CESR Sextupole Calibration (II)

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Machine Studies Meeting
26 August 2021
Update from 19 Aug 21

CBN 78-1
Sextupole Magnetic Measurements
(D. Larson, L. Roberts and R. Talman)

Parameter table (bore radius 47.24 mm, L_{pole}=248 mm, L_{mag}=272 mm)

Sextupole, vertical corrector strengths versus excitation current

S L = 1.18 m^{-2} at 13.2 A and 10 GeV

CON 95-6
CESR Sextupole Upgrade
A. Mikhailichenko

Motivation: improved field uniformity to accommodate pretzel orbits (x_{beam} = ± 2 cm)

Hall probe measurements ($\delta B \simeq 10$ G, poletip field B ≃ 1000 G)
for one sextupole before and three sextupoles after cutting 7.4 ± 0.2 mm from pole tip
Multipole expansion for measured field values

CBN 98-2
Sextupole for CESR
A. Mikhailichenko

Mermaid 3D FE model matched to field measurements of CBN 95-6

Modeled L_{mag} = 278 mm (Bmad lattice element not updated from 272 mm)

Multipole expansion of modeled field integrals

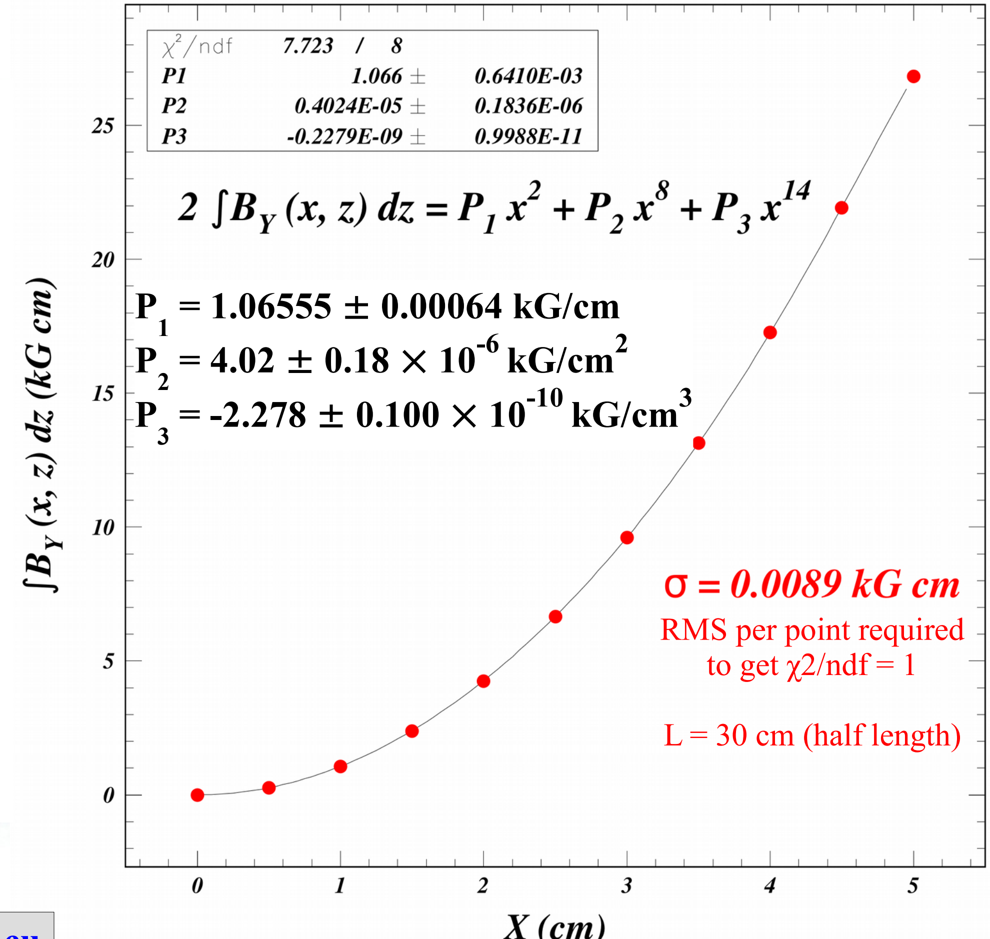
$\int B_Y (x, z)\, dz$ **(kG cm) = 1.06533 x^2 + 4.023e-6 x^8 – 2.278e-10 x^{14} (10 A, 160 A-turns)**

