Status of Accumulator Ring Simulation

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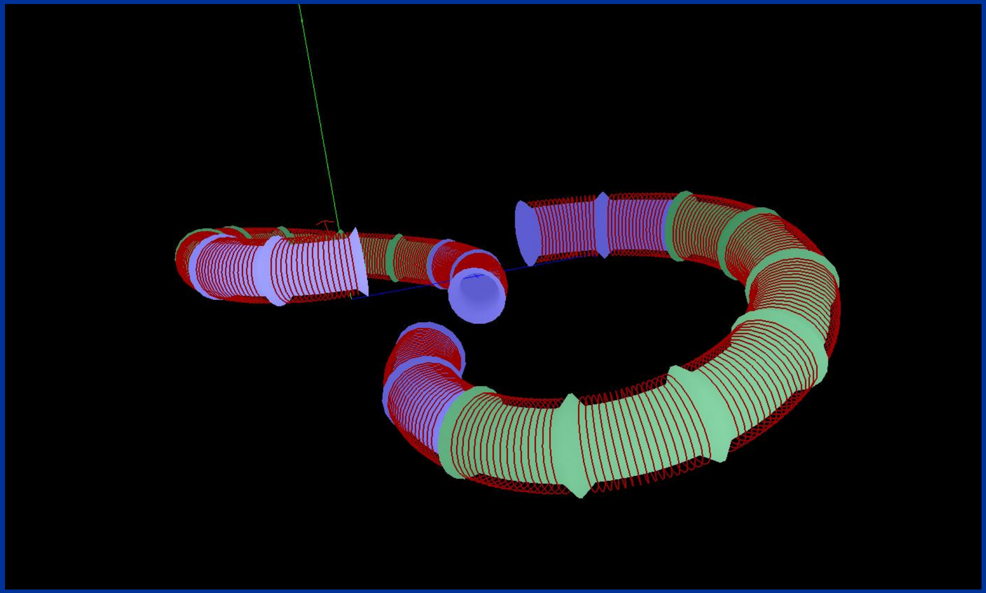
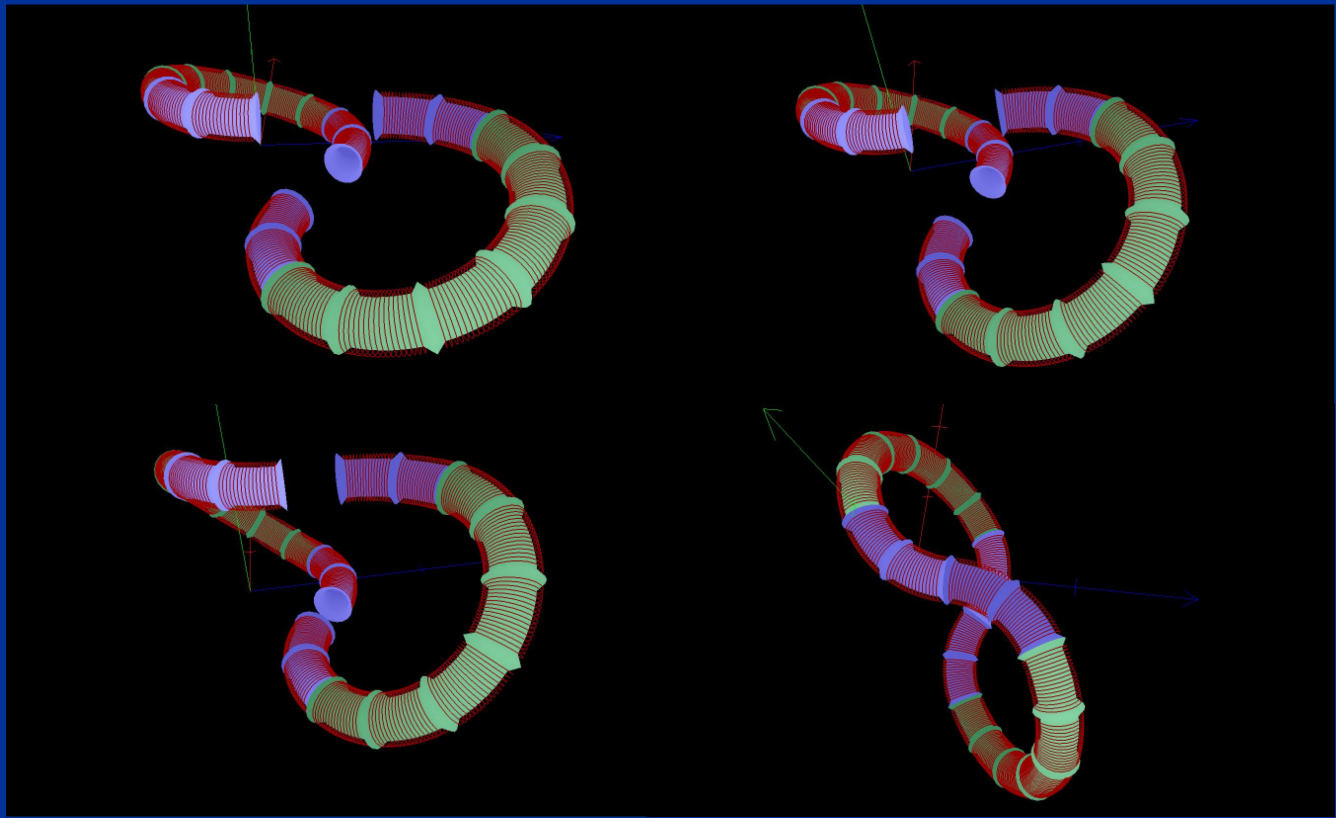
Motivation

- Accumulator ring with magnetic surfaces
- Example : 8-figure ring
  - 30° sectors, R=0.5m, R1=0.08m
- Different designs
- Calculation of coordinate system for long term simulations
- PIC simulations



Motivation

- Different slope angles 20°,30°,45°,60°
- Straight sector 0.51m, 0.42m, 0.24m, 0m



