], which uses the Transfer Function data stored in the magnet_field Table [1].
The *magnet strength* is defined as $kL = 1/f$ for quadrupoles and $\rho/L = \alpha$ for dipoles. Given a strength, the program calculates, displays and sets the current in the relevant power supply, and viceversa. Information about wiring is read directly from the database.

**References**

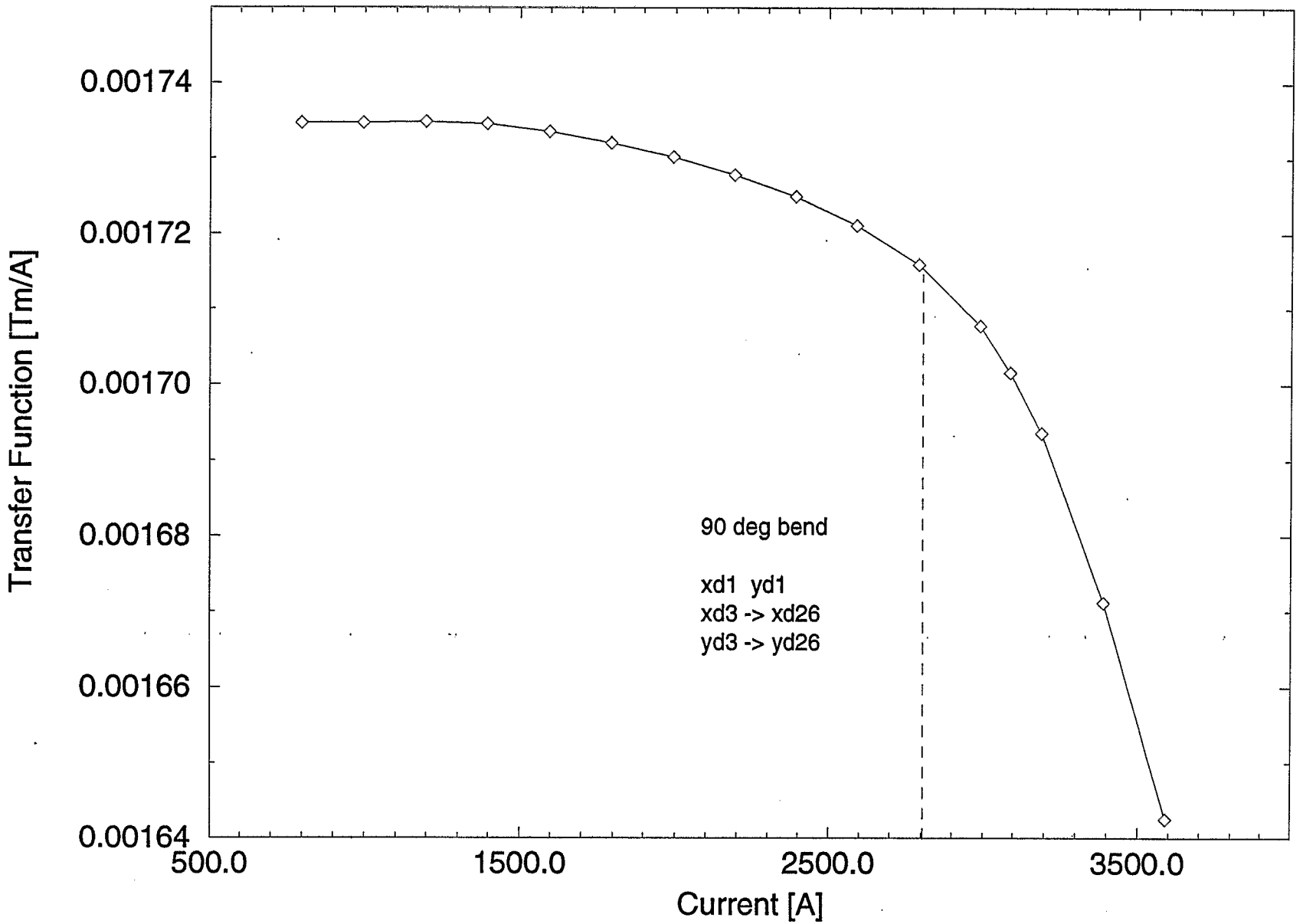
[1] J.Kewish, Private Communication

