Ionenstrahlsimulationen außerhalb verfügbarer Standardprogramme

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Contents

- Motivation
- LORASR
- Magnetic codes
- TNSA – LASIN
- Conclusion & Outlook

Standard Tracking Programs

- TRACE3D, PARMILA, PARMTEQ, LORASR, DYNAMION
  - Paraxial Approximation, realistic fields input
  - Space charge routines – PIC, PPI
- WARP-Code – Plasma simulation – PIC
- Other – IGUN

Motivation

- Realistic fields – Improvements of field maps
- Higher space charge fields
- Stronger focusing
- Parallel implementation – Clusters
- Modern computation methods
  - Parameter optimisation (PSO)
  - Multigrid methods
- Collective phenomena – Multispecies (compensation electrons, LEBT, TNSA)
- PIC+Collisions (neutron production, ion source)

LORASR – Present and Mid Term Code Development Topics

- Present activities:

- Implementation of orbit corrections (steering magnets) for error studies.

- Verification of the relativistic correction for the space charge fields.

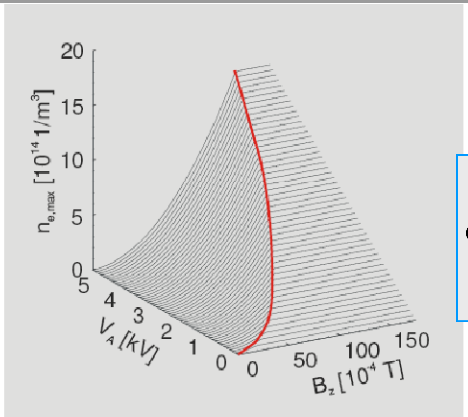
- Mid term plans:

- Field maps from numerical simulations for rf gaps and magnetic lenses

Relevance:
- asymmetric gap geometries
- fringe fields (dipole magnets and short solenoids)
- quadrupole content of CH-gaps

NNP – Breaking the symmetry

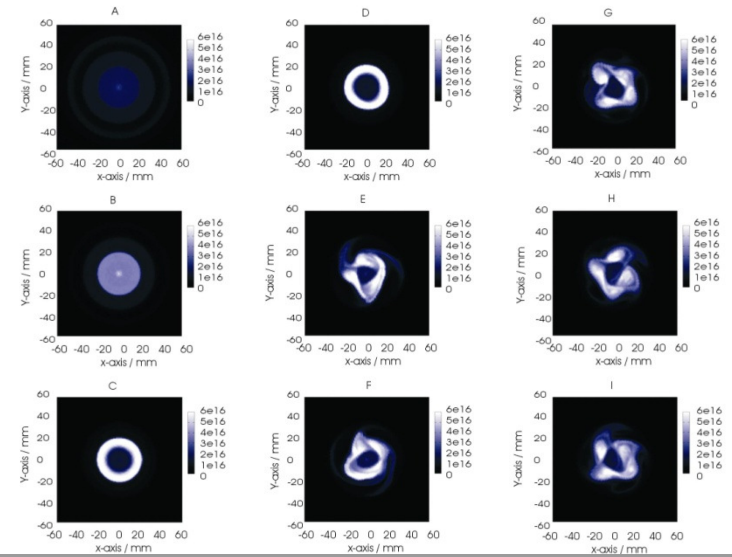
- GaborM
  (J. Pozimski & O. Meusel)
  – (r,z) - Solver
  – Magnetohydrodynamic
  – Equillibria



$$\Phi_A = \frac{e r^2 B_z^2}{8 m_e}$$

video11.avi

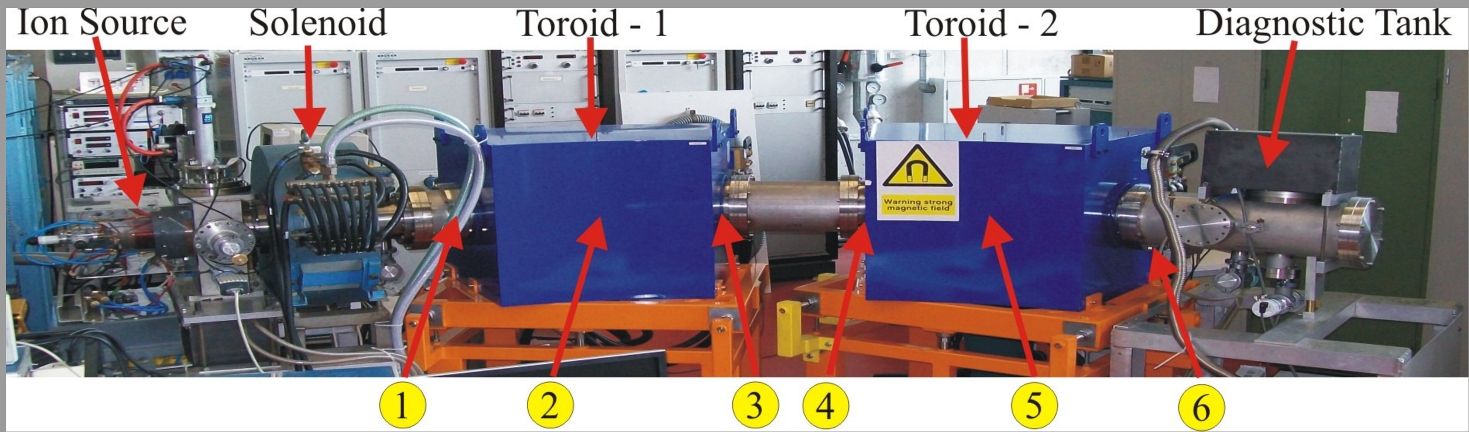
- Gab_lens 3D-Particle-In-Cell Simulation (M.Droba, O. Meusel, K. Schulte)
  – Particle tracking - parallel
  – Dynamic
  – Finite Larmor radius - effects



TBT (Toroidal Beam Transport)