CSC(Center for Scientific Computing)

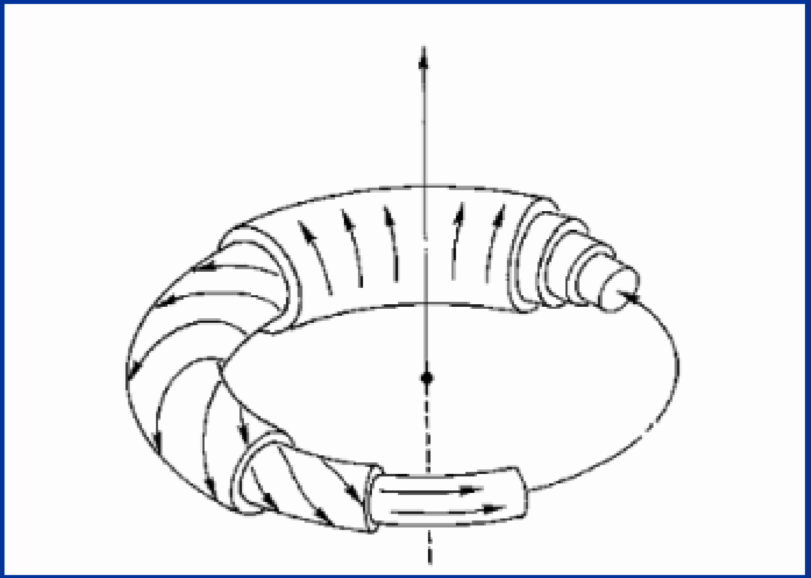
http://www.csc.uni-frankfurt.de

- Xeon Cluster 32bit
- February 2003
- 70 node Linux Cluster with 2.4 GHz dual Pentium Xeon CPUs for each node.
- 32 nodes Myrinet, 38 nodes 100Mbit Ethernet
- 2GB RAM

- Opteron Cluster 64bit
- May 2004
- 282 nodes = 564 1.8 Ghz Opteron 244 processors.
- 64 nodes Myrinet, 218 nodes Gbit Ethernet.
- Myrinet - 320 GFlop/s,
- Ethernet - 650 GFlop/s.
- 4GB RAM

Magnetic surface

- Definition: *If a magnetic field line stays within a surface, coming arbitrarily close to any point of surface, then that surface is a magnetic surface*
- Concepts: Rotational transform(field line twist) and shear
- Example: Tokamaks, Stellarators

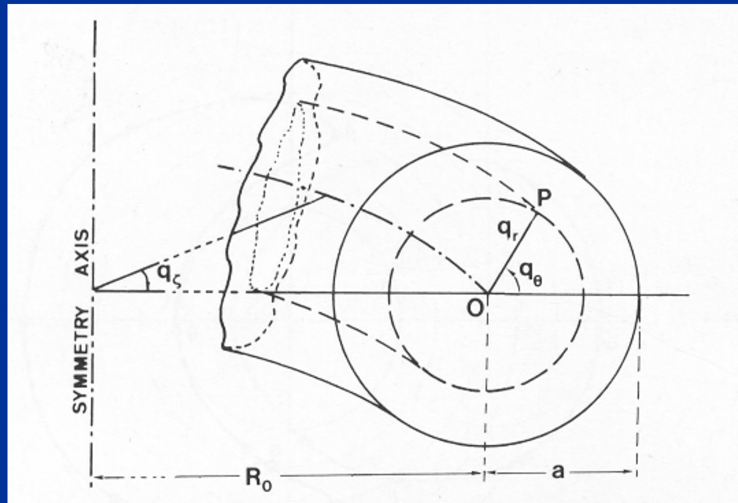


Magnetic surfaces

- ***Why calculate magnetic surfaces?***

- Example: B=1T Electrons

$$\omega_g = qB/m = 1.76 \cdot 10^{11}\,Hz$$



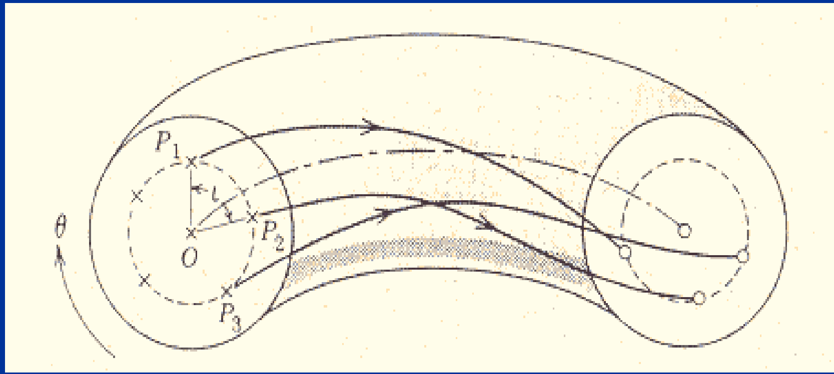
- at least 20 points per turn => time step dt = $2.8*10^{-13}$s
- Averaging through the Larmor oscillation => local curvature of the field is needed in every calculation point

Magnetic surface – Computation method

- Field line tracing method – „Follow the B-vector“ from Biot-Savart formula

$$\vec{B} = \int \frac{\mu I}{4\pi} \frac{d\vec{l} \times (\vec{r} - \vec{r}\,')}{\left|\vec{r} - \vec{r}\,'\right|^3}$$

