BPM's effect on the PS magnet field

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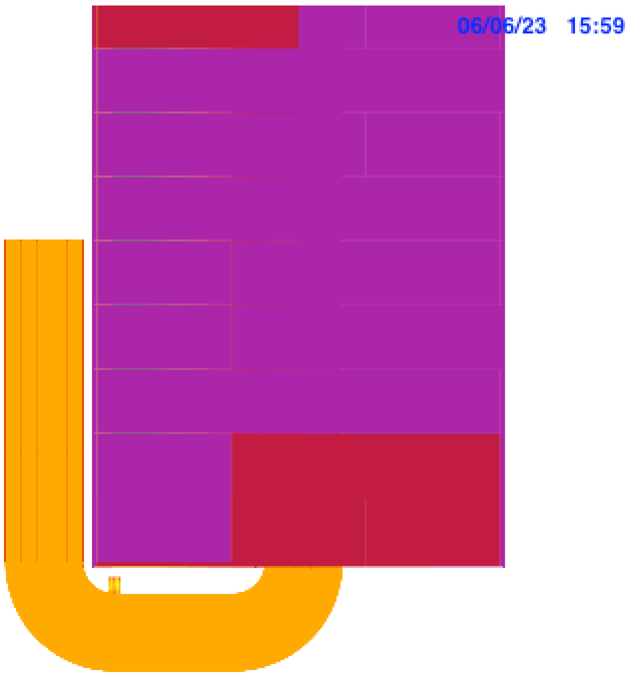
Thanks to G. Arduini, B. Auchmann, O. Berrig, S. Gilardoni

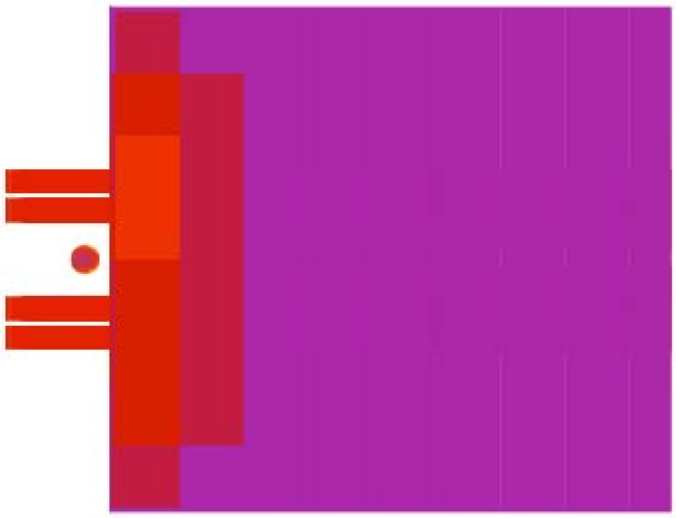
Contents

- Goal
- BPMs
- Field Data from Roxie model
- Multipoles evaluation
- MAD-X implementation and modeling
- Results
  - Tune
  - Chromaticity
  - Beta Beating
  - Dispersion
  - Chromaticity vs $\Delta P/P$

Goal

- Quantify the effect of the pick-up's shielding in the PS magnet field and study how the optical parameters are modified.