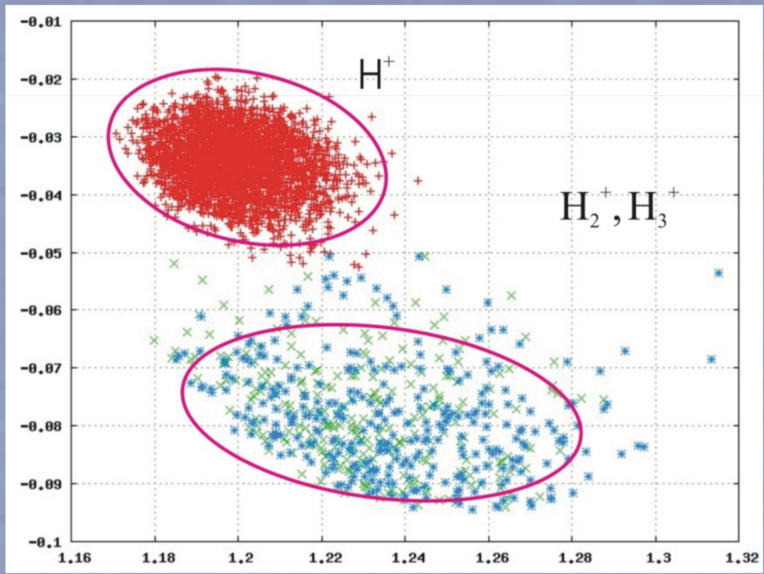
(N. Joshi, H. Niebuhr, A. Ates, M. Droba)

- Curved magnetic field – Drifts RxB, ExB
- Reflexion – Magnetic bottle configuration
- Toroidal coordinate system
- Ions and beam induced electrons
- Symplectic Integrator



Ion Species Separation

• Low energy (10keV) composited ion beam
•The separation between species due to curvature drift possible over long path length
• Separation due to phase difference in Larmor gyration

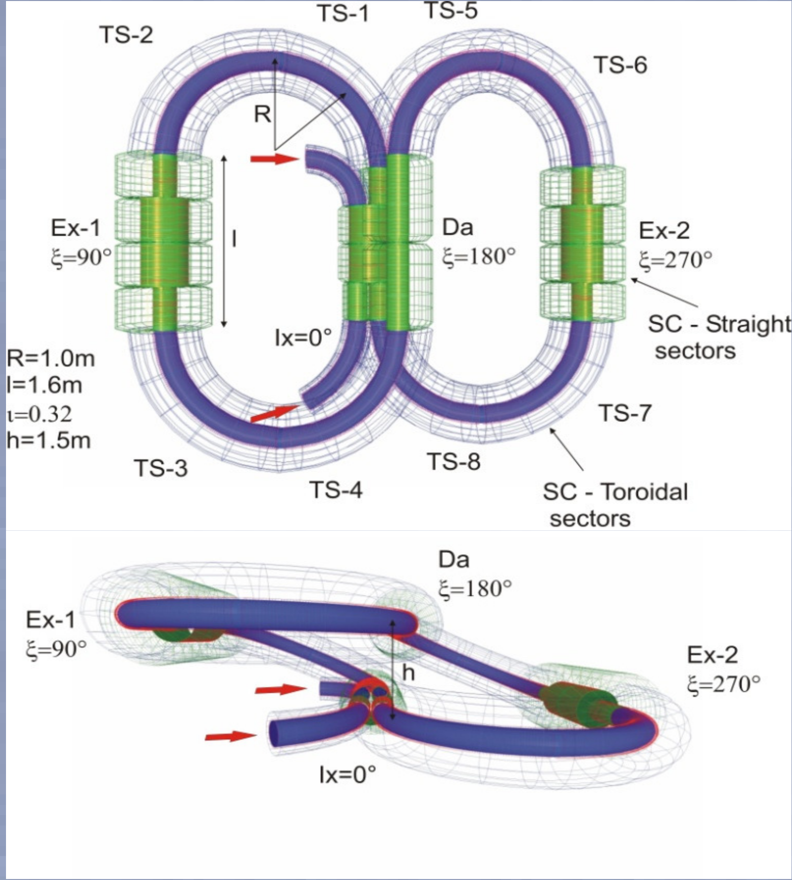


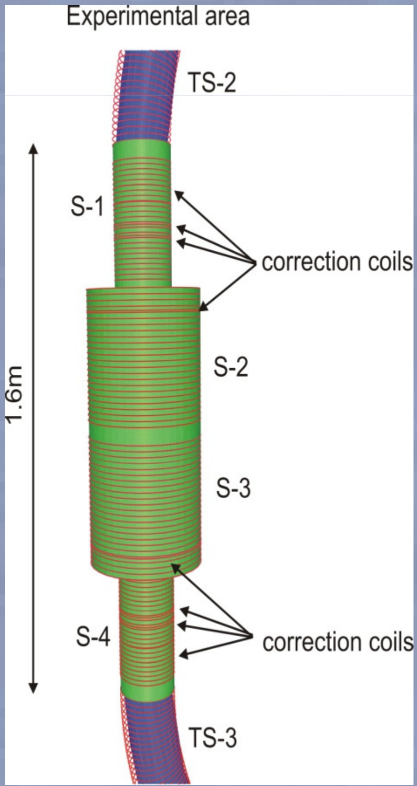
F8SR

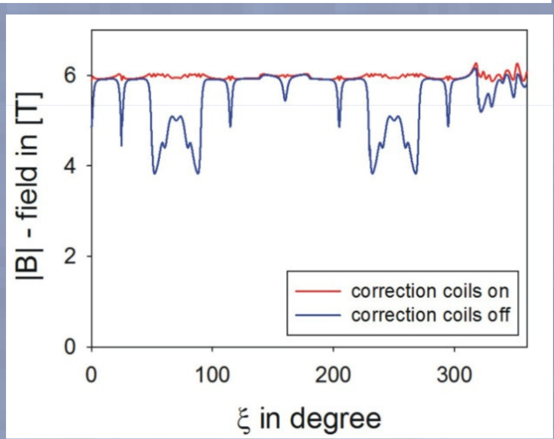
•Code - “Segments”