- Point filtering
- NURBS (Non-Uniform Rational B-Splines) - Surfaces



Magnetic surfaces as a 1^{st} test object

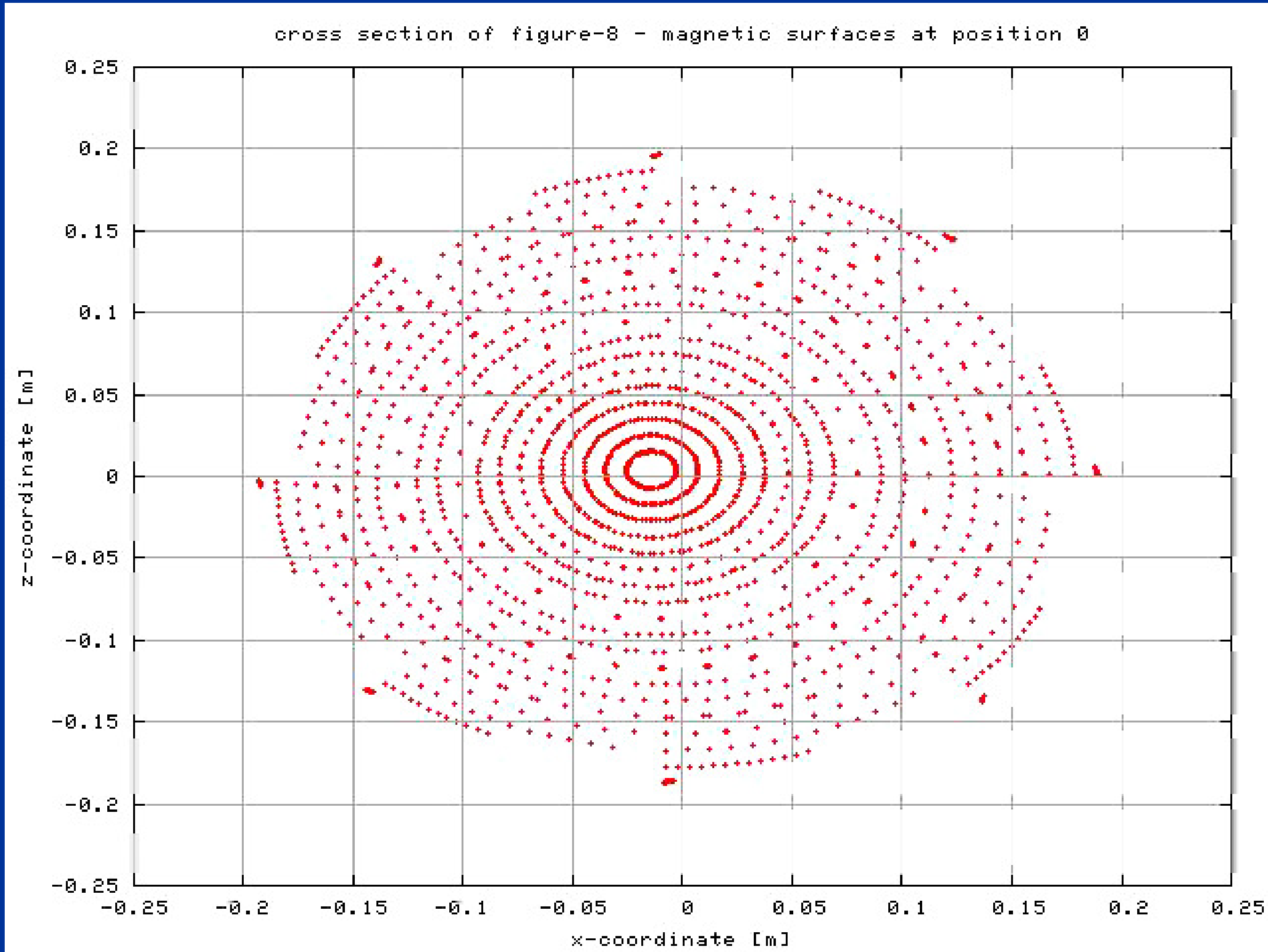
- 10000 steps around figure-8 (1step ~ 0.8mm)
- 20 surfaces at once

= 20 processors

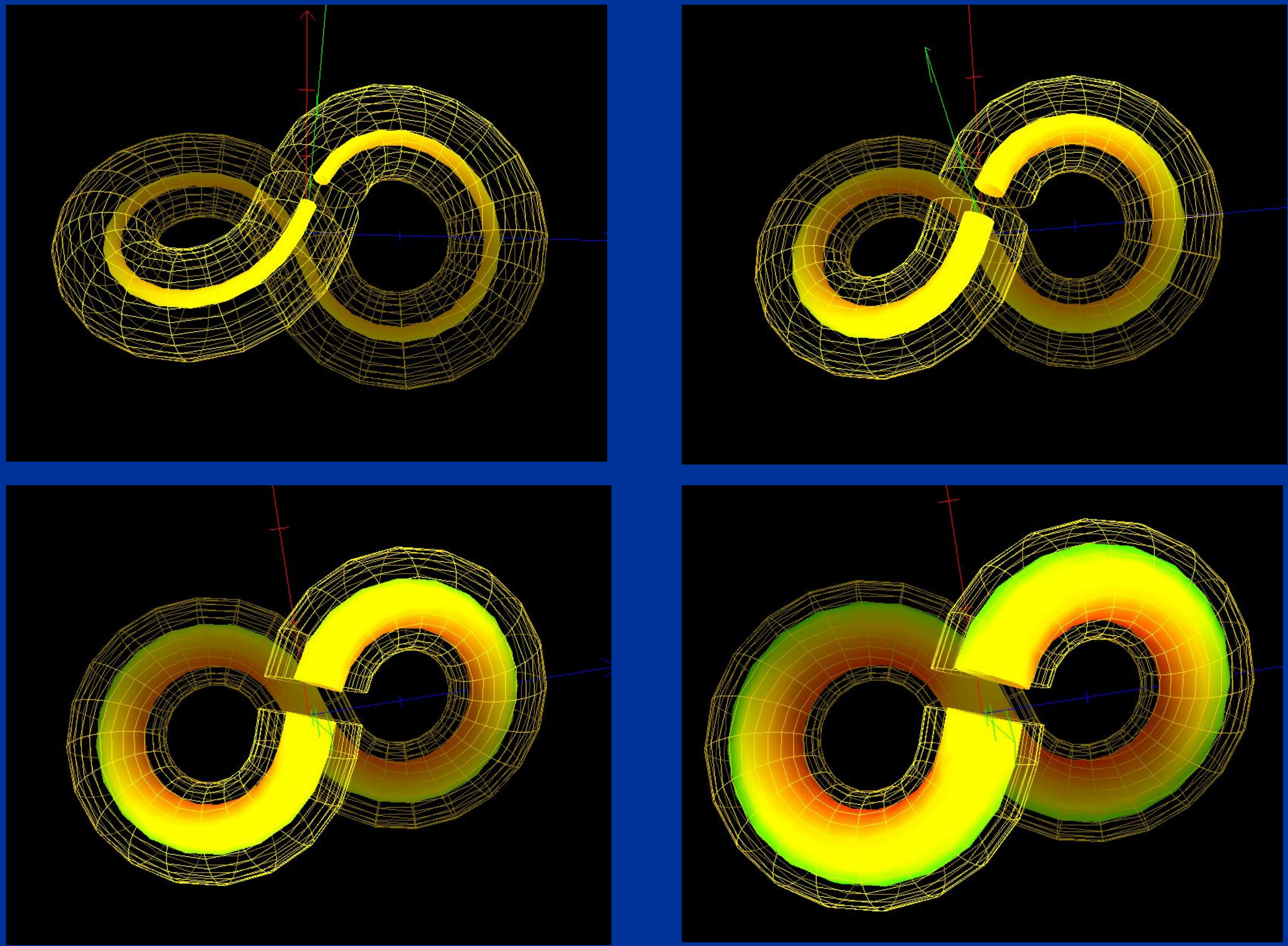
(independent calculations)

