Magnet Simulations
and
Self-optimization
at
Danfysik

Christopher W. Ostenfeld

Application Physicist

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The Danfysik Group

Danfysik A/S - Jyllinge, Denmark

Oxford Danfysik Ltd - Oxford, UK

Certified ISO 9001 by BVQI
DANAK Reg. No. 5005
BVQI Denmark A/S accredited by the Danish Accreditation

Products

Accelerator Magnets
Magnet Power Supplies
Accelerator Systems
DC current transducers
X-ray beamlines
Particle Therapy Systems(Siemens Medical)

KING FREDERIK IX's AWARD FOR EXCELLENCE IN EXPORT

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Product Groups

Research & Industry Division

- Magnets for particle accelerators
- Undulators and wigglers for Synchrotron Radiation Sources
- Electrostatics for particle accelerators
- Ion Sources and Beam Diagnostic Equipment
- Ion accelerators, Ion implanters and Isotope separators
- Electron accelerators, Microtrons and Synchrotrons

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Custom Designed Magnet Projects

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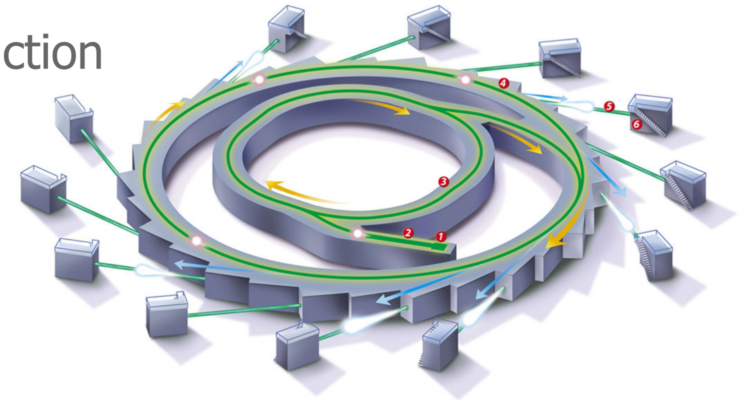
Australian Synchrotron Project

Turnkey booster



Lattice:	Combined function
Booster circumference:	130m
Injection energy:	100MeV
Peak energy:	3.0GeV
Beam current (multi bunch train):	5mA
Cycle rate:	1Hz

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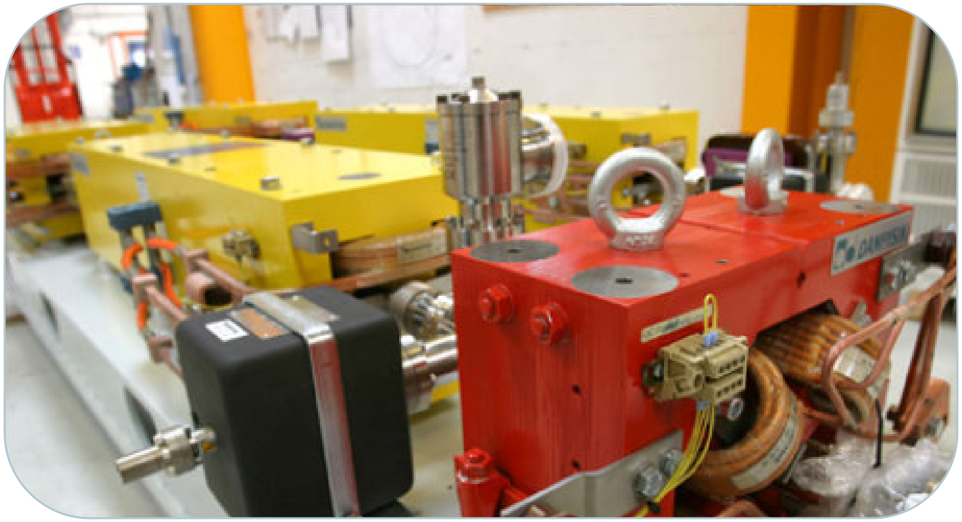
Australian Synchrotron Project

Turnkey booster



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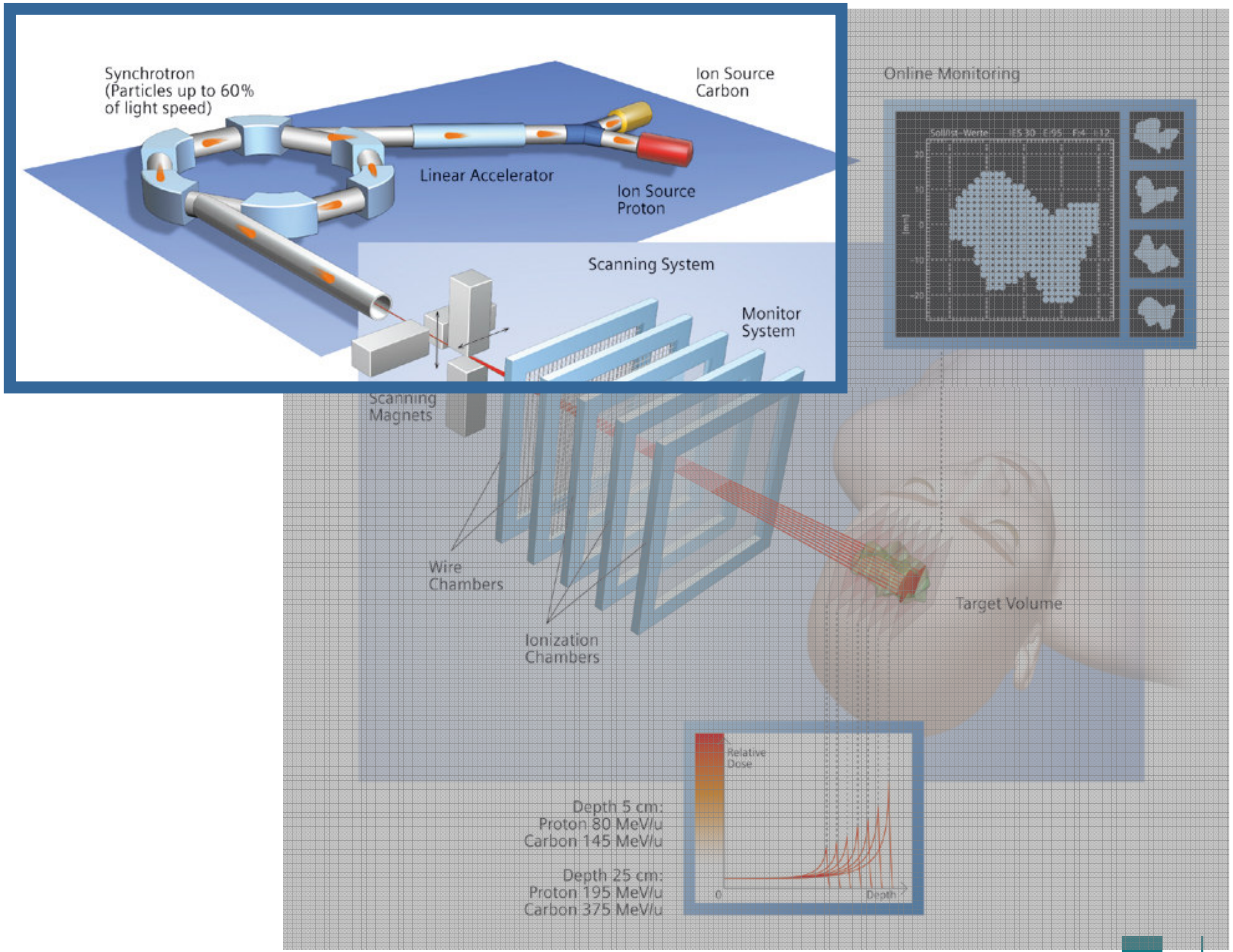
Health Care Division