Reproduce CBN 98-2 multipole fit

CBN 98-2
Table of Mermaid Field Integrals

x, cm	$I_{half\ lens}(x) = \int_0^{30cm} B_y(x,s)ds$, $kG \cdot cm$
0.0	0.0
0.5	0.1272
1.0	0.5265
1.5	1.1934
2.0	2.1277
2.5	3.3305
3.0	4.8079
3.5	6.5698
4.0	8.6291
4.5	10.9647
5.0	13.410

$\int B_Y\, dz = 1.06533\, x^2 + 4.023e\text{-}6\, x^8 - 2.278e\text{-}10\, x^{14}$



$\Delta K_2 L = (10.6533\ \text{Tm})\ (0.3/6)\ (1/10\ \text{A})\ (12.5\ \text{A}/16\text{k cu})\ \Delta cu$

$L_{eff} = 0.272$ m (Bmad lattice)

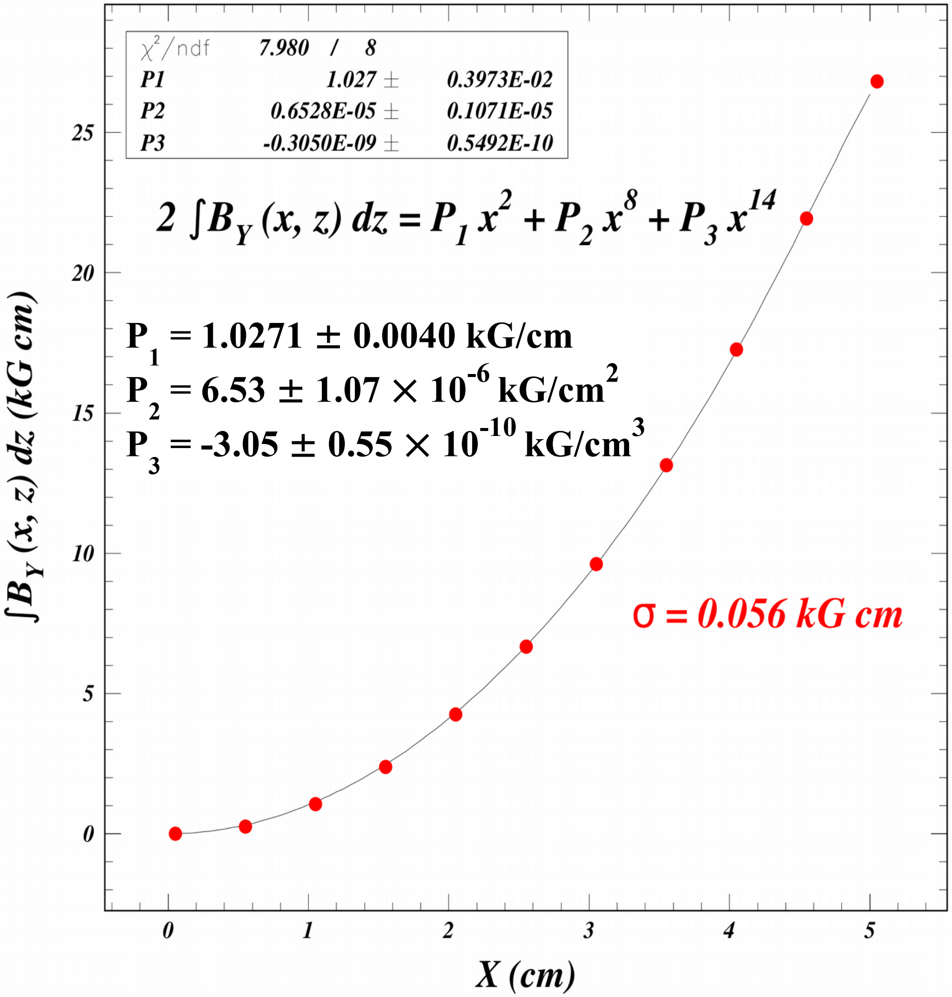
$\Delta K_2\, (m^{-3}) = 1.530e\text{-}4\ \Delta cu$

Good fit which reproduces AM result.