- 100 Turns around the figure-8
- Simulation time 50h on 20 Processors
- Computed Parameter: B, A, χ, ψ - magnetic Flux, metric tensors

Magnetic surfaces as a 1st test object



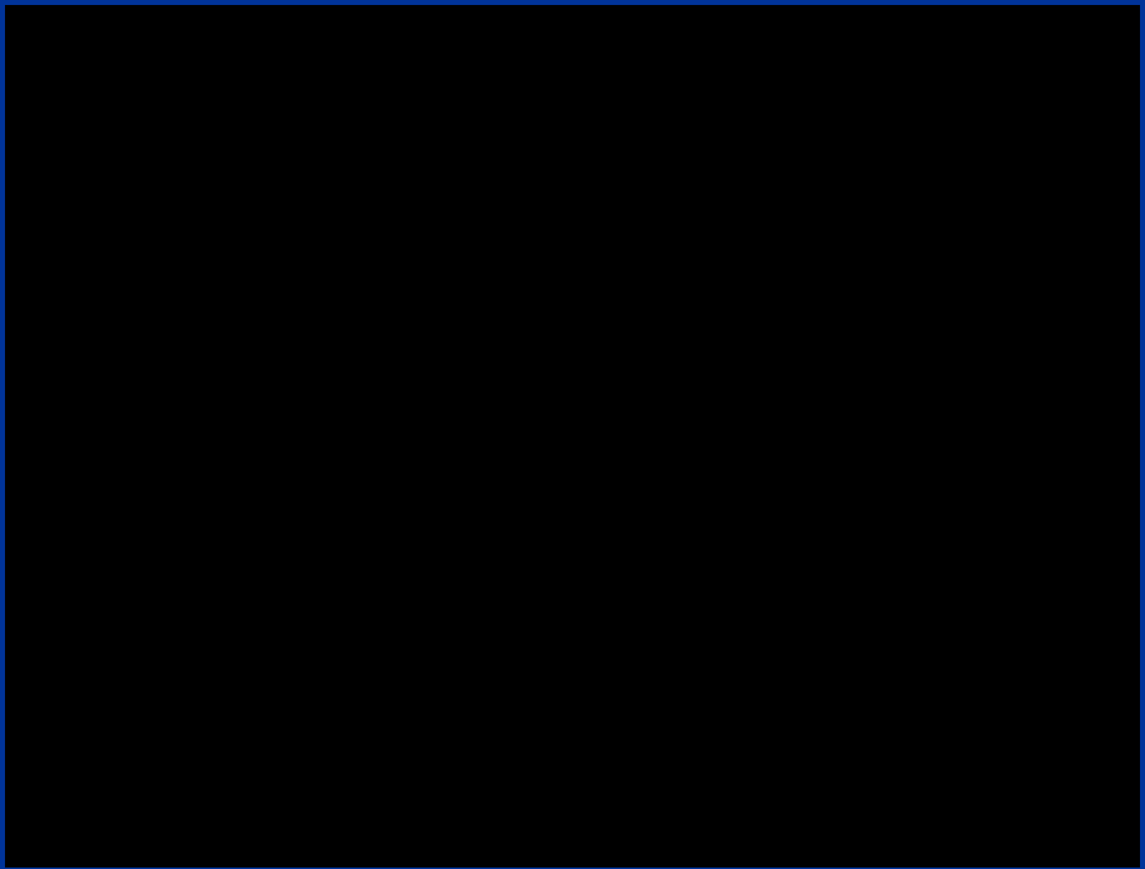
Magnetic surfaces – B field



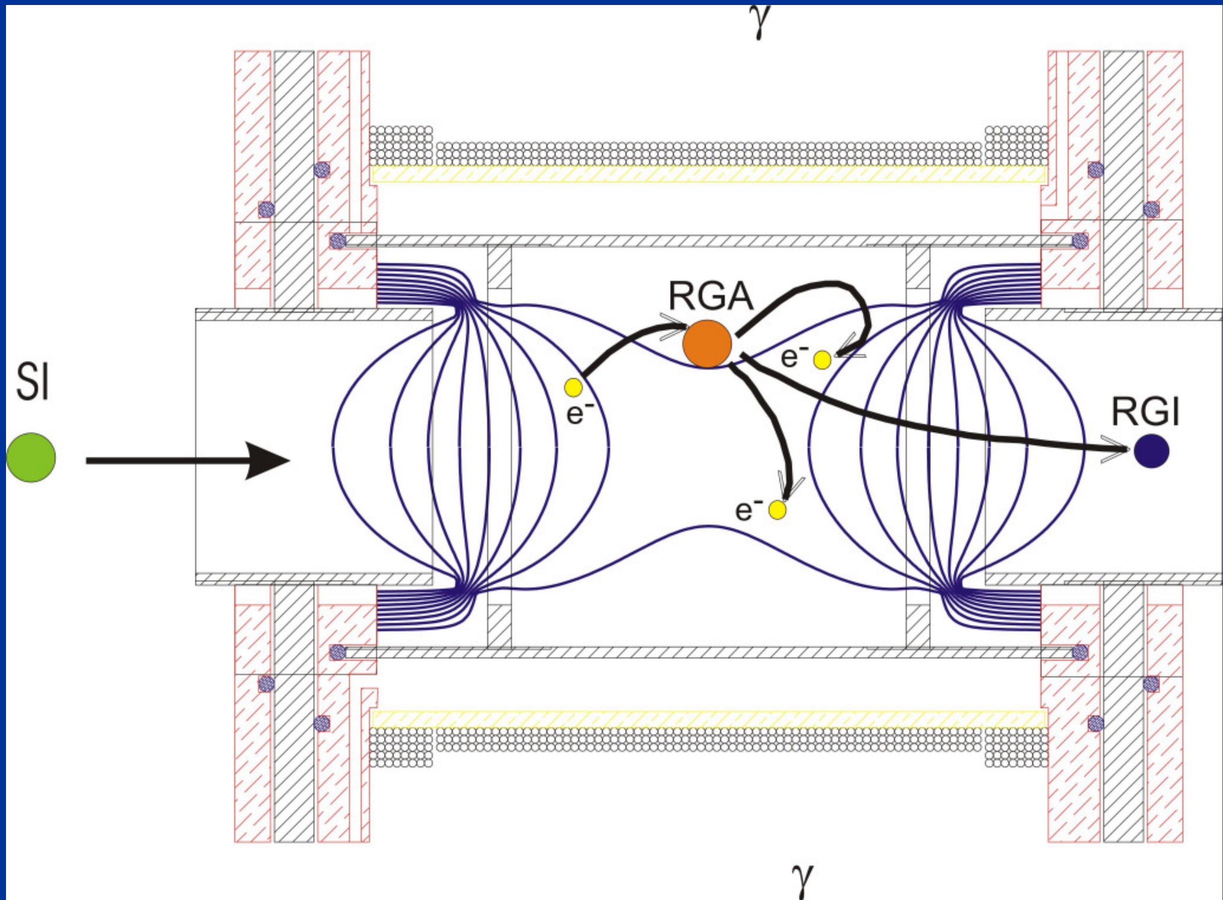
Magnetic surface

Colour coding – B-field : green 0.6T – red 1.4T

Important for reflection of particles



Gabor lens as a 2nd test object



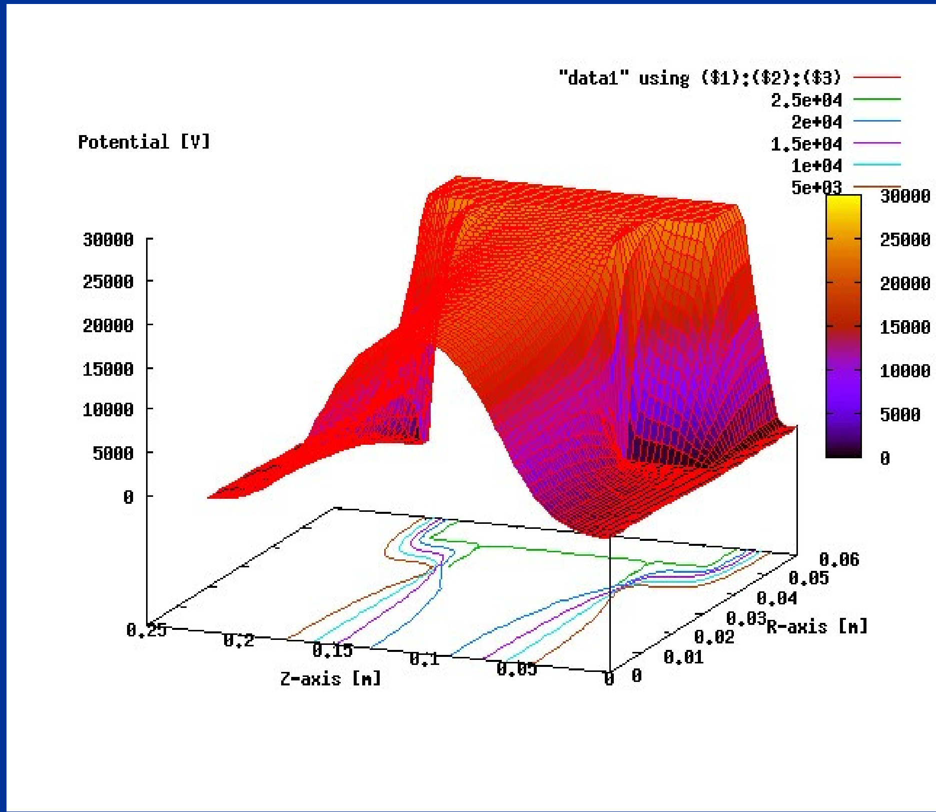
Gabor lens - Field

- Sparse matrix format – saving of memory
- Iteration methods – BiCGSTAB (Bi-Conjugate Gradient Stabilized)
- Cuting in longitudinal direction => depending on number of processors
- Changing of boundary data in every step

