Comparison of Booster ring "Bump magnet" B field measurements vs. calculations @ 1.552 and 1.995 Gev.

Bump magnet measurements on 4/9/04:
- Equipment used:

a) Gauss meter and sensor: The model YR100-3-2 is a self contained, high linearity, high stability magnetic field to analog voltage transducer for one component of a magnetic field. It is particulary appropriate for magnetic fields up to 2T with better than 0.1% absolute accuracy at 1T and with a frequency response from dc to 10kHz. Probe is garanteed flat to 1.0 Khz

b) Magnet current sensor: Pearson 101 current probe

c) Monitor scope: TDS5000 digital oscilloscope

Measurement data:

Gmeter	Bmeter (gauss)	Ipeak - DSO	Bcalc	Icalc
1	4000	238	3670	238
1.07	4280	260		
1.16	4640	280		
1.2	4800	290		
1.24	4960	298		
1.28	5120	308	4720	306
1.32	5280	312		

Notes:

1) Pulse to pulse current variations not shown in data. Was roughly +/- 1.5%
2) Pulse to pulse B field variations not shown in data. Was roughly +/- 1.7%
3) Variations included in error bar data included in graph below.

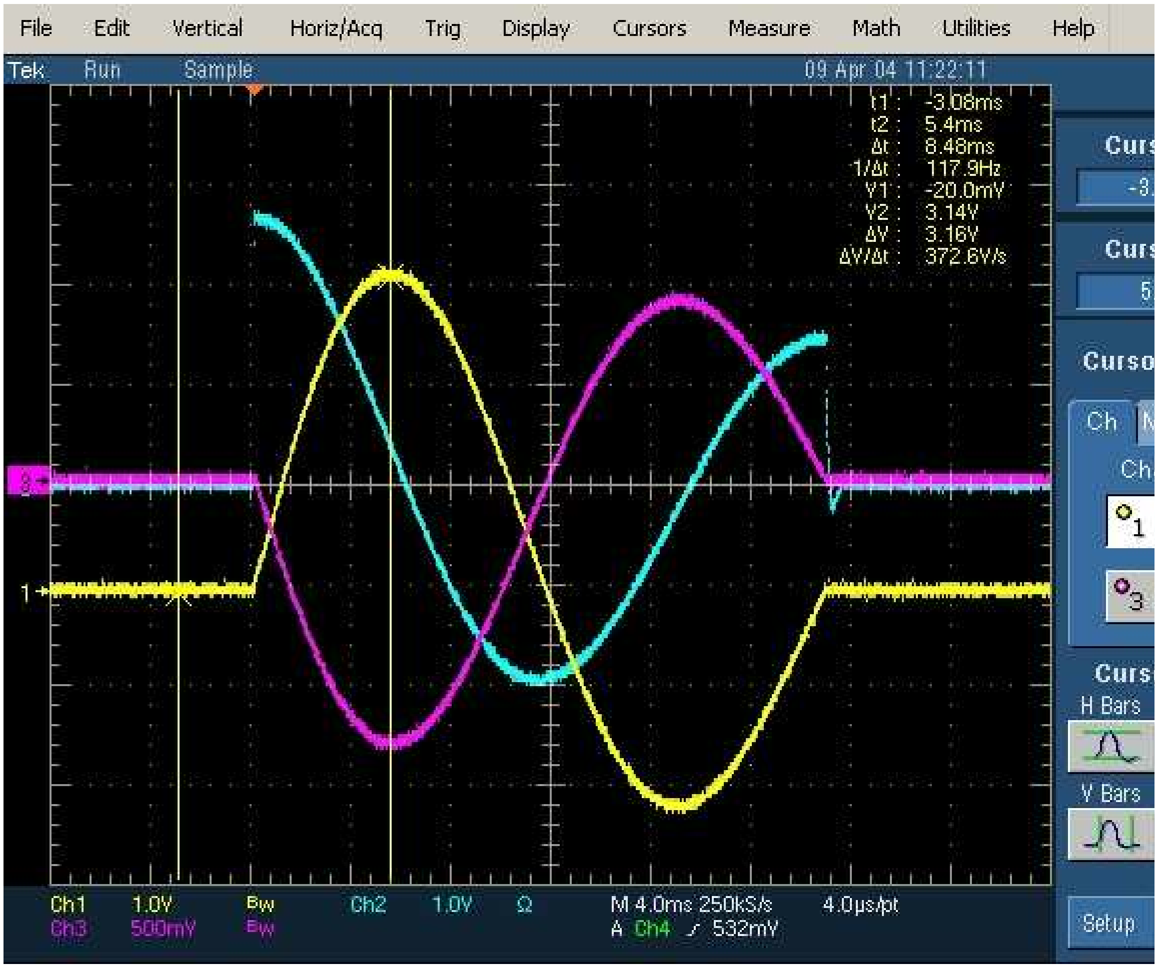
Waveform pictures taken at peak drive current of 312 amps.