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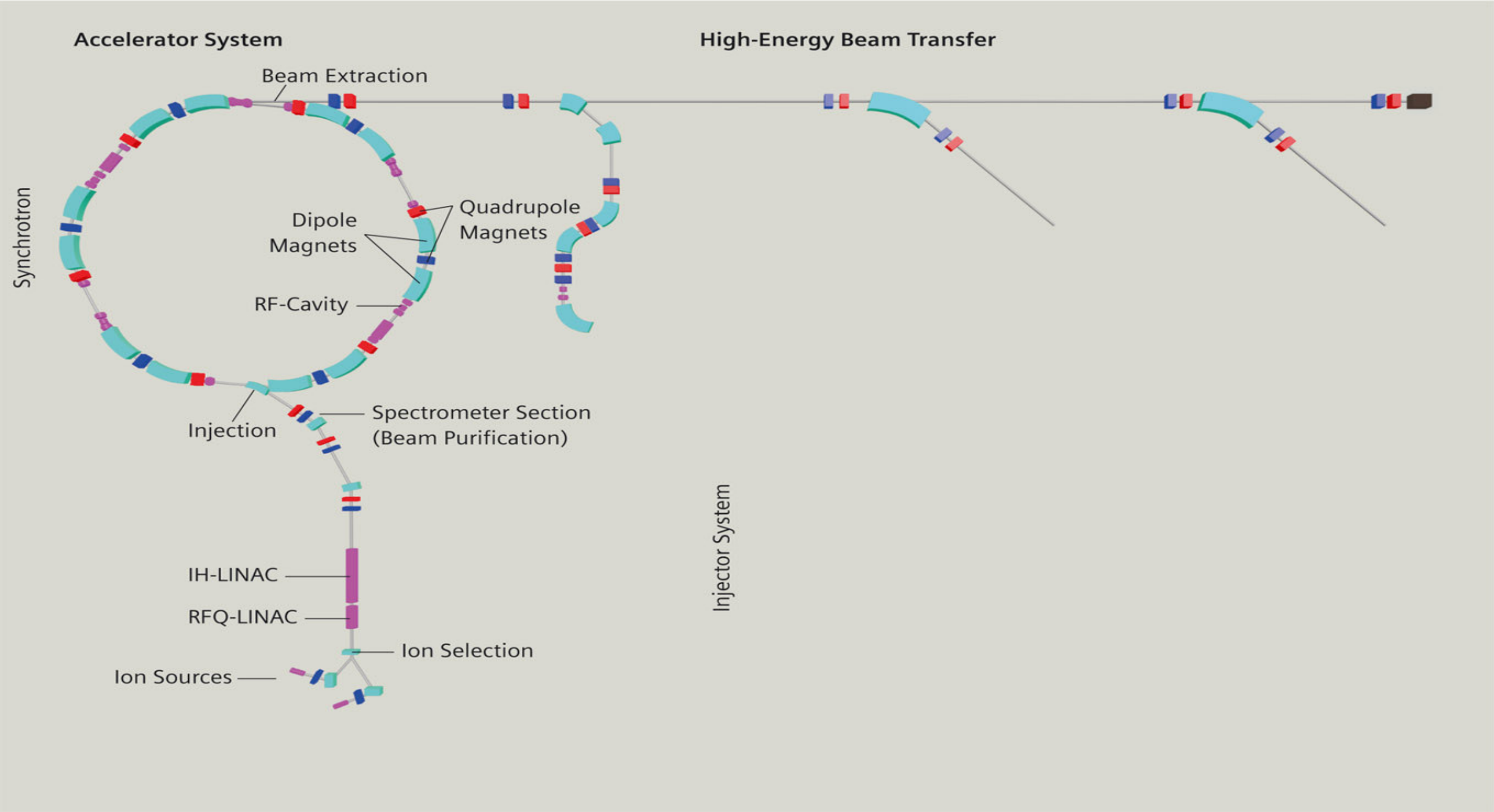
Health Care Division



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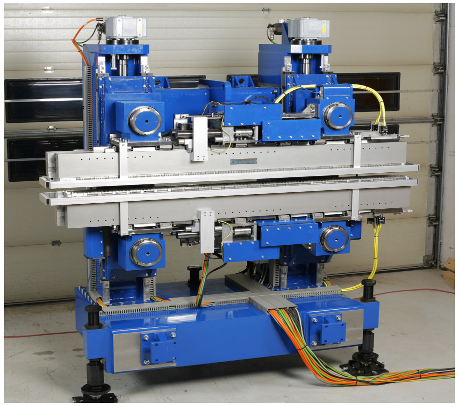
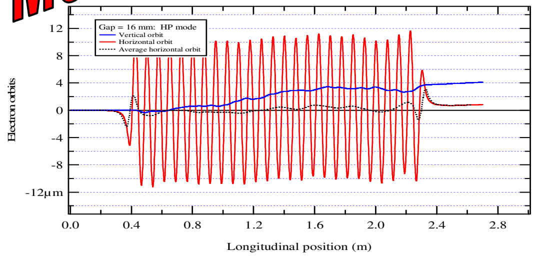
Insertion Devices

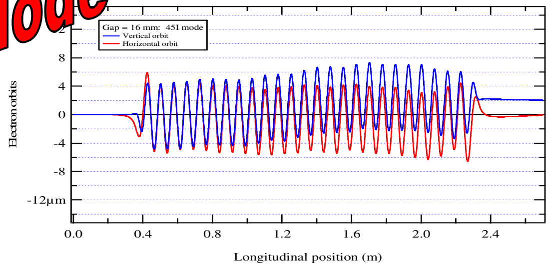
- **<u>Status:</u>** Recently completed Apple-II device for ASP(Our first !!!)
- Clamped pos./neg poles together in 3 magnet module
- Max variation in first integral: 38 Gcm
- Good trajectory straightness at all phases
- Very low multipole content
- Highly automated system for magnet sorting, and shimming