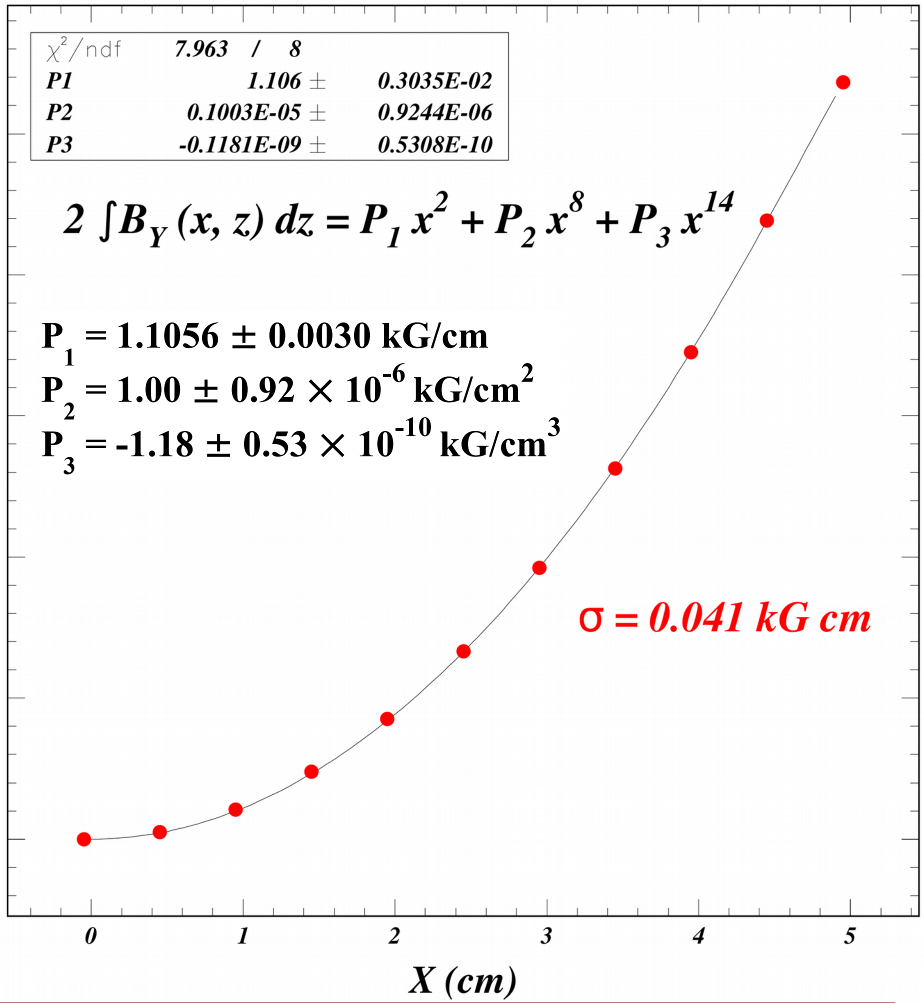
Jitter is about 0.3 Gauss.

Estimate calibration variations arising from higher-order terms

X displaced by 0.5 mm



X displaced by -0.5 mm



Calibration factor changes by ±4% for ±0.5 mm measurement displacement.

Resolution of "Dimat" factor of two

/nfs/cesr/online/machine_data/constants/calib/sextupole.cal

```
! There are two types of sextupoles, unmodified and modified.
! 4000 cu => 12.5 A
! Unmodified: see CBN 78-1   (31E/W, 32E/W)
!Sl = 1.18 /m^2  @13.2 A, 10 GeV
!   = 2.11 /m^2  @4000 cu, 5.29 GeV
!S  = 1.94e-3 /cu-m^3  @5.29 GeV
!   =>  515 cu = 1 /m^3  @5.29 GeV
!   Dimat has another factor of two  => 1030 cu-m^3
! Modified:  see CBN 98/02
!IBy = 1.06553 kG/cm x^2 + ...     @10 A
!S = 1/2 ec/E(d^2B/dx^2)  by definition
!Sl = (3e8m/s / 5.29e9V)*10.6553T/m   @10 A, 5.29 GeV
!S = 2.777 /m^3 @12.5 A, 5.29 GeV
!  => 1440.4 cu-m^3   @5.29 GeV
!
!   dk2_dcu normalized to 5.29 GeV
 $ALL_CALIB
   dk2_dcu_all = 1.736e-4  = 1.530 e-4 *  6.00 / 5.29 (modified)
```

The comments for the chopper calibration have not been changed since the upgrade from 4k cu range to 32k cu range, but the values for the sextupole calibration dk2_dcu have been updated.

Dimat is a code used prior to Bmad.

The S value in CBN 78-1 is apparently defined as Bmad's K_2L.

