A Brief Review of the Strategy and Specifications for the LHC MB Field Quality

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Phase 1 (late 1980's)

Exploration of the issues:

1. The field perturbation is dominated by random (syst.) b3.
2. The non-linear dynamics is dominated by higher-order effects of b3.
3. Modest computer ressources; early indicators (smear, amplitude detuning…), experiments at Fermilab, Tevatron.

Phase 2 (1990-1995)

1. Let's find a dipole which works and *correct the field imperfections*
2. The target dynamic aperture should be between 6 and 8.5 σ
3. Scenario: all dipoles in the same Gaussian distribution. Super-symmetric lattice.

Results: b3 and b5 correctors on each dipole,

Cell length (LHCv4) set to maximum,

Inner coil aperture increased from 50 to 56 mm

Phase 3 (1996-…)

1. Large increase of computing power.
2. Target dynamic aperture *increased to 12 σ* to provide 6σ actual with 20% safety margin.
3. New criteria: dynap scaling law (mult.by mult), conjecture for combination, analytic criteria: (1,-1) non-lin. res., chromatic coupling, chromo-geometric detunings, Q’’’.
4. One dipole error distribution *per octant*
5. Realistic non-super-periodic lattice
6. *Target error tables* produced: MB, MQ, …
7. *Tolerance* on target imperfections calculated

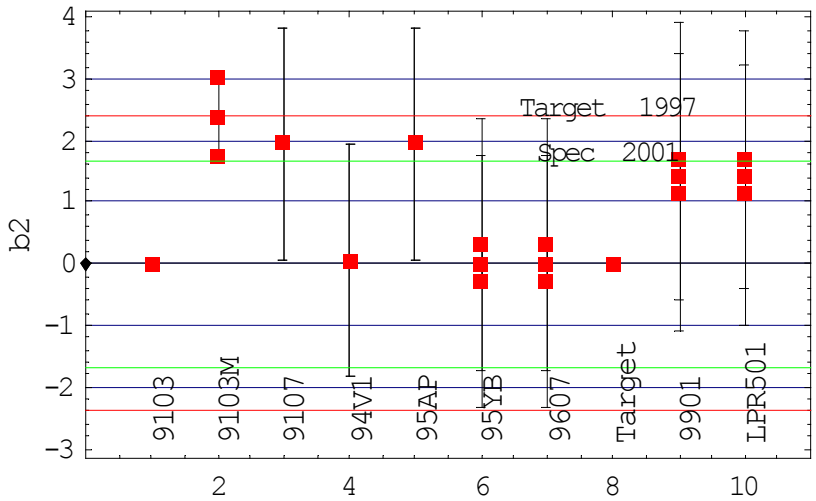
Phase 3 (1996-…)

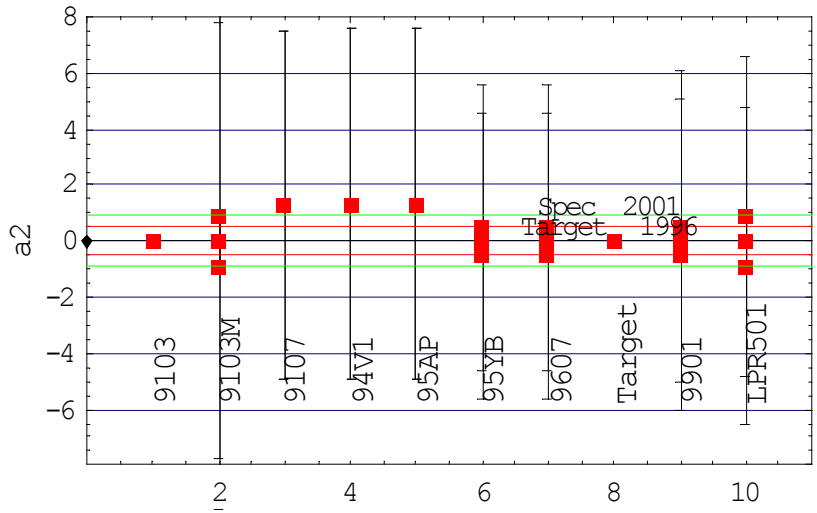
Results:

- a3 + b4 correction added;
- b5 correctors reduced by *2 in number;
- a4 assumed controlled by good manufacturing principle and b5 feed-down by good dipole geometry.
- space for one additional corrector circuit
- many improvements on the magnet side leading to meeting the targets (5 to 6 block coils, collar design, permeability,…)
- tune split of 4..5; choice of tunes relaxes specs.
- alignt of correctors to < 0.3 mm sys.±0.5mm rms
- Table 9901 meets the dynap requirements.

n=1,2

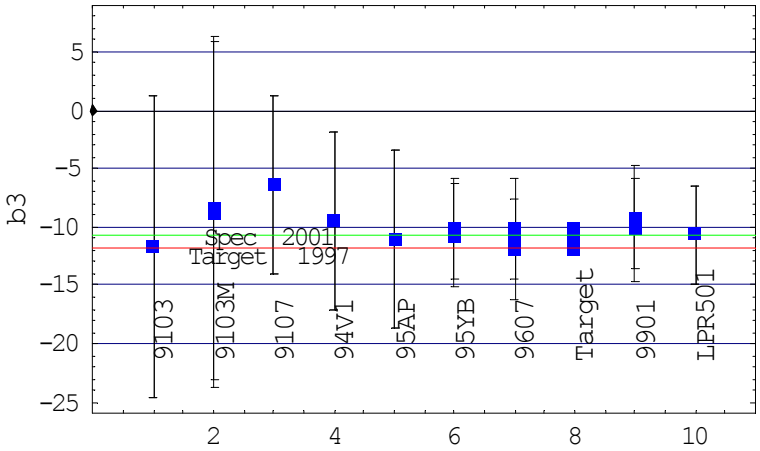
	b1	*a1*	
9901	±10.9 ±5	±5 ±.4	*accepted*
LPR501	±6.5 ±8	±6.5 ±8	*specified*