HP Mode



CP Mode



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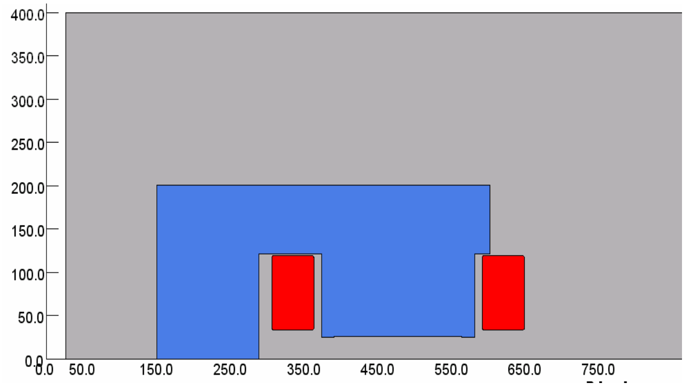
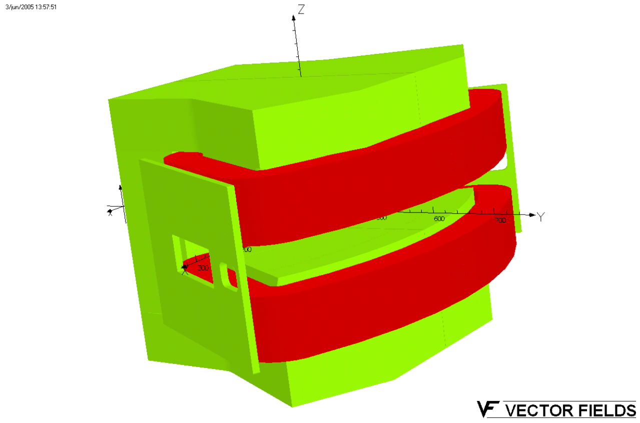
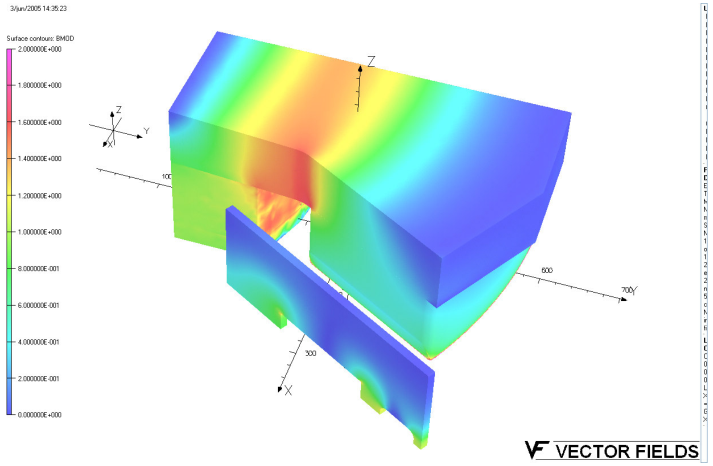
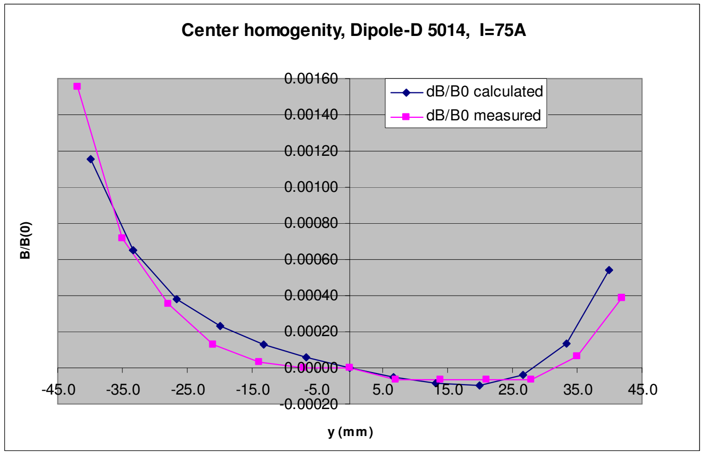
Magnetic 2D and 3D design