Color code:

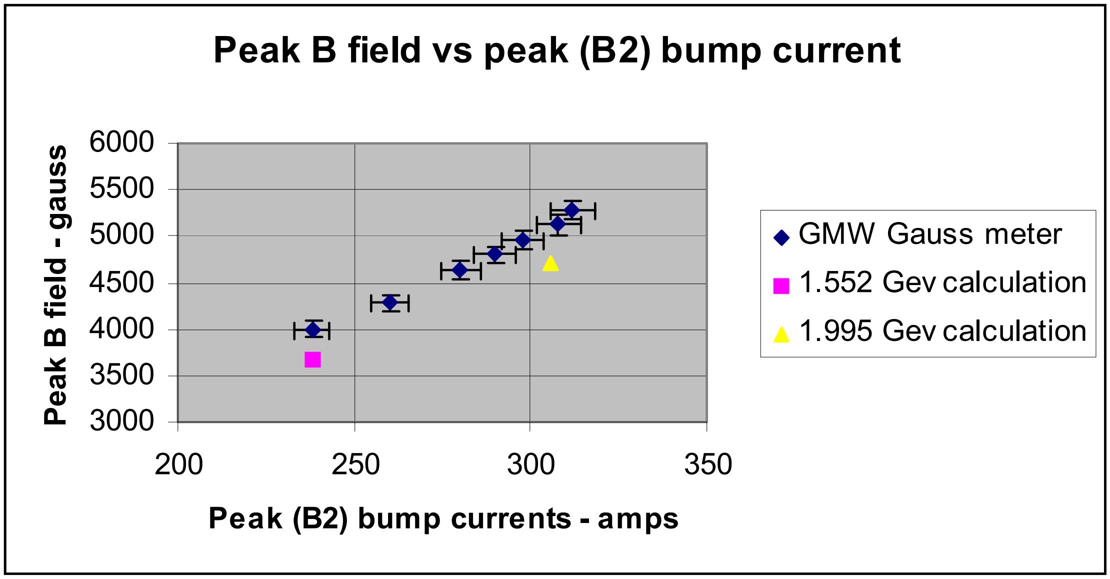
- Yellow is magnet current @ 100 amp/volt - value measured by pair cursors.

- Turquoise is applicd voltage @ 100 volts/volt

- Purple is B field measured with Hall elemet @ 4000 gauss/volt



Plotted data:



Key notes results observed:

1) Only cental bump magnet (B2) was measured for following resons:
   a) Center axis of magnet above the beam tube most easily accessed by Hall probe
   b) From calculations below B2 has the highest current requirements.
2) Theoretical data points for 1.552 and 1.995 are colored square and triangle. Calculated results are derived blow
3) **Measurement anomoly: Off axis (from beam center line) B field measurements increased linearly up to approximately 1.5 x 5280 = 7920 gauss.**

Theoretical calculations:

1) Key numeric results enclosed in rectangular boarders

2) Key facts or conclusions in Bold and Blue.

3) Data for calculations from Engineering note AL0323, M4852, 6/20/89

Global varible assignments:

$Gev \equiv 1\cdot 10^{9}\cdot volt$ $\quad KV \equiv 10^{3}$ $\quad mrad \equiv 10^{-3}$ $\quad mm \equiv 10^{-3}\cdot m$ $\quad \mu \equiv 10^{-6}$

$ms \equiv 10^{-3}\cdot sec$ $\quad \mu_0 \equiv 4\cdot\pi\cdot 10^{-7}\cdot\frac{henry}{m}$ $\quad m\Omega \equiv 10^{-3}\cdot ohm$ $\quad K \equiv 10^{3}$

Peak B field nominal deflections at 1.552 Gev:

Bρ = beam stiffness

$Z := 1$ Z = charge = 1

$E_{1.5} := 1552$ Nominl Beam extraction energy in Mev.

$E_o := .51$ Eo = electron rest energy

$L_{eff} := 0.129\cdot m$ Effective length from (note 1) derived from POISSON using varible permiability steel - **This may change due to saturation and end effects**

$$B\rho := \frac{1\left(E_{1.5}^{2} + 2\cdot E_{1.5}\cdot E_o\right)^{\frac{1}{2}}\cdot tesla\cdot m}{300\cdot Z}$$

$B\rho = 5.175\,tesla\cdot m$ Beam rigidity fm. note 1 = 5.00346 T-M (assumes 1500 Gev but we actually inject at 1.552 Gev.)

