CORRECTION OF THE OCTUPOLE TERM INTRODUCED BY THE WIGGLER MAGNET

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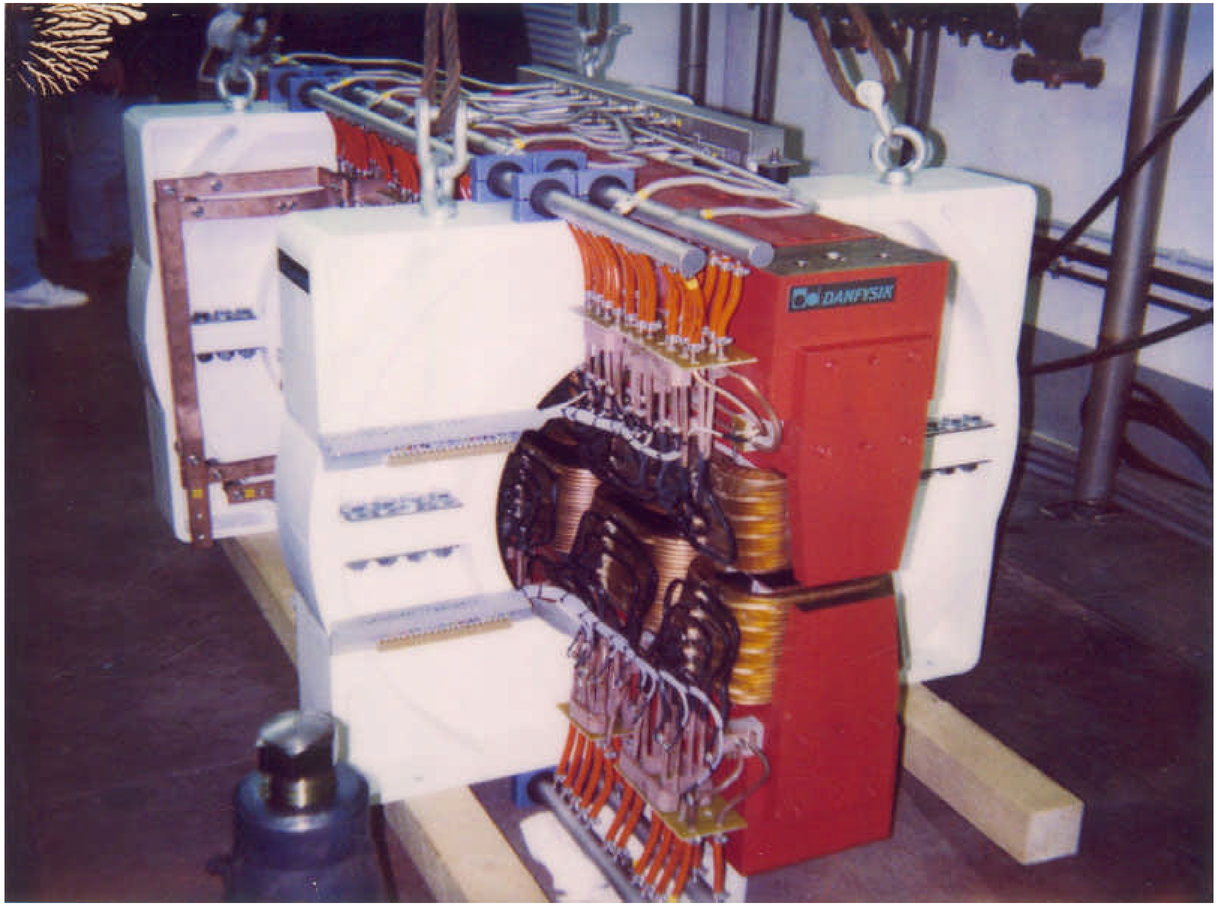
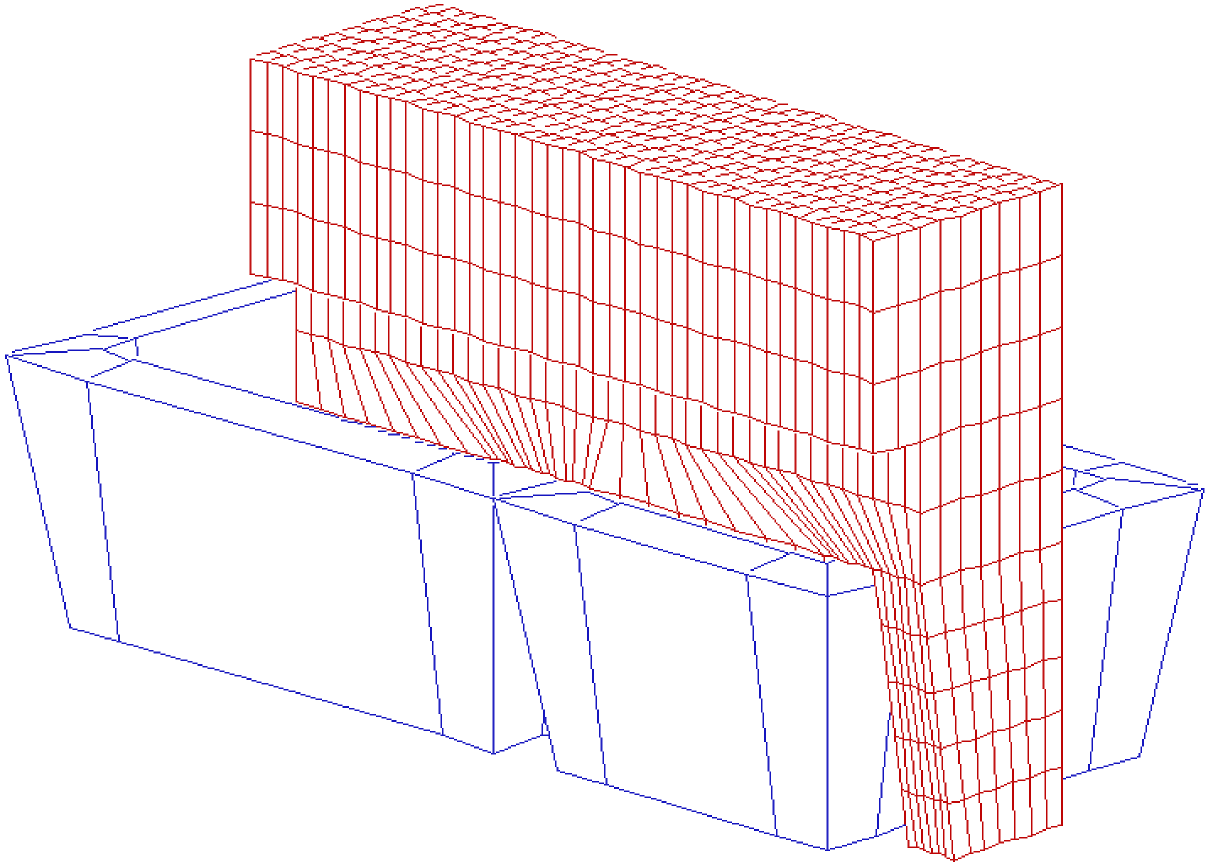
Preliminary considerations

- **Measurements with beam on the wiggler have shown the presence of an octupole-like term coming from the combination of a decapole term in the wiggler field with the wiggling trajectory of the beam**
- **The tune shift as a function of beam position in the wiggler has been fitted in the machine model with a single octupolar thin lens at the wiggler center and with 5 thin lenses, one in each pole**
- **The intensity of the octupole lens, according to the different models, in MAD units is**
- $$\mathbf{500\ m^{-3} < K_{MAD} < 1000\ m^{-3}}$$

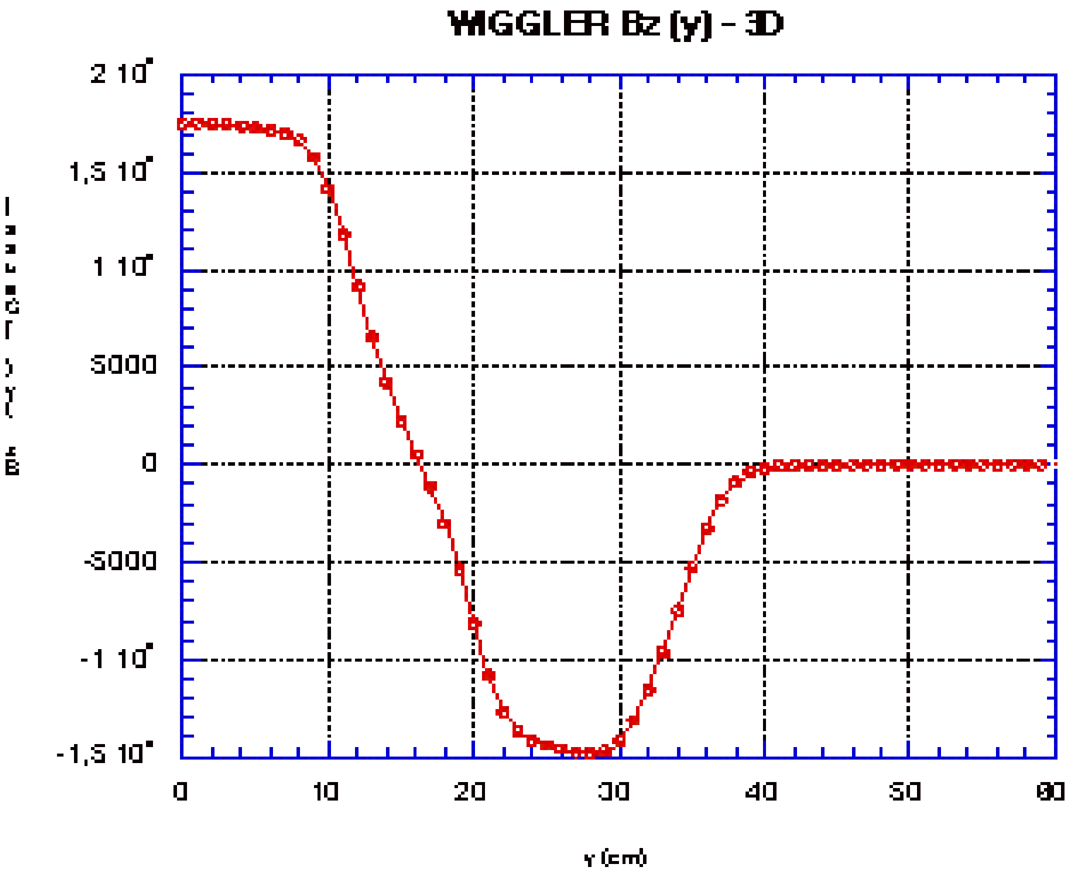
First attempt:
Wiggler end plate modification



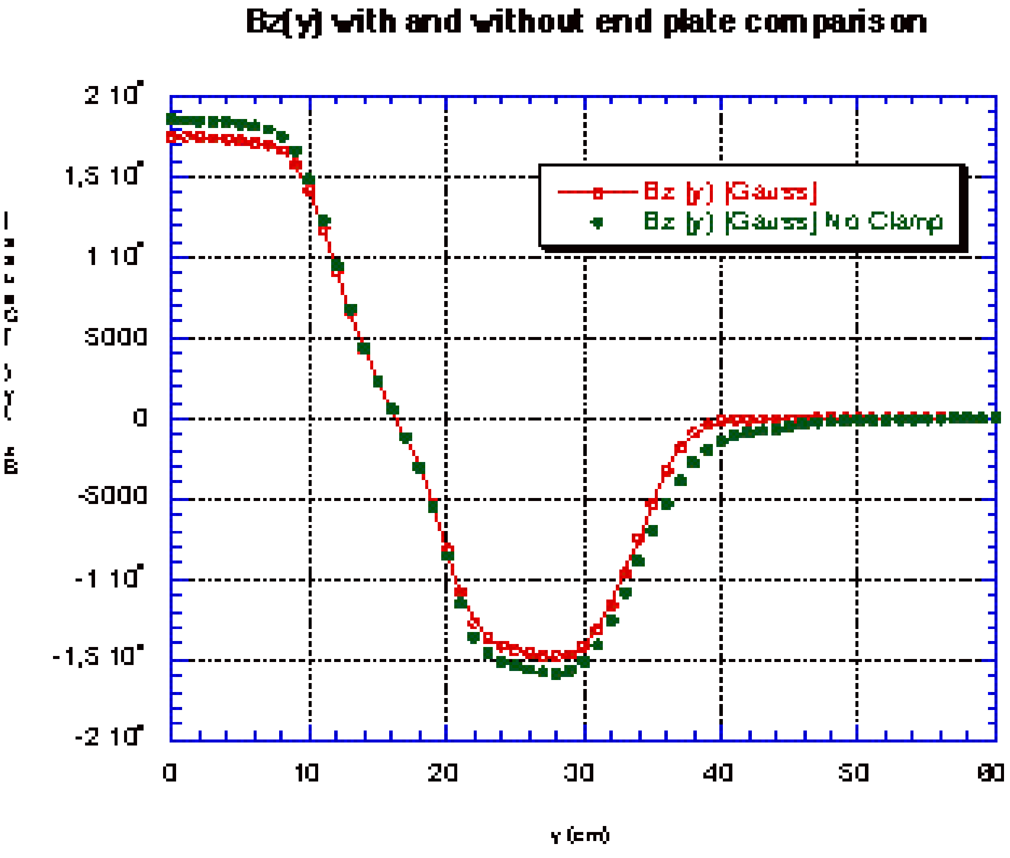
Wiggler 3D simulation



Longitudinal field profile (3D simulation)