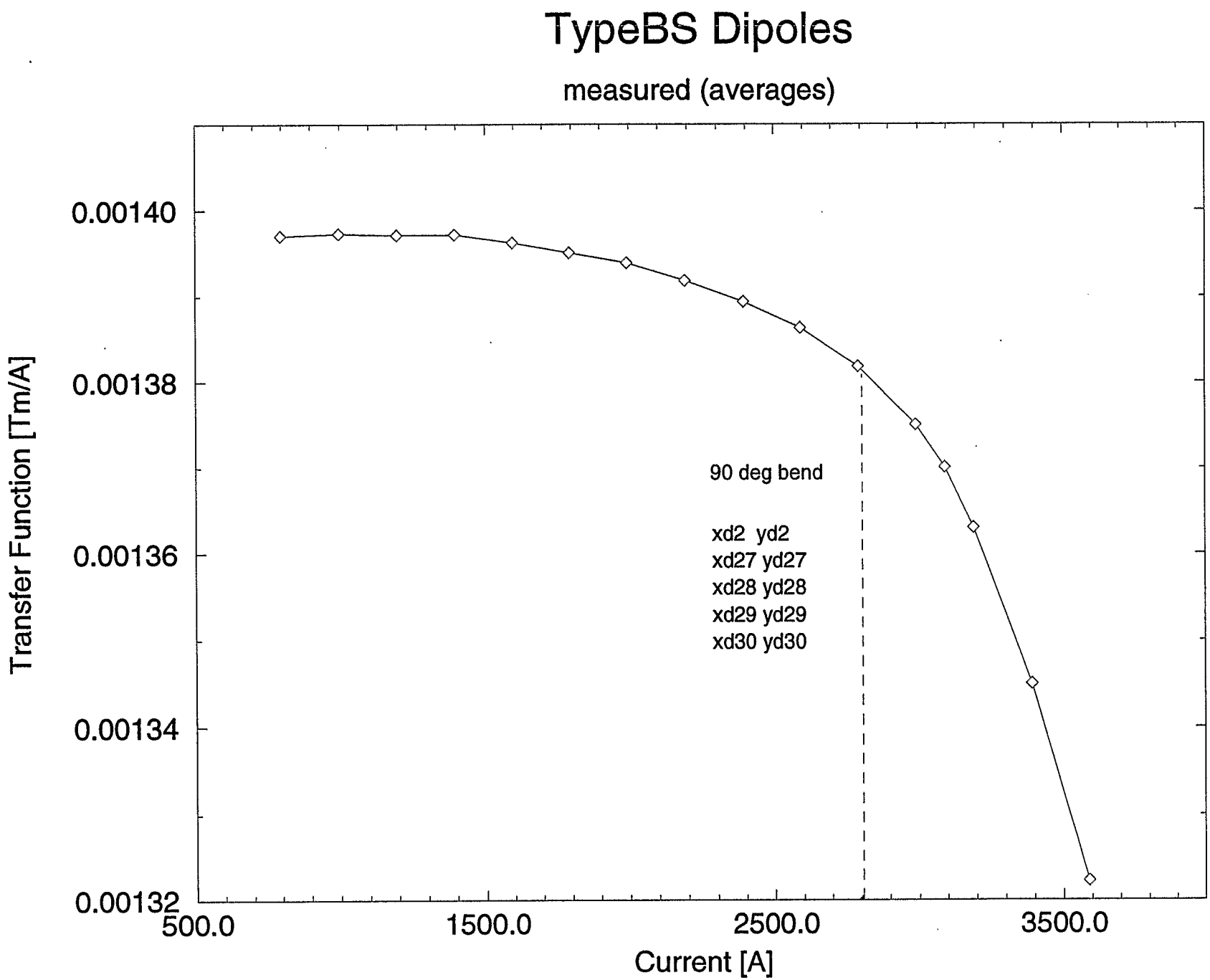

TypeAfat Dipoles
measured (raw data)
Transfer Function [Tm/A]
0.0011155
0.0011150
0.0011145
0.0011140
0.0011135
0.0011130
500.0
1500.0
2500.0
3500.0
Current [A]
4 deg bend
ud1
ud2


TypeCL Dipoles
measured (averages)
0.001430
0.001420
0.001410
0.001400
0.001390
Transfer Function [Tm/A]
500.0
1500.0
2500.0
3500.0
Current [A]
8 deg bend
ud3
ud4
ud5
ud6
20 deg bend
wd1
wd2
wd3
wd4
wd5
wd6
wd7
wd8