- 3D-Poisson Equation in cylindrical mesh
- r=0 Problems => Gauss formula

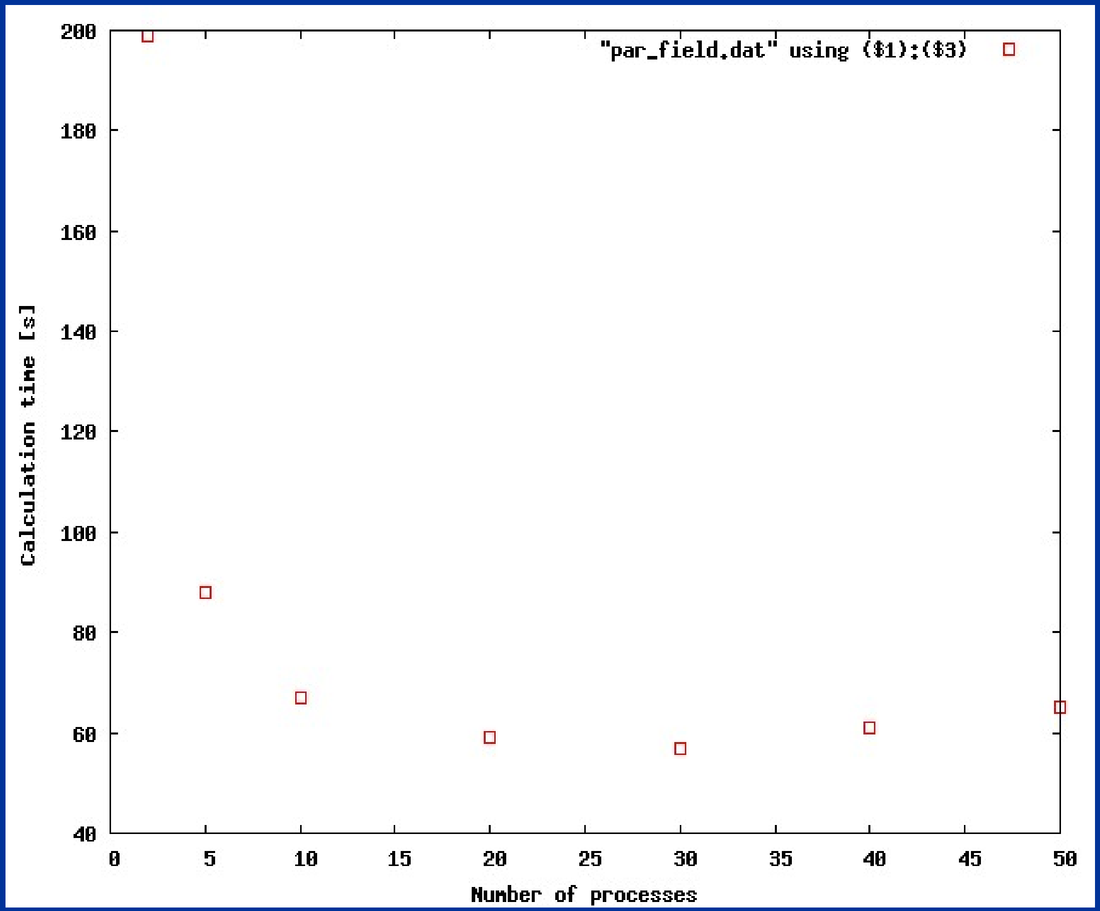
Gabor lens - Field

- Mesh 61x61x217 = 807457 points
- Number of processors
  - 2 – 50
- 150 iteration steps => residual norm ~ 10^{-10} = accuracy
- Computation time
  - 60 – 200 s