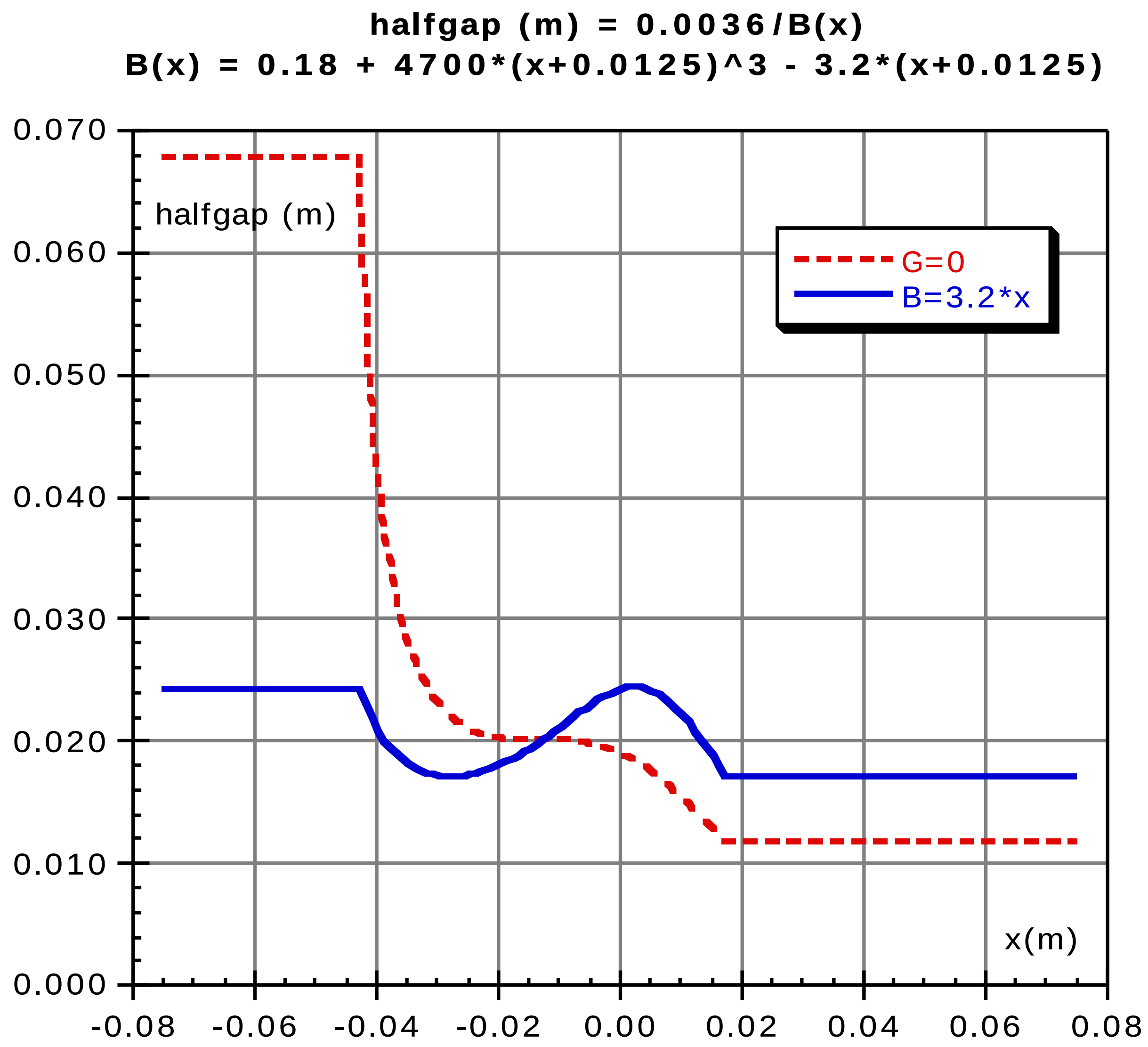


Longitudinal field profile comparison with and without end plate

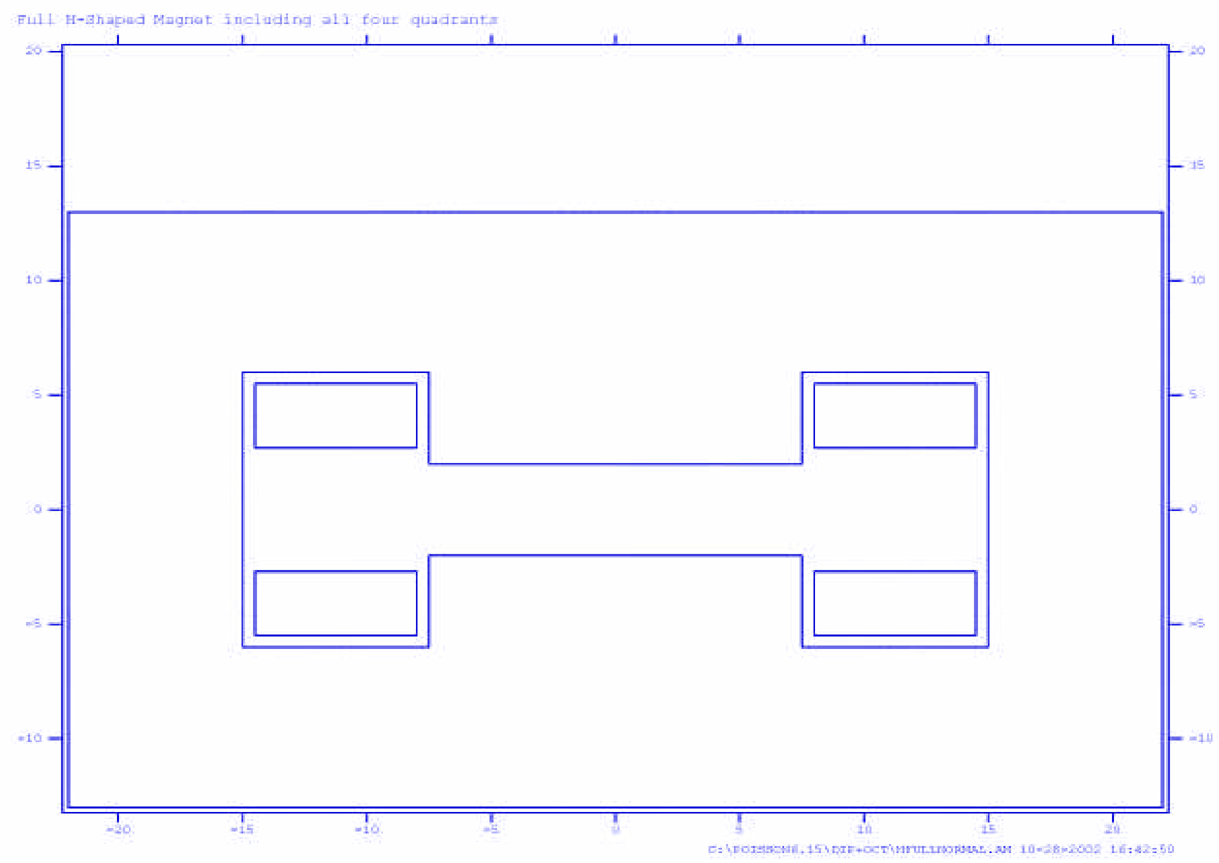


Naive approach to endplate profile shaping

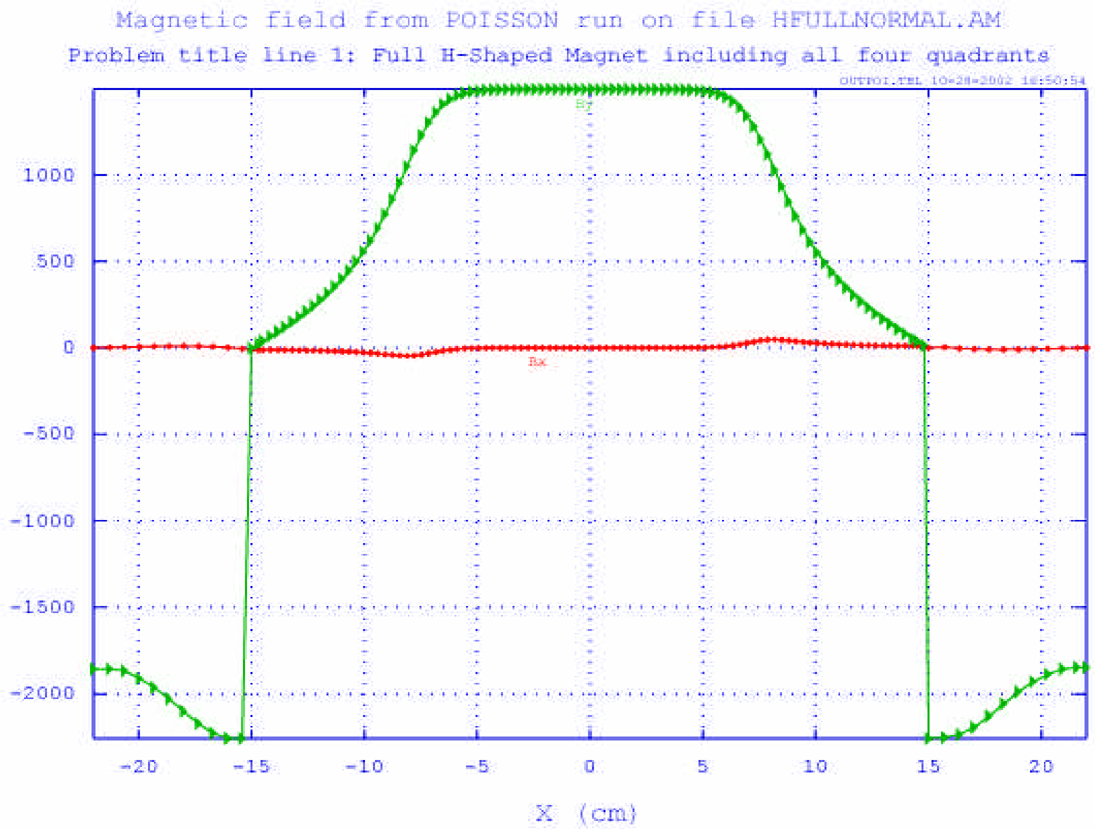
- **Assume field inversely proportional to endplate gap g:**
- $$(B_c + hx^3)*g = const = B_c*g$$
- **Assume endplate contribution to the field from magnetic calculations $B_c \approx 0.18$ T**
- **Add linear term in the field to avoid excessive reduction of the gap:**
- $$(B_c + kx + hx^3)*g = const = B_c*g$$
- **Truncate gap oscillation to constant to avoid excessive reduction of the gap**
- **Run magnetic calculation to find the real field**


halfgap (m) = 0.0036/B(x)
B(x) = 0.18 + 4700*(x+0.0125)^3 - 3.2*(x+0.0125)
halfgap (m)
G=0
B=3.2*x
x(m)
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
-0.08
-0.06
-0.04
-0.02
0.00
0.02
0.04
0.06
0.08

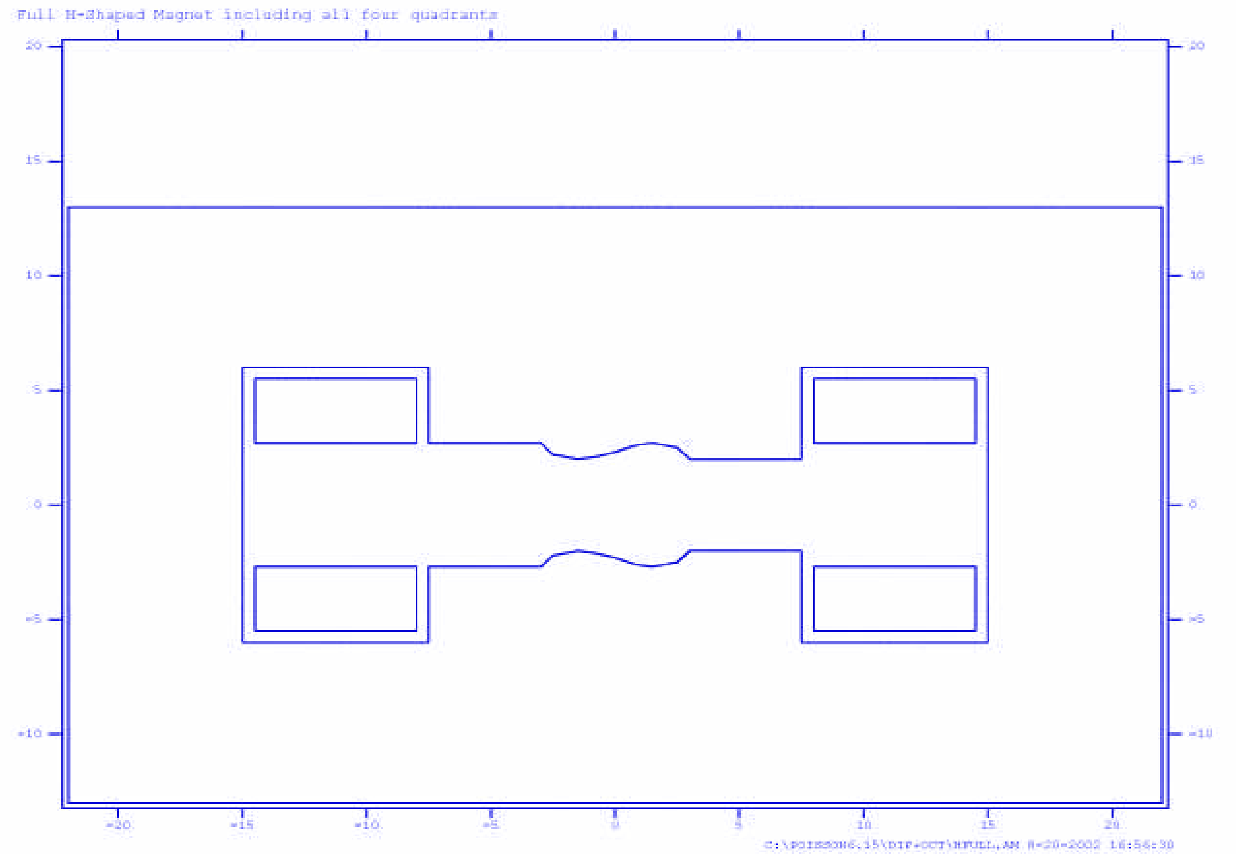
End plate 2D simulation



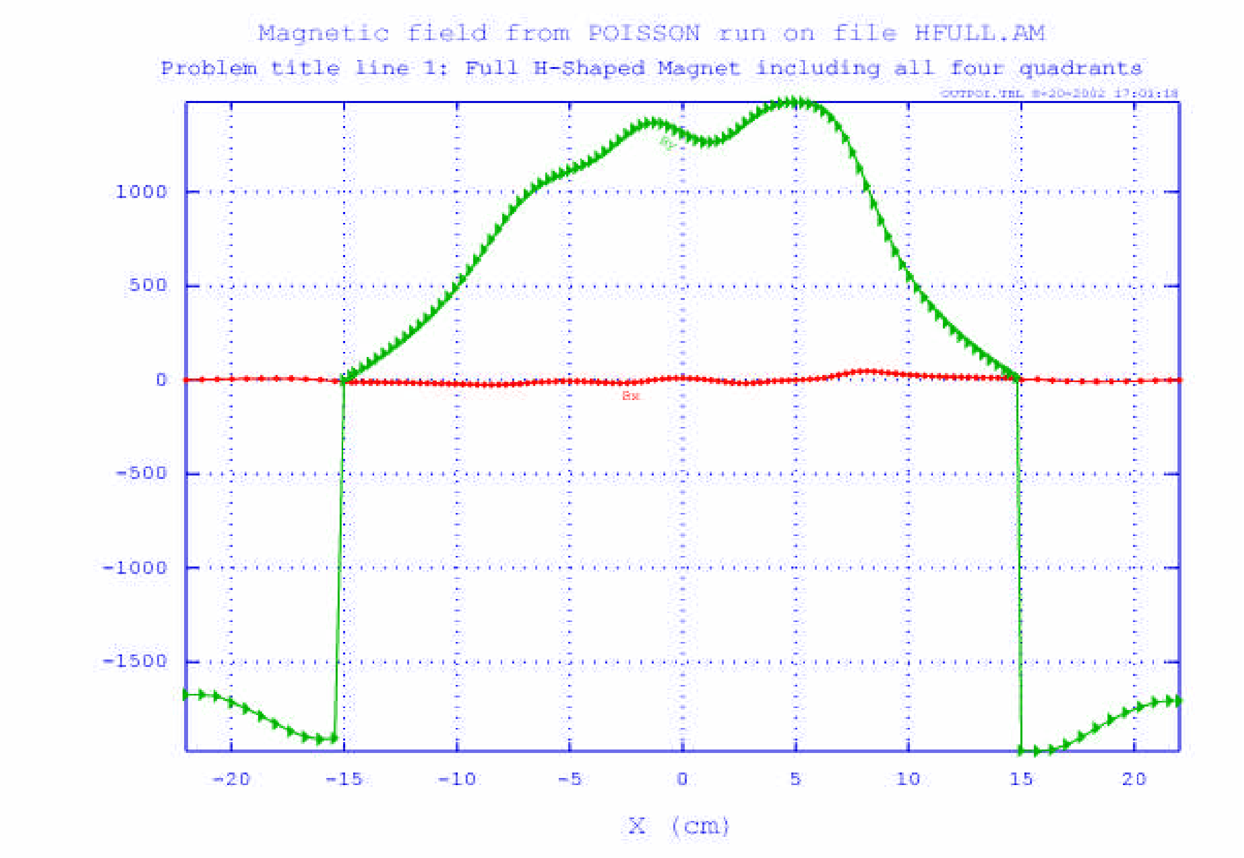
Transverse field profile under the end plate – no shaping