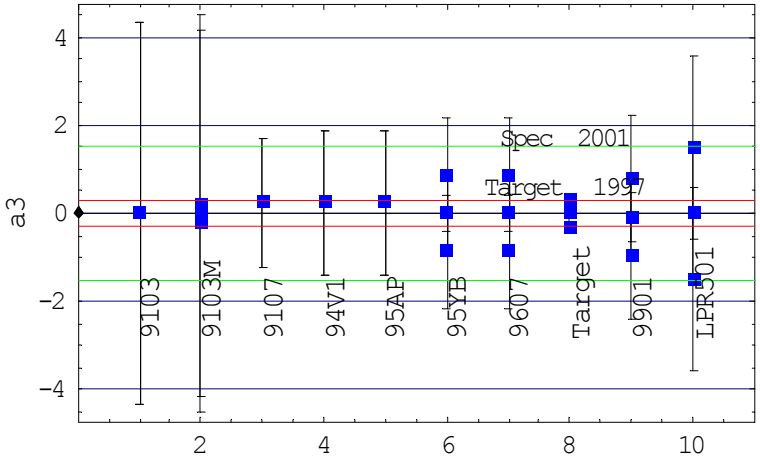


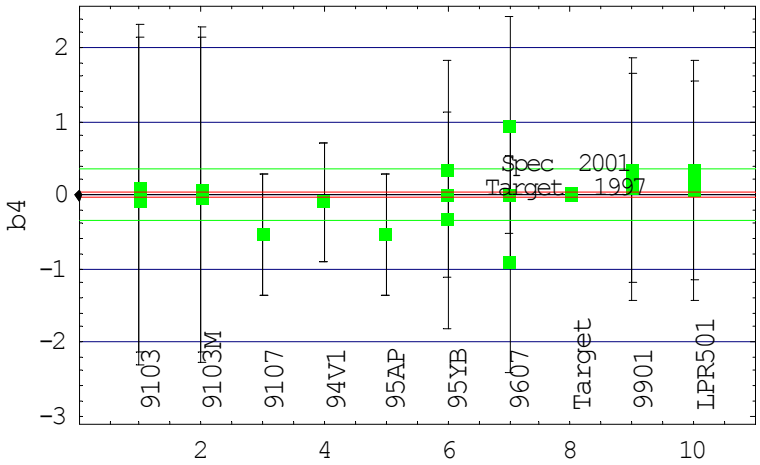


Tolerance=ring average + uncertainty/sqrt(8) or uncertainty

n=3, n=4


b3
Spec 2001
Target 1997
9103
9103M
9107
94V1
95AP
95YB
9607
Target
9901
LPR501


a3
Spec 2001
Target 1997
9103
9103M
9107
94V1
95AP
95YB
9607
Target