$B\cdot L_{eff} := B\rho\cdot\theta$ And

$$\theta_i := \frac{\left(B\cdot L_{eff}\right)}{B\rho}$$

To find theta we need to know the peak B field which is defined by the peak current values measured during the standard injection operation.

For: $j := 0..2$ And: $\eta := .98$ $\quad N := 84$ $\quad g := 67\cdot mm$ $\quad \mu_0 = 1.257\times 10^{-6}\,\frac{henry}{m}$

$Ipk_j :=$

138·amp
–238·amp
93·amp

Ipkj (left) are the peak current values for nominal injection energy measured on 3/26/04 for bump magnets B1,2, and 3 respectively.

Note: Calculated Currents from note AL0323 for 11mm deflections are: 199, -389, and 152 amps respectively.

$$B := \frac{Ipk}{g} \cdot N \cdot \mu_0 \cdot \eta$$

And:

$$B = \begin{pmatrix} 0.213 \\ -0.367 \\ 0.144 \end{pmatrix} \text{tesla}$$

Calculated flux densities at 1.552 Gee for for bump magnets B1,2, and 3 respectively. **B2 shown as red square in graph above.** Calculated fields for 11mm deflection from note AL0323 are: .308, -.600, .235 Tesla

And the calculated angles are 1.552 Gee are:

$$\theta_i := \frac{(B \cdot L_{eff})}{B\rho}$$

$$\theta_i = \begin{pmatrix} 5.311 \\ -9.16 \\ 3.579 \end{pmatrix} \text{mrad}$$

Max bend angles for 11mm deflection from Engineering note 1 are 7.95, -15.47, 6.07 mad

Peak B field nominal deflections at 1.995 Gev:

Bρ = beam stiffness

$Z := 1$ Z = charge = 1

$E_{1.9} := 1995$ Beam extraction energy in Mev. + 5% overange

$E_o := .51$ Eo = electron rest energy

$L_{eff} := 0.129 \cdot m$ Effective length from (note 1) derived from POISSON using varible permiability steel - **This will change due to saturation which according to Poisson plots from** note AL0323 **are still relatively minor at 1.995 Gev**

$$B\rho := \frac{1\left(E_{1.9}^{\ 2} + 2 \cdot E_{1.9} \cdot E_o\right)^{\frac{1}{2}} \cdot \text{tesla} \cdot m}{300 \cdot Z}$$

$B\rho = 6.652\,\text{tesla}\cdot\text{m}$ Beam rigidity for 1.995 Gev

$B\cdot L_{eff} := B\rho\cdot\theta$ And

$\theta_i := \frac{(B\cdot L_{eff})}{B\rho}$ To find theta at 1.995 Gev we need to know the peak B fields which are defined by the peak current values measured during the injection operation. A linear ratio (1.995/1.552) assumes a low core saturation which is confirmed by Poisson plots for 11mm deflection case.

For: $k := 0..2$

$Ipk_{1.9} := \overrightarrow{\left(\frac{E_{1.9}}{E_{1.5}}\right)\cdot Ipk}$ And: $\eta := .98$ $N := 84$ $g := 67\cdot\text{mm}$ $\mu_0 = 1.257\times 10^{-6}\,\frac{\text{henry}}{\text{m}}$

$$Ipk_{1.9} = \begin{pmatrix} 177.39 \\ -305.934 \\ 119.546 \end{pmatrix}\text{amp}$$

Peak currents for required deflection at 1.995 Gev

$B := \frac{(Ipk_{1.9})}{g}\cdot N\cdot\mu_0\cdot\eta$ And:

$$B = \begin{pmatrix} 0.274 \\ -0.472 \\ 0.185 \end{pmatrix}\text{tesla}$$

Calculated flux densities at 1.995 Gev for for bump magnets B1,2, and 3 respectively. **B2 shown as "blue" square in graph above.** Calculated fields for 11mm deflection from AL0323 note are: .308, -.600, .235 Tesla

And the calculated angles are:

$\theta_i := \frac{(B\cdot L_{eff})}{B\rho}$

$$\theta_i = \begin{pmatrix} 5.312 \\ -9.161 \\ 3.58 \end{pmatrix}\text{mrad}$$

Max bend angles for 11mm deflection from AL0323 note are 7.95, -15.47, 6.07 mrad


Buttons
s1 Pos
08ms
s2 Pos
4ms
r Source
Math
Ref
annel
2
4
or Type
Paired
Split
Close