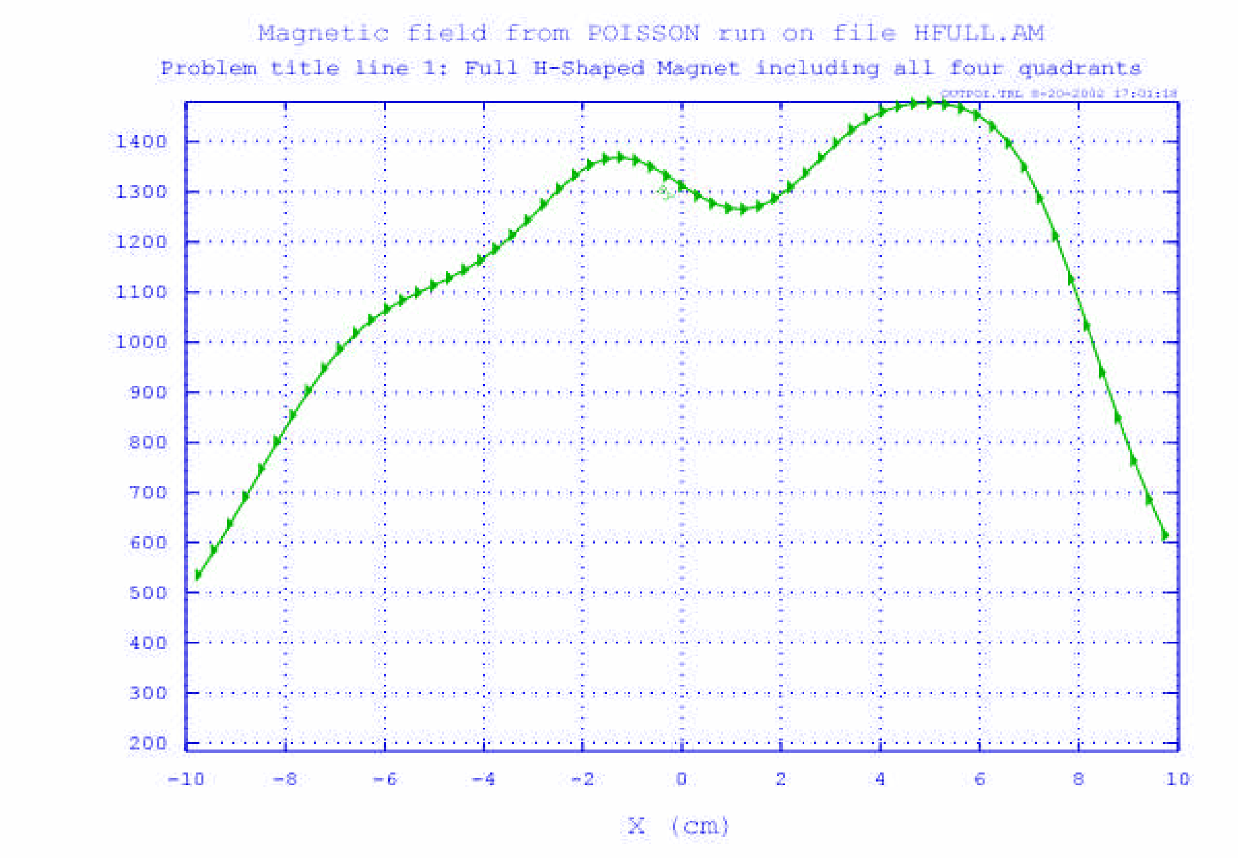
End plate shaping (2 D simulation)

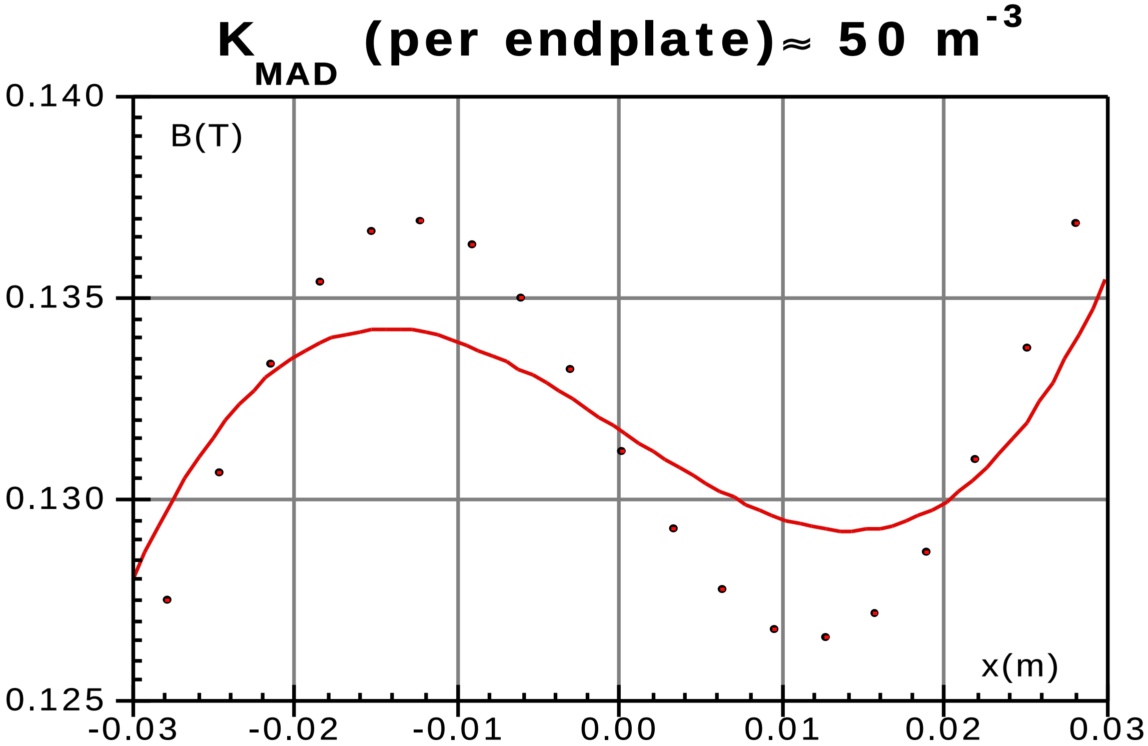


Transverse field profile under the end plate



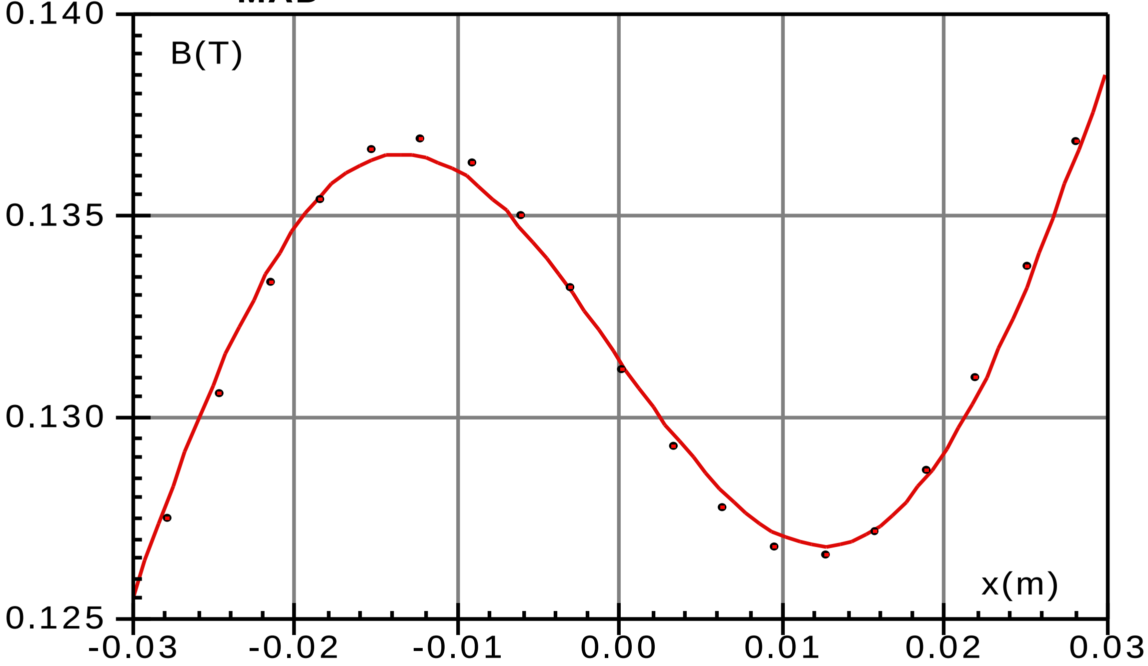
Field profile modification





Y = M0 + M1*x + ... M8*x^8 + M9*x^9	
M0	0.13171
M1	-0.26269
M2	0.095223
M3	431.42
R	0.95406

K_{MAD} (per endplate) ≈ 135 m^{-3}



$Y = M0 + M1*x + \dots M8*x^8 + M9*x^9$	
M0	0.13141
M1	-0.57437
M2	1.8053
M3	1259.3
M4	-1160.9
M5	-4.2274e+05
R	0.99854

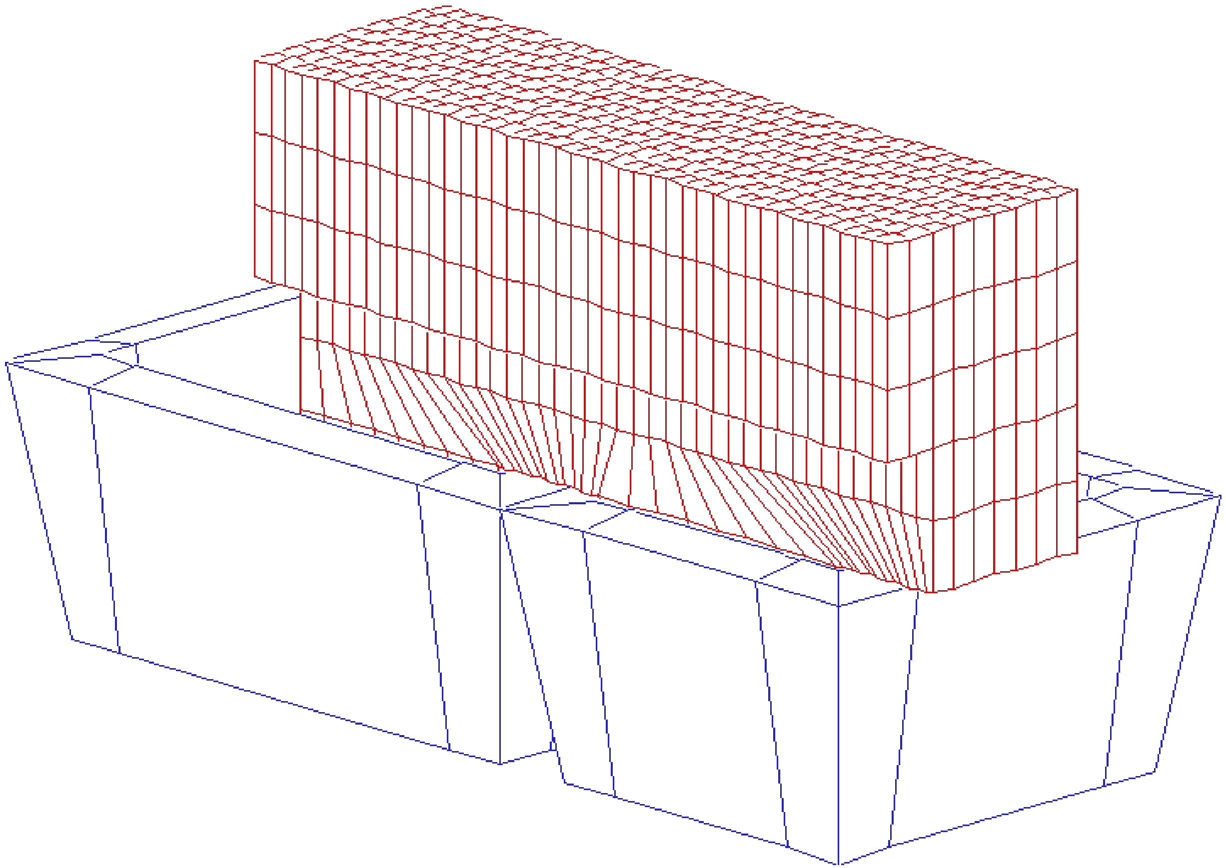
1st Attempt: Conclusions

- Bad magnetic field profile
- Insufficient octupole term correction

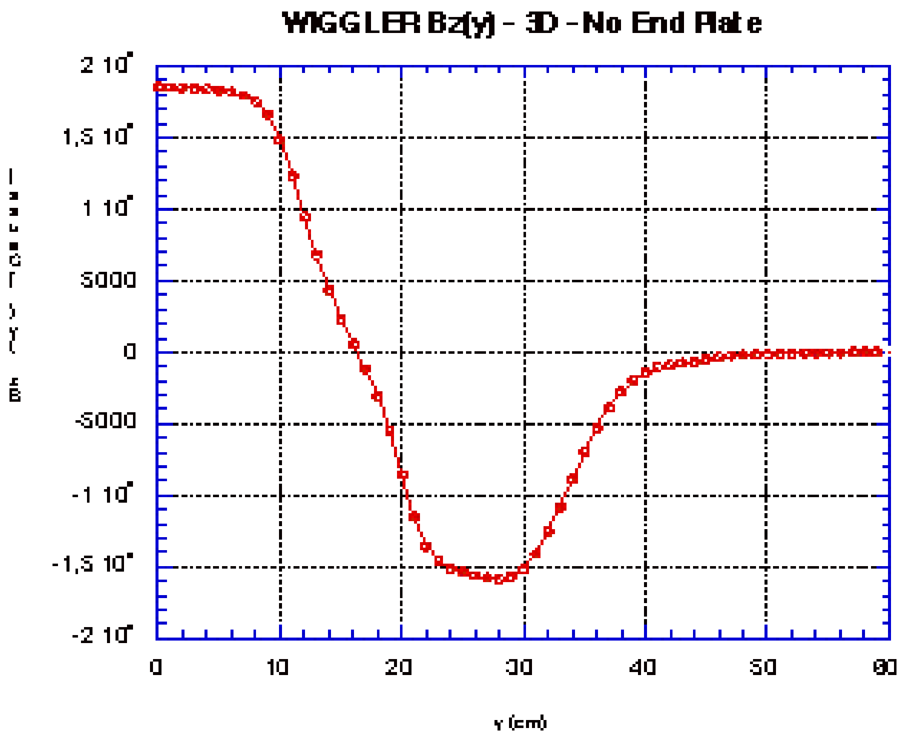
<u>DISCARDED</u>

Second attempt:

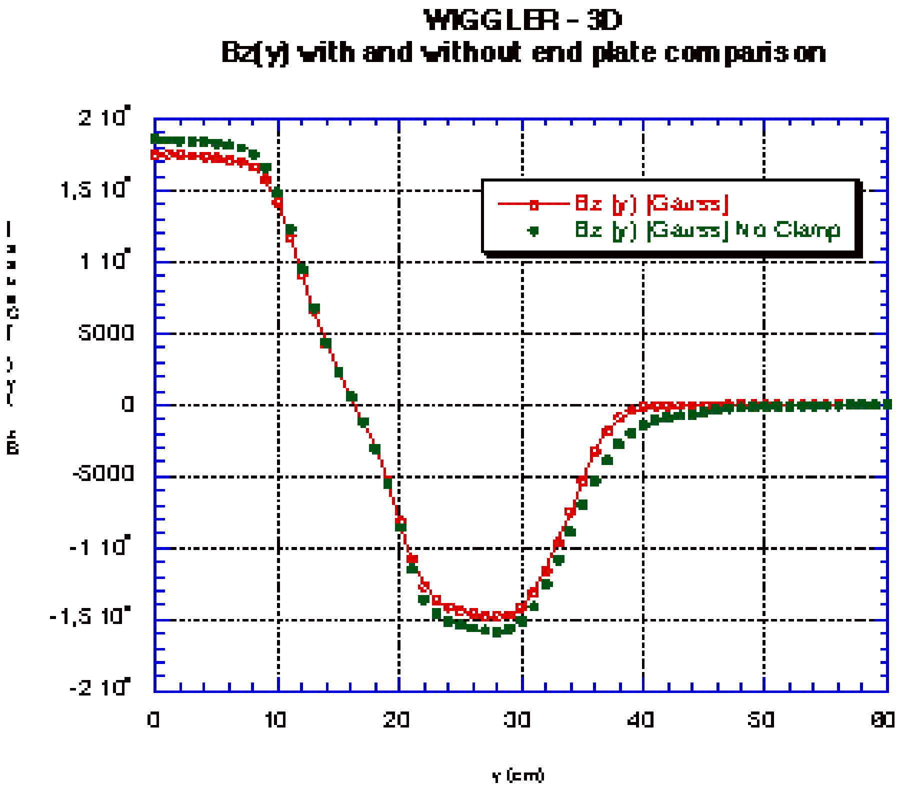
Substitution of the end plate with PM blocks



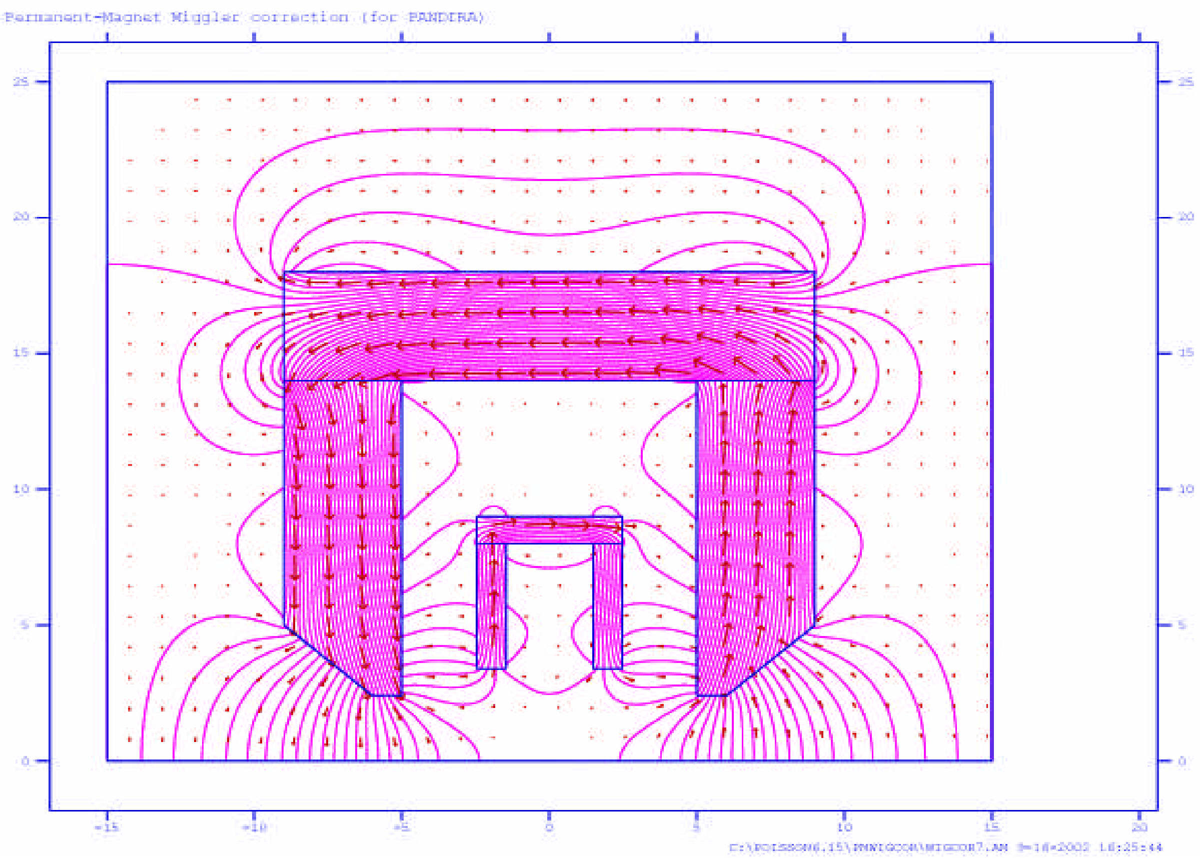
Longitudinal field profile
(3 D simulation)



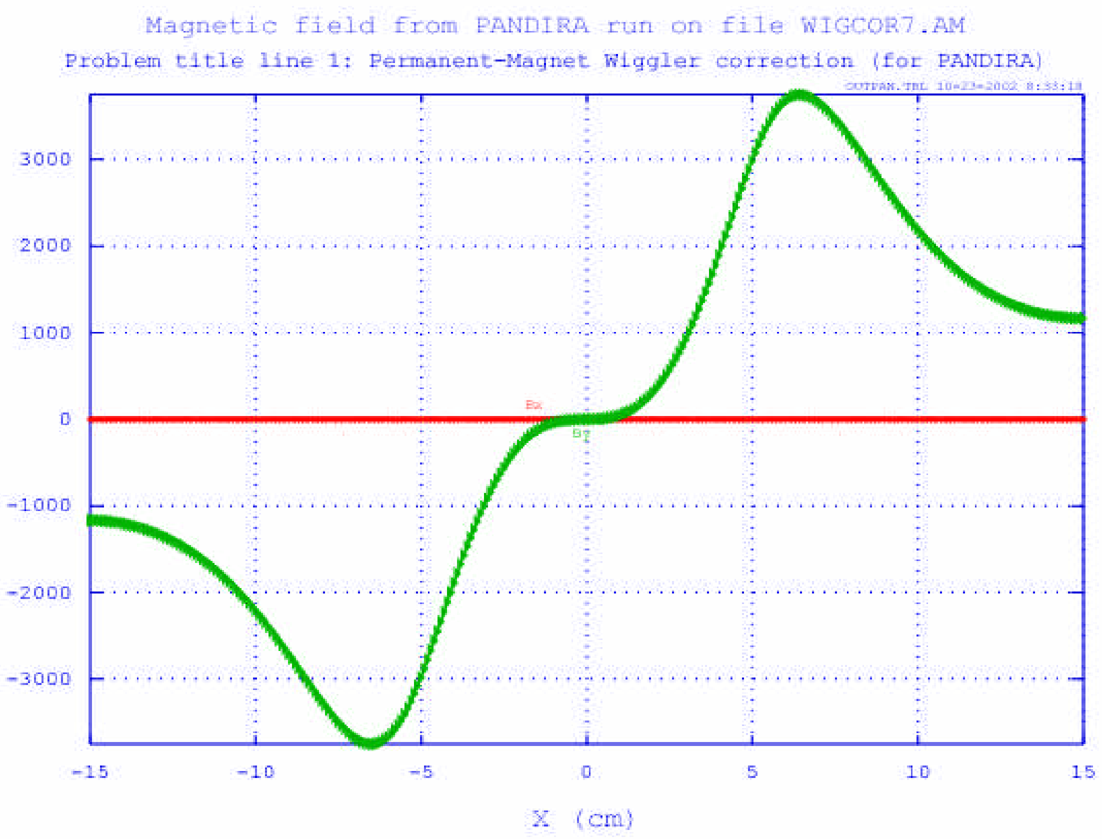
Longitudinal field profile comparison with and without end plate



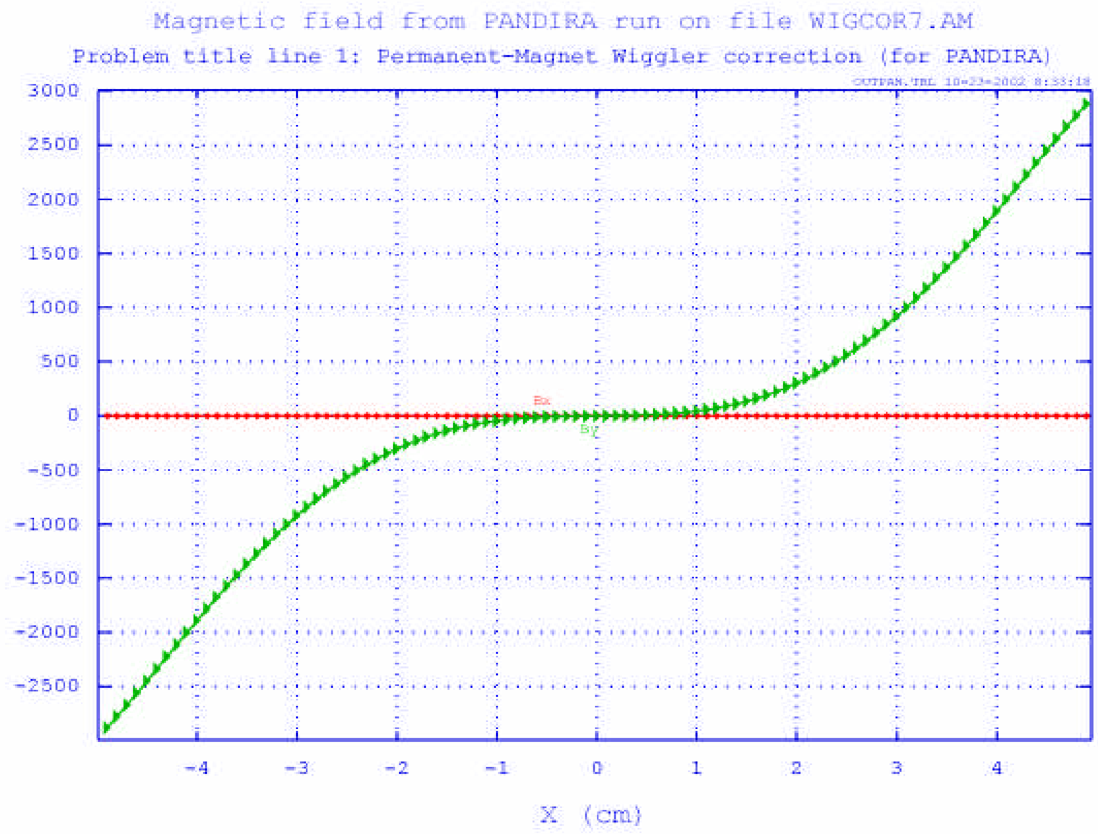
PM Block geometry
(2 D simulation)