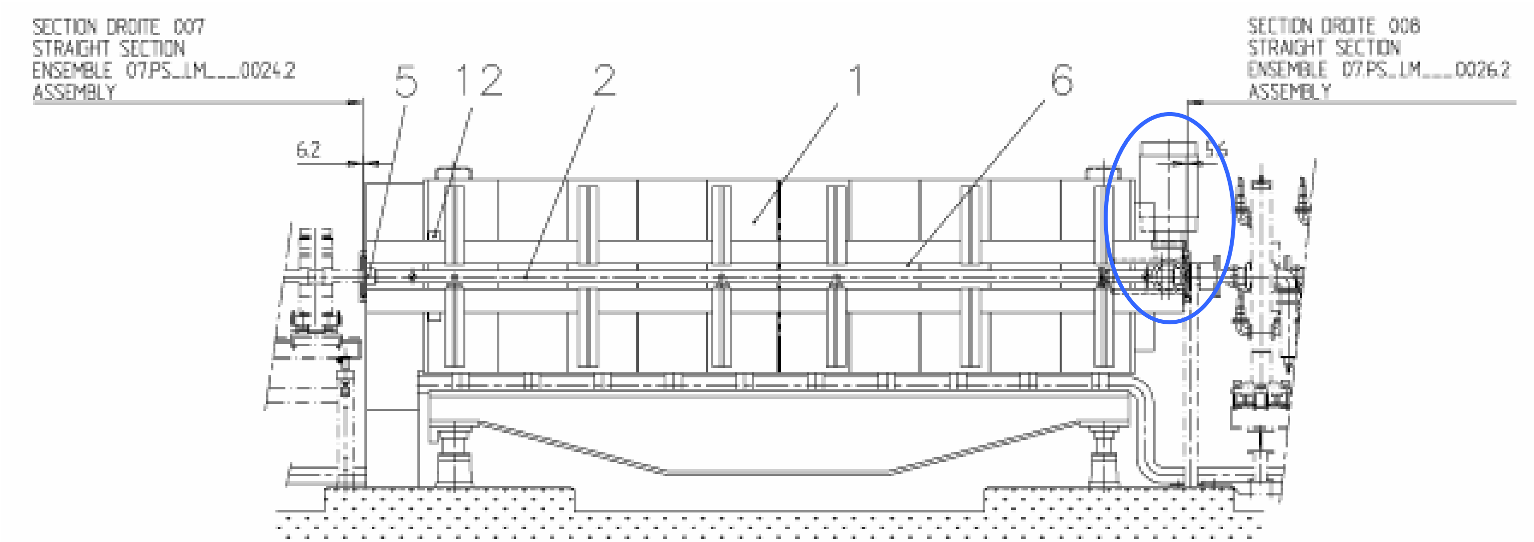


(*) Courtesy of B. Auchmann

- The different colors indicate the magnetic induction of the iron (*).

BPMs

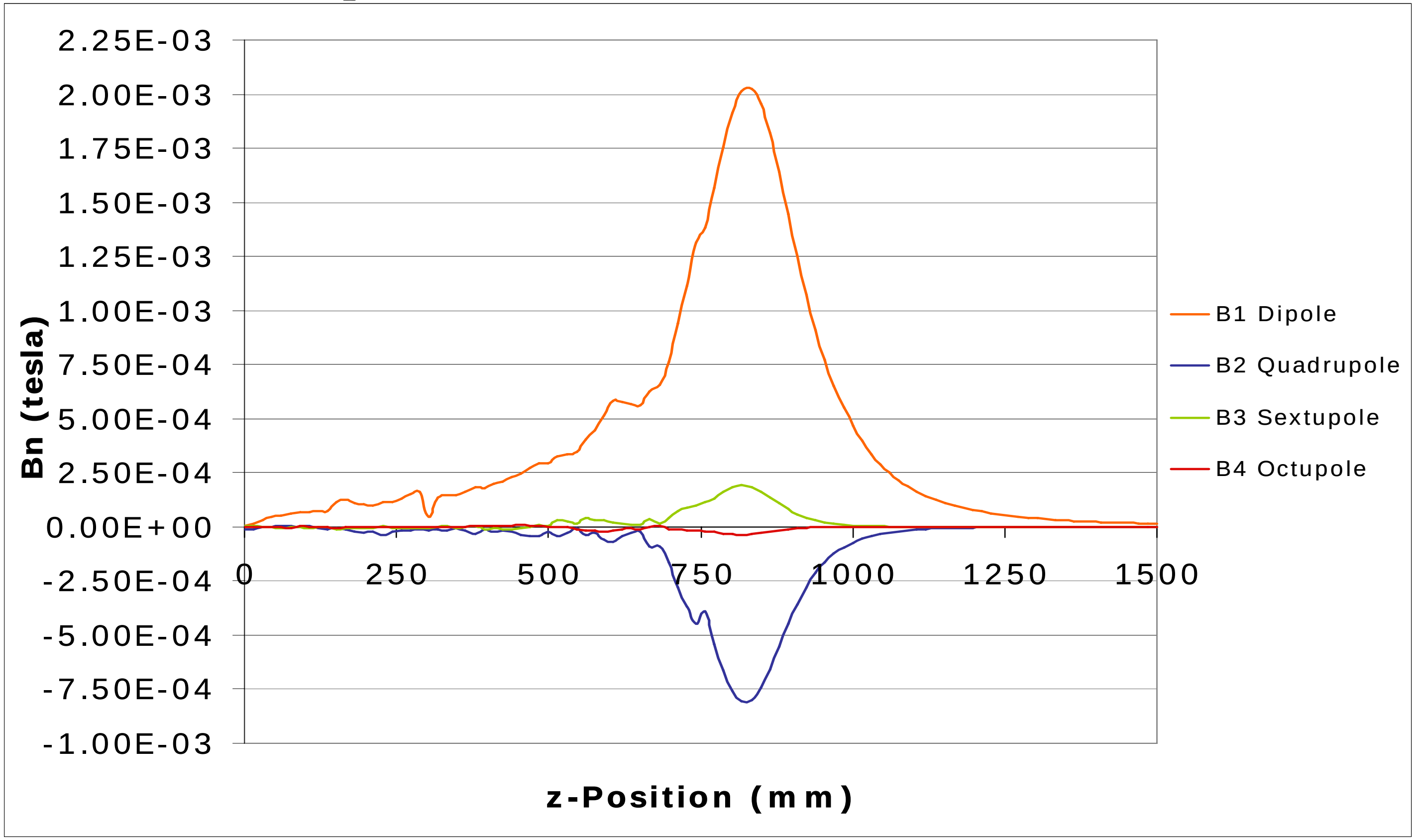
- A total of 40 BPMs are distributed along the PS ring (magnets ending in 0, 3, 5, 7). 38 of them are close enough (80 mm far from the end of the yoke) to the magnet to influence the field quality. The effect of the other 2 can be neglected (BPMs 17 and 63).