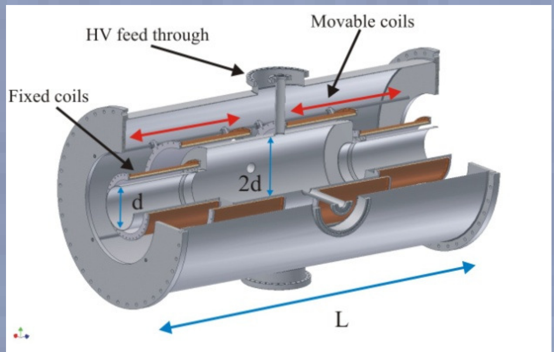
F8SR Design

– Biot-Savart Solver
- Coil Settings 3D
- Establishment of flux coordinates









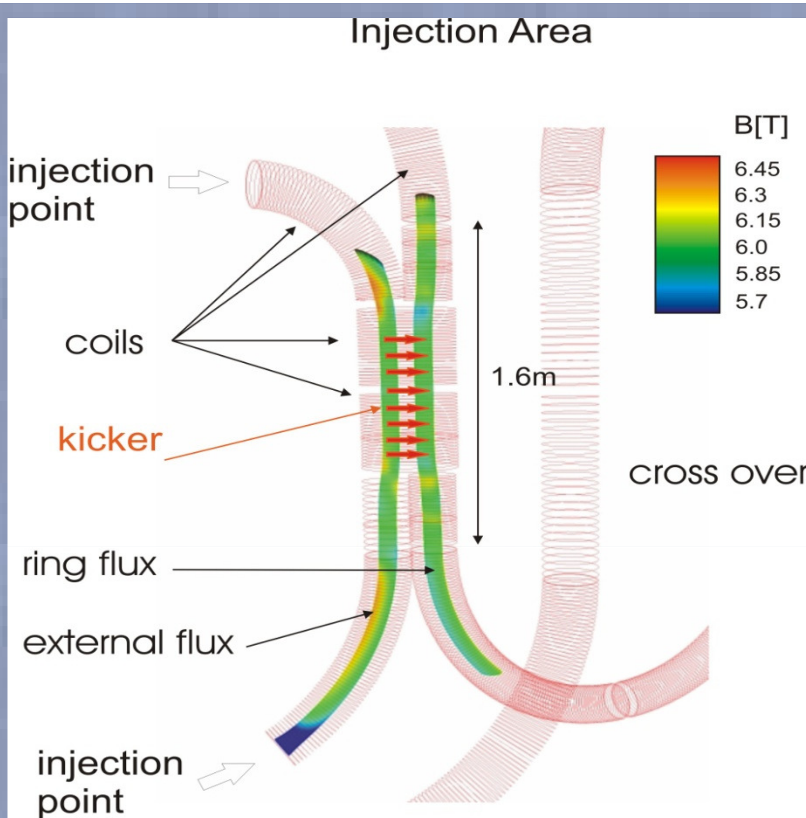
F8SR

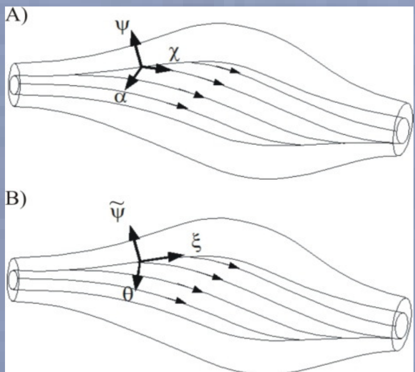
•Code - “Infinity”

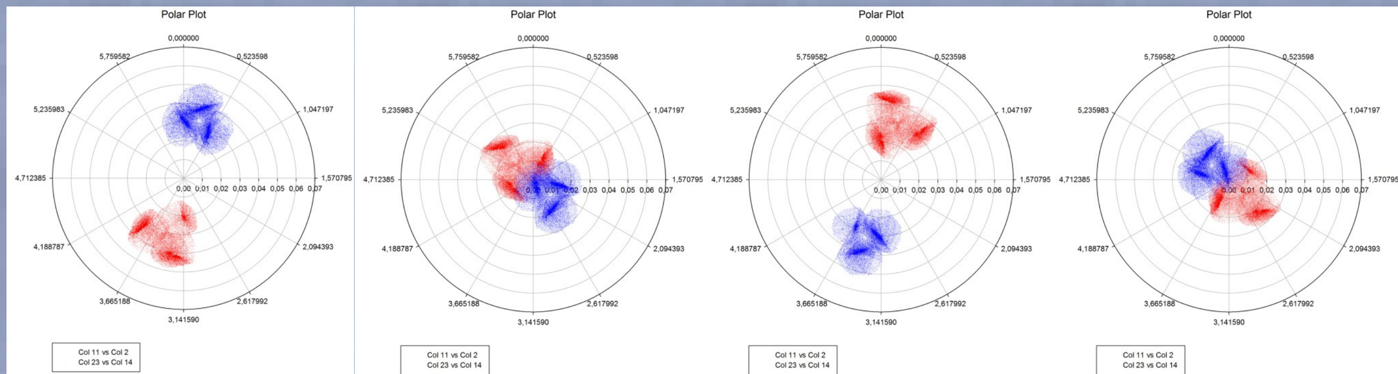
Particle tracking in flux coordinate

– 3D Poisson solver
- Guiding center approximation
- Explicit Symplectic Integrators?
- Singularity on axis -> switching to real space