# TypeBL Dipoles

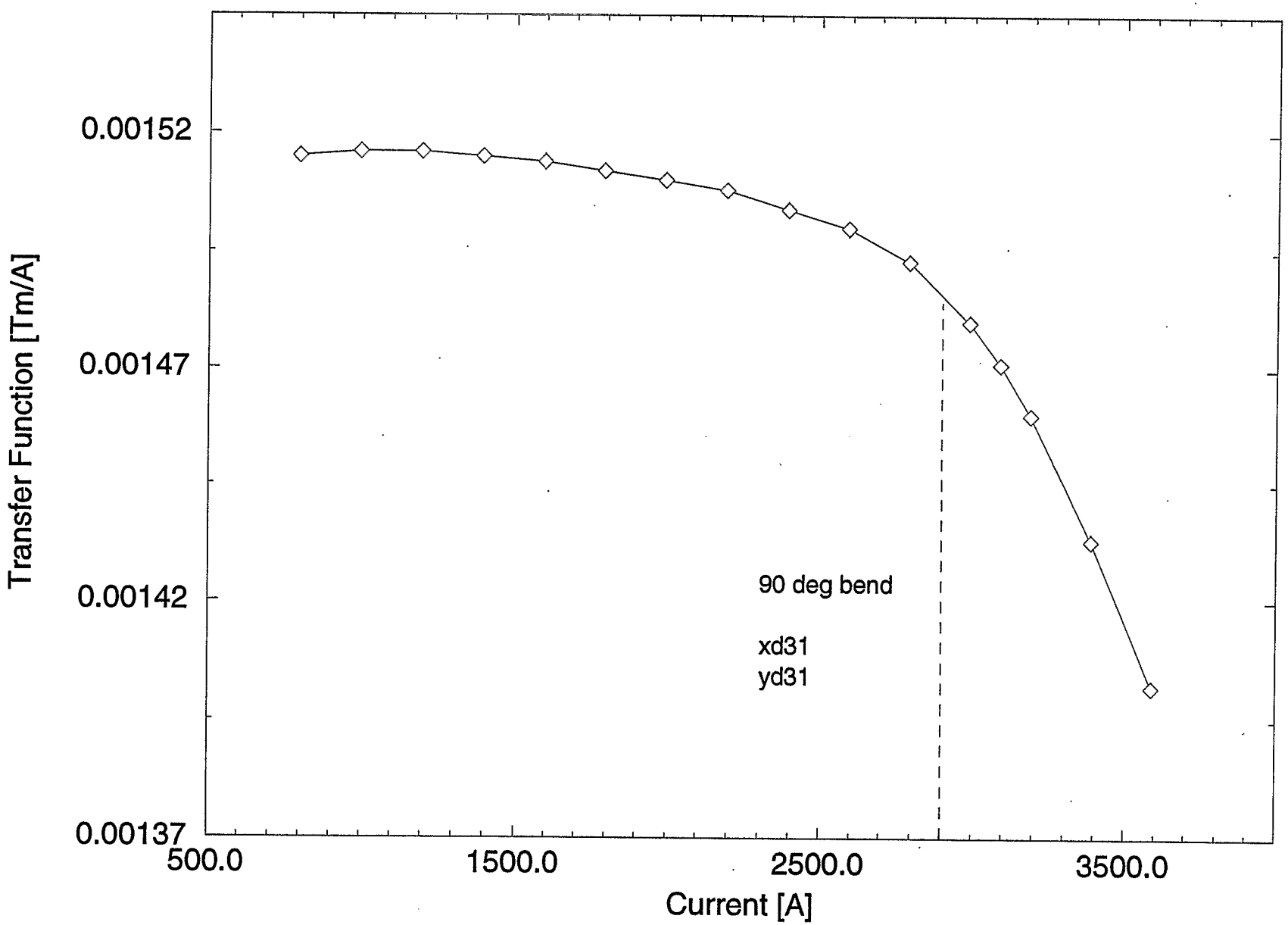
measured (averages)