The S value in CBN 98-2 is apparently defined as Bmad's $K_2/2$.

Proposed comment revision
/nfs/cesr/online/machine_data/constants/calib/sextupole.cal

```
! There are two types of sextupoles, unmodified and modified.
! See CON 96-5 for field measurements of both types.
!
! Chopper resolution   dcu/dI = 32000 cu /12.5 A
! Sextupole length L=0.272 m
!
! Unmodified  (31/32 W/E): see CBN 78-1   (NB: “S”=K2)
!      SL = 1.18 m^-2  @13.2 A, 10 GeV
!           = 2.11 m^-2  @ 12.5 A, 5.29 GeV
!      K2 = S = SL/L = 7.757 m^-3   @12.5 A, 5.29 GeV
!           => dK2/dcu = 2.424E-4  m^-3/cu @ 5.29 GeV
!           => dcu/dK2 = 4125 cu/m^-3  @ 5.29 GeV
!
! Modified:  see CBN 98/02
!      Int By dz = 1.06553 kG/cm x^2 + ...     @10 A
!      S = 1/2 ec/E(d^2B/dx^2)  by definition
!      SL = (3e8m/s / 5.29e9V)*10.6553T/m   @10 A, 5.29 GeV
!      S = SL/L = 2.777 m^-3 @12.5 A, 5.29 GeV
!         => dS/dcu = 8.678E-5  m^-3 /cu    @ 5.29 GeV
!         => dcu/dS = 11523 cu/m^-3           @ 5.29 GeV
!      K2 = 2S = 5.554 m^-3 @ 12.5 A, 5.29 GeV
!            => dK2/dcu = 1.736E-4  m^-3/cu  @ 5.29 GeV
!            => dcu/dK2 = 5762 cu/m^-3          @ 5.29 GeV
!!
!    dk2_dcu normalized to 5.29 GeV
$ALL_CALIB
   dk2_dcu_all = 1.736e-4
```

Update the chopper resolution.

Add reference to CON 96-05 where Hall probe measurements for both types of sextupole are available.

Make equations explicit.

Adapt units to the quantity they describe (personal preference?)

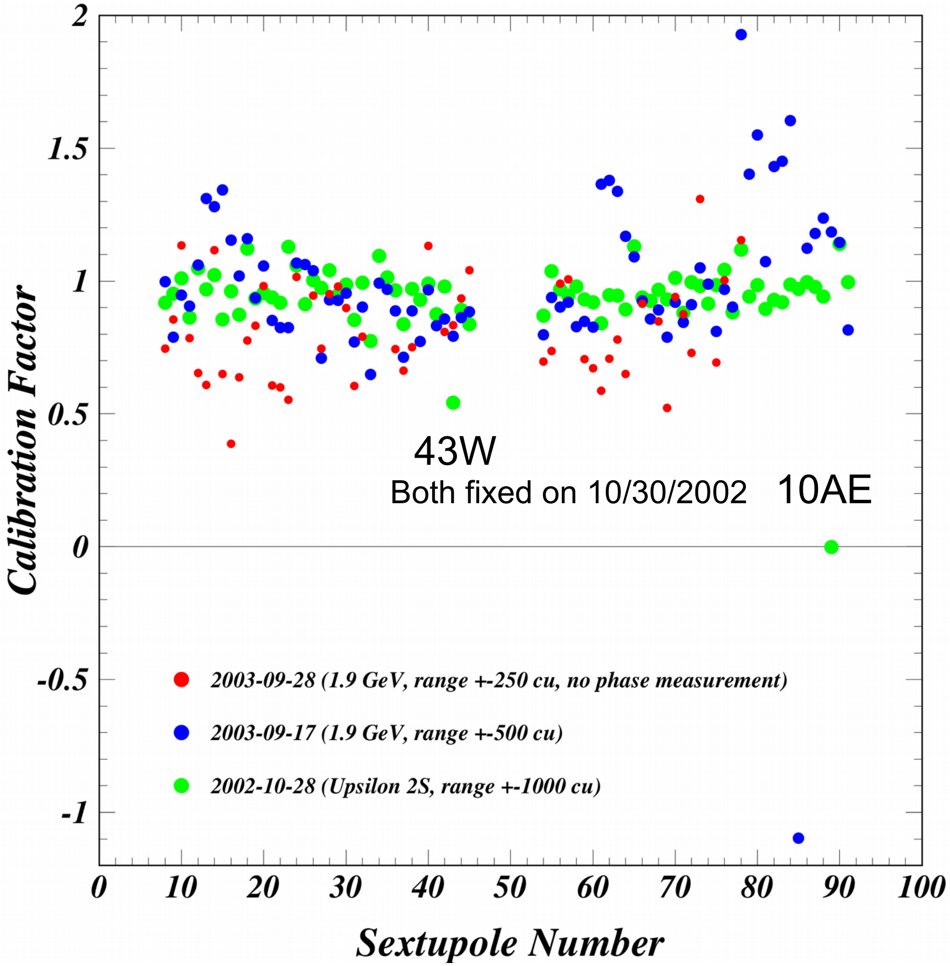
Make explicit that CBN 78-1 and CBN 98-2 use different conventions for S.