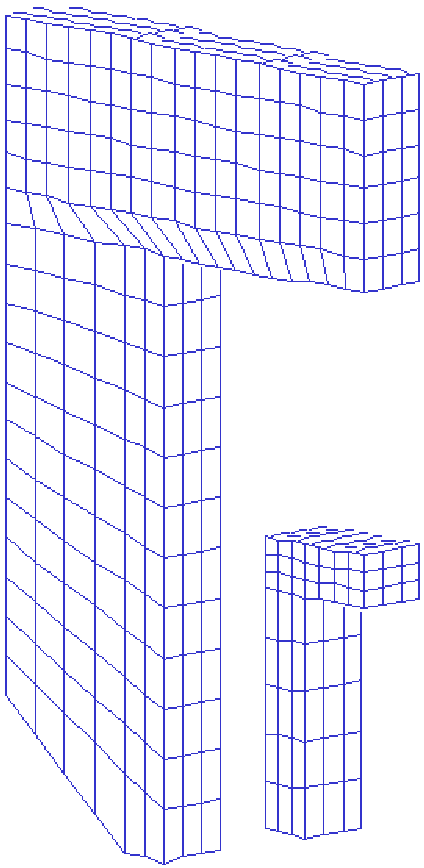
Transverse magnetic field profile



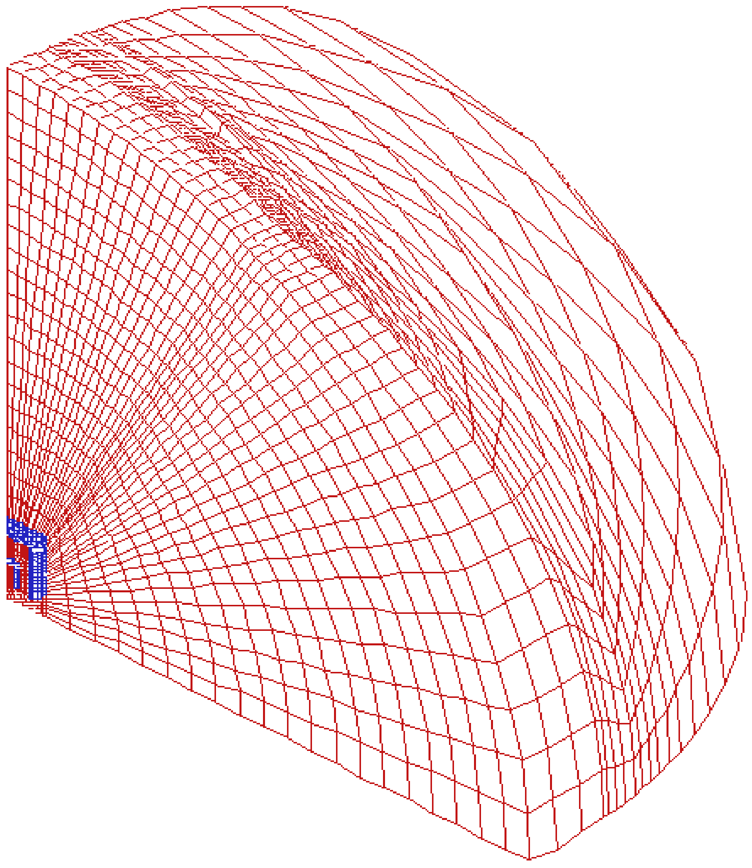
Magnetic field near the beam axis



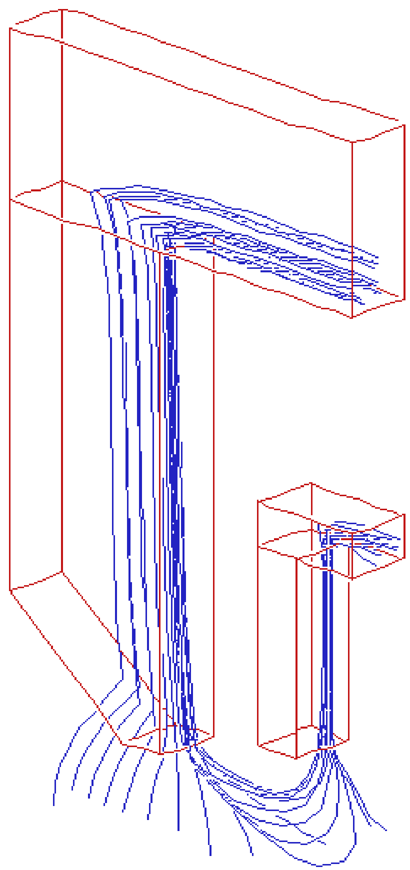
PM Blocks – 3 D geometry



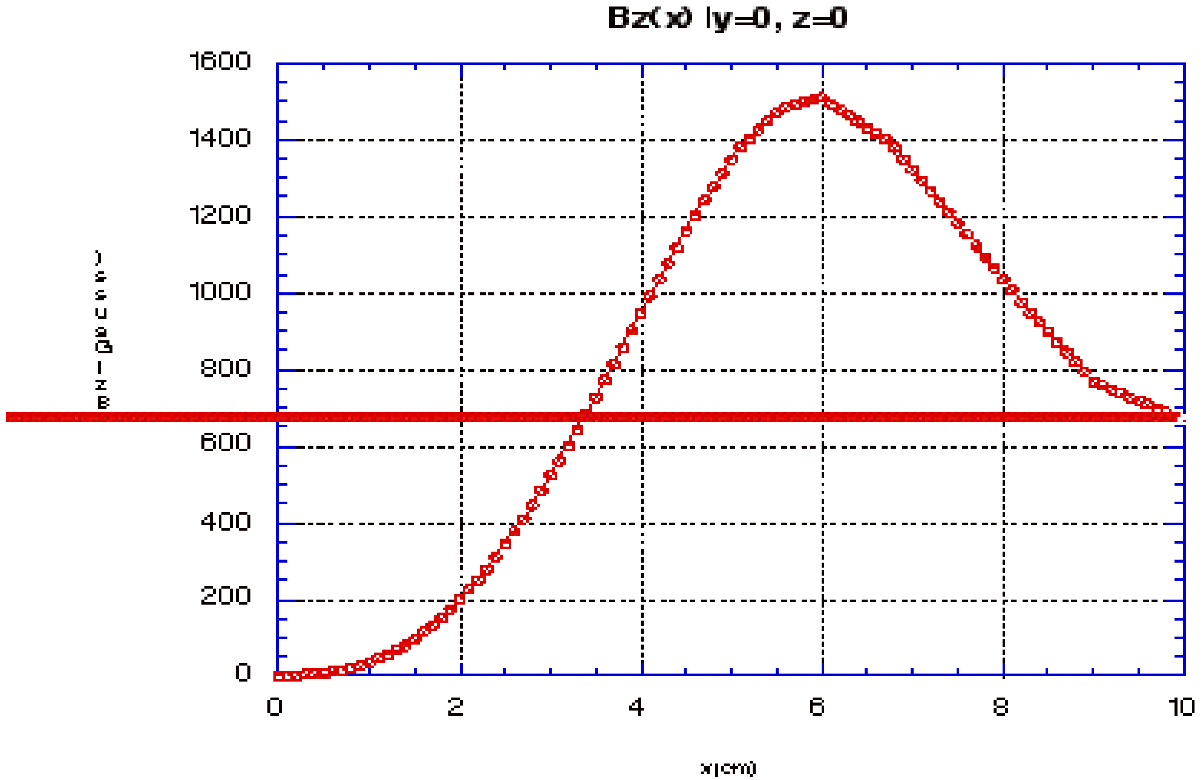
PM Blocks – 3 D solution area



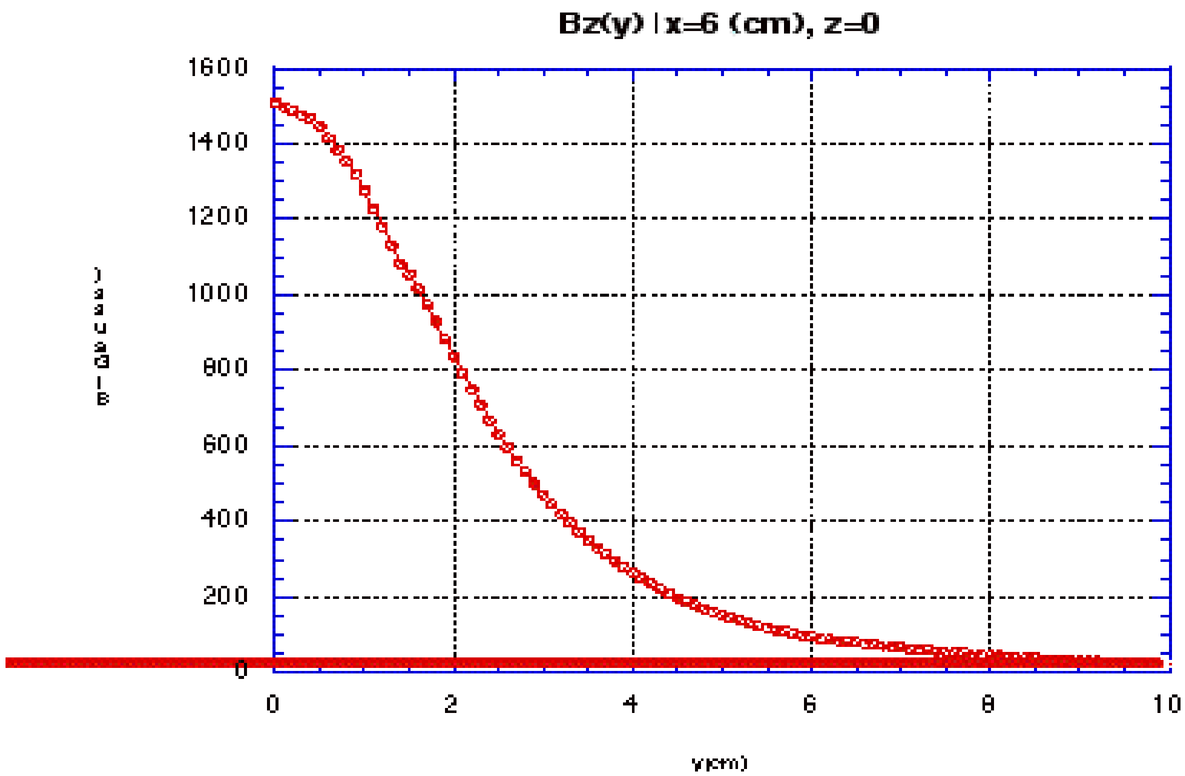
PM Blocks – 3 D solution



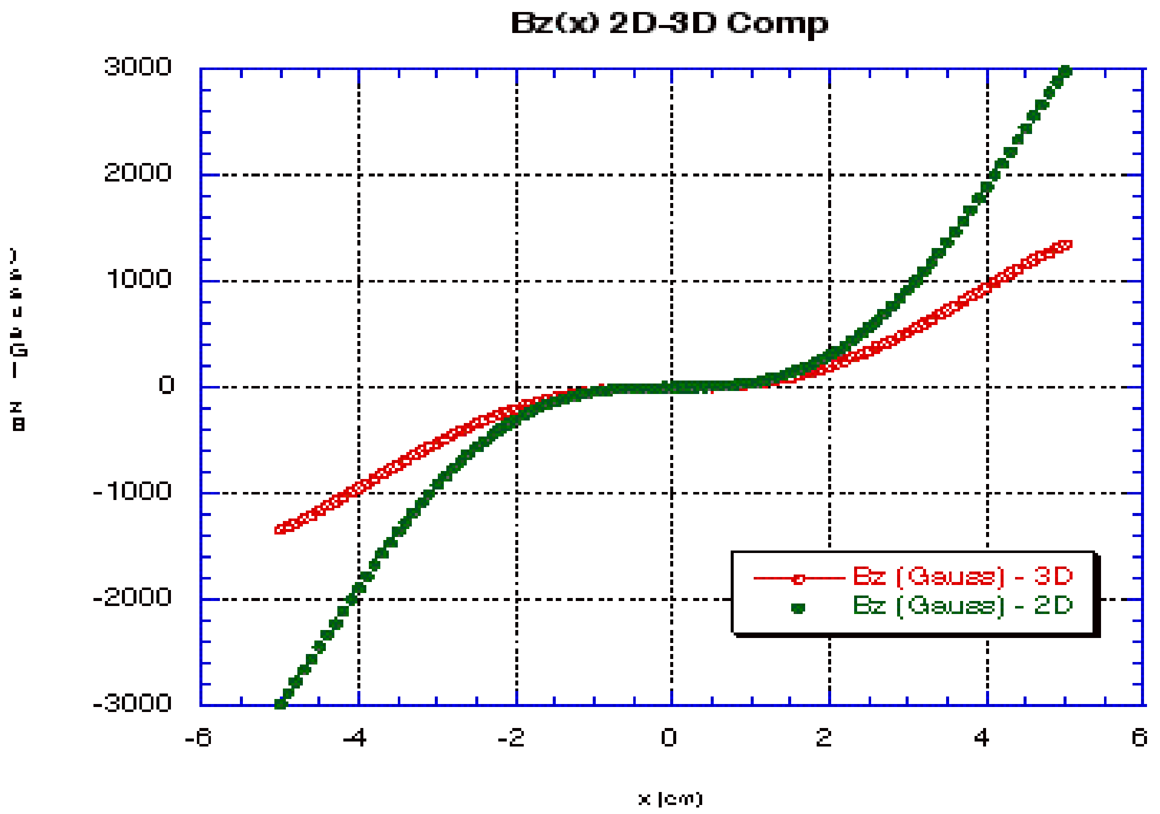
Transverse magnetic field profile



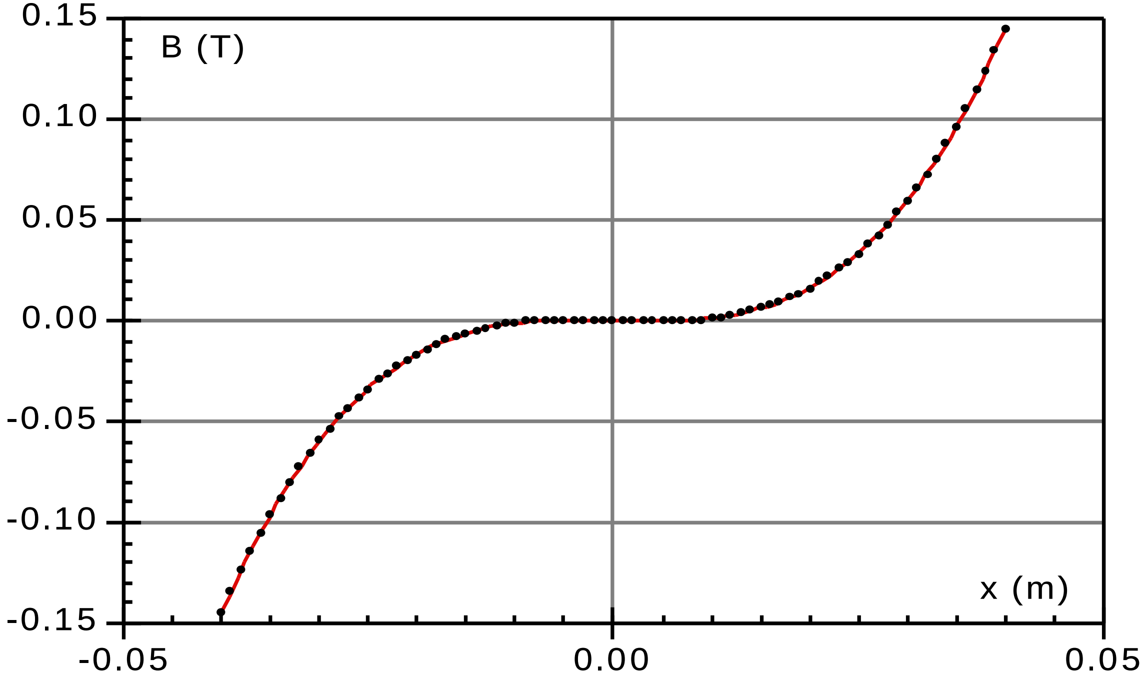
Longitudinal magnetic field profile



2 D – 3 D comparison
Transverse field profile

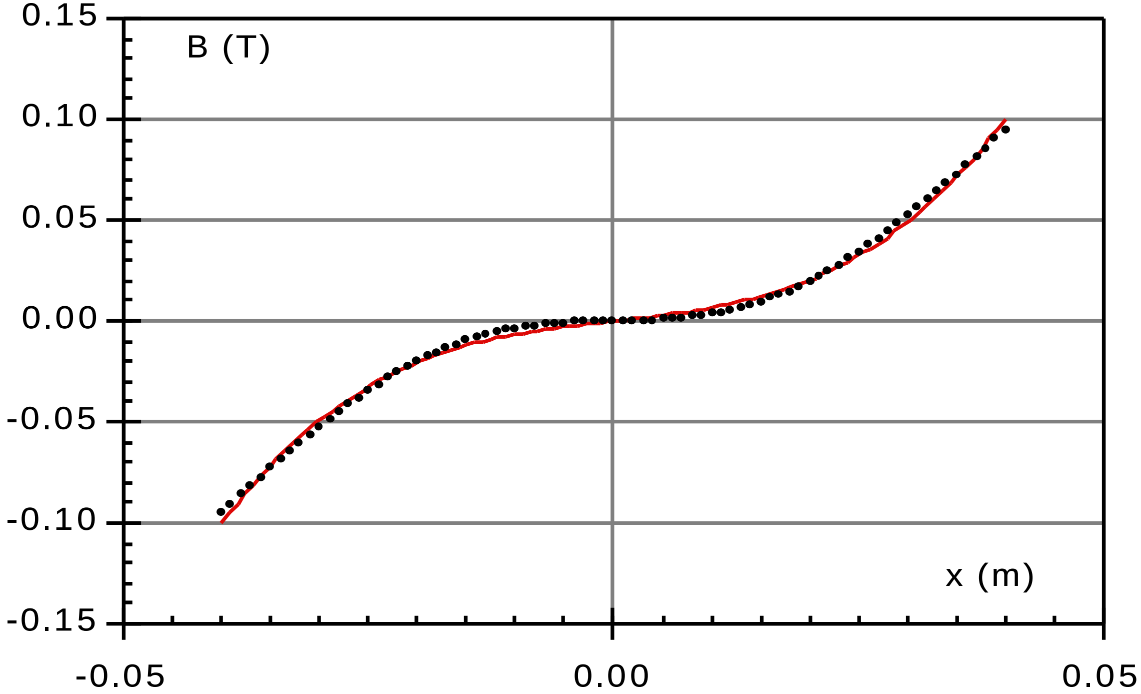


2-D $K_{MAD} \approx 230\ m^{-3}$ (per endplate)



$Y = M0 + M1*x + \ldots M8*x^8 + M9*x^9$	
M0	2.0254e-07
M1	-0.12356
M2	-0.00010666
M3	2343.8
R	1

3-D $K_{MAD} \approx 120\ m^{-3}$ (per endplate)



$Y = M0 + M1*x + \ldots M8*x^8 + M9*x^9$	
M0	-7.9512e-18
M1	0.52448
M2	1.0372e-14
M3	1239.5
R	0.9985