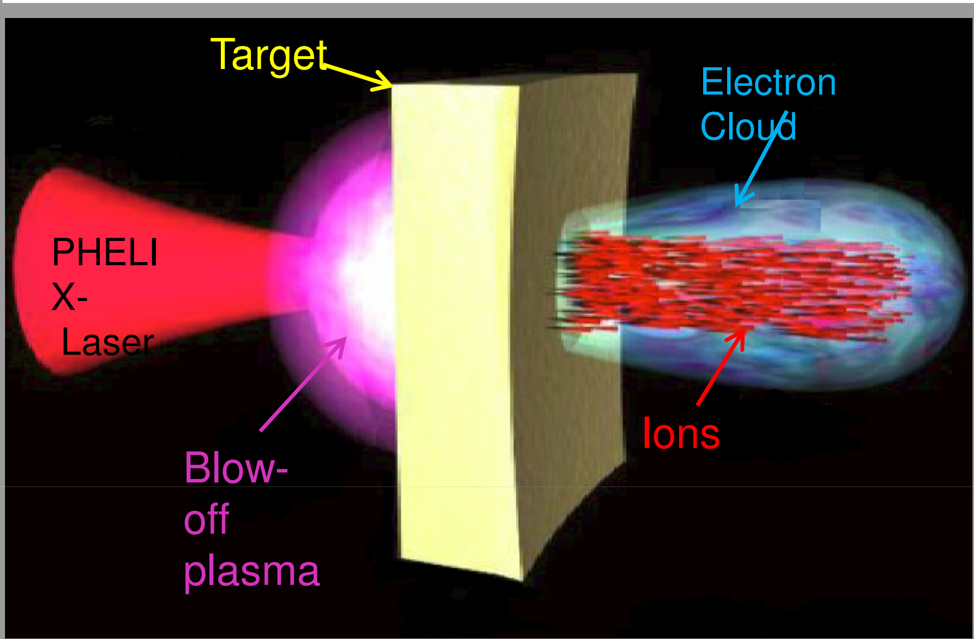
ToDo : role of iota parameter for clockwise and counterclockwise moving beams

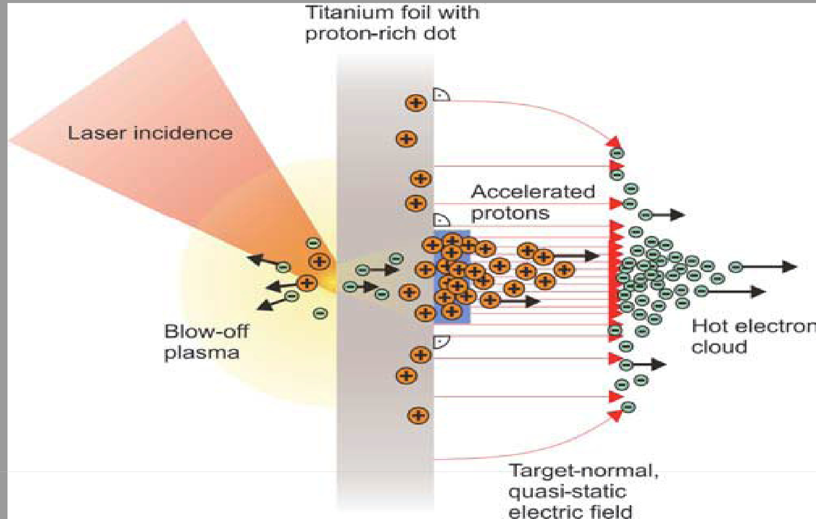






Project LIGHT





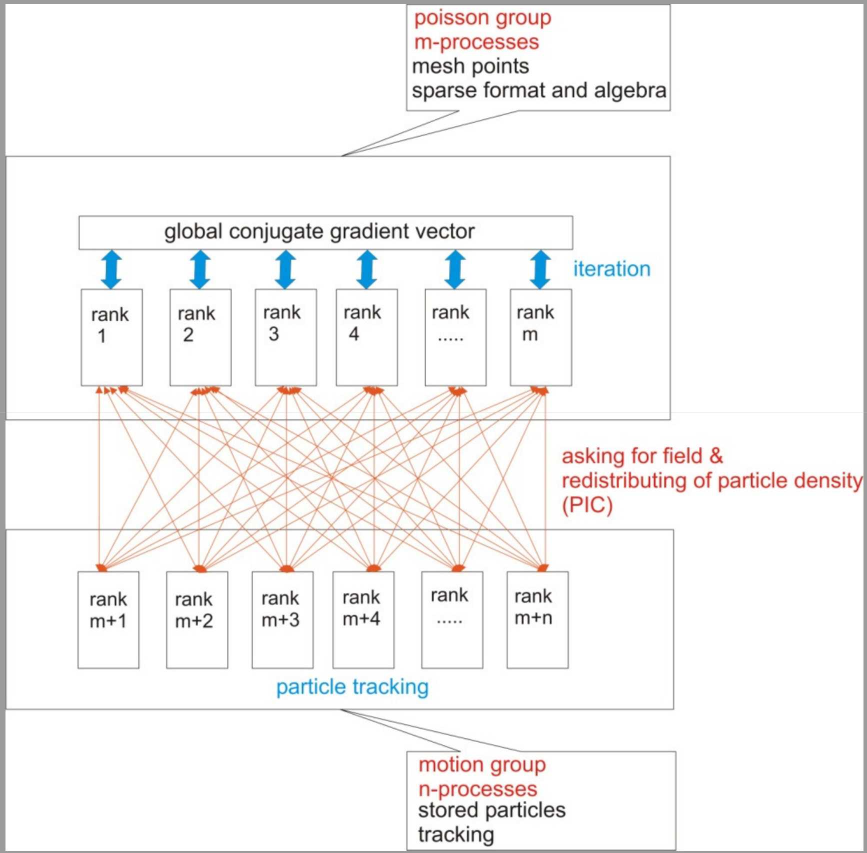
H. Schwoerer et al., Nature **439**, 26.