9901
LPR501


b4
Spec 2001
Target 1997
9103
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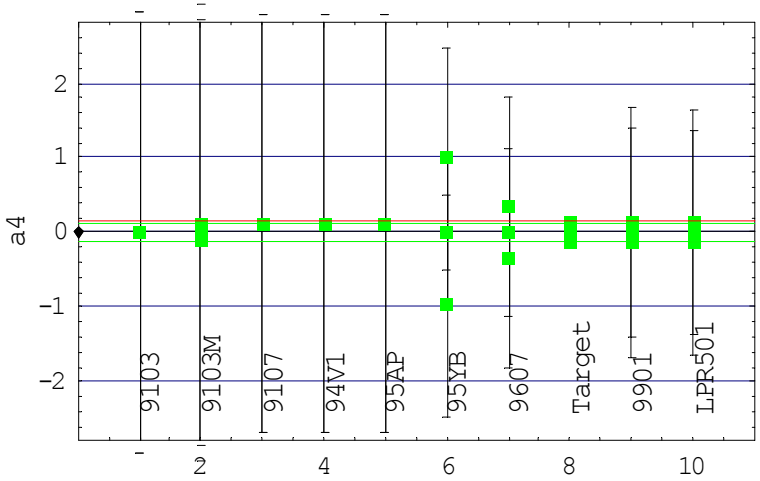
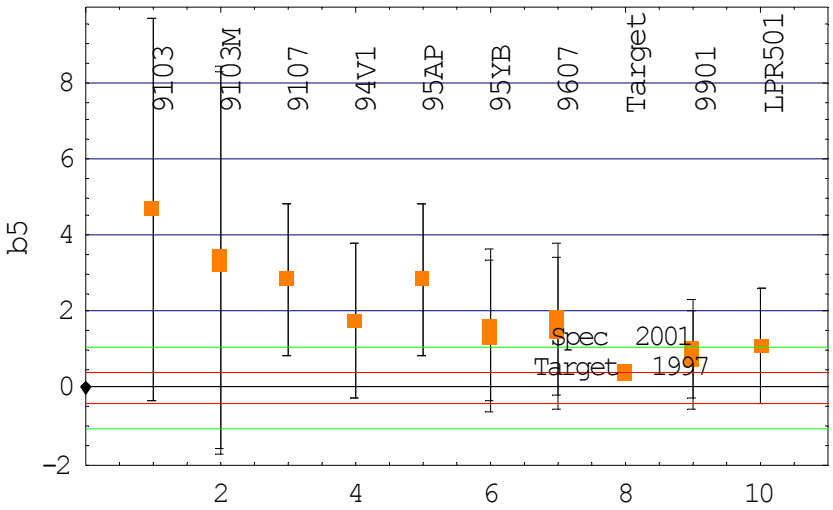
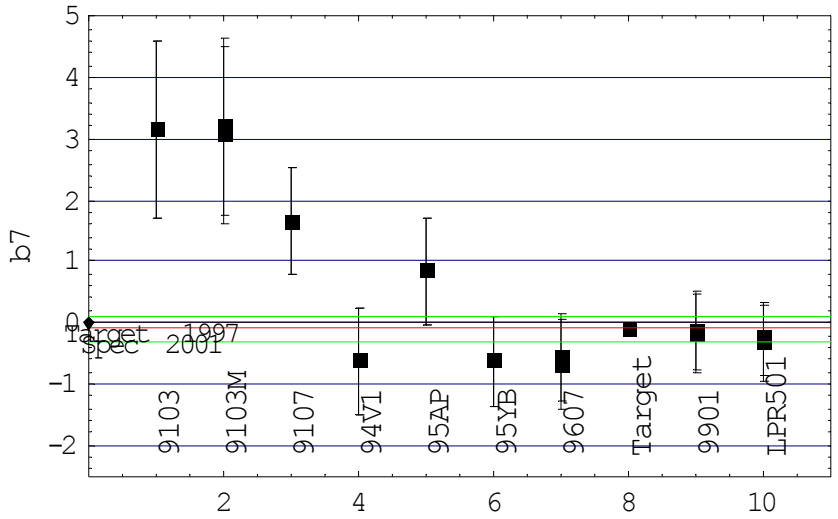
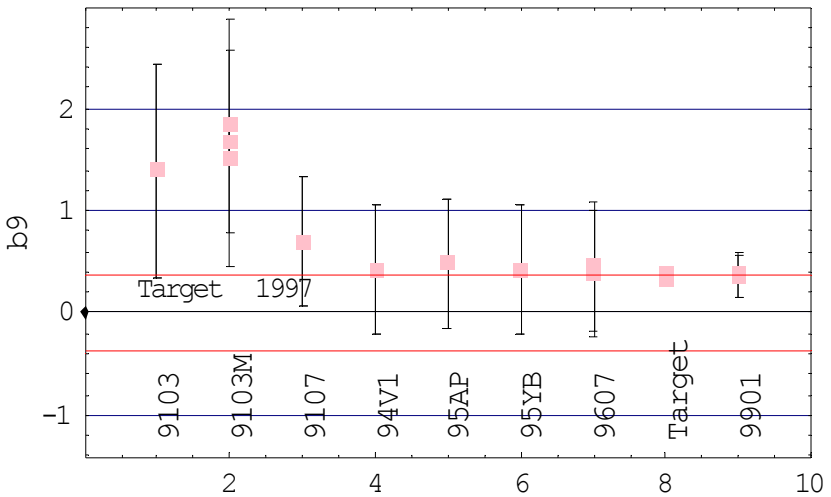
9107
94V1
95AP
95YB
9607
Target
9901
LPR501