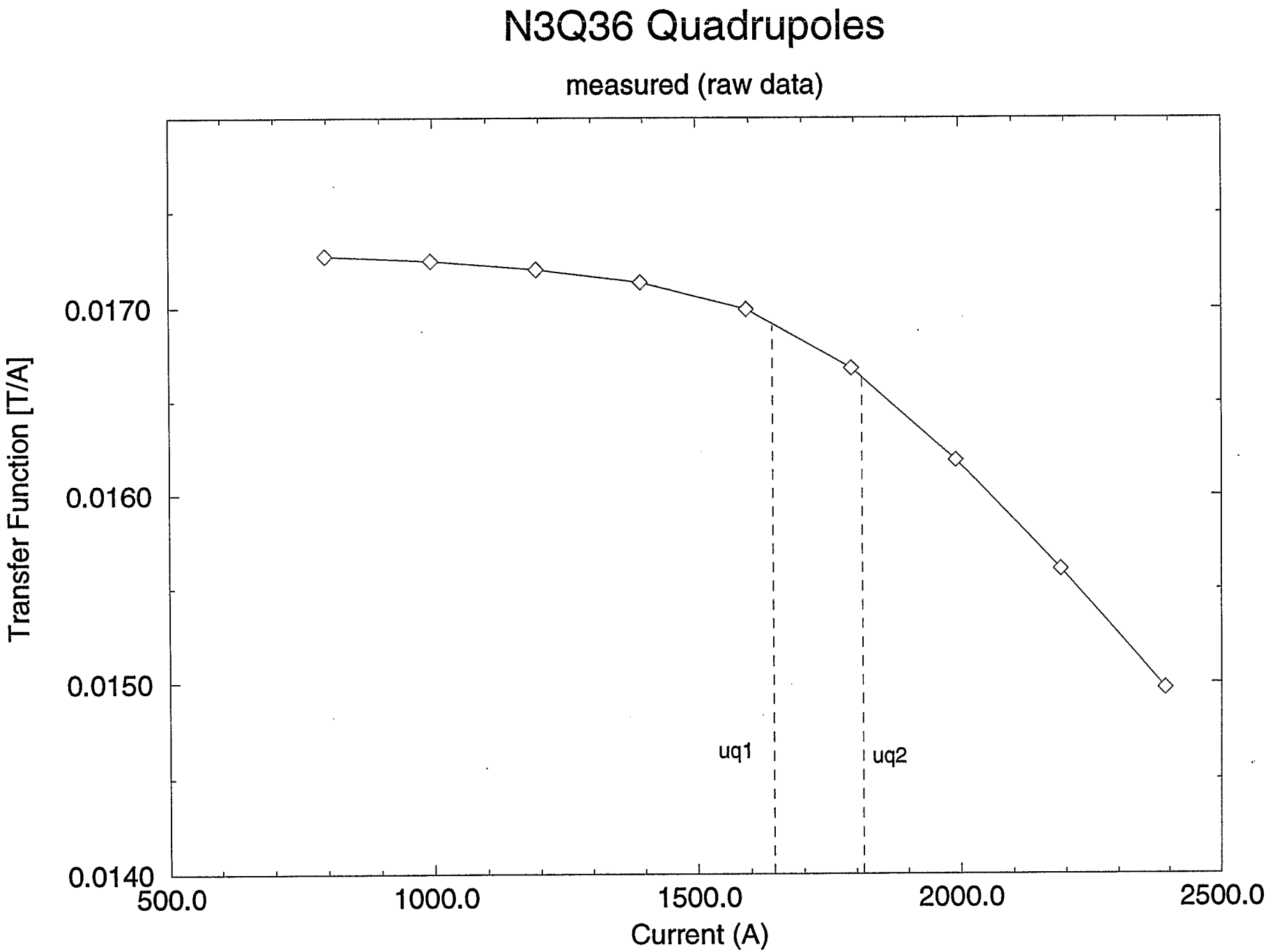



TypeBS Dipoles
measured (averages)
Transfer Function [Tm/A]
0.00140
0.00138
0.00136
0.00134
0.00132
500.0
1500.0
2500.0
3500.0
Current [A]
90 deg bend
xd2 yd2
xd27 yd27
xd28 yd28
xd29 yd29
xd30 yd30