Target Normal Sheath Acceleration (TNSA)

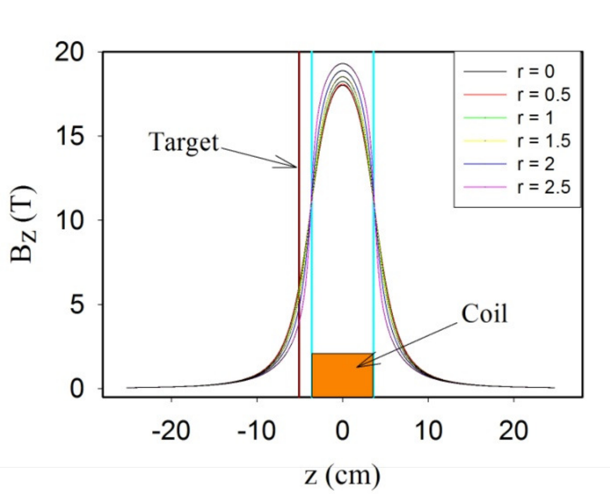
-Focusing (Pulsed Solenoid ~ 18T)
-Injection and Post-acceleration in CH-Structure

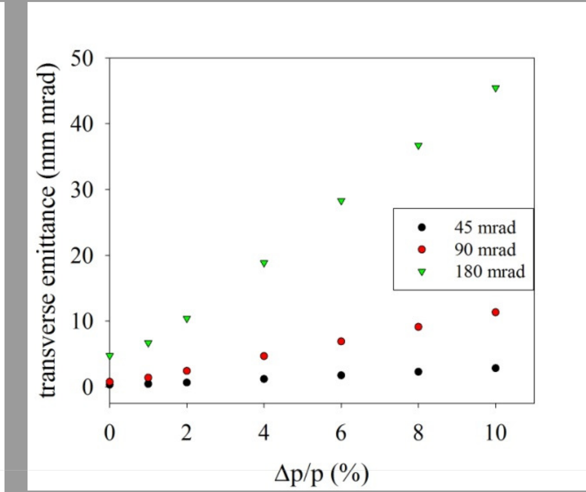
LASIN - Code

- Parallel PIC-program – implemented on FUCHS (CSC-Cluster)
- Multispecies tracking (x,y,z)
- Poisson – solver – iterative BiCGSTAB method
- Cylindrical coordinates 3D
- Typically 50 Processors



Space charge off

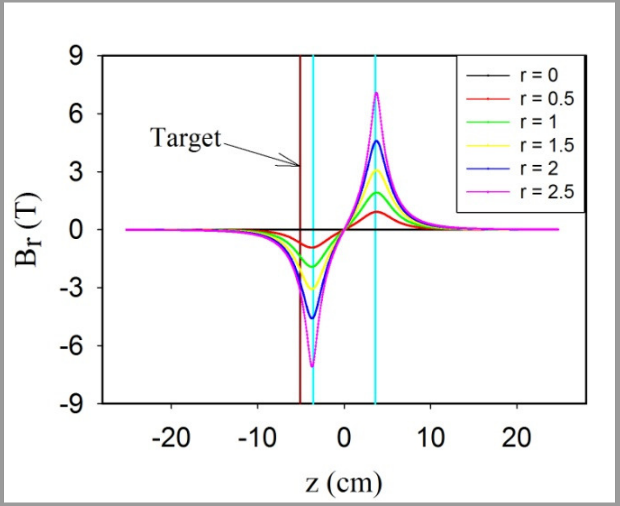


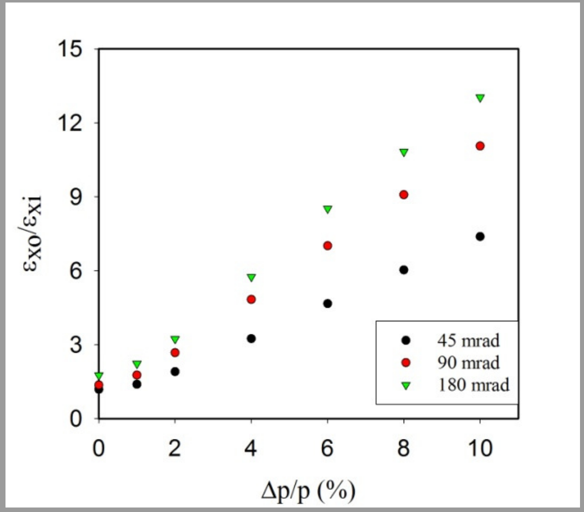


Successfully comparison with:

DYNAMION (Yaramishev)

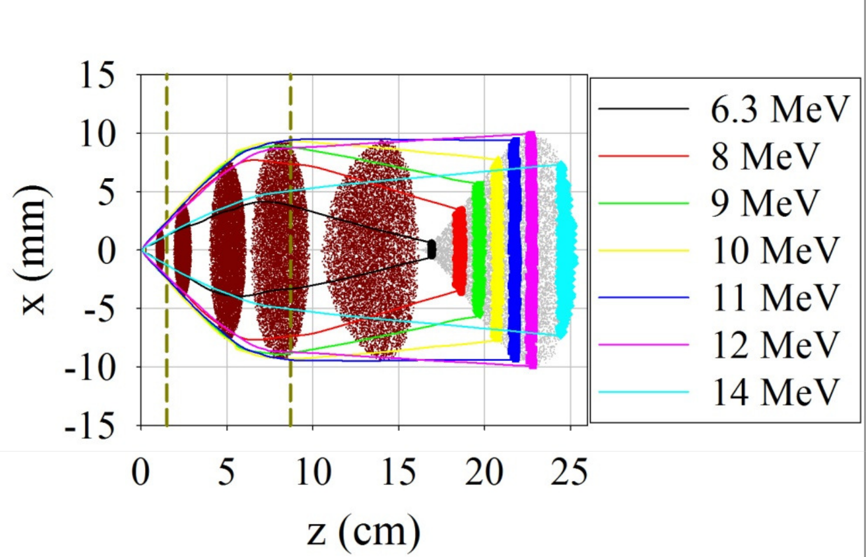
LORASR (Ratzinger,Tiede Droba)