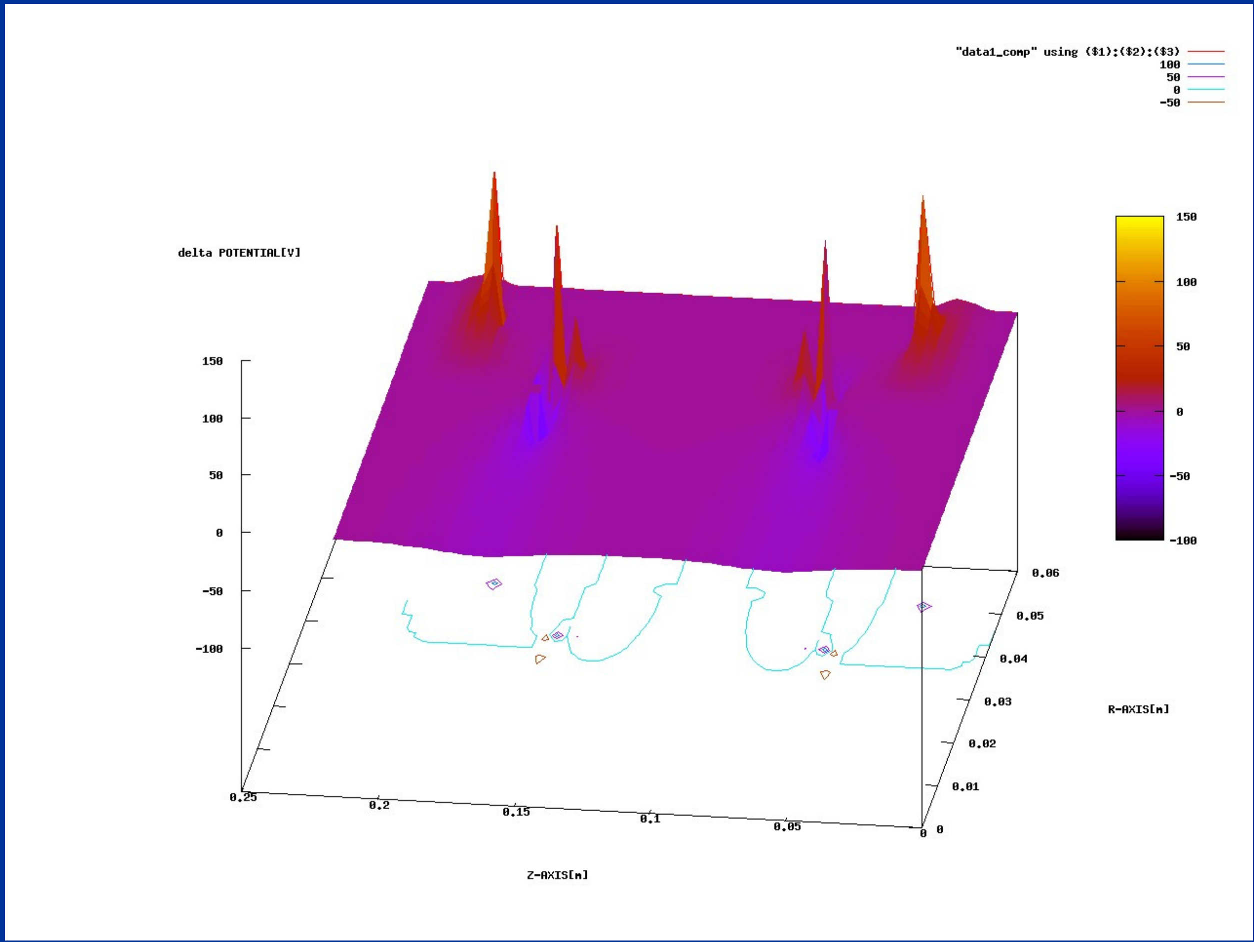
Gabor lens - Field

- Time scaling
- Comparison with 2D-Program – 0.01%
- By changing of mesh-resolution also on axis variation in 0.01%