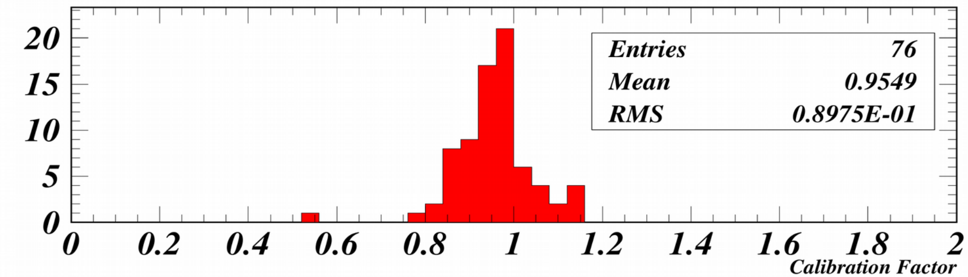
Calibration factors dk2_dcu are unchanged.

Cornell University
Laboratory for Elementary-Particle Physics

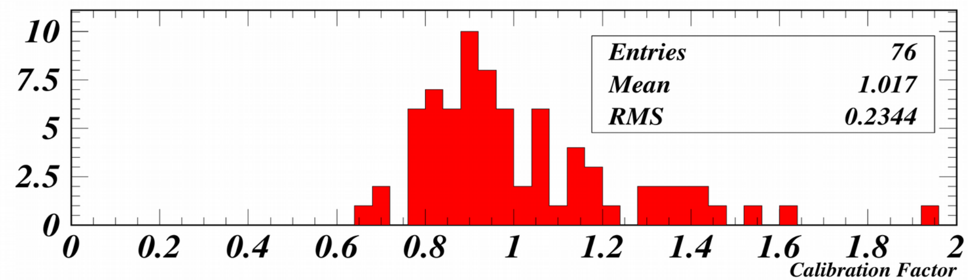
JAC & DCS Sextupole Calibrations 2002-2003

https://www.classe.cornell.edu/~critten/cesr/machinestudies/sextupoles/all/

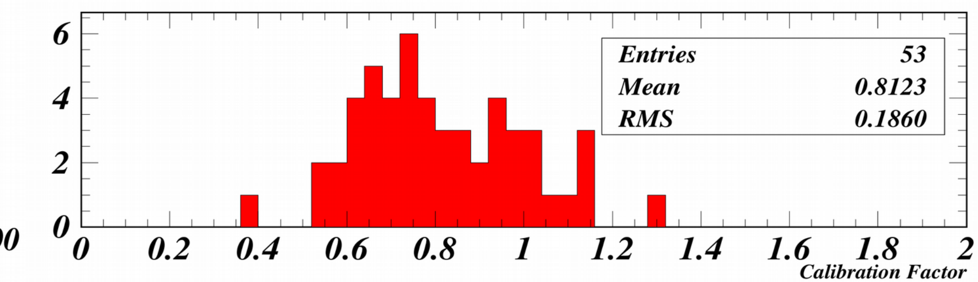




2002-10-28 (Upsilon 2S, range +-1000 cu)