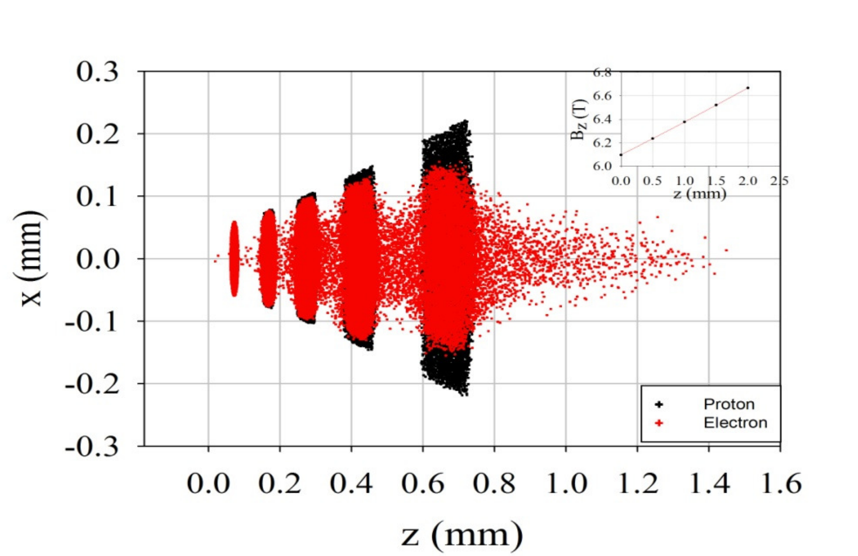




Aberrations – Chromatic
- Geometric

LASIN – Space charge

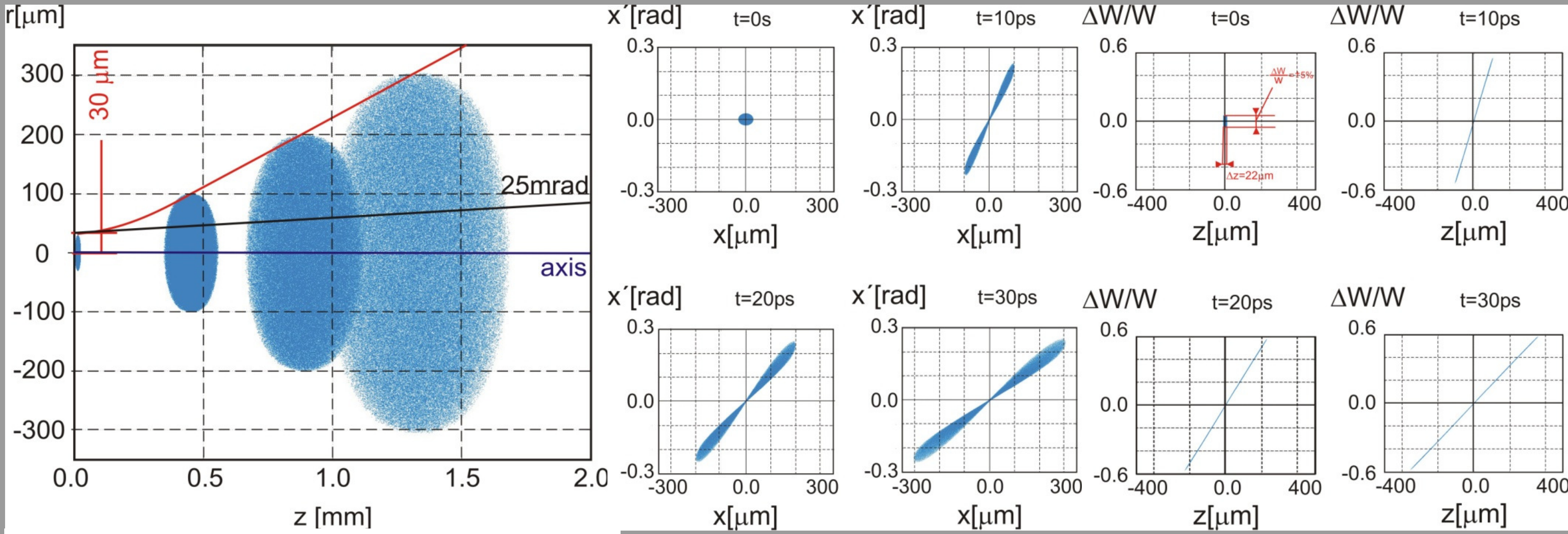




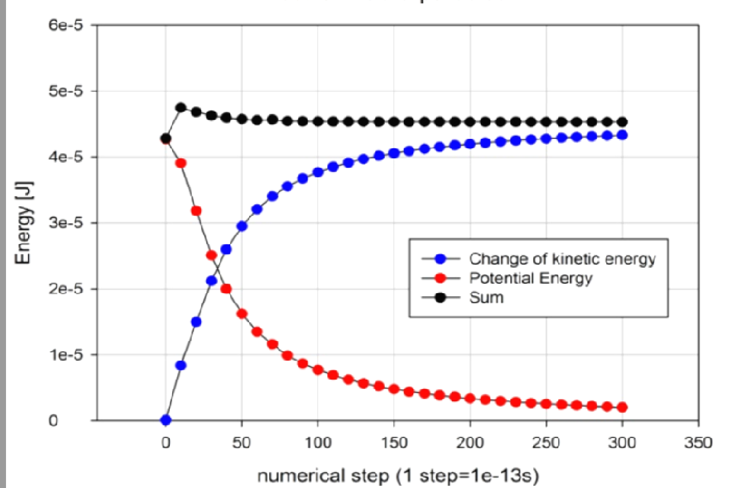
Preliminary studies with space charge:

- Important interaction on 1st mm
- Energy spread ?
- Opening angles ?
- Energy conservation ?
- Momentum transfer between Species ?