- The reference radius used for the measurements is 17 mm.

Field Data from Roxie Model

- Our starting data was the field measurements with and without the box shielding of the BPMs (*). Field measurements go up to the octupole component. In the following chart the difference of field components (with and without BPMs) is plotted.



(*) Courtesy of B. Auchmann

Multipoles evaluation

- The effect of the shielding box in the field quality would be introduced in MAD X using multipoles.
- Our starting data is the variation in the field measured. From this we can calculate the multipoles as follows:

$$kn = \frac{1}{B\rho} \frac{\partial^{n-1} B}{\partial x^{n-1}}$$

  - The integral of the field components has been evaluated by a numerical routine in mathematica, a simple trapezoidal integration rule and it has been compared with the integral of the logarithmic estimations of the curves.

Multipoles evaluation

- Results of integrals

	Logarithmic Estimation	Trapezoid Integration	Mathematica (ListIntegrate)
B_1L [Tm]	0.000572392	0.000619439	0.000619449
B_2L [Tm]	-0.000144304	-0.000155372	-0.000155377
B_3L [Tm]	3.40401E-05	3.2382E-05	3.23801E-05
B_4L [Tm]	-6.93606E-06	-6.5825E-06	-6.58E-06

Multipole evaluation

- The coefficients implemented for are:

Normalized Integrated Multipoles (MADX convention)	**Coefficients**
K_0L [-]	$7.14729*10^{-6}$
K_1L [m^{-1}]	$-1.05457*10^{-4}$
K_2L [m^{-2}]	0.001292754
K_3L [m^{-3}]	-0.015459435

MAD-X implementation and modeling

- The MAD-X sequence was modified by intoducing the multipoles in the corresponding magnets (38 magnets - 38 multipoles).

```
PR.BHT000003 : SEQUENCE, refer = CENTRE,  L = 5.00318530718;  ! F-D unit, yoke inside
    PR.BHT000003.c1      ```` : c,              AT = 0.1492863;
    PR.BHT000003.mpfi1  ``   : mpfi1,        AT = 0.2985726;
    PR.BHT000003.FINFF1    : FINFF1,       AT = 0.8476326;
    PR.BHT000003.mpfm        : mpfm,         AT = 1.3966926;
    PR.BHT000003.FINFF2    : FINFF2,       AT = 1.9457526;
    PR.BHT000003.mpfi2       : mpfi2,        AT = 2.4948126;
    PR.BHT000003.j               : j,              AT = 2.4973126;
    PR.BHT000003.mpdi1       : mpdi1,        AT = 2.4998126;
    PR.BHT000003.DINDD1    : DINDD1,      AT = 3.0510126;
    PR.BHT000003.mpdm        : mpdm,         AT = 3.6022126;
    PR.BHT000003.DINDD2    : DINDD2,      AT = 4.1534126;
    PR.BHT000003.mpdi2       : mpdi2,        AT = 4.7046126;
    PR.BHT000003.mpsf         : mpsf,          AT = 4.7846126;
ENDSEQUENCE;
```

Analytical calculations (26 GeV)

- By definition the variation of the tune is

$$\Delta Q_{x,y} = \pm\frac{1}{4\pi}\int \beta_{x,y}(s)\delta k(s)ds \approx \pm\frac{1}{4\pi}k_1 l\left(N_D\overline{\beta^D_{x,y_n}} + N_F\overline{\beta^F_{x,y_n}}\right)$$

  - Horizontal plane

$$\Delta Q_x \approx \frac{1}{4\pi}*\left(-1.054*10^{-4}\right)*\left(552.562\right) = -0.00463$$

  - Vertical plane

$$\Delta Q_y \approx -\frac{1}{4\pi}*\left(-1.054*10^{-4}\right)*\left(717.702\right) = 0.006020$$

Analytical calculations (26 GeV)

- By definition the variation of the chromaticity is

$$\Delta\xi_{x,y} = \frac{1}{4\pi}\int\left(\pm\beta_{x,y}(s)\delta k_2(s)D(s) + \beta_{x,y}(s)\delta k_1(s)\right)ds \approx$$

$$\frac{1}{4\pi}\left(\pm k_2 l\left(N_D\overline{\beta^D_{x,y_n}}\,\overline{D^D_{x\ n}} + N_F\overline{\beta^F_{x,y_n}}\,\overline{D^F_{x\ n}}\right) + k_1 l\left(N_D\overline{\beta^D_{x,y_n}} + N_F\overline{\beta^F_{x,y_n}}\right)\right)$$