Dipole for the Energy Recovery Linac Prototype (ERLP) at Daresbury Laboratory



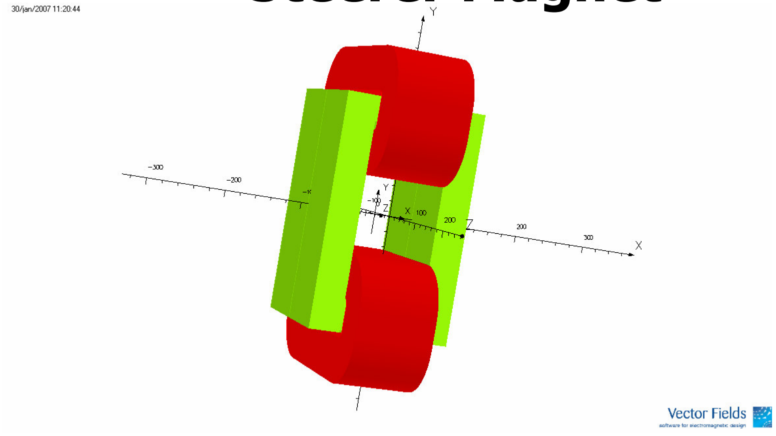




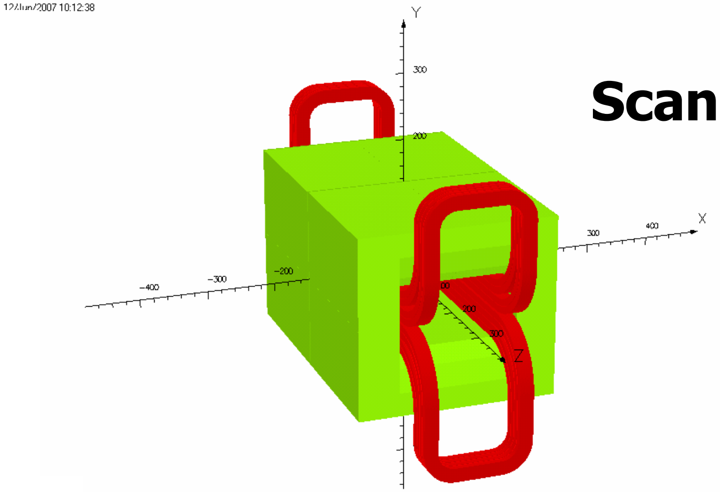


Magnet Types for Particle Therapy

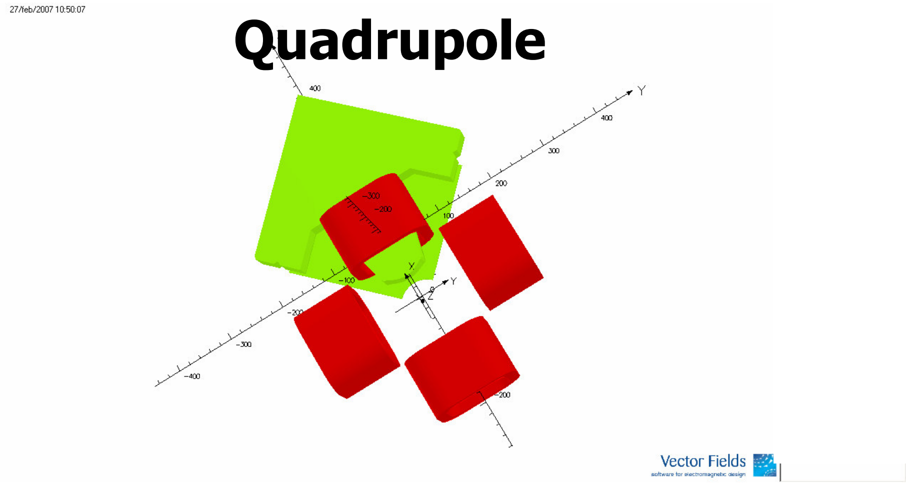
Steerer Magnet



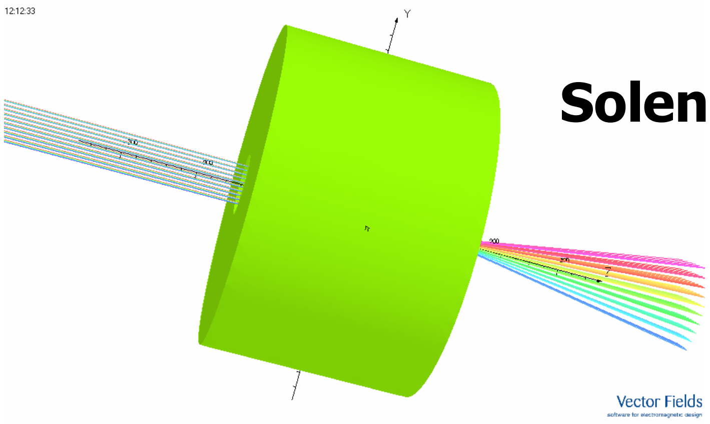
Scanner Magnet



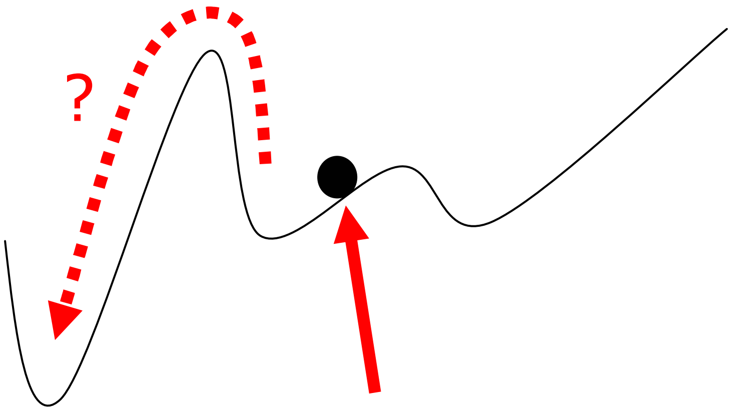
Quadrupole



Solenoid



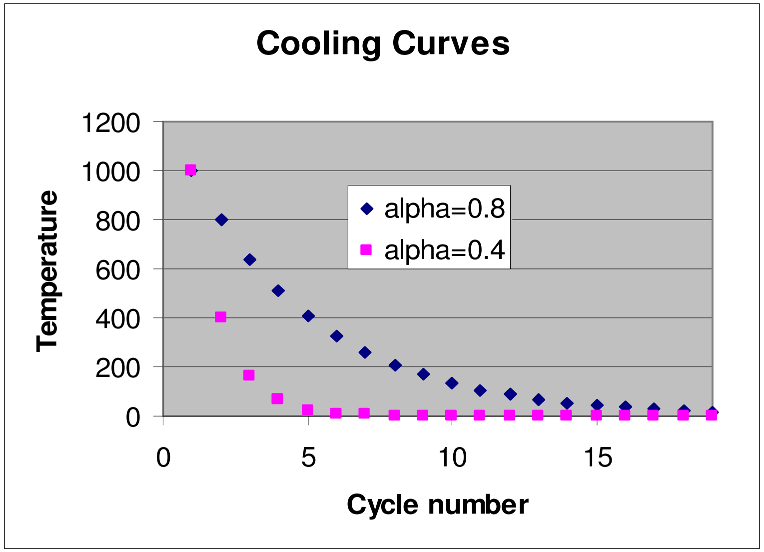
Global Optimization



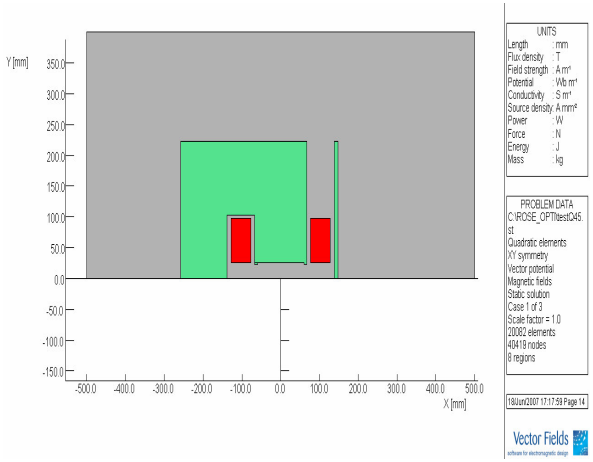
Thermal energy needed for potential jump

Simulated Annealing method

•Truly global optimization method
•”*Heating system to high temperature, followed by slow cooling*”
•Higher temperatures allow ”uphill” jumps
•After cooling, system should have reached lowest energy state
•$T_{n+1}=\alpha\ T_{n+1}$
•P(move)=exp(-ΔQ/RT)