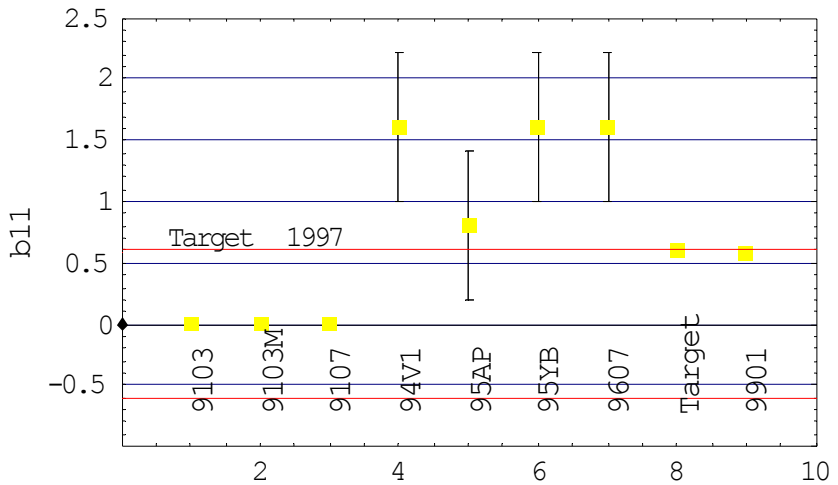

a4
9103
9103M
9107
94V1
95AP
95YB
9607
Target
9901
LPR501

b5,b7,b9,b11

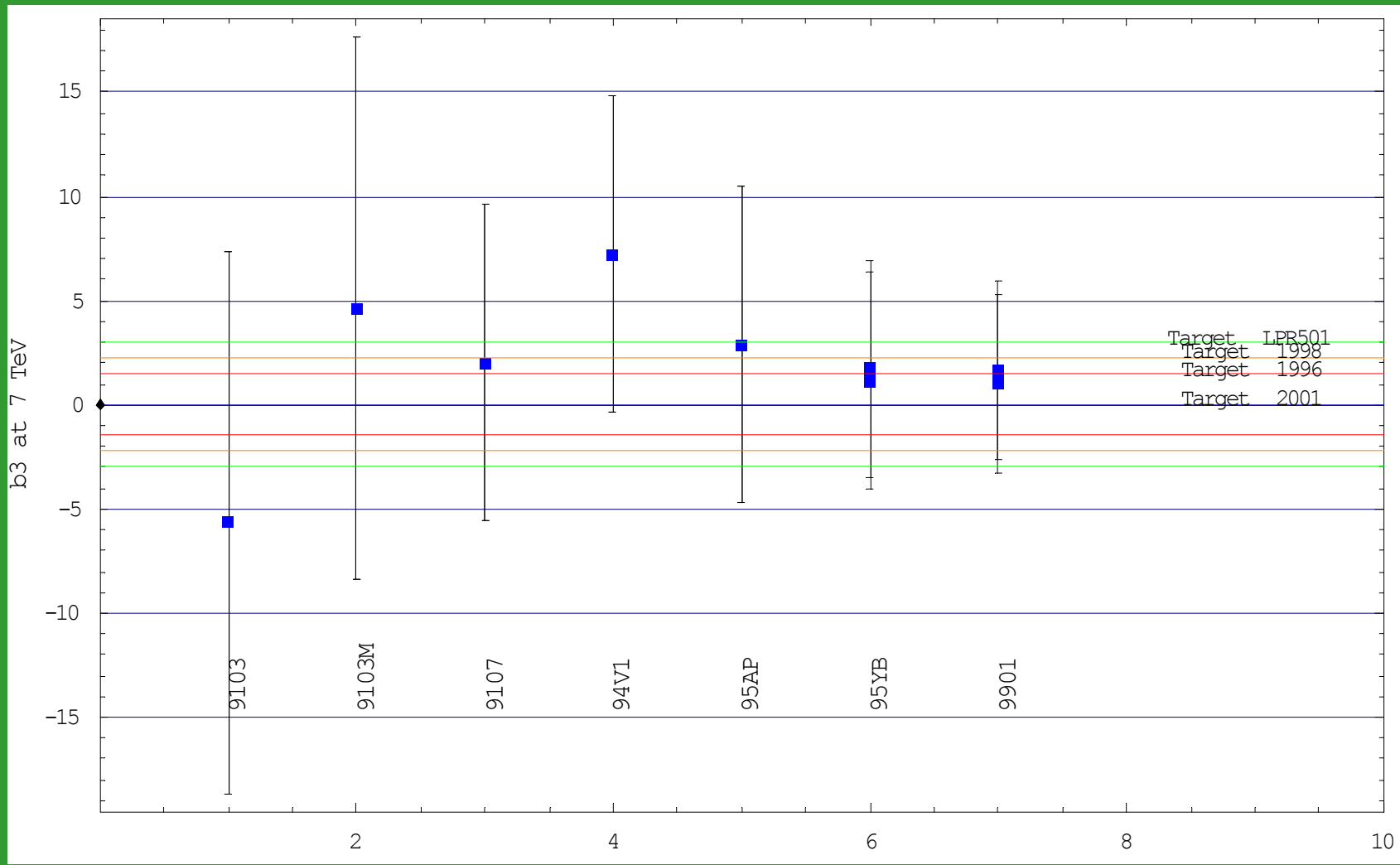

b5
9103
9103M
9107
94V1
95AP
95YB
9607
Target
9901
LPR501
Spec 2001
Target 1997


b7
Target 1997
Spec 2001
9103
9103M
9107
94V1
95AP
95YB
9607
Target
9901
LPR501


b9
Target 1997
9103
9103M
9107
94V1
95AP
95YB
9607
Target
9901


b11
Target 1997
9103
9103M
9107
94V1
95AP
95YB
9607
Target
9901

b3 at 7 TeV


b3 at 7 TeV
15
10
5
0
-5
-10
-15
2
4
6
8
10
9103
9103M
9107
94V1
95AP
95YB
9901
Target LPR501
Target 1998
Target 1996
Target 2001

Conclusion

Over the last 6 years, the overall trends for specs is a consolidation:

1. Unchanged: b3, a4, b11
2. Relaxed: a1 (×1.3), a2 (×1.5/tune split), a3 (×6/correction), b4 (×8/correction), **b5 (×2.9), b7 (×3 on one side)**
3. Tightened: b1 (×1.7), b2 (×1.3),

…except for b3 at 7 TeV: 2.2 → 0 → 3