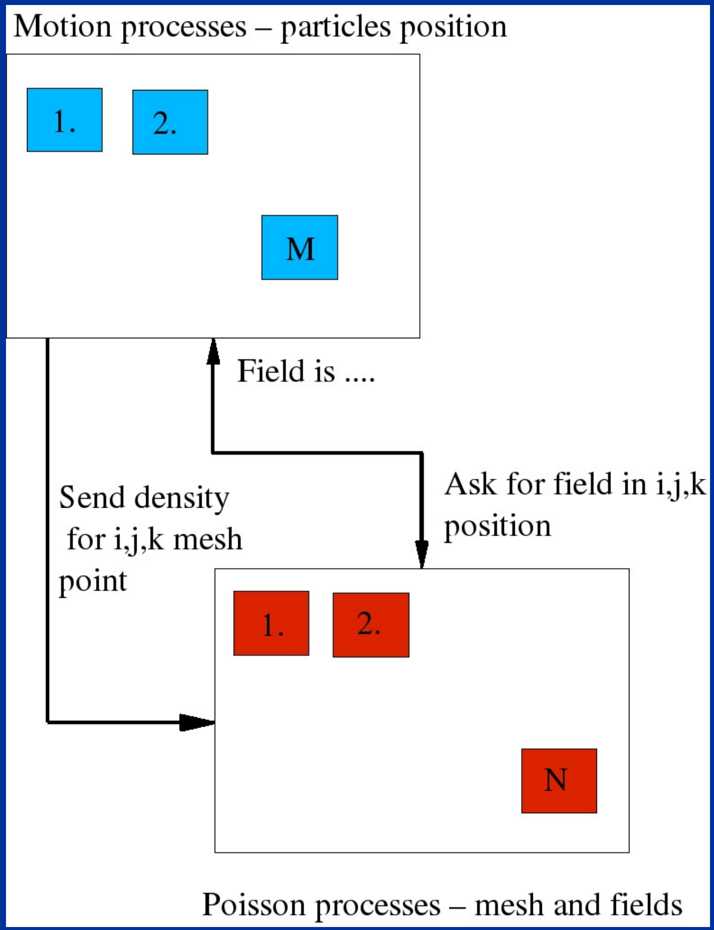
Gabor lens - Field

Comparison between 2 simulations – step1=2*step2



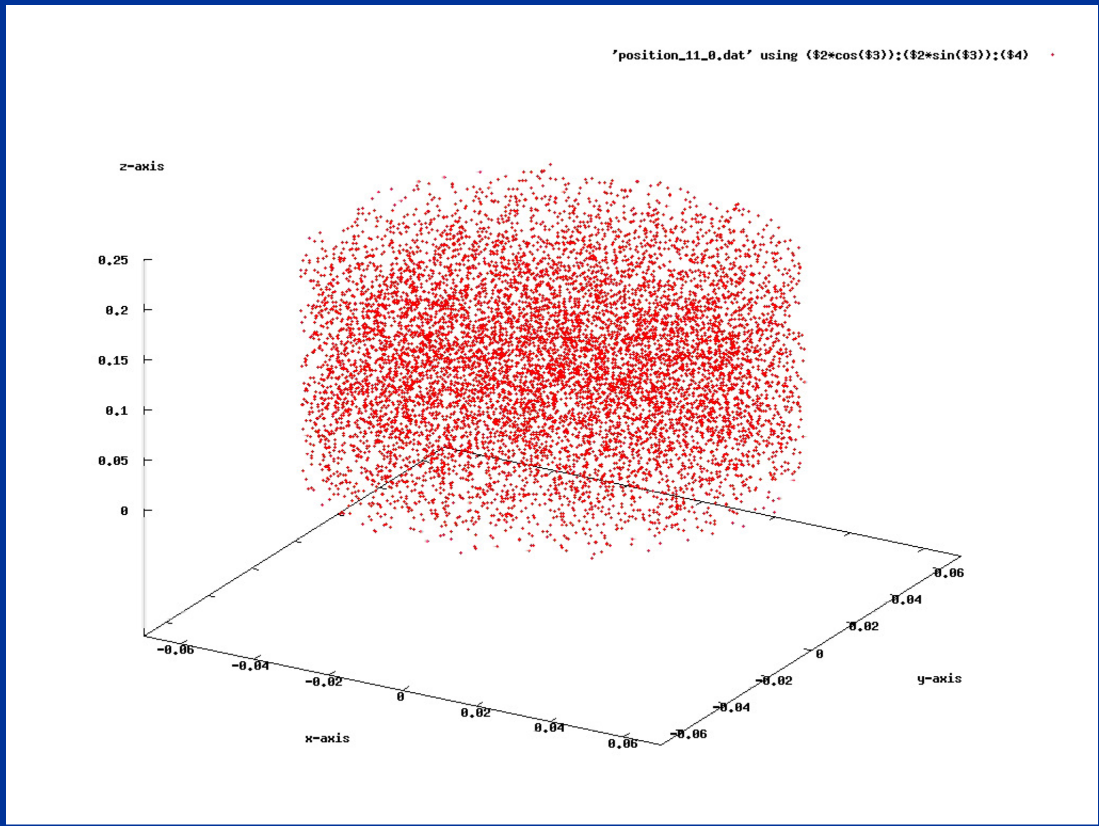
Gabor lens - Motion

- PIC - Method
- Boundary condition – electrodes
- Poisson processes ⇔ Motion processes – sending and receiving of data
- 1^{st} test only with external field => no space charge effects

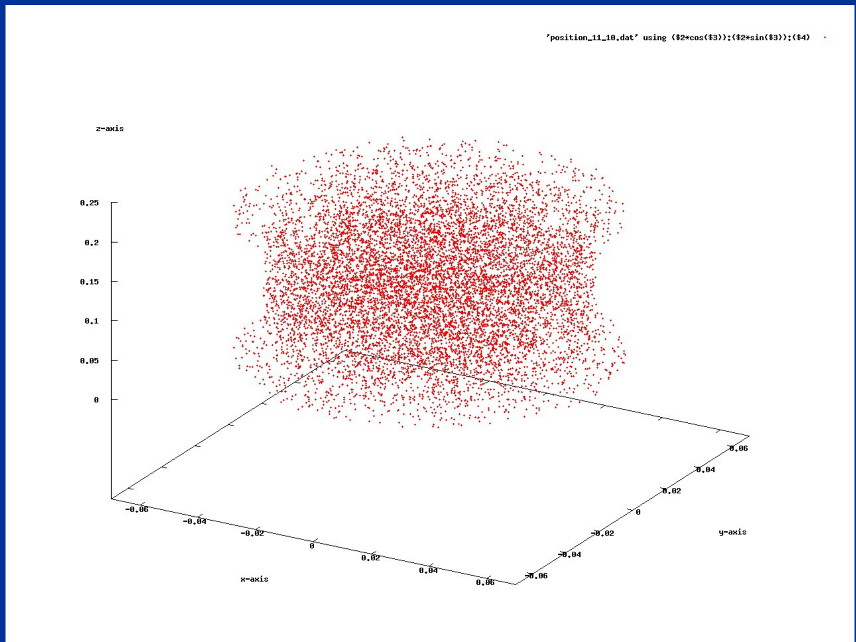


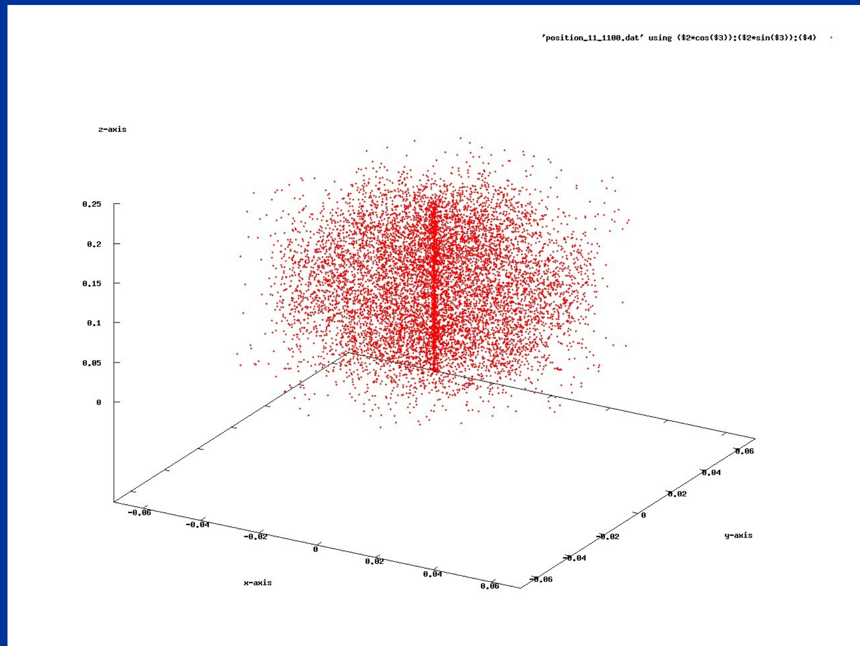
Gabor lens - Motion

- First results
- B=0.007T
- U=2kV
- Initial kinetic energy <0 – 4keV>
- Time step
  dt = 4e-11s
- Calculation time for 2200 steps = 90min – 10000 particles per processor



Gabor lens - Motion





Conclusion and Outlook

- Magnetic surfaces were calculated – coordinate system for the accumulator
- Field calculation code was written and tested
- Motion in cylindrical coordinate was calculated

Future plans:

- PIC – Space charge effects have to be include
- Motion in accumulator – averaging through Larmor oscillation
- Long term simulation – stability !

Some calculations

$$B = 1T, n_B = \varepsilon_0 B^2 /(2m_p) = 2.65 \cdot 10^{15} m^{-3}$$

$$\delta B / B \approx (n_e / n_B)^2 \left(\frac{a}{c/\omega_c} \right)^2$$

$$\nabla^2 \phi = \frac{e}{\varepsilon_0} N(\psi) \exp\left(\frac{e\phi}{T_e(\psi)} \right)$$

$$j_{kritisch} = n_B e v = 2.65 \cdot 10^{15} \cdot 1.602 \cdot 10^{-19} \cdot 0.018 \cdot c = 2292.5 A/m^2 = 0.229 A/cm^2$$