Principles



→ Describe by comi file → **Solve**

↓

Evaluate goodness **Q1**

↓

Define new parameter vector
P={#a1,#a2,.....}

← **Solve** **Q2**

← Accept new parameter??
YES/NO

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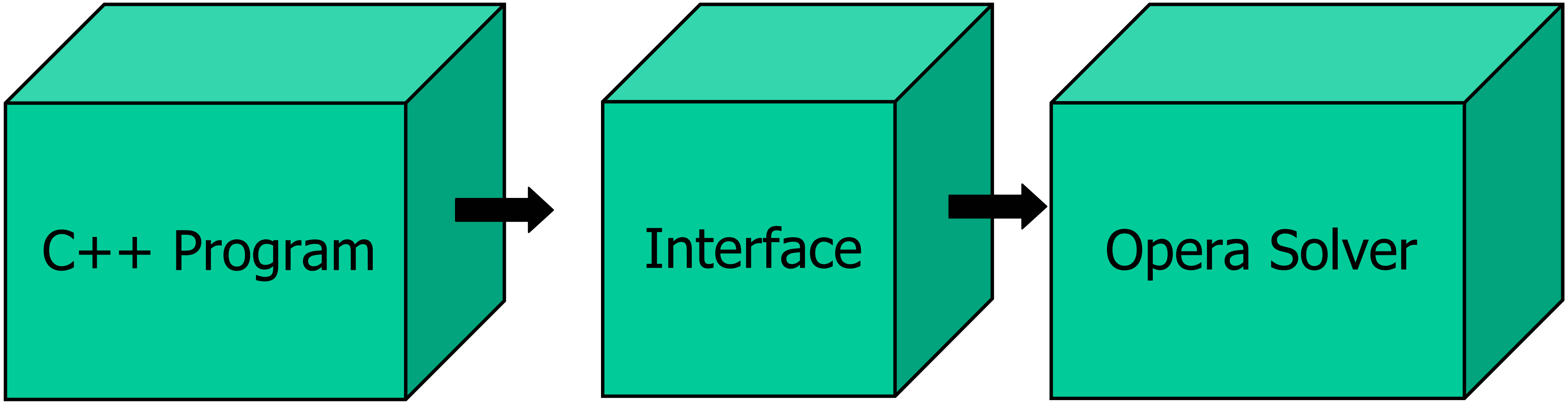
Software Details



ActiveX/Com Interface

Allows for variable values and opera commands to be transferred back and forth, between C++ program and Opera, without having to open Opera.

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Input files

Qfunction.txt

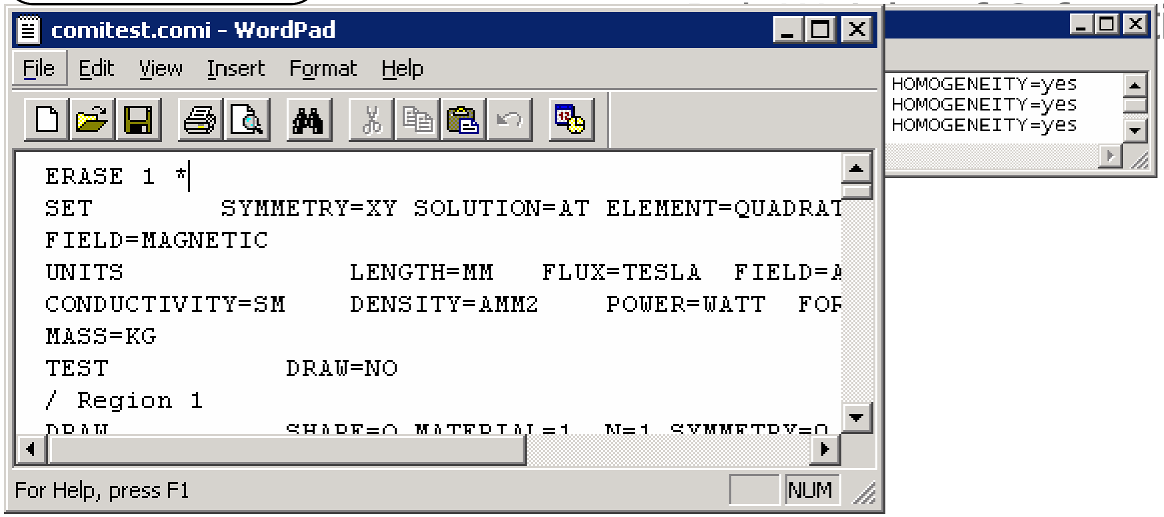
Input file

Comi file

Contains Q-functions, which evaluate the quality of the parameter choice.
Usually field homogeneity along a line, or circle.

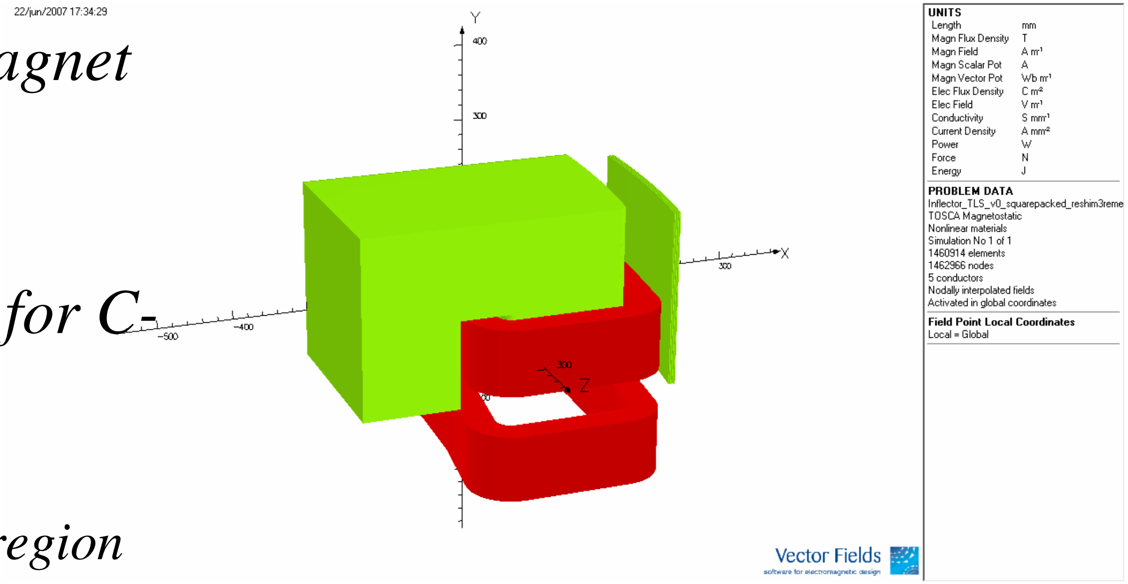
Contains problem details
- Parameter name
- Parameter limits
- ... of Q-functions

Contains all information about model, written as a comi file,
Fully parametrized.