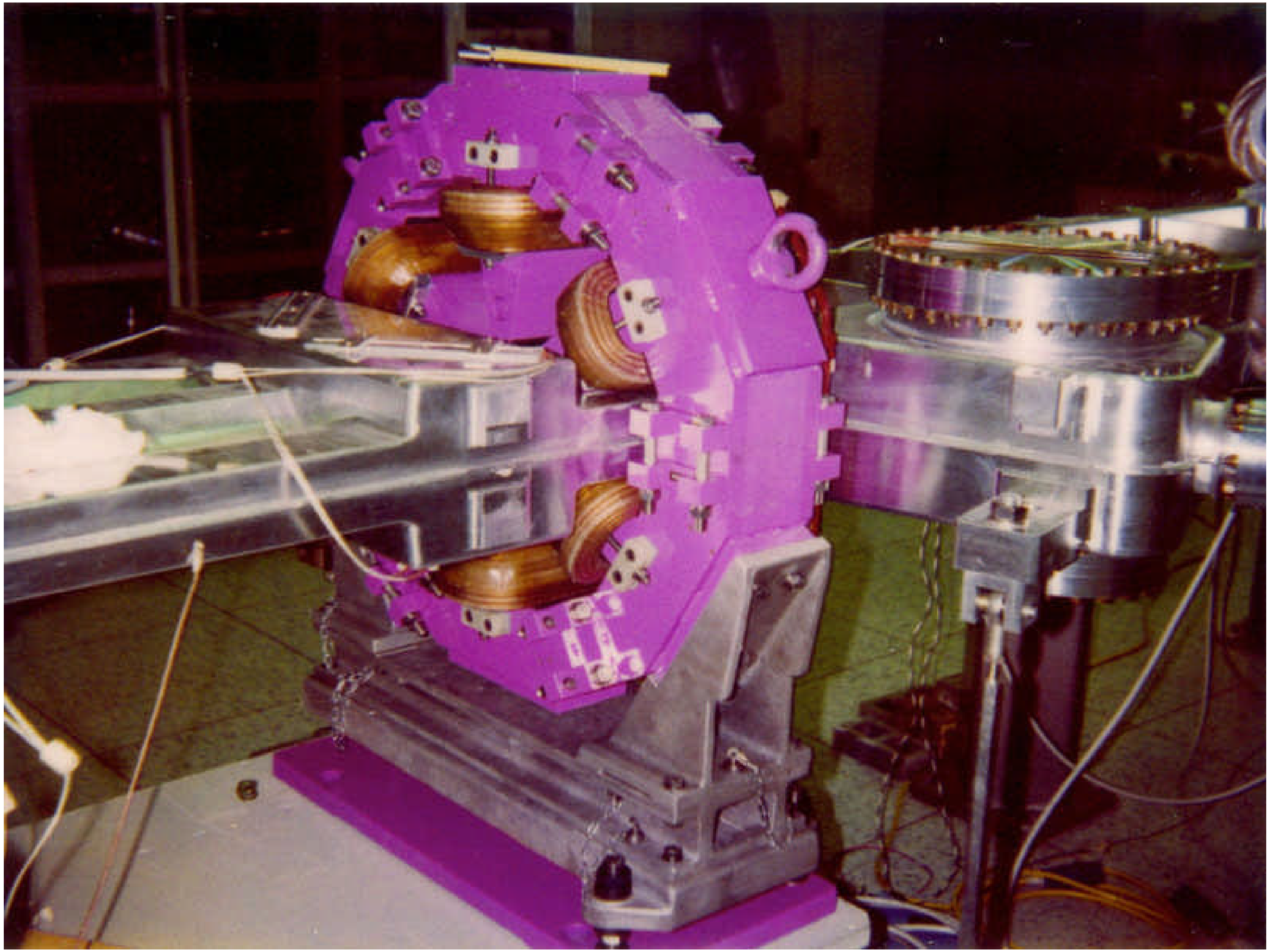
2nd Attempt: Conclusions

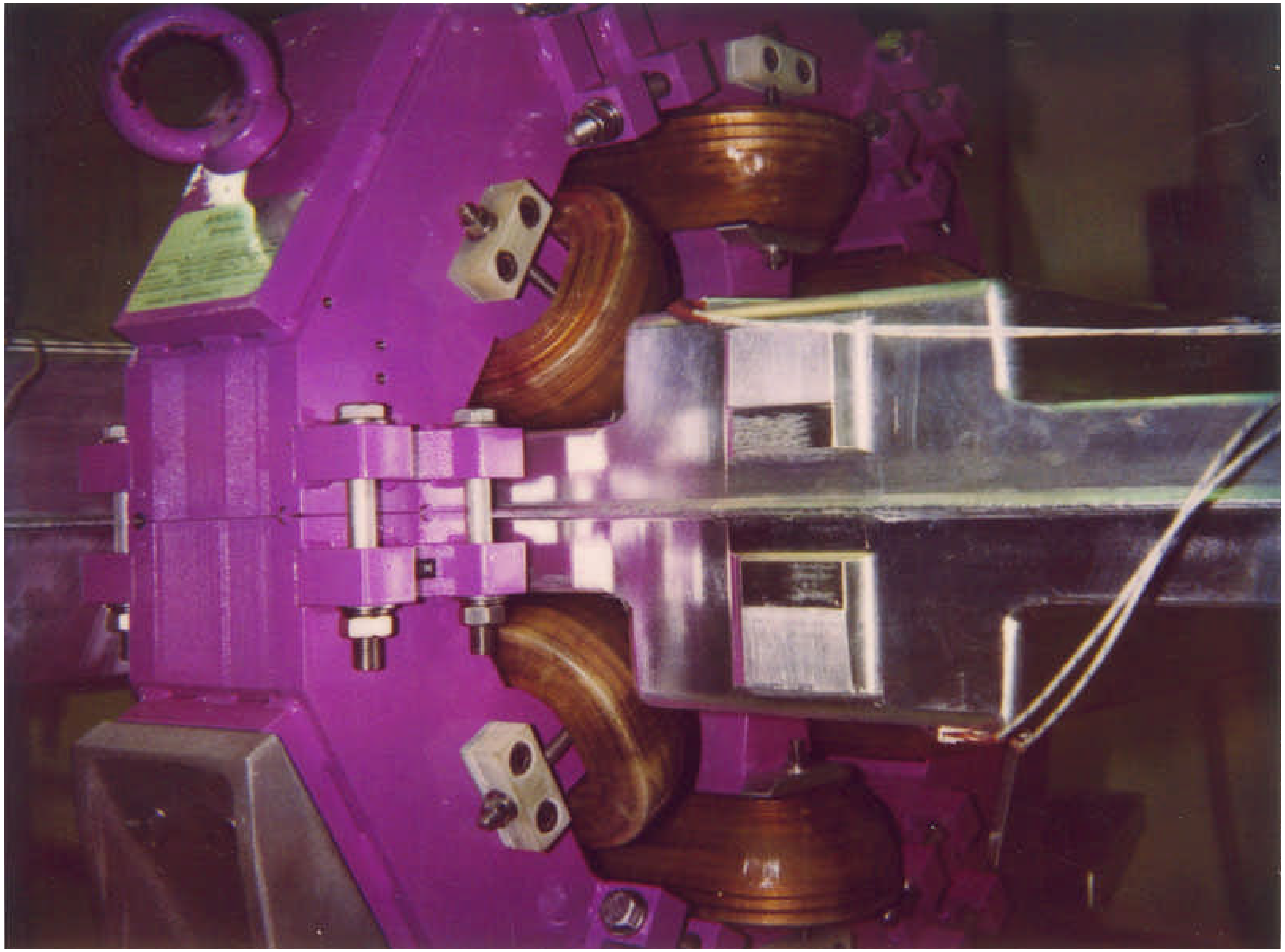
- Acceptable field quality but very critical with respect to magnet position and size
- Insufficient octupole term correction

DISCARDED

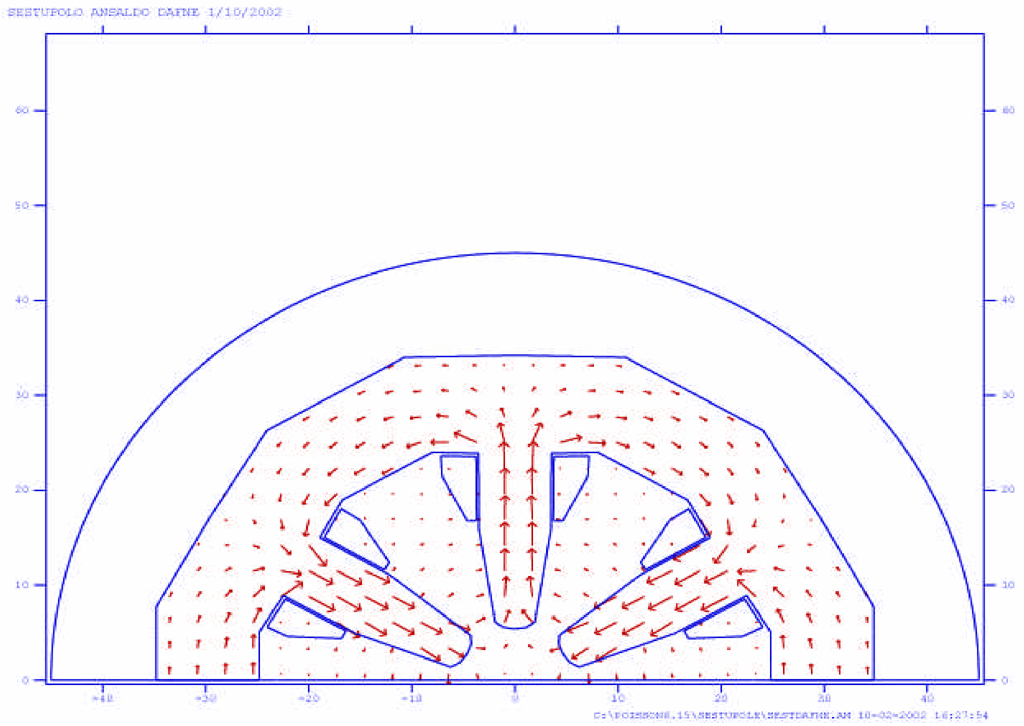
Third attempt:

Octupole correction added into ANSALDO Large Sextupole by means of a wired, air cooled, coil