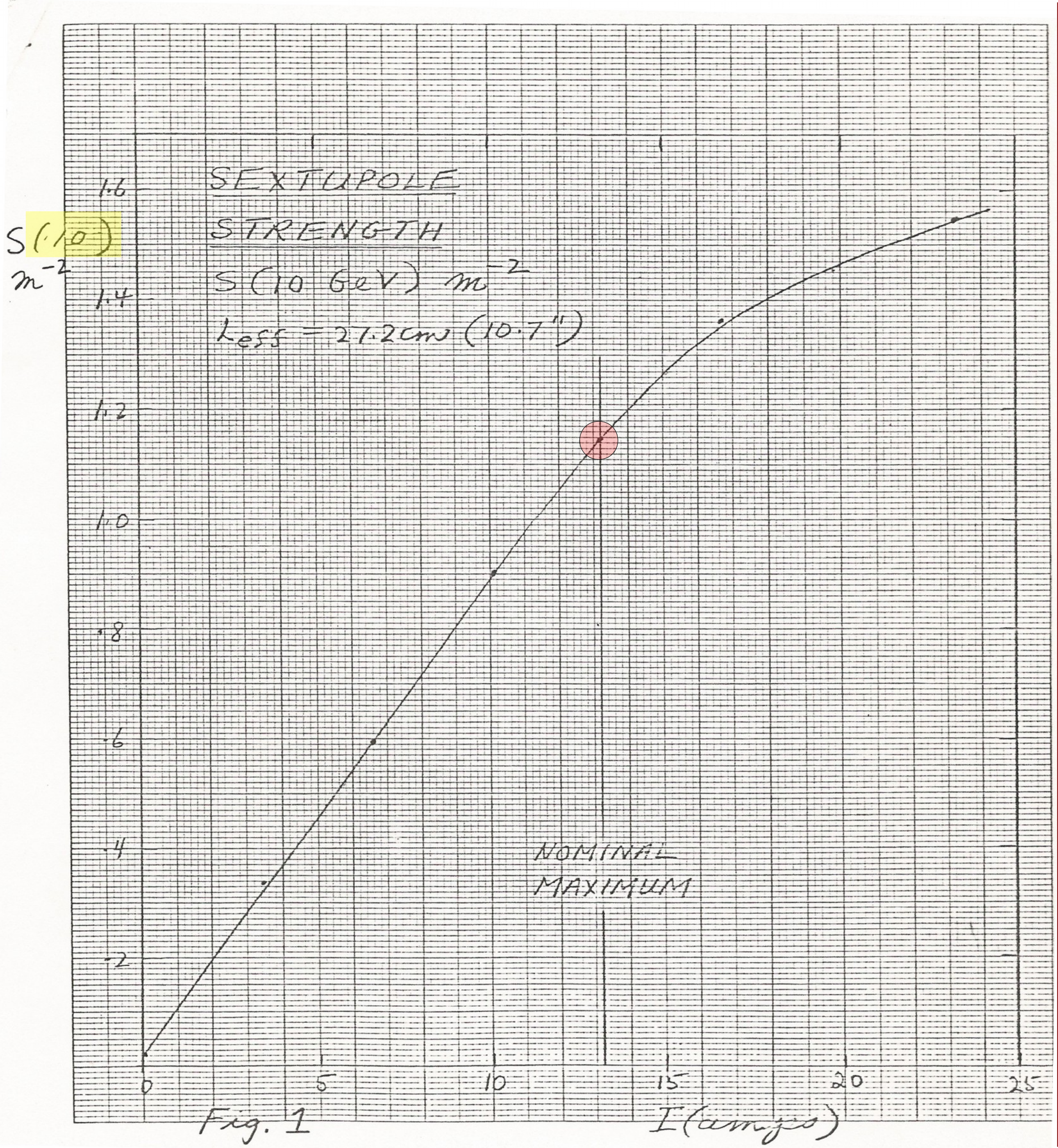
2003-09-17 (1.9 GeV, range +-500 cu)



2003-09-28 (1.9 GeV, range +-250 cu, no phase measurement)

The measured calibration factors are accurate to much better than a factor of two.
They vary by 7% for the October 2002 measurements at 5.012 GeV.
Contribution from measurement accuracy at 3.125 A (1000 cu then, 4000 cu now) unknown.

CBN 78-1: Sextupole Magnetic Measurements
Larson, Roberts, and Talman



"S = 1.18 m^{-2} for 13.2 A at 10 GeV"

This is the integrated strength SL.

According to the definition
$SL = 0.5\ (0.3/10)\ L\ (d^2B_Y/dx^2)$
$L\ (d^2B_Y/dx^2) = 2\ (10/0.3)\ SL = 78.6$ T/m

So $B_Y = 78.6/2/0.272\ x^2 = 144\ x^2$

However, the measurement of the unmodified sextupole in CON 96-05 found
$B_Y = 66.5\ x^2$ for 13.2 A.

The discrepancy is resolved at the level of 8% if we suppose CBN 78-1 measured K_2L instead of SL.