  - Horizontal plane

$$\Delta\xi_x \approx \frac{1}{4\pi}*(0.001293)*(1419.9002)+$$

$$+\frac{1}{4\pi}*(-1.054*10^{-4})*(552.5616) = 0.1414$$

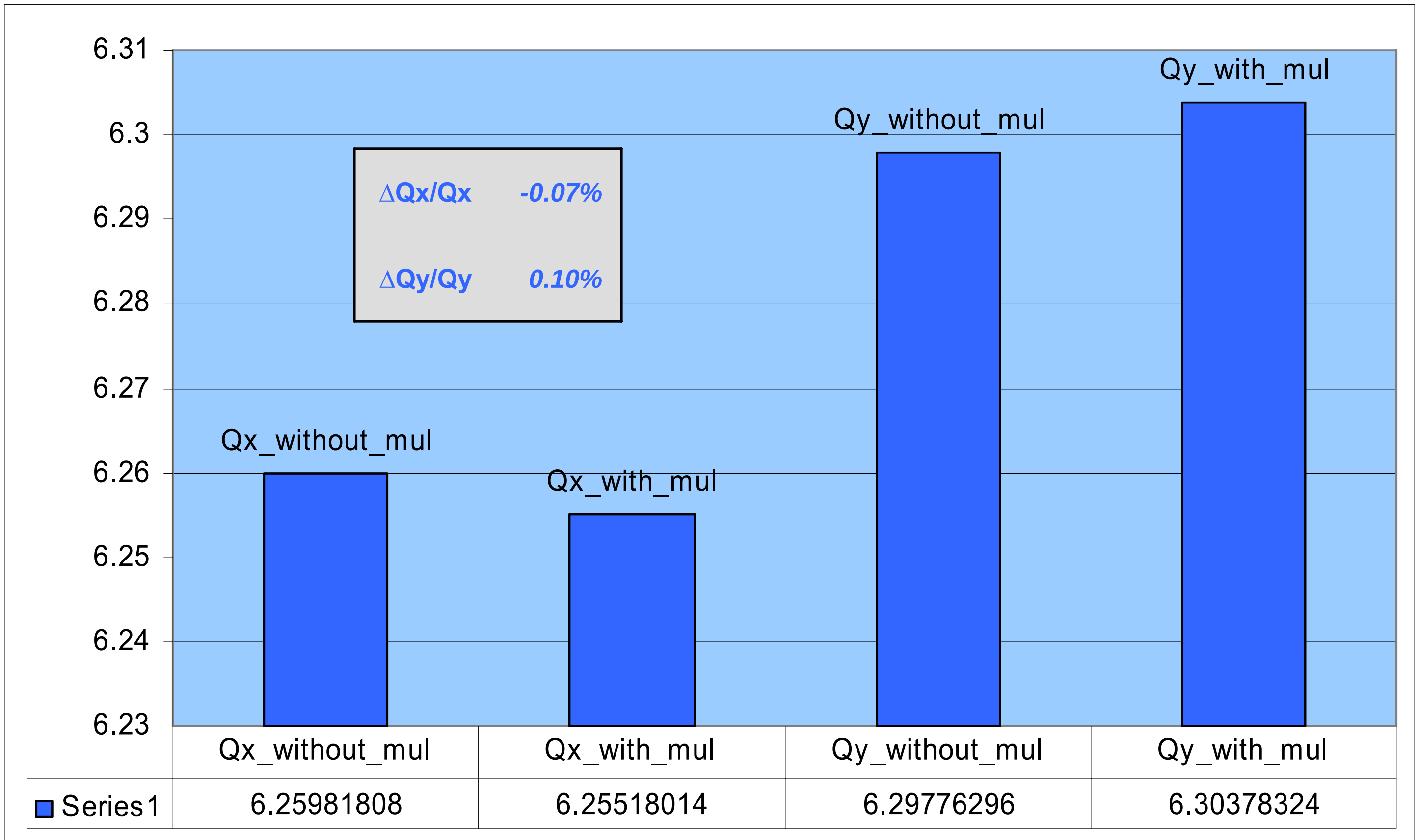
  - Vertical plane

$$\Delta\xi_y \approx -\frac{1}{4\pi}*(0.001293)*(1739.3495)+$$

$$+\frac{1}{4\pi}*(-1.054*10^{-4})*(717.702) = -0.1850$$

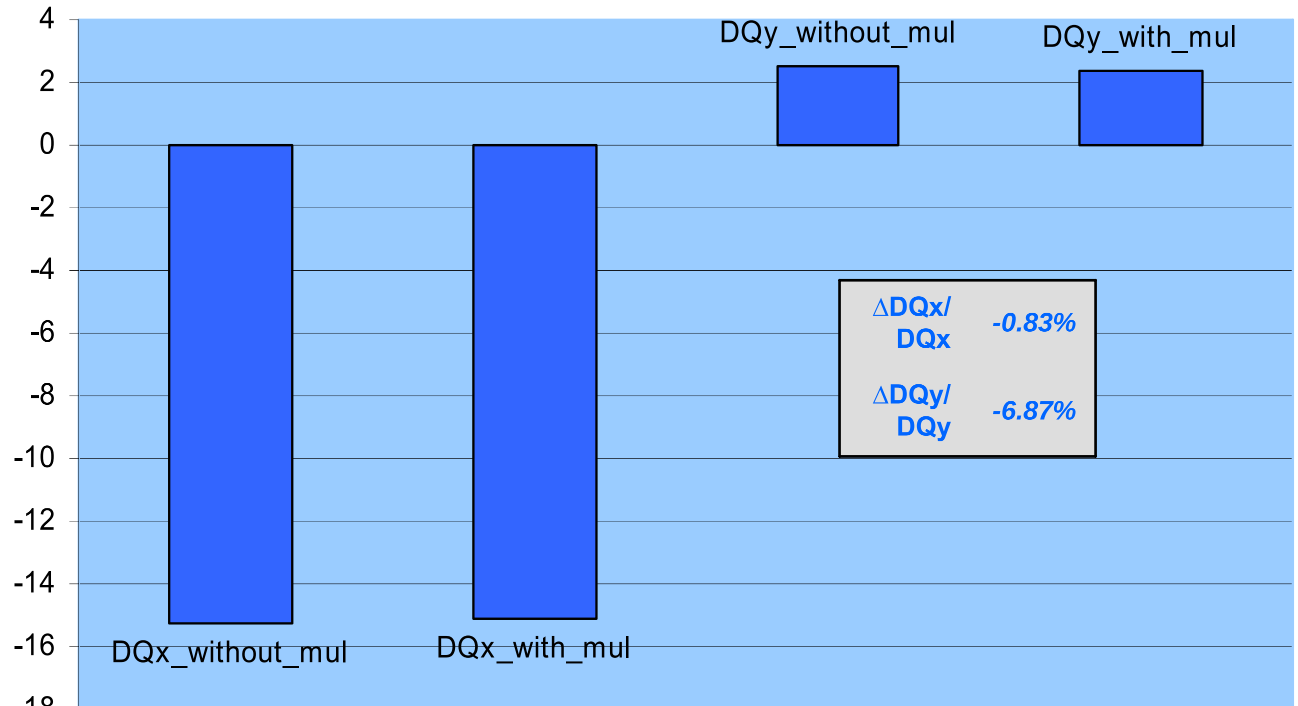
