Final report on ANSYS PS magnet model study

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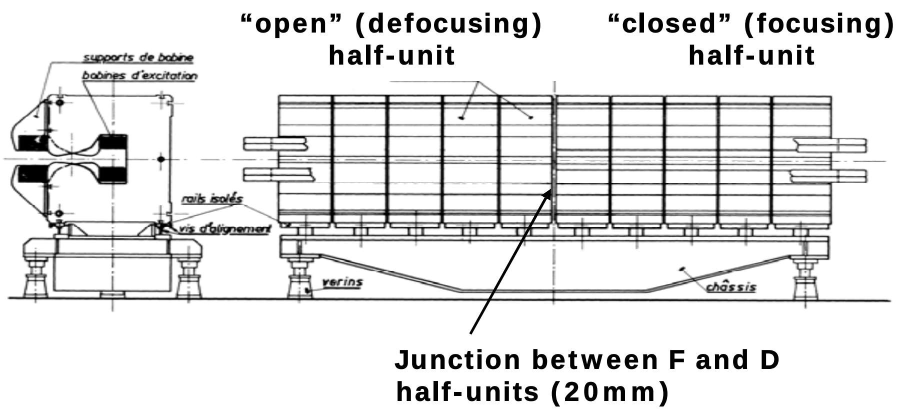
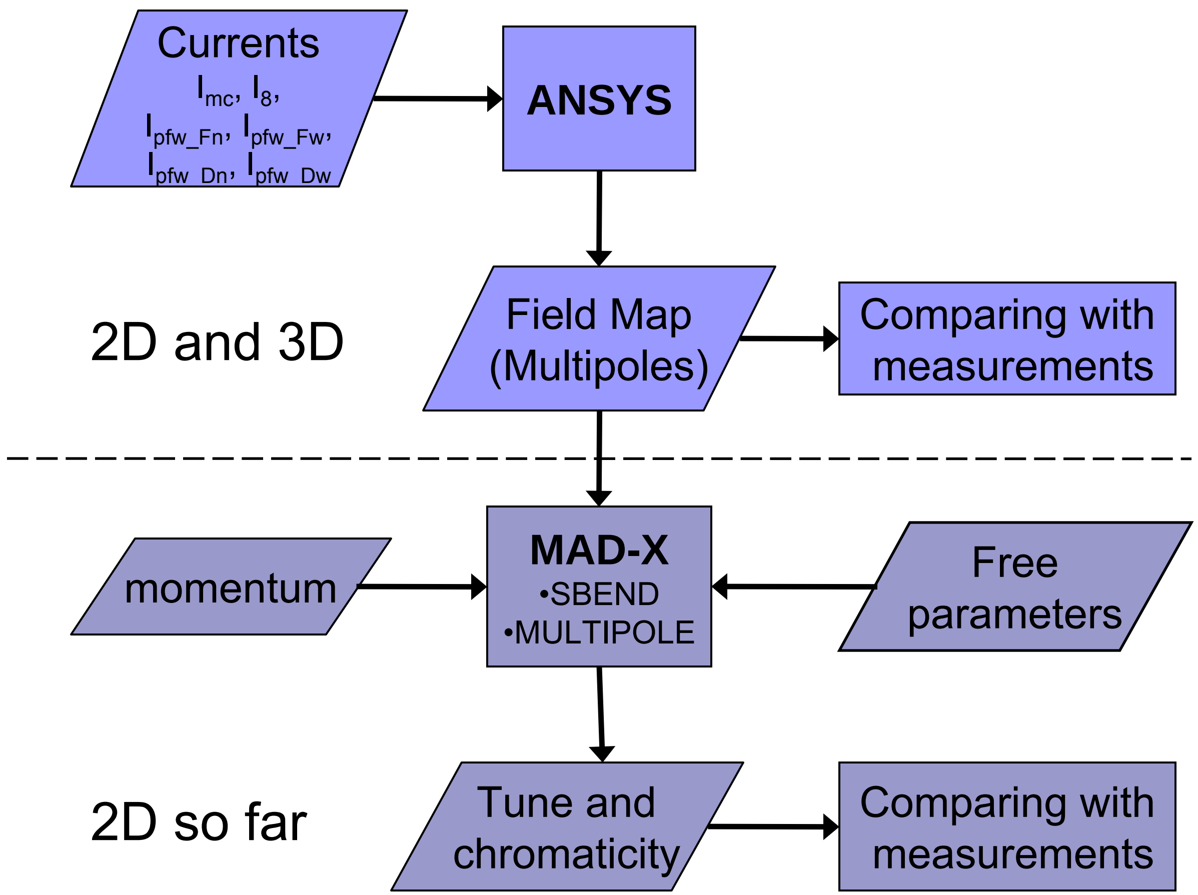
Thanks to: Simone Giladroni