Self-optimization:Case Study

- *20.5 degree inflector magnet*
- *B=0.58 T*
- *C-magnet, with shield*
- *Rose shim optimization for C-magnet*
- *Optimize against*
  - *Rectangular good-field region*
  - *3 Different currents*
- *Relatively narrow pole(134 mm)*
- *Homogeneity spec. $dB/B=\pm 5 \cdot 10^{-4}$*



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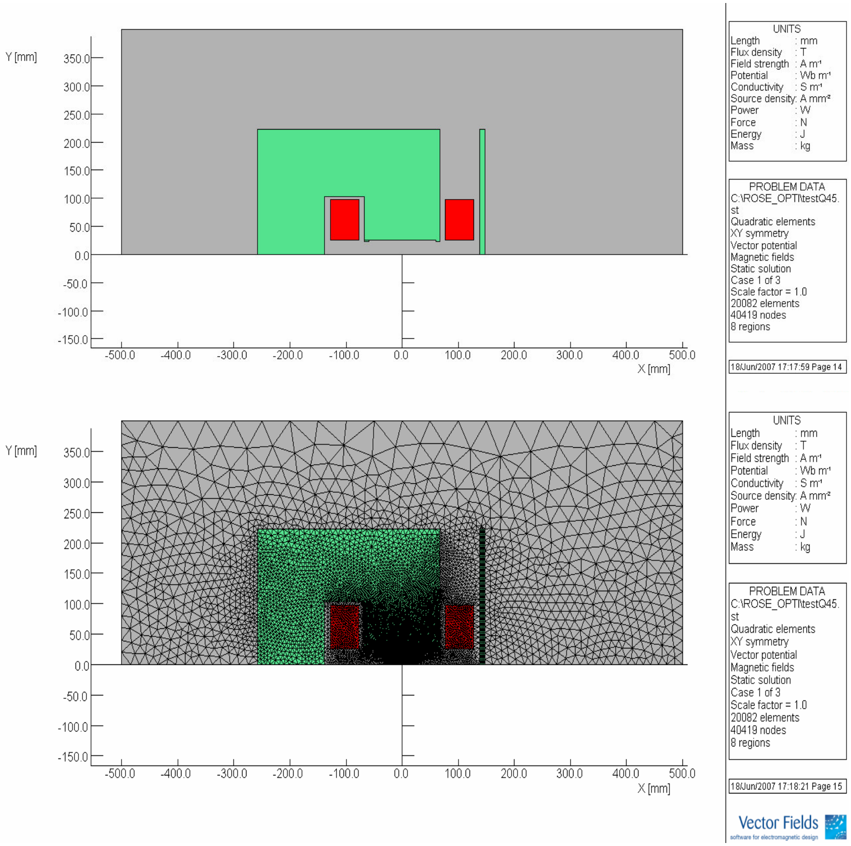
Case Study: C-Magnet

- *2D Inflector Magnet*
- *Homogeneity Spec: $\Delta B/B = \pm 5 \cdot 10^{-4}$ in rectangular box 60x40 mm*
- *Quadratic elements*
- *Tolerance=0.1*



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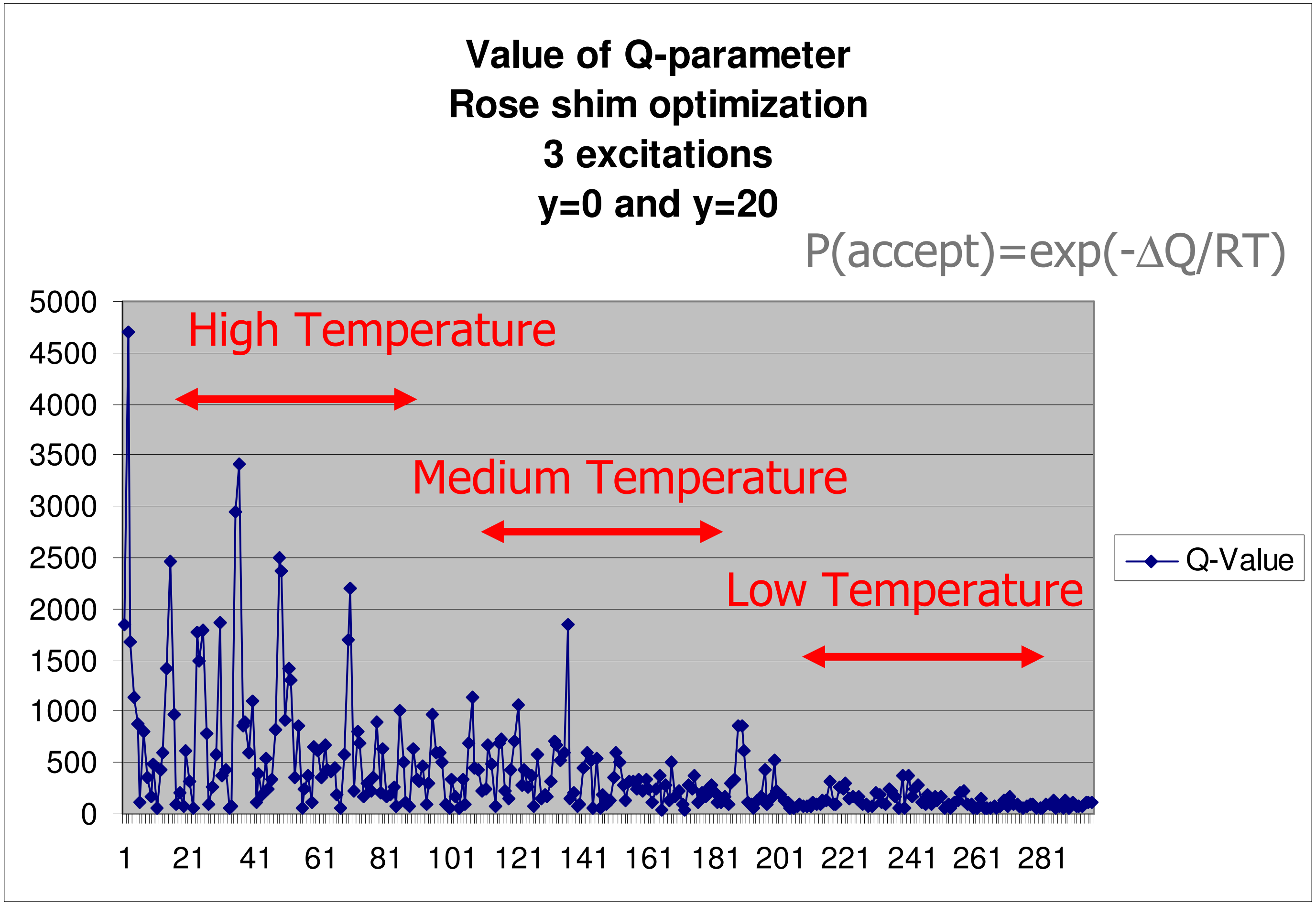
Optimization process