# TypeAthin Dipoles

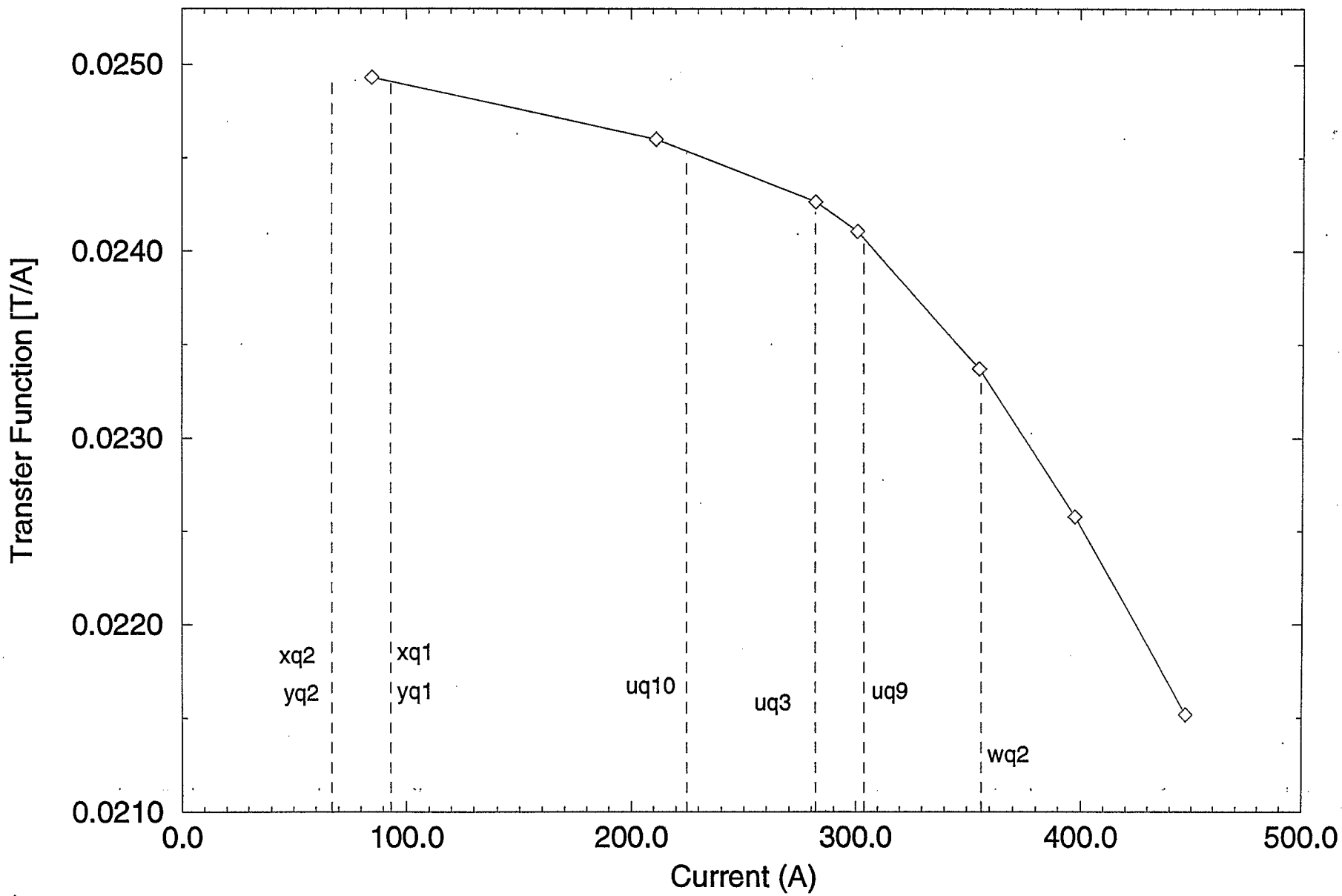
measured (raw data)