MAD-X Results (26 GeV)

- We run the new MAD X model for LHC extraction energy obtaining the following results:
  - Tune



MAD-X Results (26 GeV)

- Chromaticity



	DQx_without_mul	DQx_with_mul	DQy_without_mul	DQy_with_mul
Series1	-15.25159636	-15.12579504	2.53542805	2.36121976

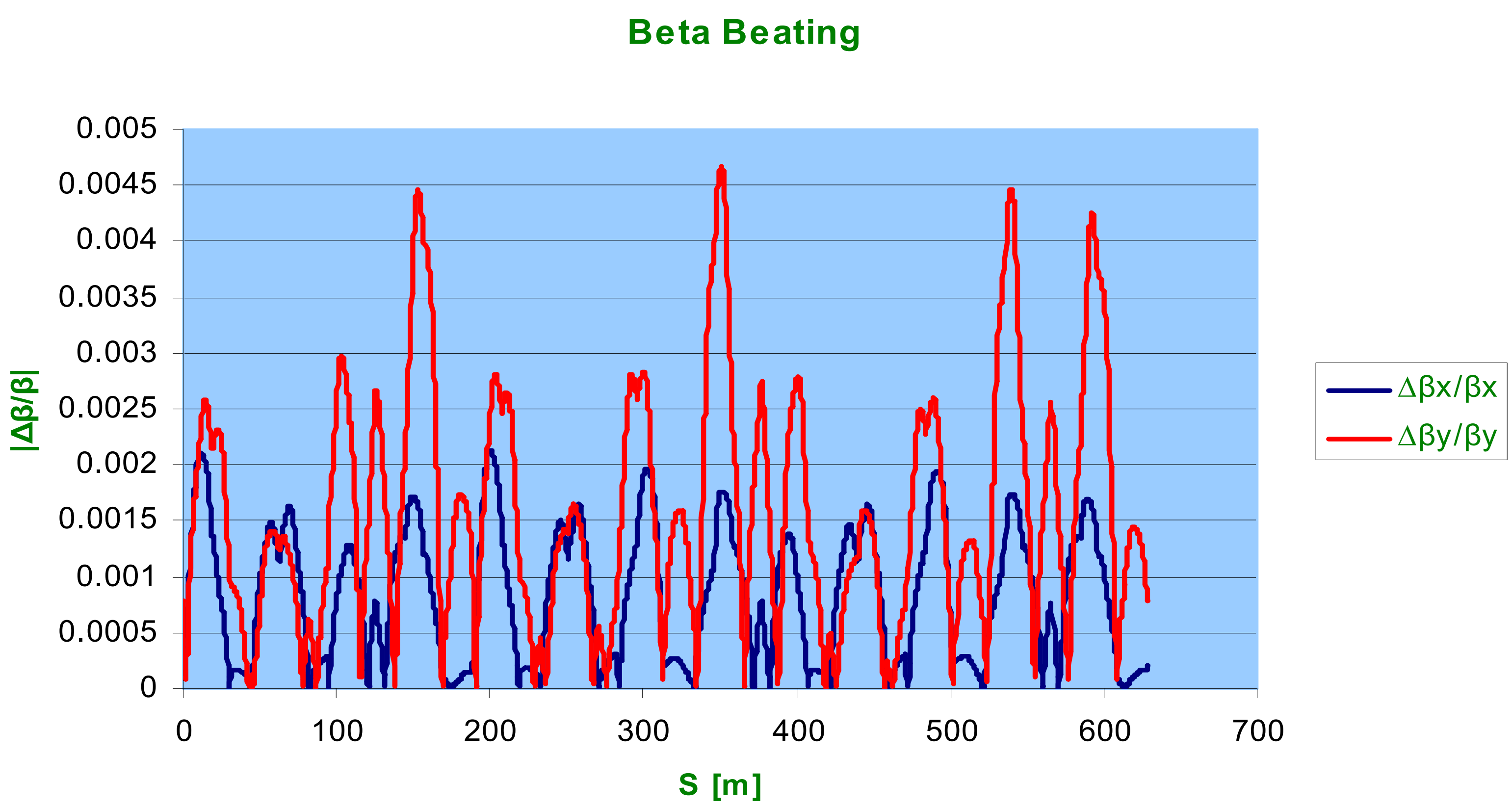
MAD-X Results (26 GeV)