Aim of the study

- Generating multipoles for MAD-X using 2D or 3D ANSYS model



Calculation Process Summary



Limitations

- ANSYS model limitations
  - 2D model does not simulate 3D effects

    (quadrupolar and sextupolar junction multipoles)
  - 3D model is limited by number of nodes

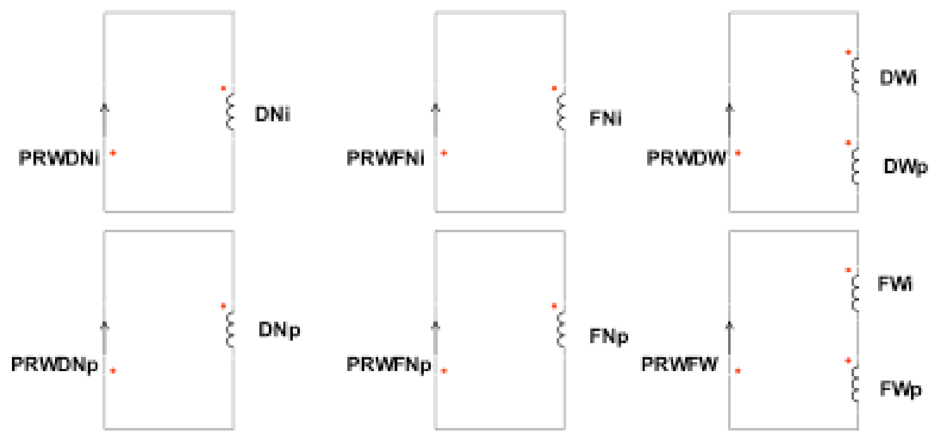
    (lots of computer resources needed)
- MAD-X model limitations
  - No distinction between odd and even magnets

    (separate powering circuits)
  - Free parameters and simplifications

    (junction length and multipoles, correction bending lengths (DLF and DLD), poleface angles)

MAD-X PS model limitations

- PFW modeling is not taking into account the new powering scheme yet

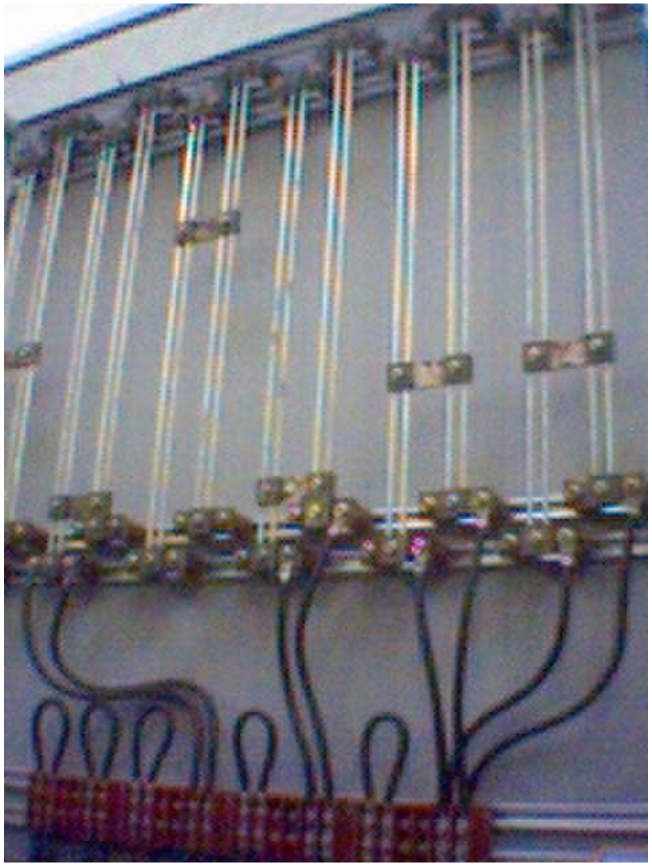


Narrow power converter circuit is separated for even and odd magnets: in total 7 power converters for 5 current mode (1 Figure of 8 loop + 6 PFW)

Courtesy of S. Gilardoni

MAD-X PS model limitations II

- An asymmetry between even and odd circuit can be artificially introduced by resistors mounted in the reference magnet which were introduced to avoid asymmetry in the circuit



- Due to refurbishing of more even than odd magnets during renovation campaign without the readjustment of the resistors, current in even and odd PWF in narrow circuit is different by about up to 1 A
(typical max current 100 A).