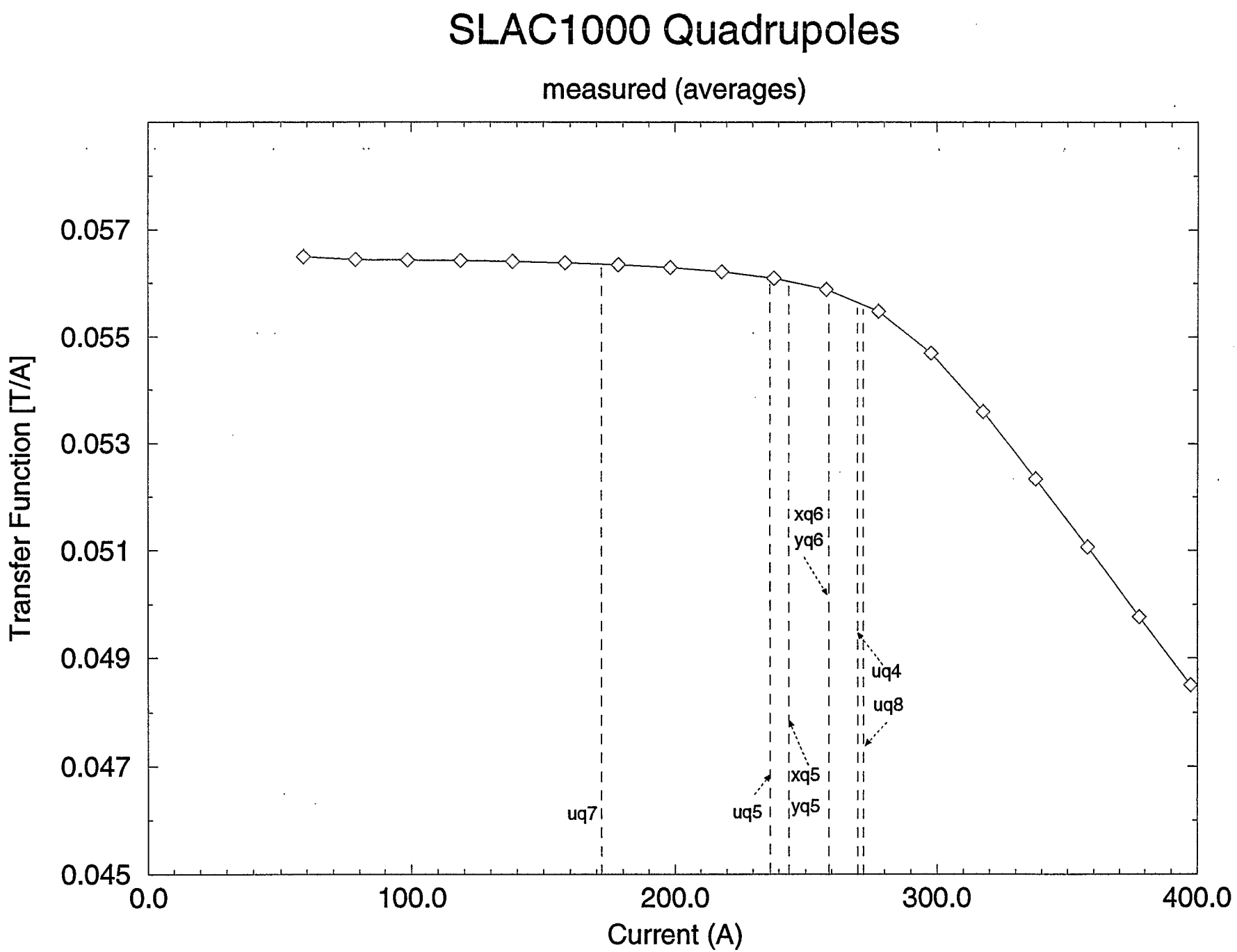


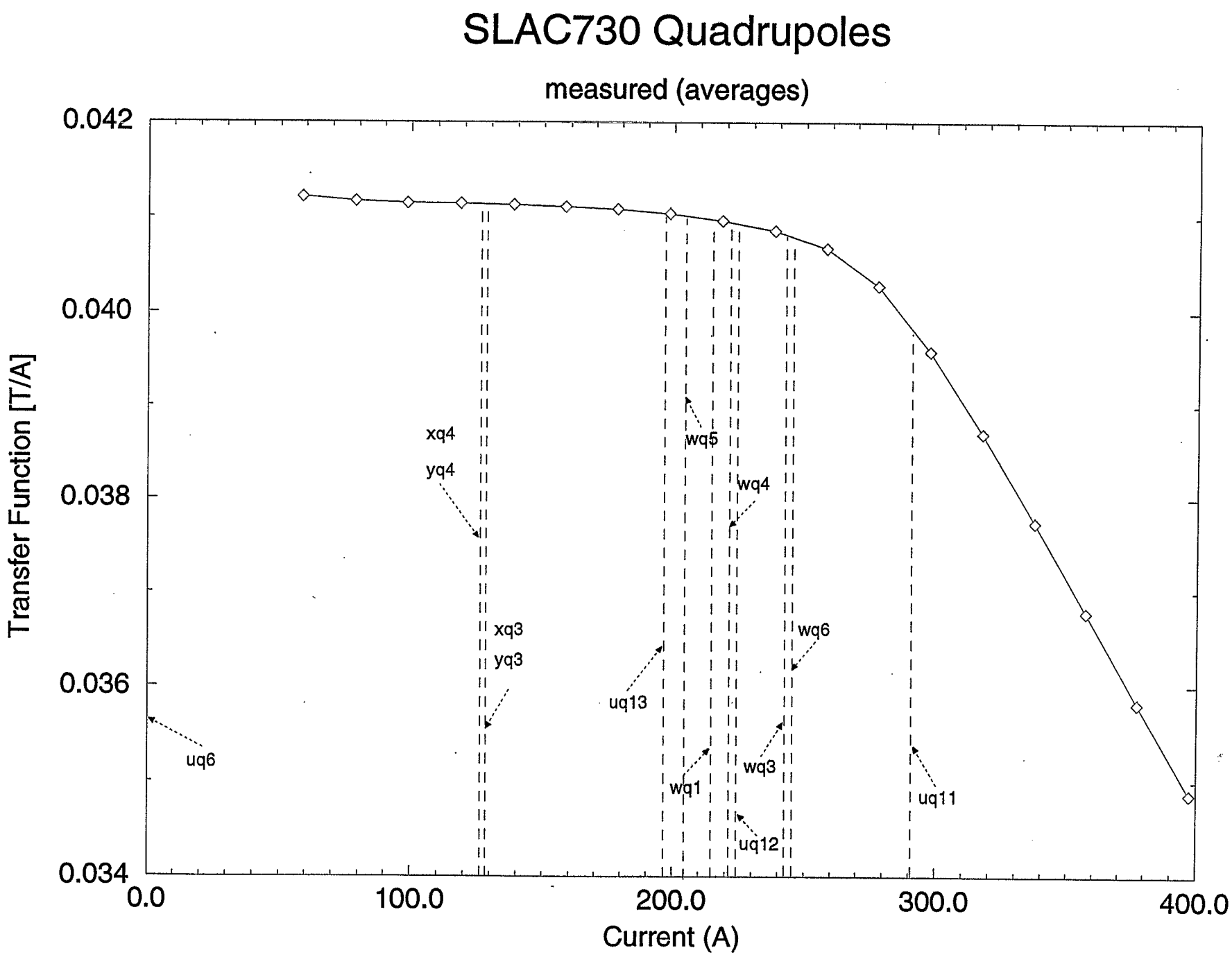

N3Q36 Quadrupoles
measured (raw data)
Transfer Function [T/A]
0.0170
0.0160
0.0150
0.0140
500.0
1000.0
1500.0
2000.0
2500.0
Current (A)
uq1
uq2