- Comparison between analytical results and MAD-X results.

	Analytical result	MAD-X	Difference
ΔQ_x	-0.00463	-0.00463	0%
ΔQ_x	0.006020	0.006020	0%
$\Delta \xi_x$	0.1414	0.1258	11%
$\Delta \xi_y$	-0.1850	-0.1742	6%

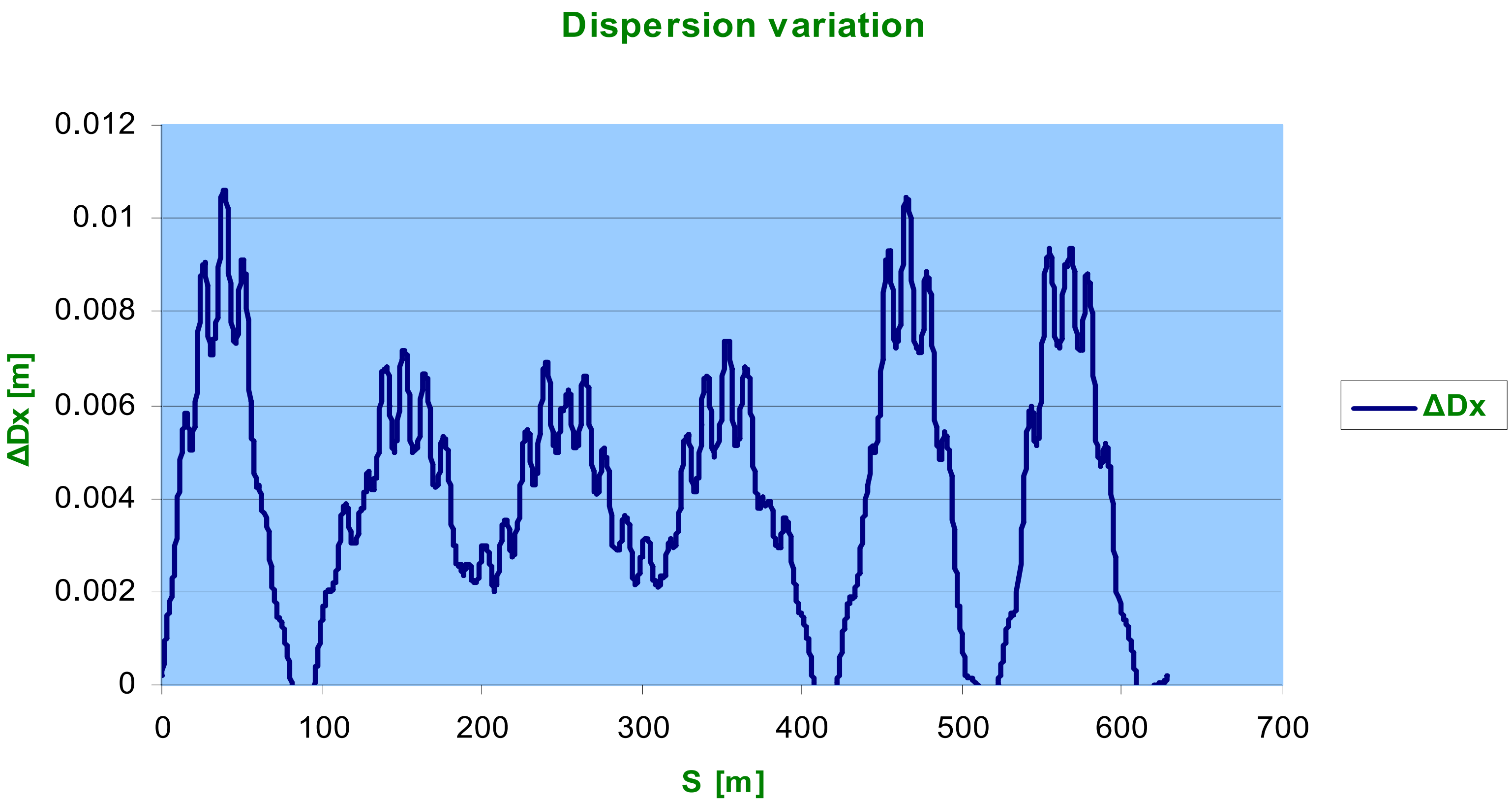
MAD-X Results (26 GeV)