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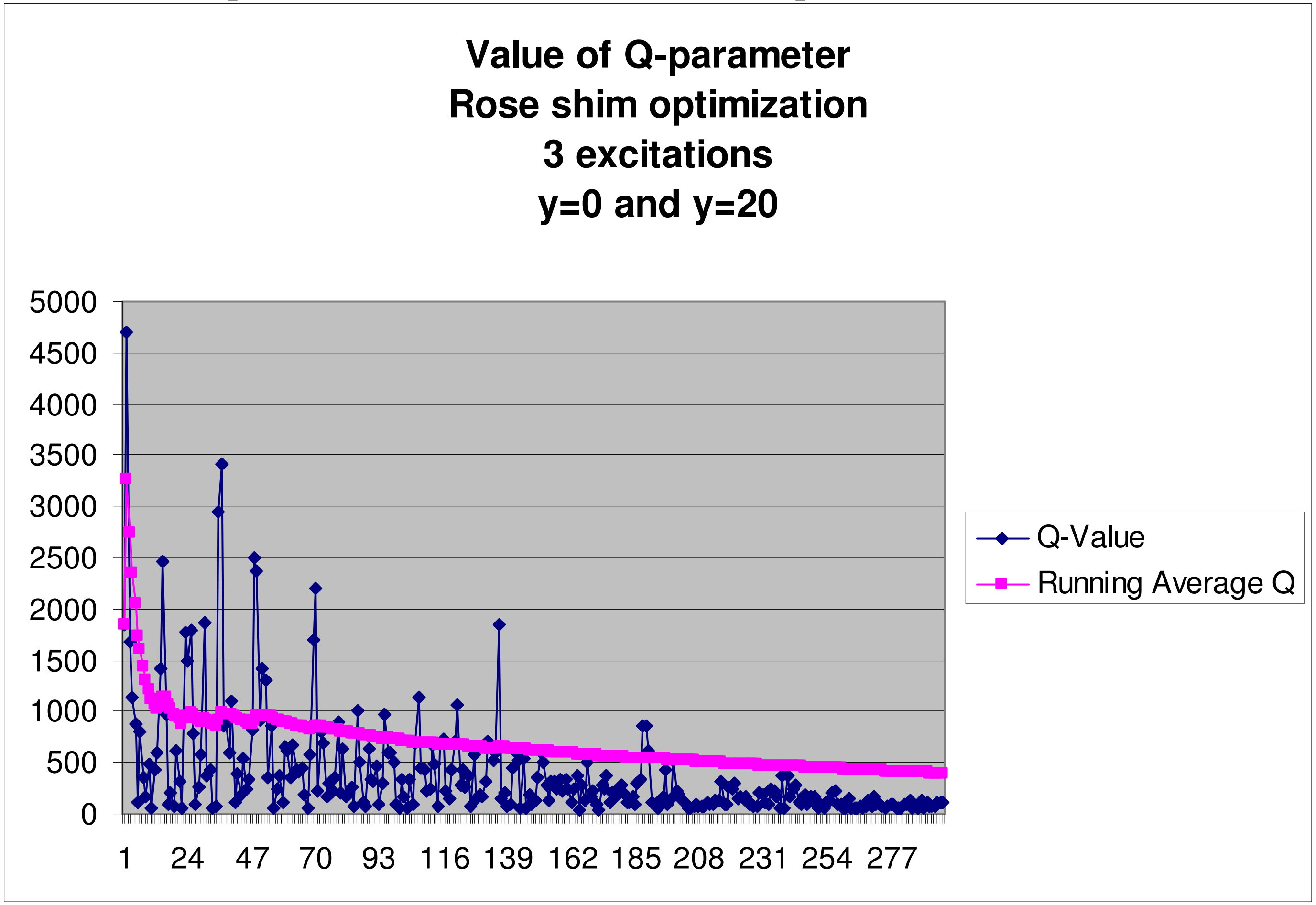
Optimization process



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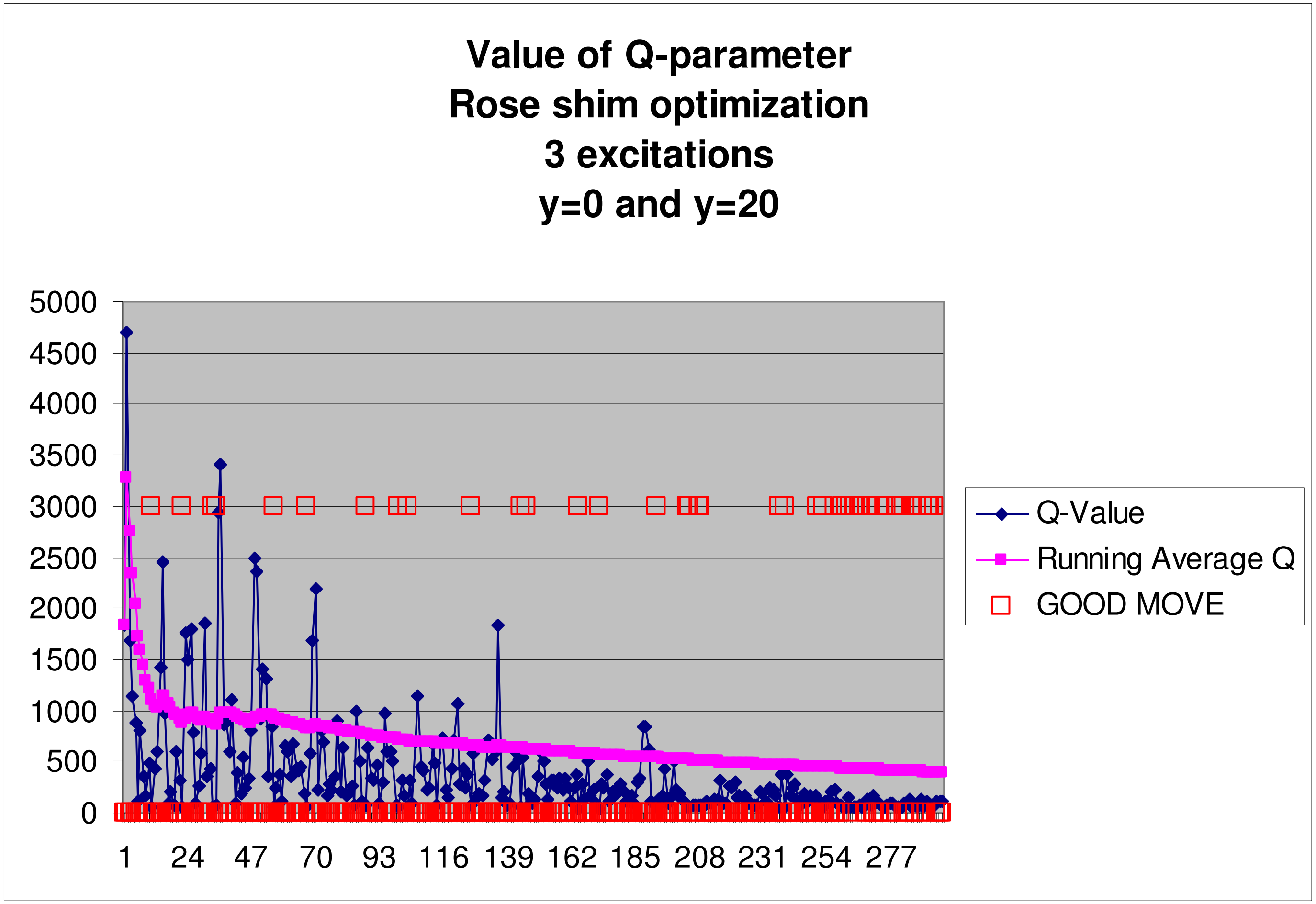
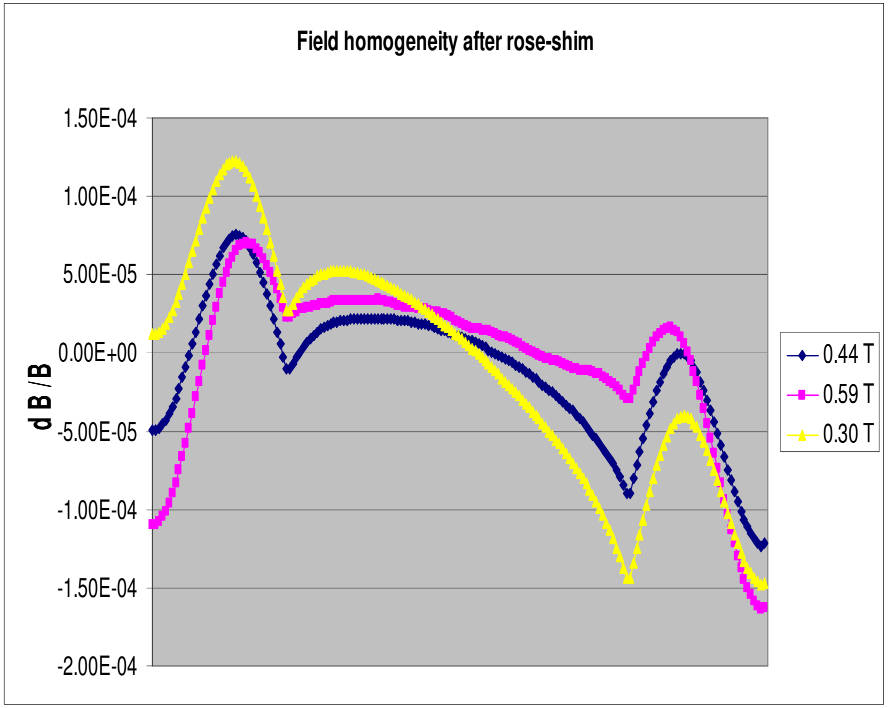
Optimization process