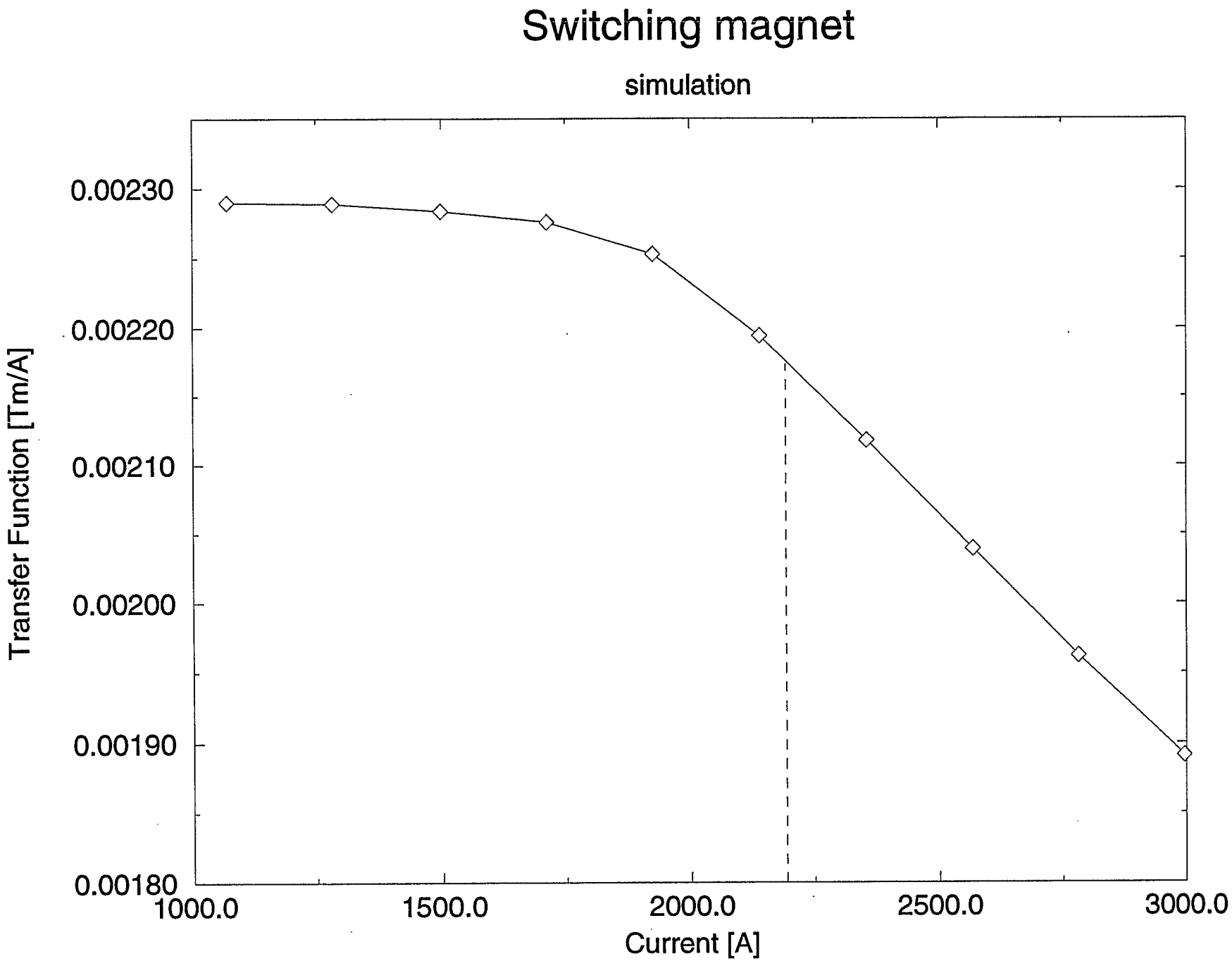
# 4Q26.5 Quadrupoles

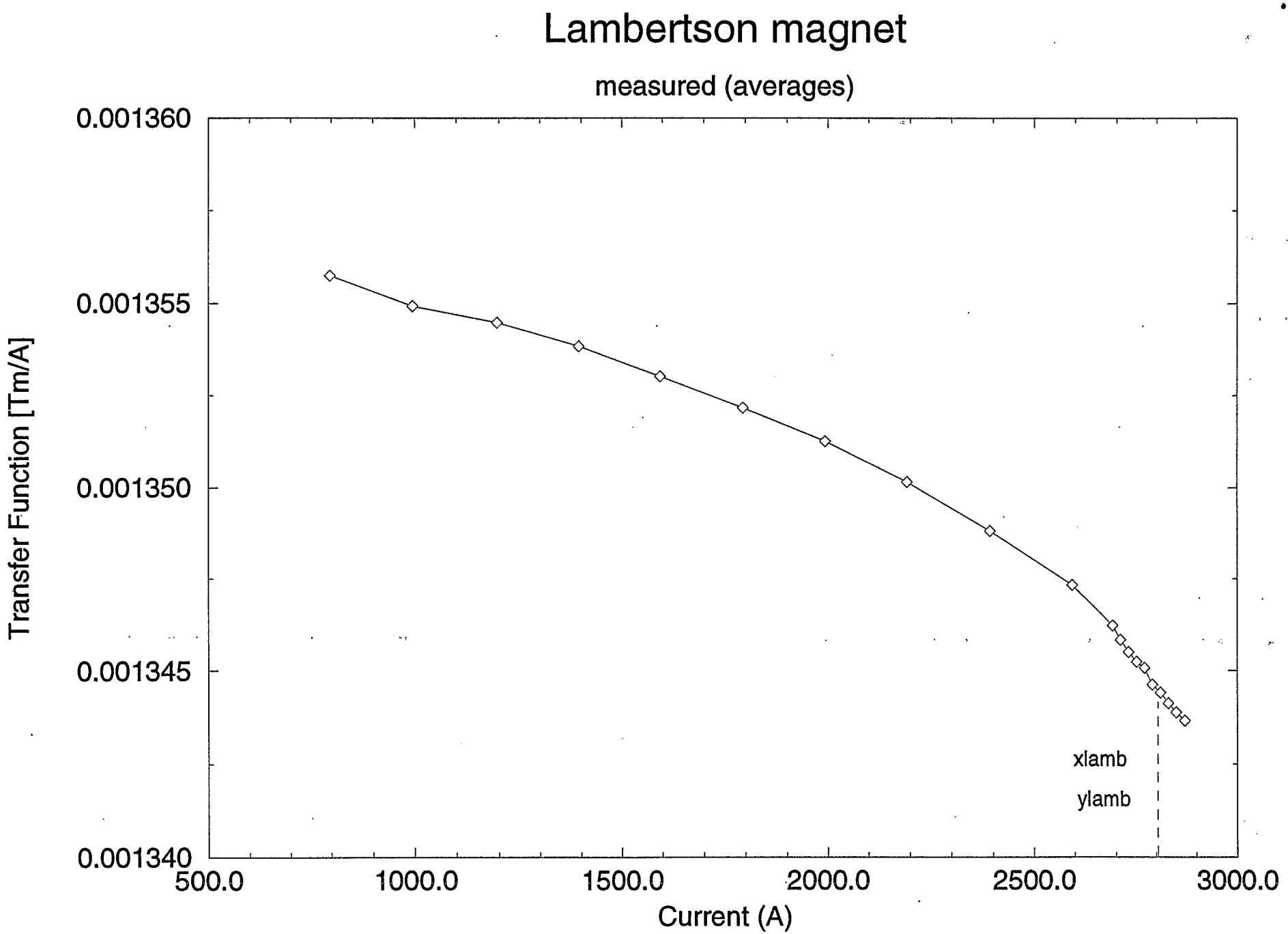
measured (averages)




SLAC1000 Quadrupoles
measured (averages)
Transfer Function [T/A]
0.057
0.055
0.053
0.051
0.049
0.047
0.045
0.0
100.0
200.0
300.0
400.0
Current (A)
xq6
yq6
uq4
uq8
xq5
yq5
uq5
uq7


SLAC730 Quadrupoles
measured (averages)
Transfer Function [T/A]
Current (A)
0.042
0.040
0.038
0.036
0.034
0.0
100.0
200.0
300.0
400.0
xq4
yq4
xq3
yq3
uq6
uq13
wq1
wq5
wq4
wq3
uq12
wq6
uq11


Switching magnet
simulation
Transfer Function [Tm/A]
0.00230
0.00220
0.00210
0.00200
0.00190
0.00180
1000.0
1500.0
2000.0
2500.0
3000.0
Current [A]


Lambertson magnet
measured (averages)
0.001360
0.001355
0.001350
0.001345
0.001340
Transfer Function [Tm/A]
500.0
1000.0
1500.0
2000.0
2500.0
3000.0
Current (A)
xlamb
ylamb