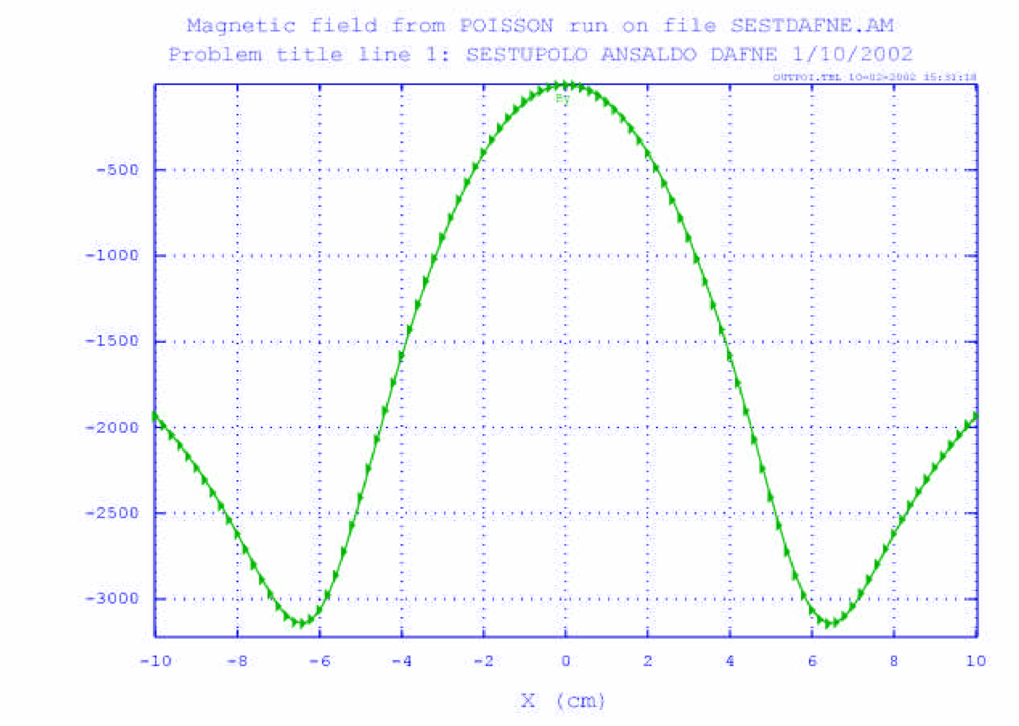




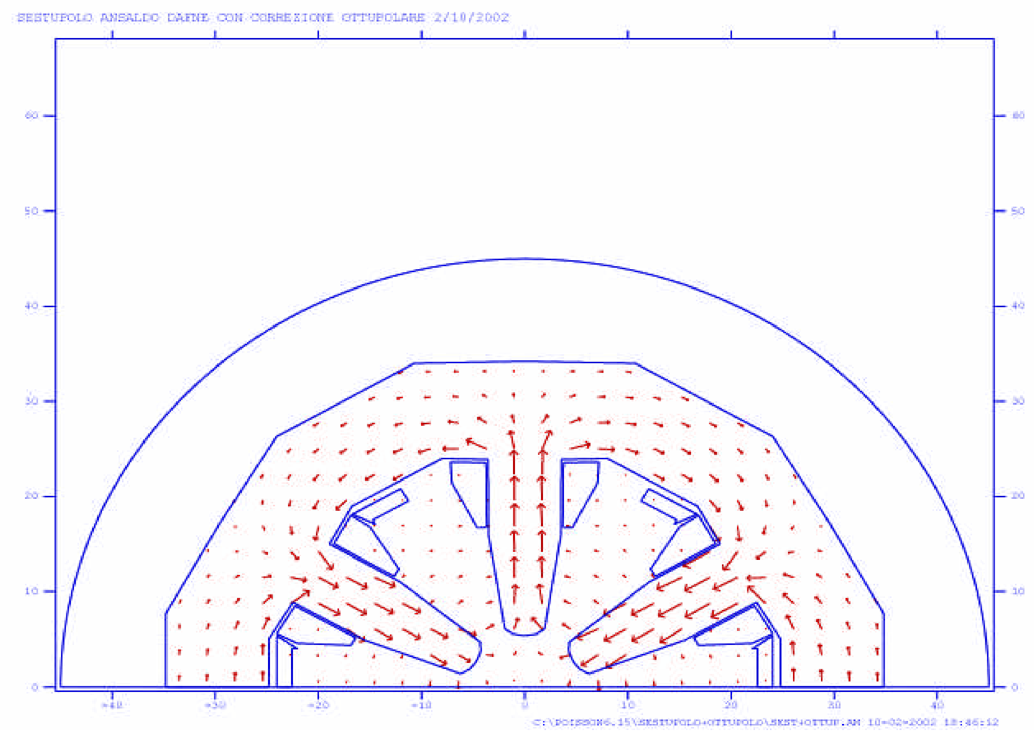
Sextupole 2D simulation



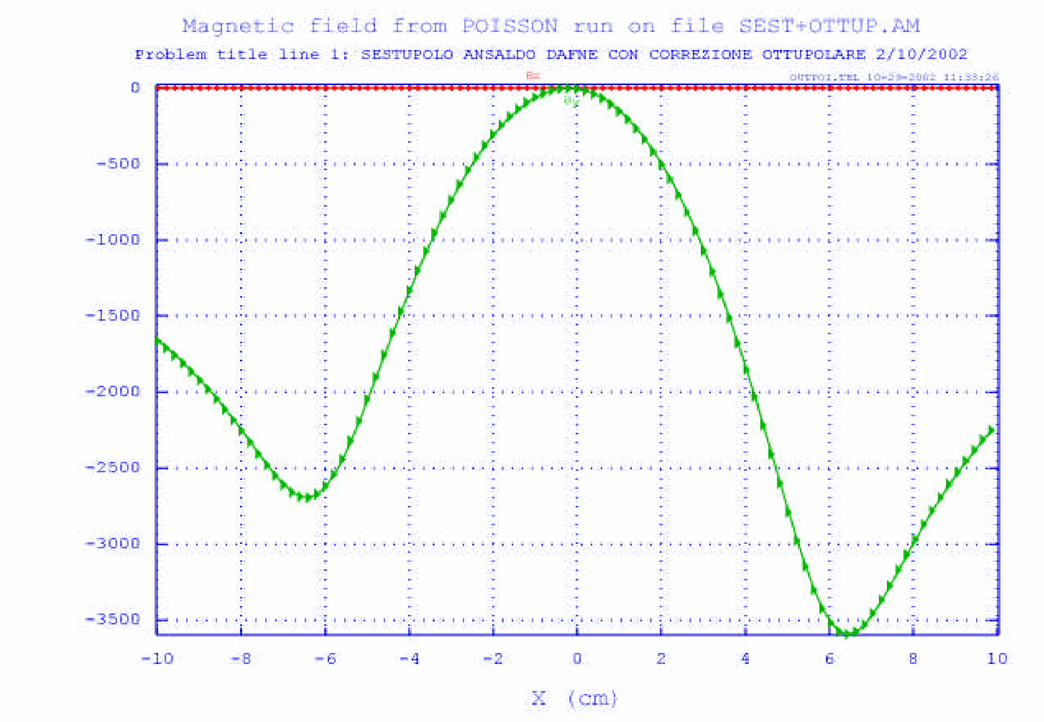
L.S. Symmetric Sextupole Field Profile



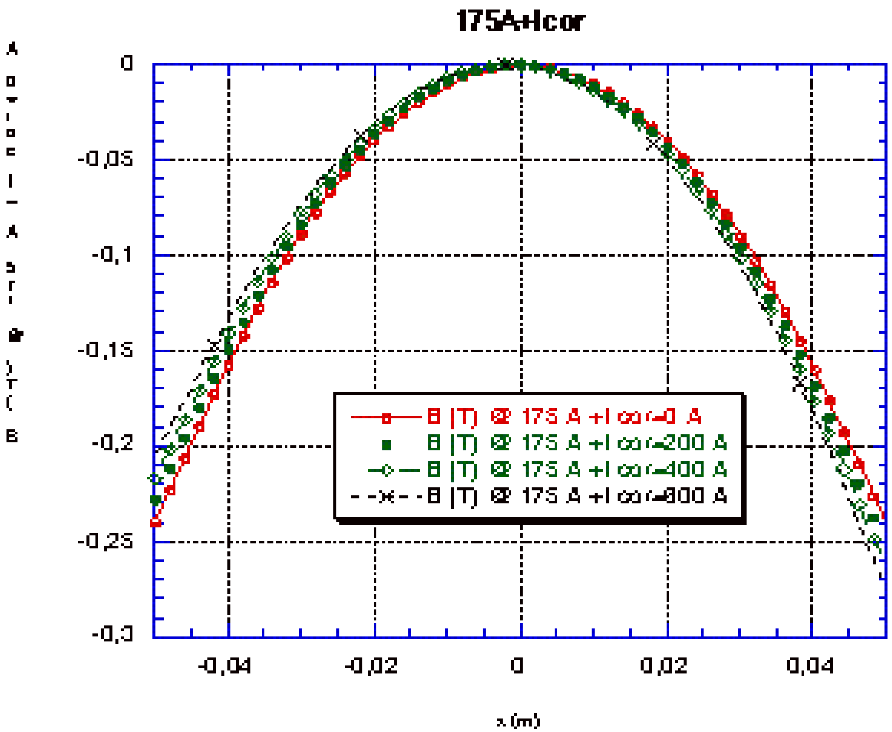
Sextupole + Octupole



Sextupole + Octupole
Icorr = 600 A-turns

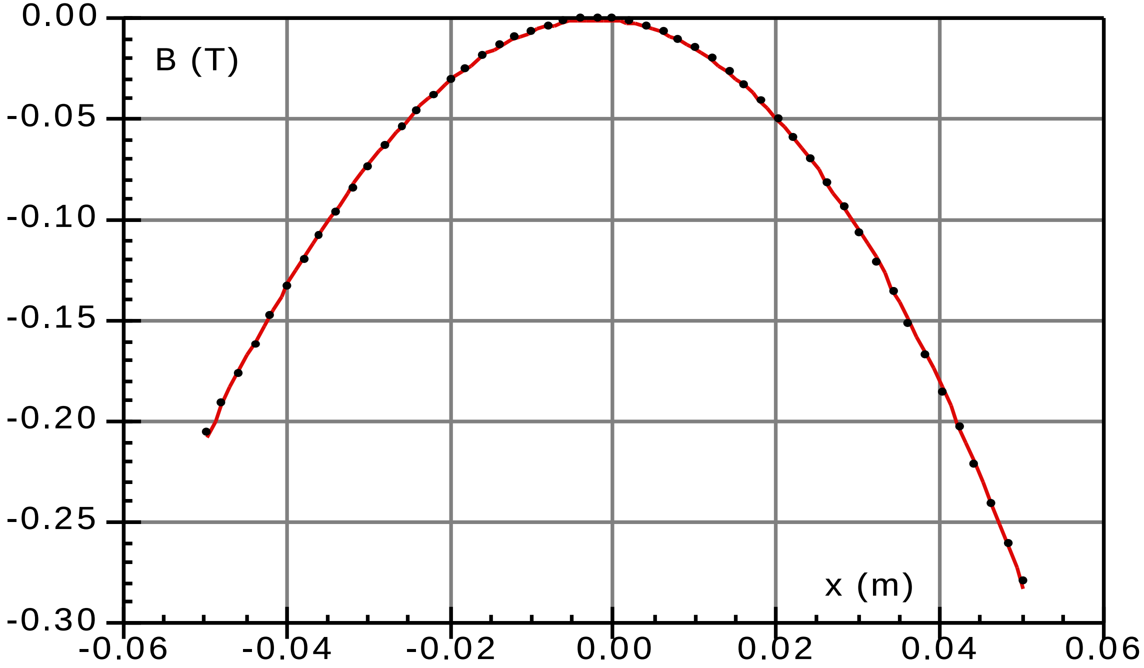


Sextupole + Octupole correction Bz(x, Icorr)



Sextupole @ 175A, Octupole @ 600A

$K_{MAD} \approx 60\ m^{-3}$



$Y = M0 + M1*x + ... M8*x^8 + M9*x^9$	
M0	-0.0013124
M1	-0.42625
M2	-97.241
M3	-111
R	0.9999

3rd Attempt: Conclusions

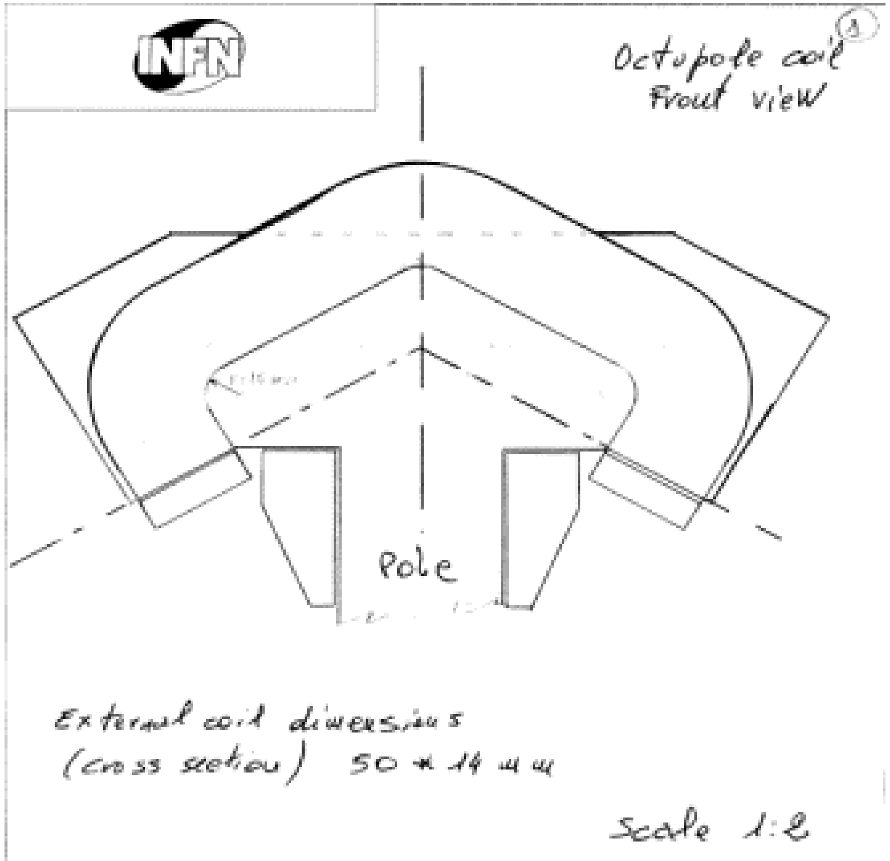
- Reasonably good magnetic field profile
- Insufficient octupole term correction

DISCARDED

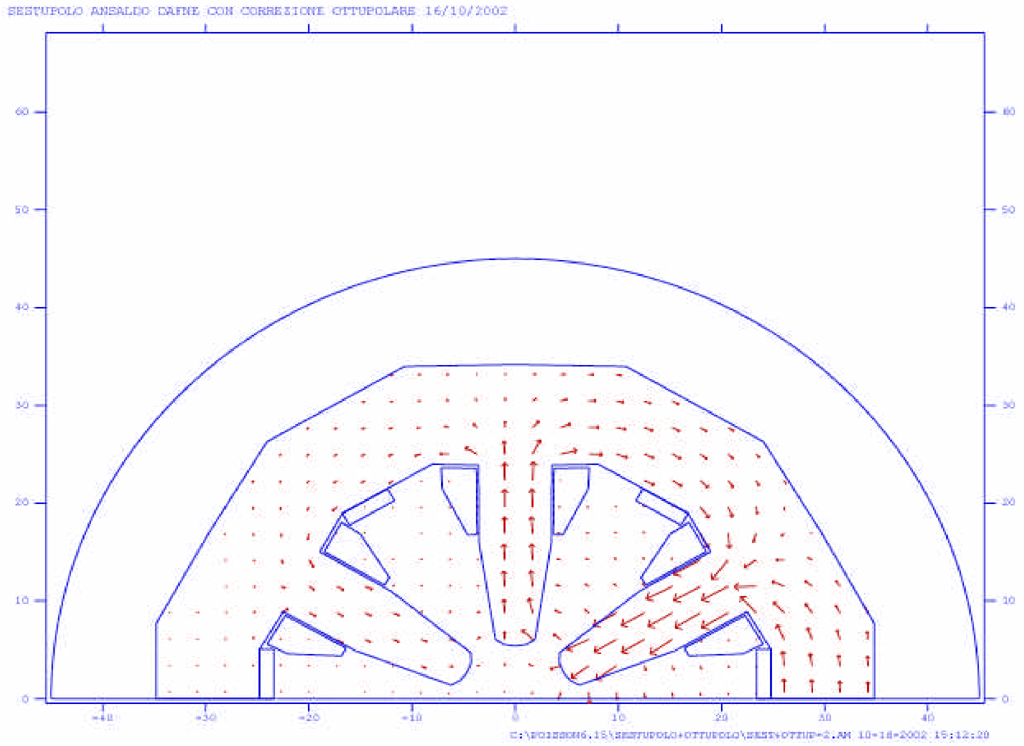
Fourth attempt:

Octupole correction added into
ANSALDO Large Sextupole
by means of a
water cooled, coil