  This is already enough to make to make the comparison machine-MADX model not precise.

Courtesy of S. Gilardoni

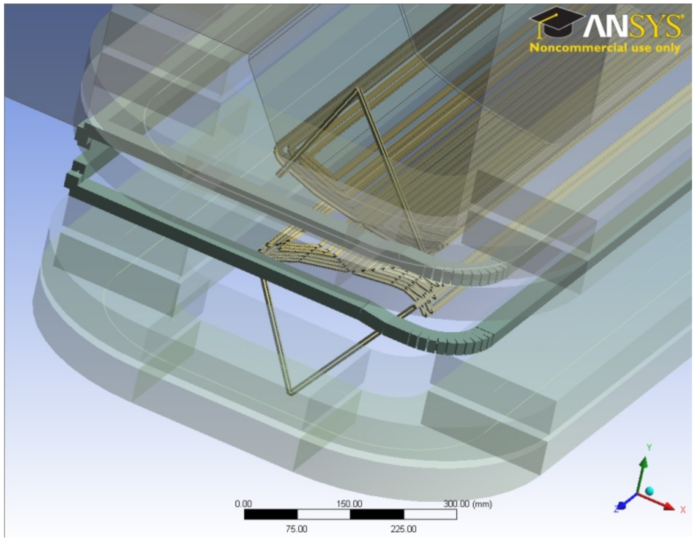
2D model solution summary

	3.5 GeV			24 GeV			26 GeV		
FOC	ANSYS	MEAS.	ERR [%]	ANSYS	MEAS.	ERR [%]	ANSYS	MEAS.	ERR [%]
K0	0.168	0.166	0.86	1.153	1.148	0.38	1.245	1.234	-0.90
K1	0.691	0.682	1.21	4.783	4.762	0.45	5.258	5.209	-0.95
K2	-0.008	-0.022	-64.03	0.457	0.506	-9.71	2.445	2.471	1.05
K3	0.64	0.69	-5.90	-15.00	-18.21	-17.62	-36.60	-30.08	-21.69
DEF	ANSYS	MEAS.	ERR [%]	ANSYS	MEAS.	ERR [%]	ANSYS	MEAS.	ERR [%]
K0	0.168	0.167	0.77	1.152	1.147	0.43	1.297	1.282	-1.17
K1	-0.692	-0.685	1.06	-4.797	-4.765	0.66	-5.272	-5.198	-1.43
K2	0.001	-0.001	-209.99	0.752	0.709	6.12	-1.319	-1.283	-2.79
K3	-0.59	-0.57	2.62	15.05	18.16	-17.10	55.58	32.98	-68.54

Data measured in 1991, used in old MAD 8 files

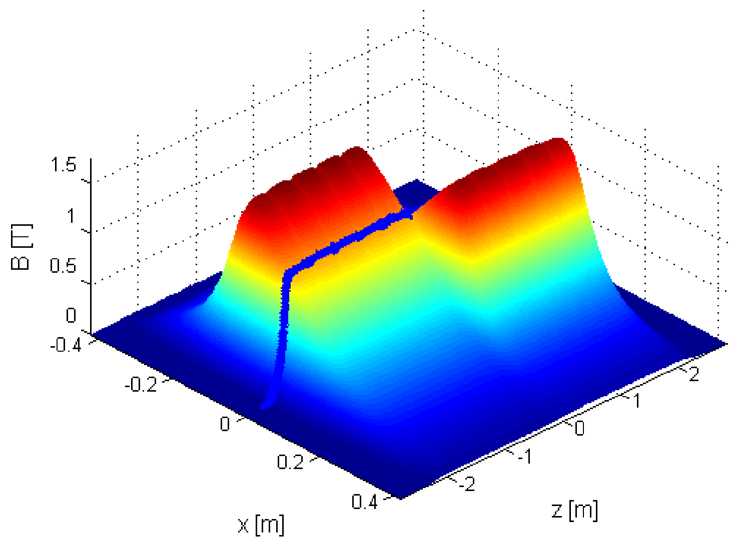
- Validation of 2D model with measured data well within experimental error bars.