- Beta Beating



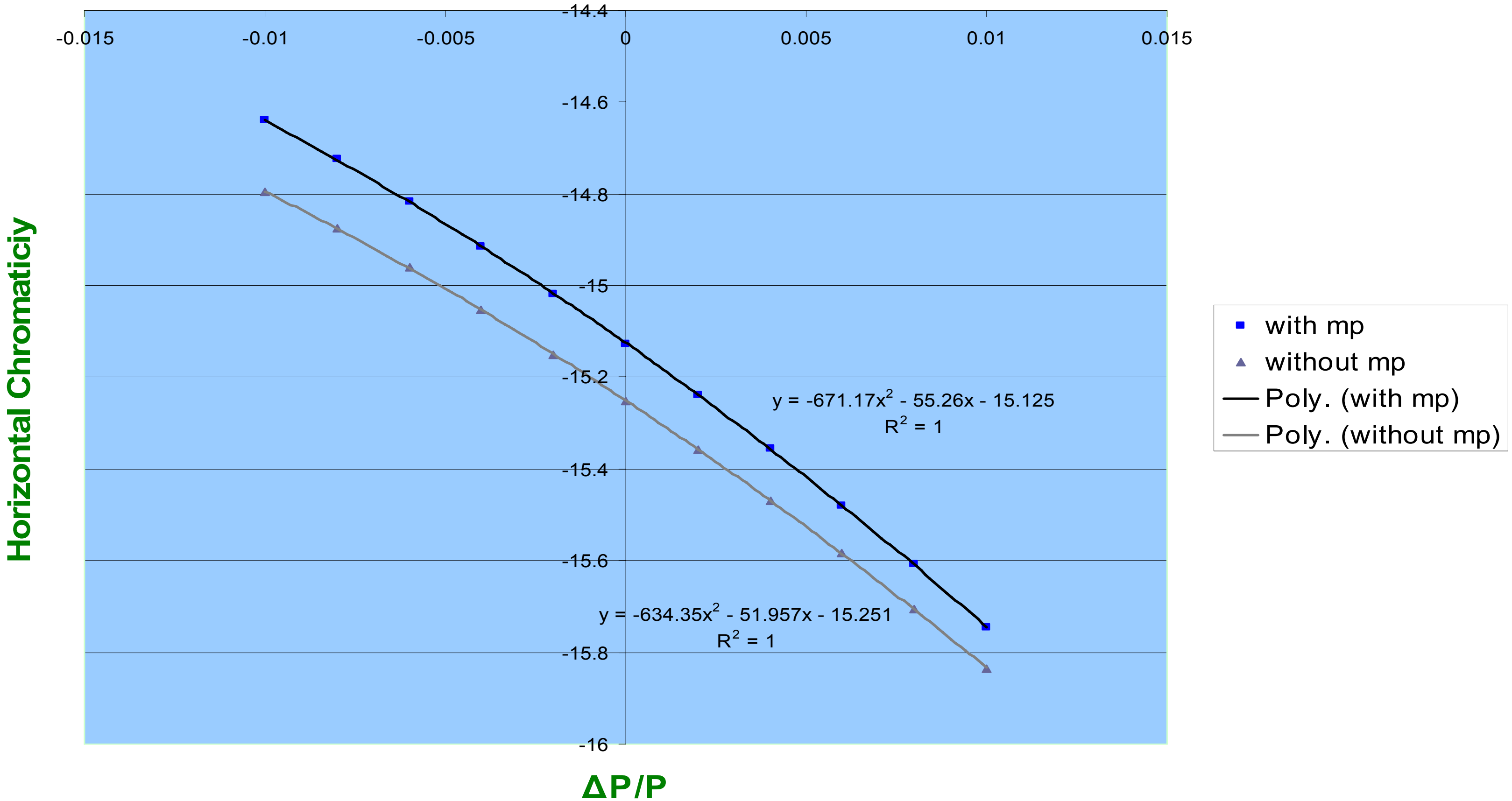
MAD-X Results (26 GeV)