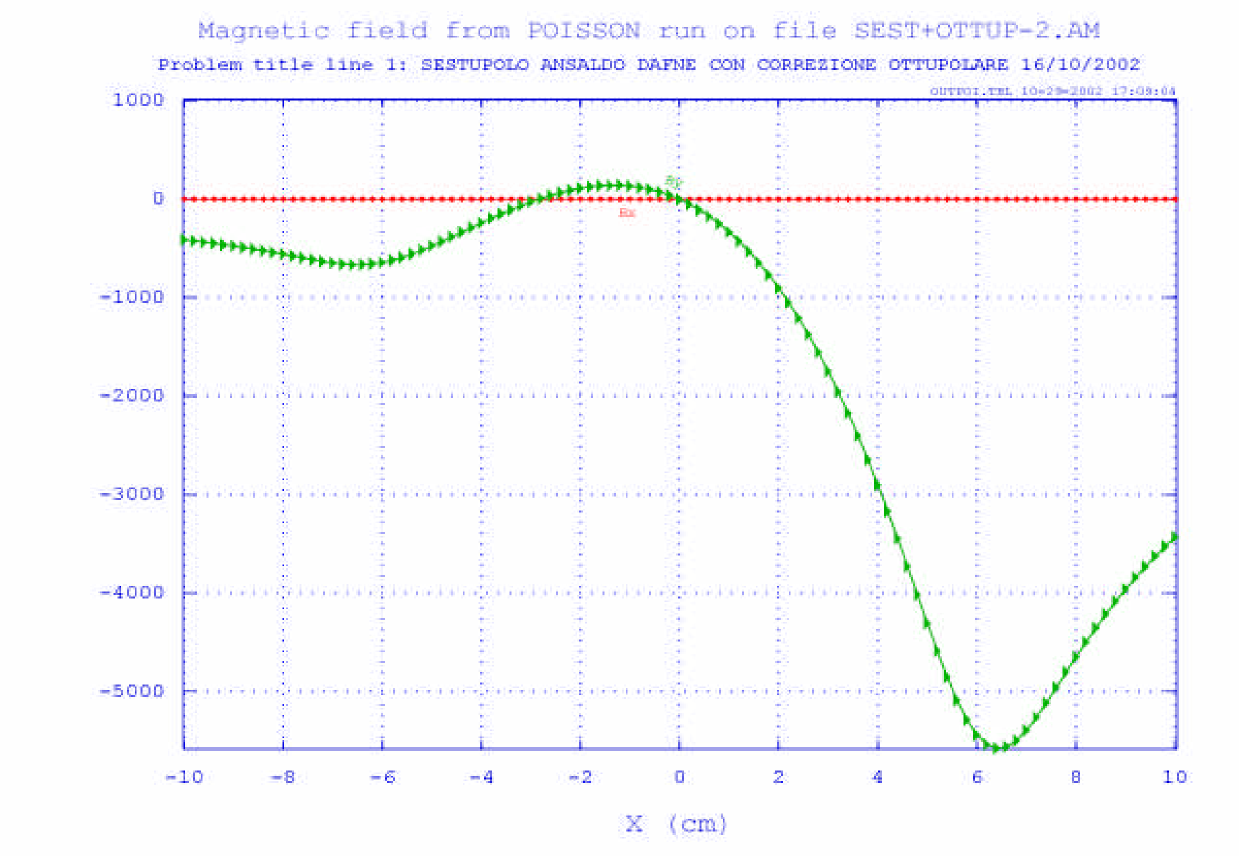
W.C. coil front view



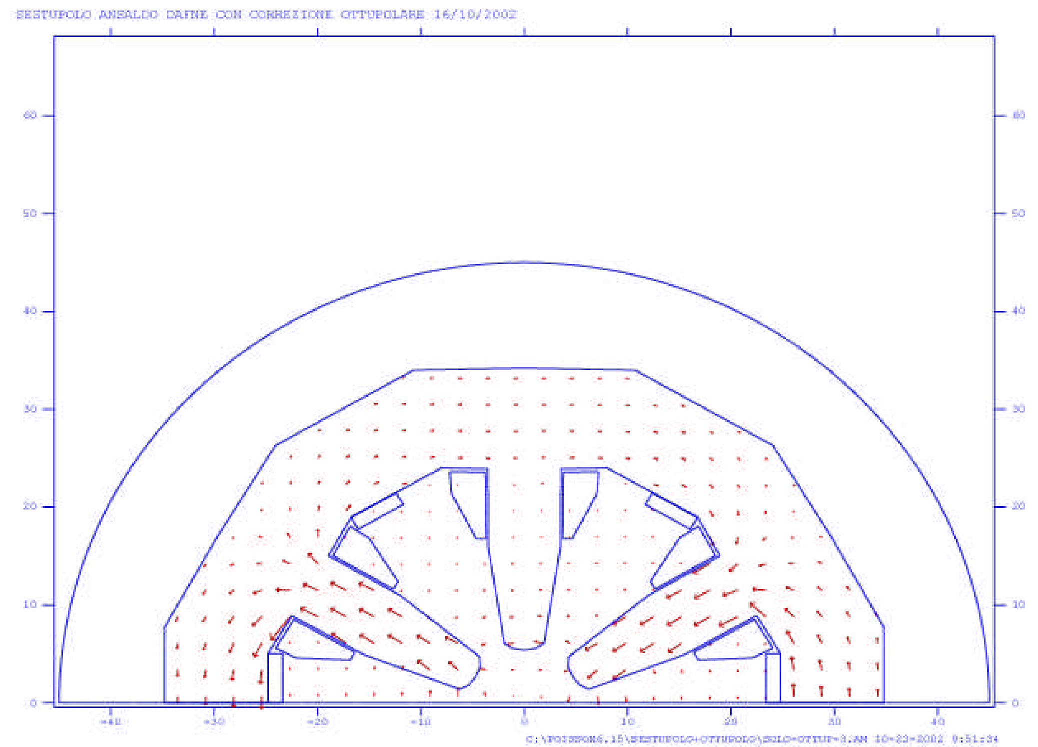
Sextupole + Octupole 2D simulation



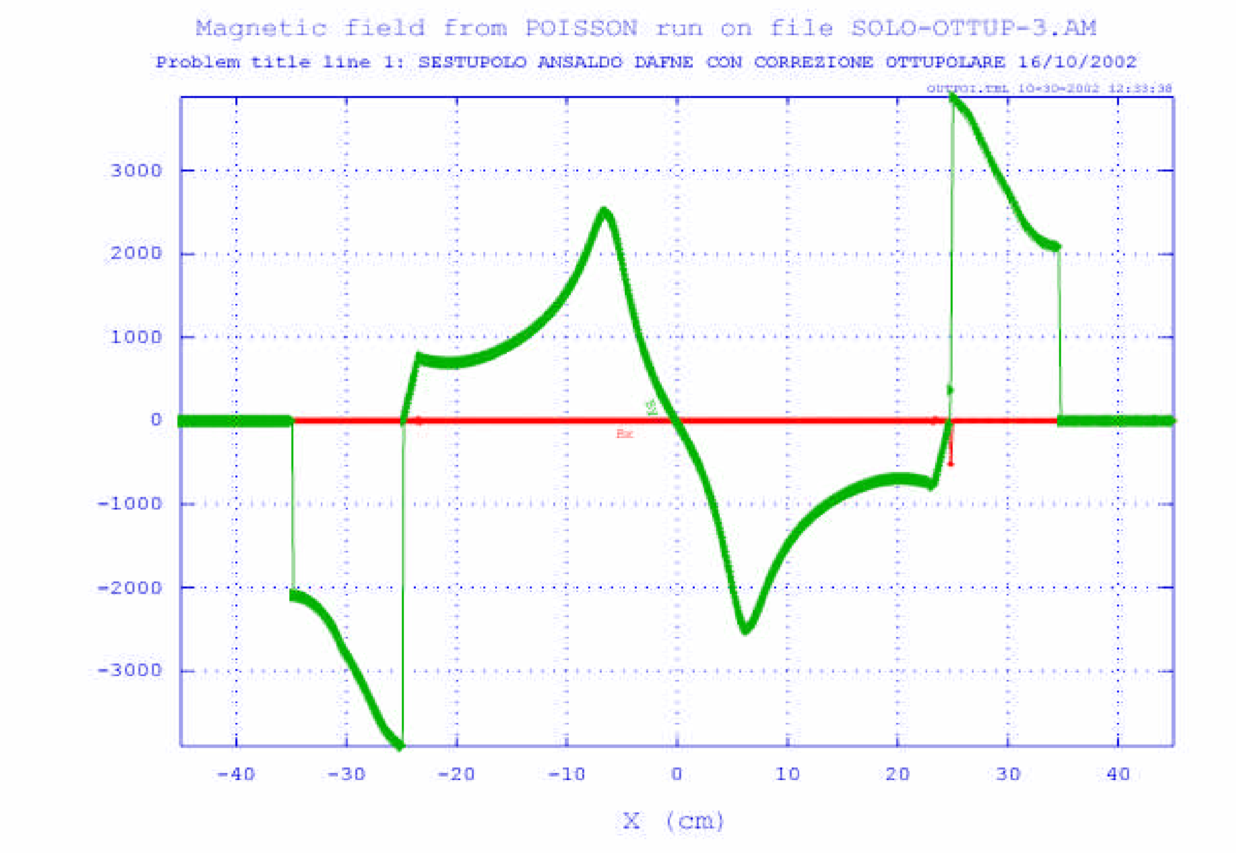
Sextupole + Octupole
Icorr=3296A∗t – Field profile



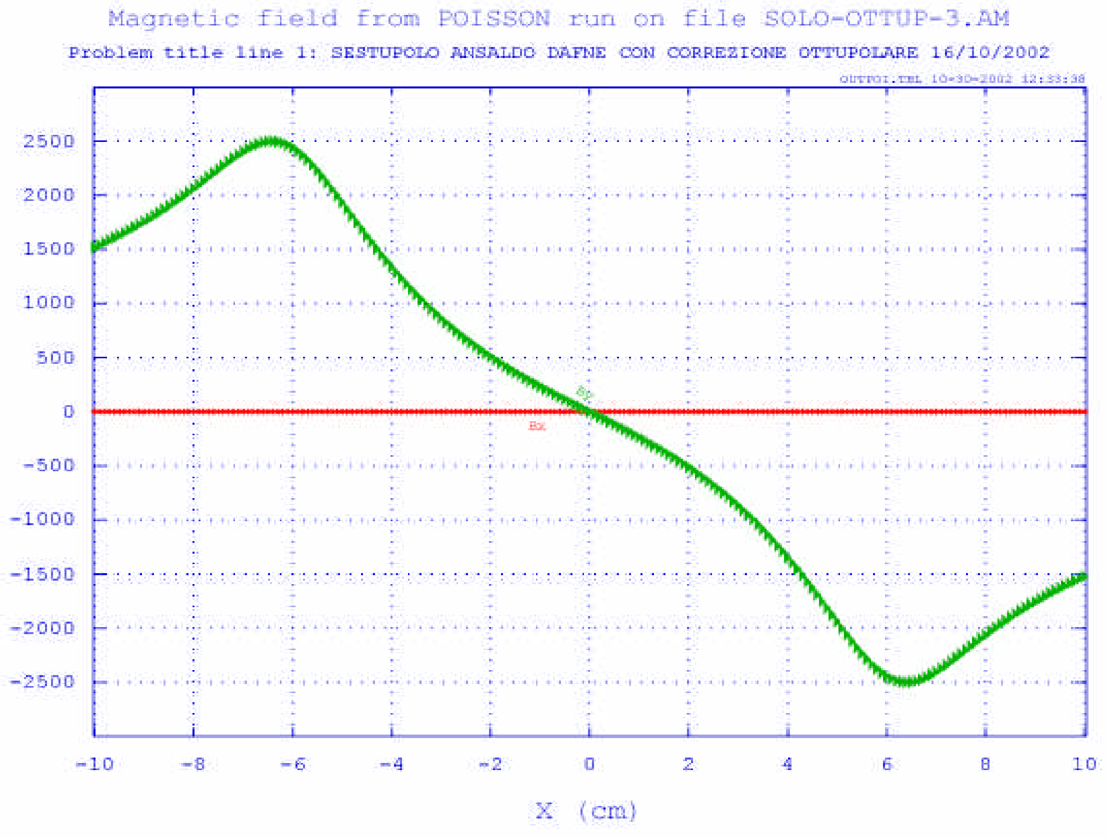
Sextupole used as Octupole
Icorr = 3296 A*t



Sextupole as Octupole
Magnetic field profile

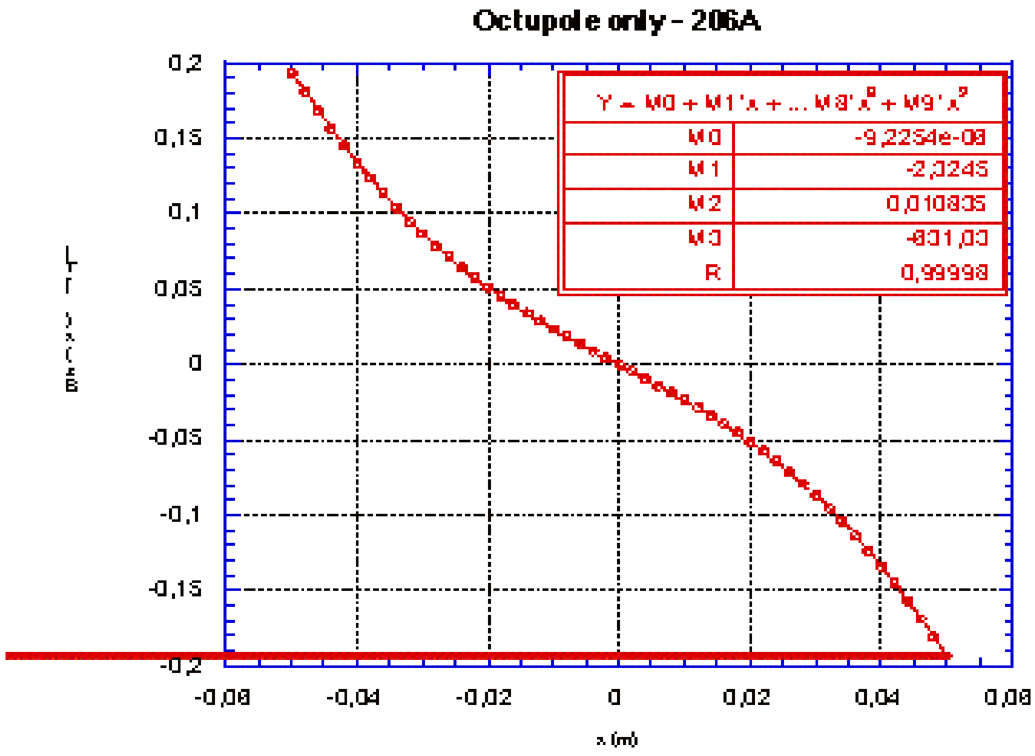


Sextupole as Octupole
Magnetic field profile

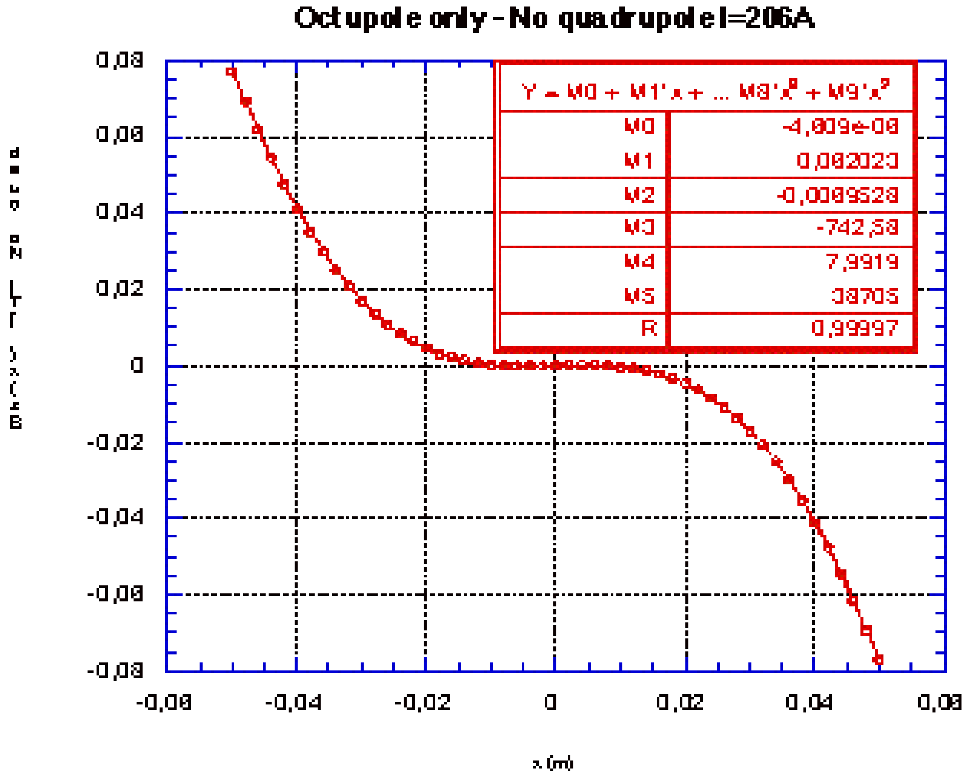


Sextupole as Octupole

$$K_{MAD} \approx 330\ m^{-3}$$



Sextupole as Octupole
No quadrupole



Coil data (1st option)

•	Coil cross section	mm*mm	50 * 14
•	Conductor: Cu	mm*mm	5.6*5.6
•	Cooling hole dia.	mm	3.6
•	Turns per coil		16
•	Coils per Sextupole		4
•	Maximum current	A	206
•	Current density	A/mm^2	10.14
•	Magnet voltage	V	17.32
•	Magnet power	W	3568
•	Hydr. Circ. per magnet		4
•	Water velocity	m/s	1.05
•	Water flow per magnet	m^3/s	4.3E-5
•	Temperature increase	°C	20
•	Pressure drop	MPa	0.143

Coil data (2nd option)

Coil cross section	mm*mm	44 * 14
Conductor: Cu	mm*mm	5.6*5.6
Cooling hole dia.	mm	3.6
Turns per coil		14
Coils per Sextupole		4
Maximum current	A	235.4
Current density	A/mm^2	11.58
Magnet voltage	V	18.21
Magnet power	W	4288
Hydr. Circ. per magnet		4
Water velocity	m/s	1.26
Water flow per magnet	m^3/s	5.2E-5
Temperature increase	°C	20
Pressure drop	MPa	0.18

However, before going ahead:

- Systematic check of the available space between vacuum chamber-sextupole
- Mechanical coil design (electric terminals, hydraulic spigots, coil supports, etc.)
- Mechanical 3D check to verify coil insertion without sextant splitting
- Preliminary industry check

4th Attempt: Conclusions

- Good magnetic field profile
- Quadrupole gradient of about 2.3 T/m to be corrected
- Reasonably good technical solution

POSSIBLE SOLUTION