3D model solution summary

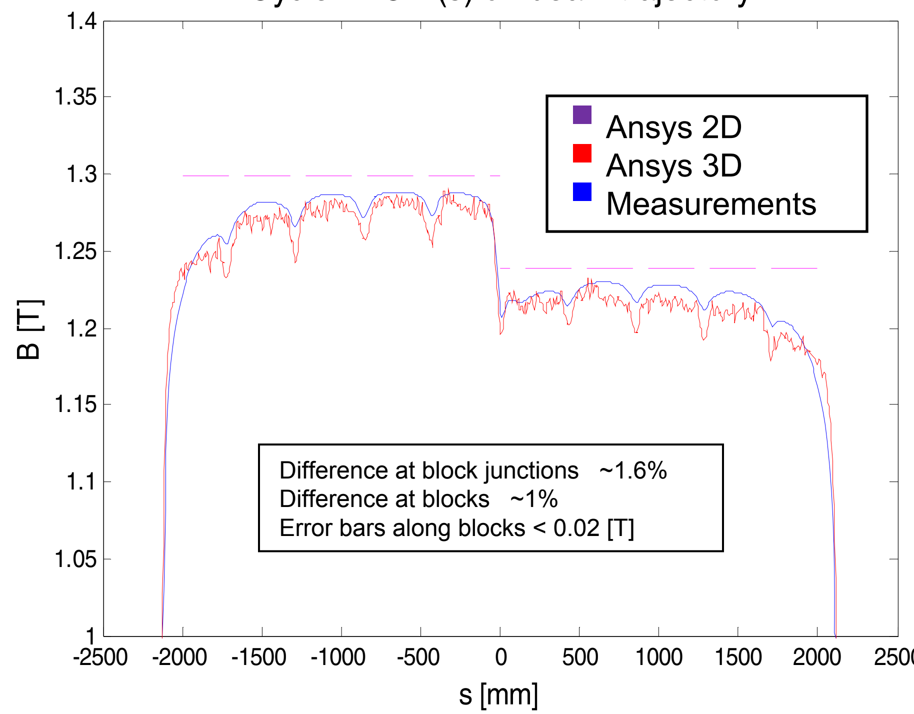


- Complete geometry and coils (simplified)
- Solution improved (quality still not satisfactory)
- Computer resource-demanding (2.2M nodes)

Cycle E dipole field component B(x,z)



Cycle LHC B(s) on beam trajectory



Calculating multipoles (2D)

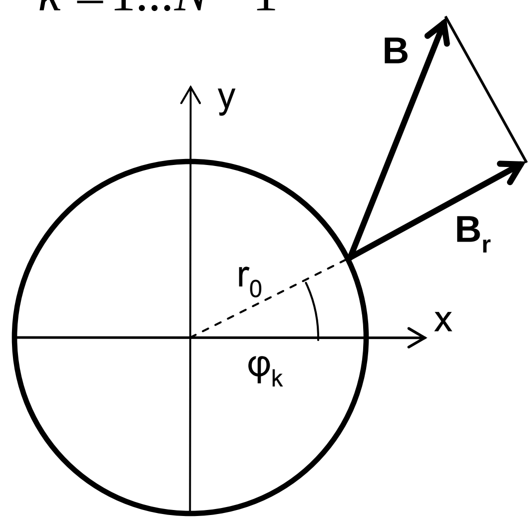
- Discrete Fourier series expansion

$$A_n(r_0) = \frac{2}{N}\sum_{k=0}^{N-1} B_r(r_0,\varphi_k)\cos(n\varphi_k)$$

$$B_n(r_0) = \frac{2}{N}\sum_{k=0}^{N-1} B_r(r_0,\varphi_k)\sin(n\varphi_k)$$

$$\varphi_k = \frac{2\pi k}{N}$$

$$k = 1 \ldots N-1$$



- Multipoles coefficients

(independent from reference radius)

$$\mathbf{A_n} = A_n \frac{(n-1)!}{r_0^{n-1}}$$

$$\mathbf{B_n} = B_n \frac{(n-1)!}{r_0^{n-1}}$$

Summary of meeting about PS magnet ANSYS modeling

- B. Auchmann (AT/MEL) will keep a “working” copy of ANSYS
- S. Gilardoni will keep the same copy to do simulation on the spot
- For a long simulation campaign like matrix calculation:
  - Either measured before the end of the run
    -> M. Juchno could try to compute them
  - New resources have to be found
- L. Bottura (AT/MTM) foresees the possibility to measure in the future the multipolar components at the junction if needed

Future

- Modeling beam optics at extraction using simulated 3D field map
- Improving ANSYS 3D model (mesh, solution quality, multipoles)
- Improving PS MAD-X model (junction, separation between odd and even magnets)
- Master thesis