- Horizontal Dispersion Variation



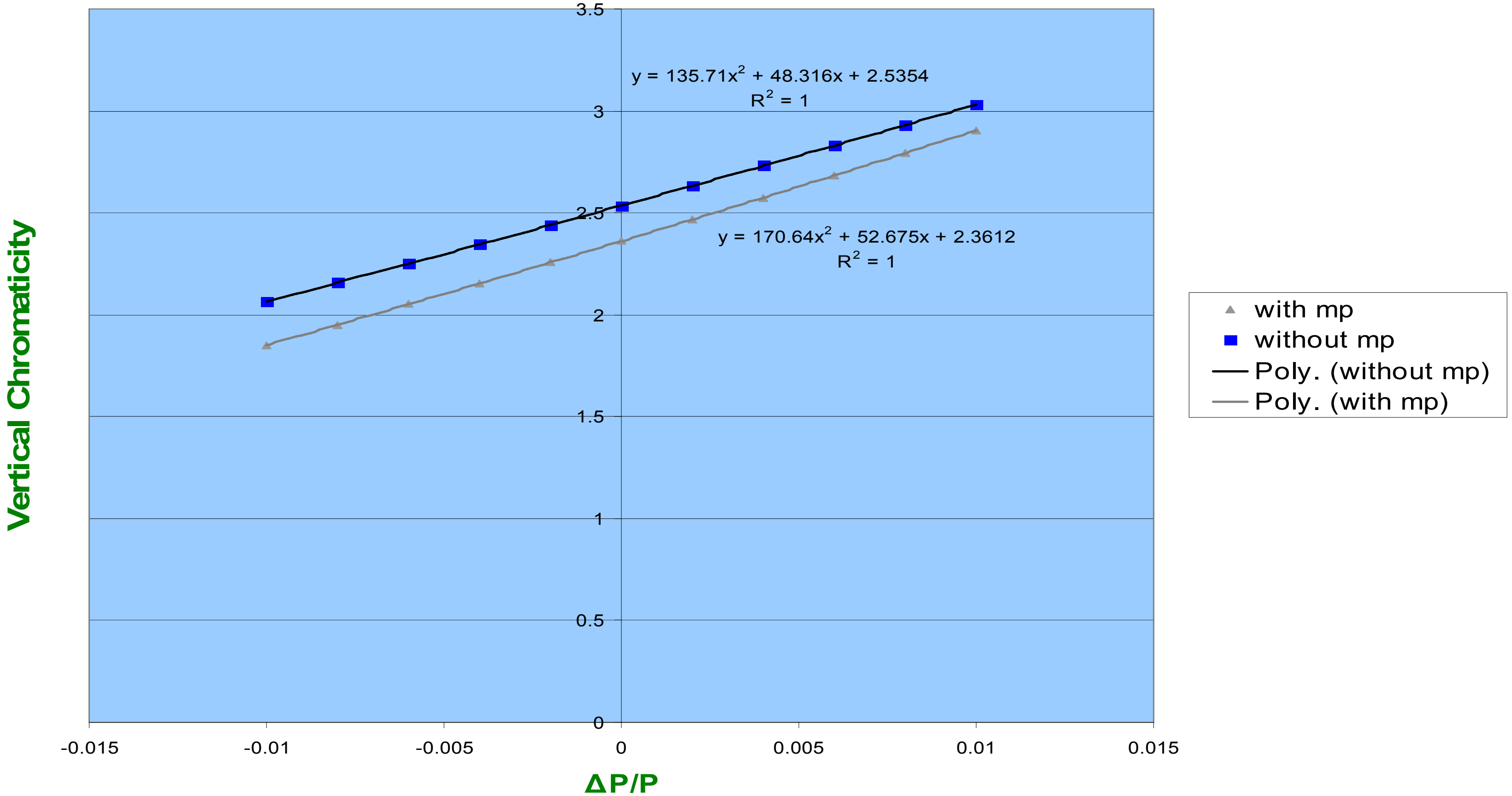
MAD-X Results (26 GeV)

- Horizontal Chromaticity vs ΔP/P



MAD-X Results (26 GeV)

- Vertical Chromaticity vs ΔP/P



Conclusions

- The simulation performed with Roxie show a clear effect on the PS magnet field coming from the shielding box of the BPMs, that has to be taken into account.
- Multipoles, up to the octupole component, have been used for modelling this effect in MAD-X. The results coming from these new model show that the **optical parameters** have not suffered great variation, but the effect is not **negligible**.
- The same study will be carried out for others energies (injection, 14 GeV), but no great differences are expected.