Results

- *Results after self-optimization(overnight)*
  - *$dB/B=2.5 \cdot 10^{-4}$*
- *Manual optimization done earlier*
  - *$dB/B=4 \cdot 10^{-4}$*



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Self-Optimization: Pros and Cons

- *Complete control over optimization progress*
  - *Start temperature, Stop temperature, cooling rate, equilibrium conditions, goodness functions*
- *Model can run without user intervention*
- *Slow, compared to strictly downhill methods*
- *Many parameters*
- *Need to know ”energy landscape”*

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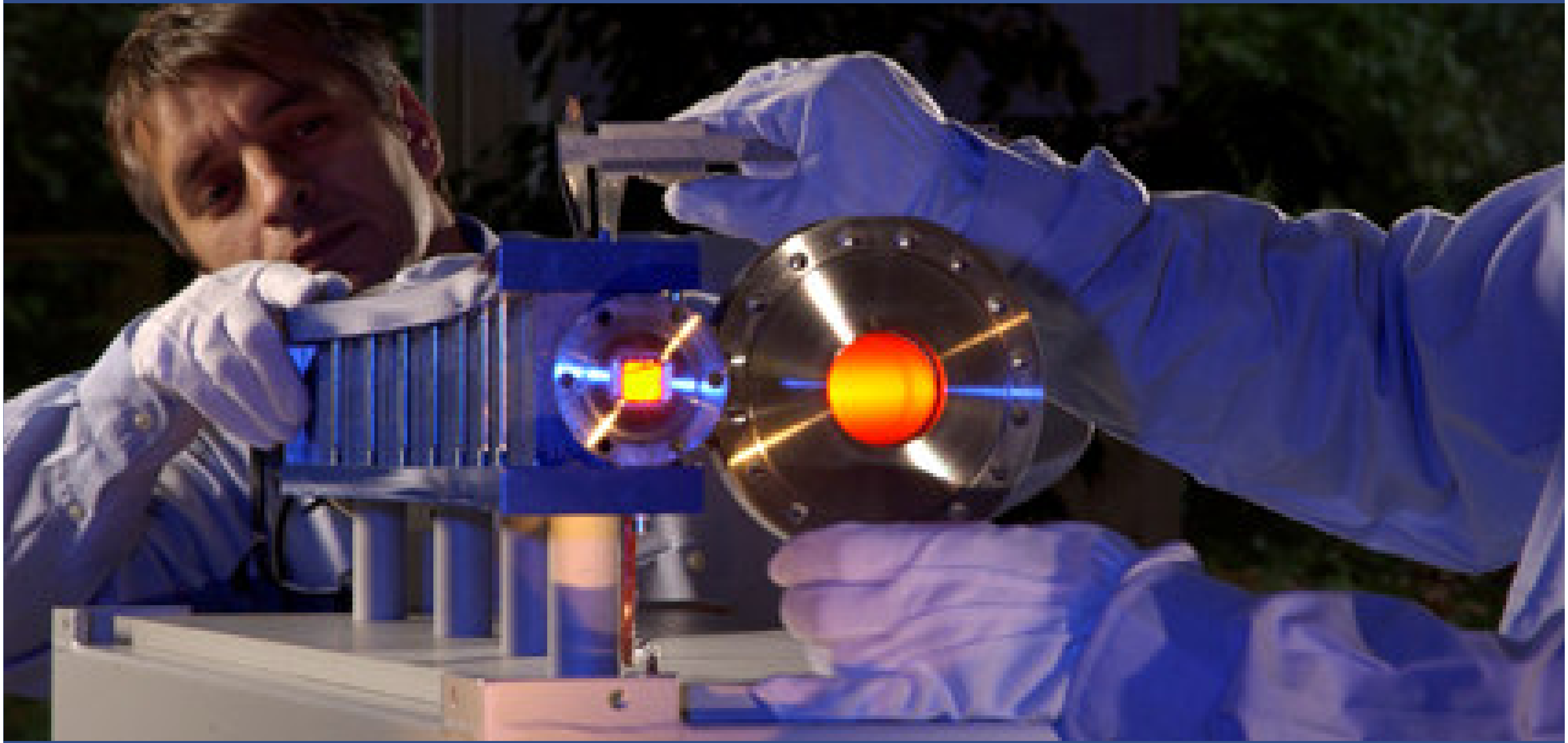
Self-Optimization: Further Applications

- *Optimization of pole profiles for multipoles*
  - *Reduction of harmonic content*
- *Method has been used in Mathematica/Radia*
  - *Optimize end section for Apple-II*
    - Low phase/gap variation
    - 6 parameters
- *Anything which can be parametrized can be optimized*

Accelerating Technology



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