LASIN – Space charge

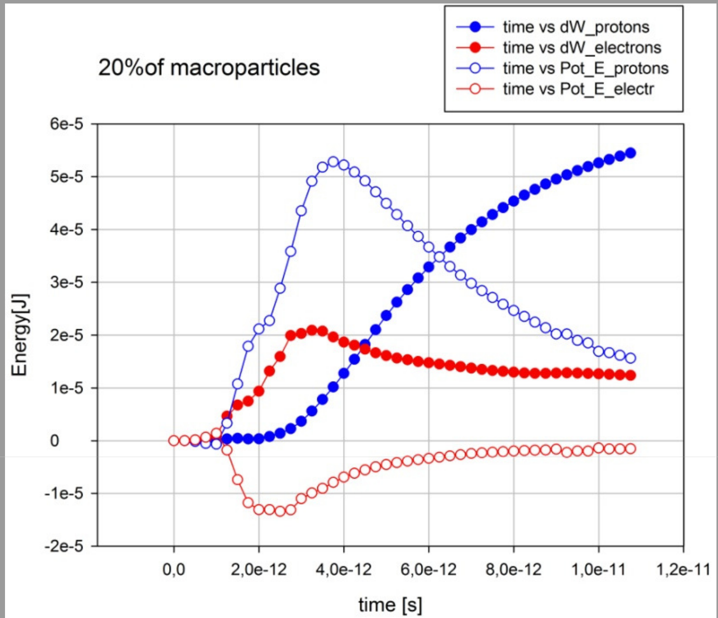


20% of macro-particles



Homogenous ellipsoid R=30μm, L=22μm
Bunch – equiv to 10^{10} protons
Mesh (r,phi,z) = 250x30x10000,
(dr,dphi,dz)=(6μm,0.2rad,2μm)
W~10MeV

Simulation – Protons&Electrons



dt=25fs

R=30μm, L=22μm

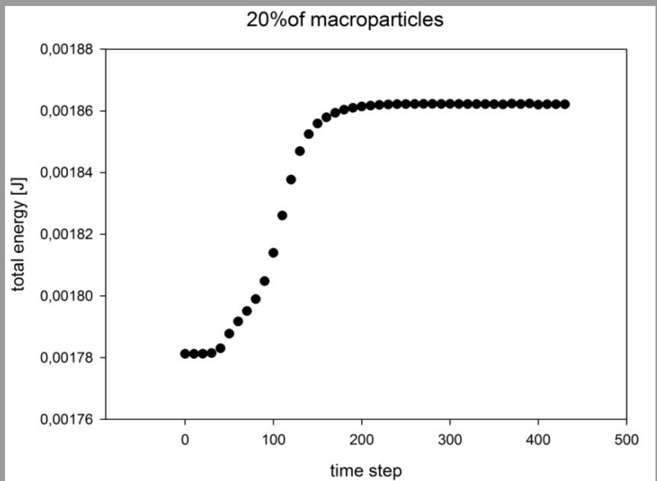
Protons W=10MeV

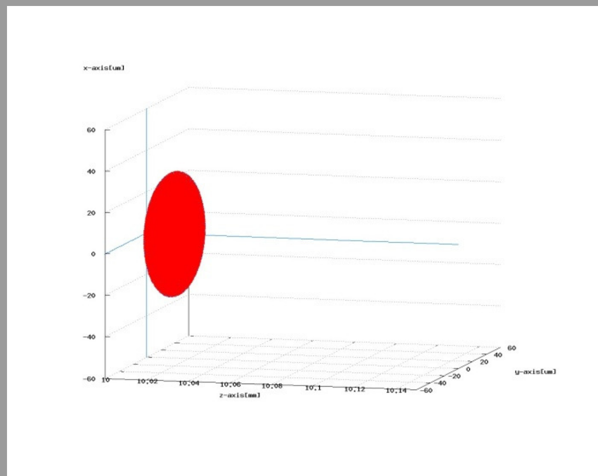
Electrons W=5.5keV

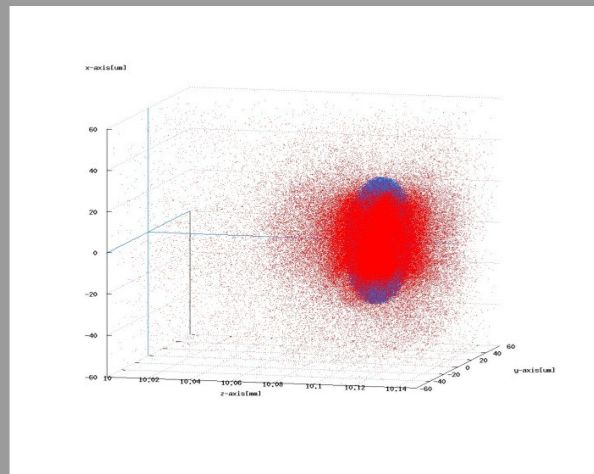
Particles/1 Macroparticle=4444 =>4.5Mio Macroparticles

Mesh:

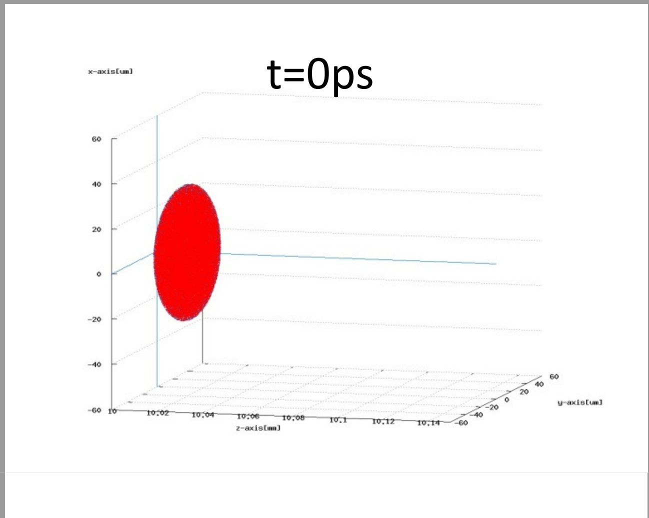
- dr=6μm
- dφ=0.2rad
- dz=2μm

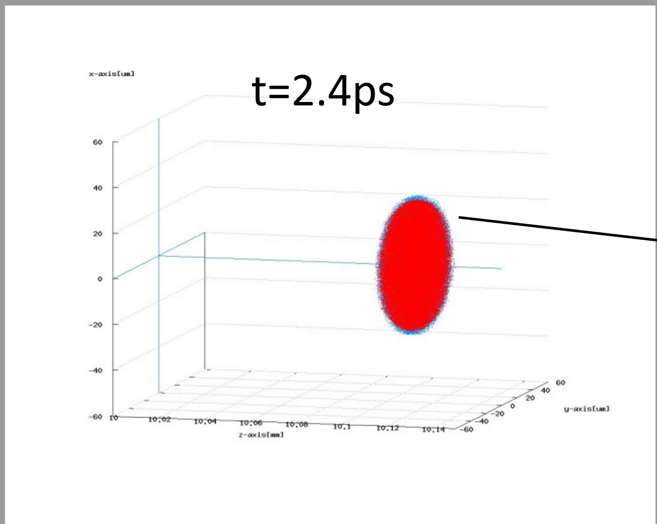






Simulation - Improvements





dt=5fs

R=30μm, L=22μm

Protons W=10MeV

Electrons W=5.5keV

Particles/1 Macroparticle=4444 =>4.5Mio Macroparticles

Mesh:

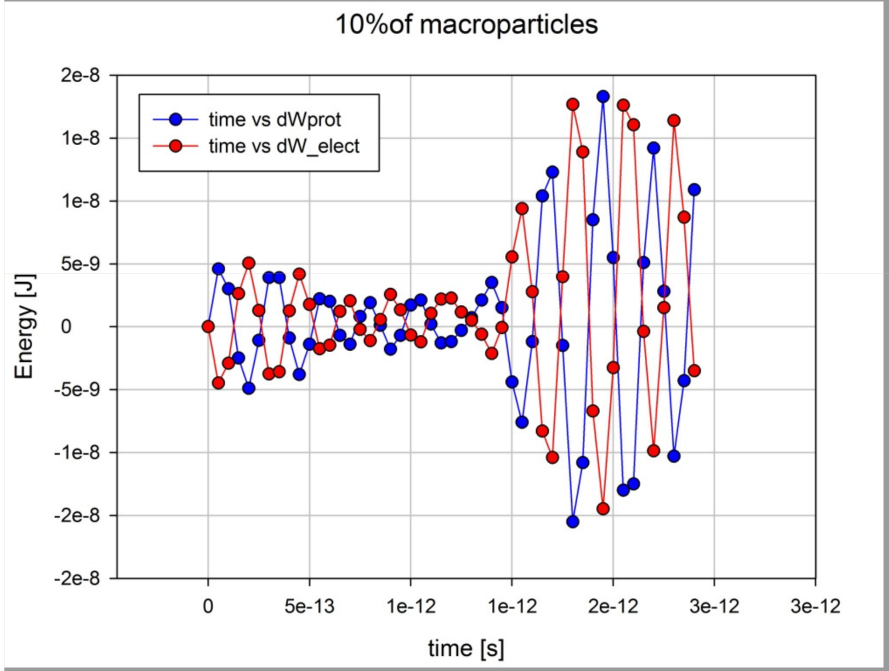
- dr=6μm
- dϕ=0.2rad
- dz=2μm

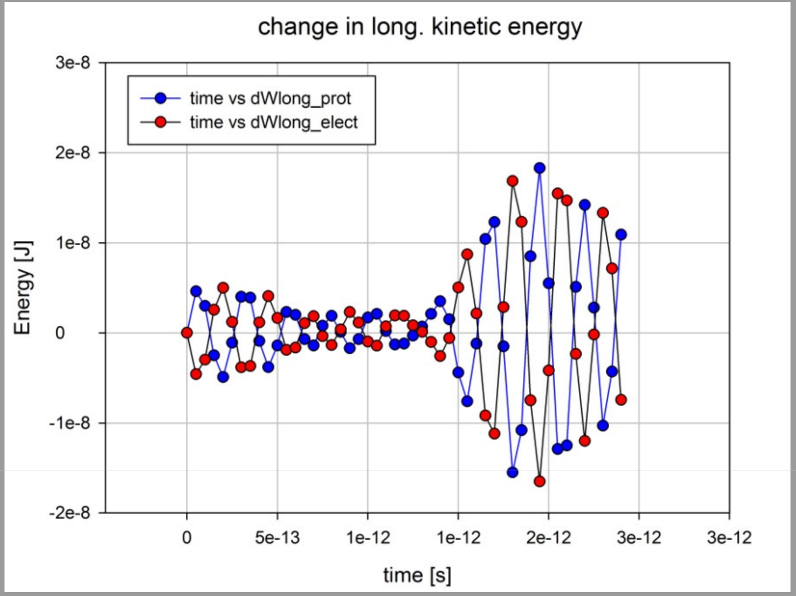
Less separation

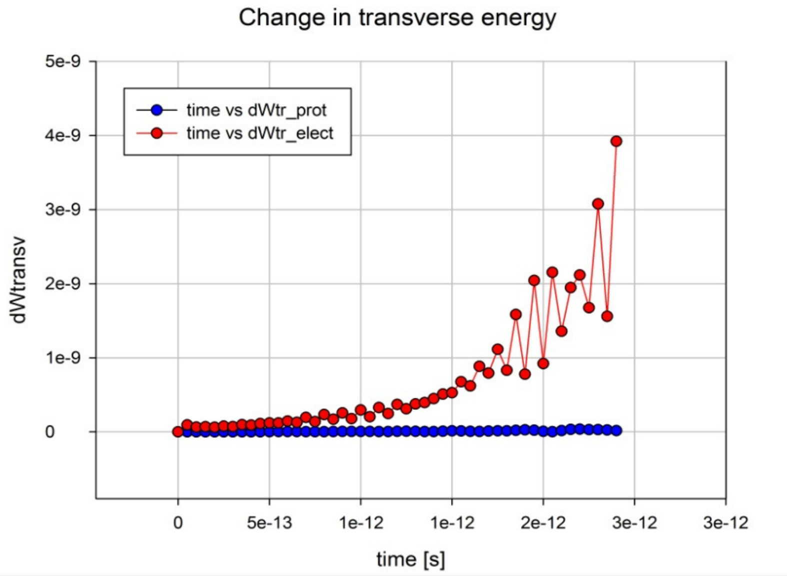
Lower electric fields and potential

LASIN – Kinetic Energy

Plasma oscillation longitudinally
Along magnetic field

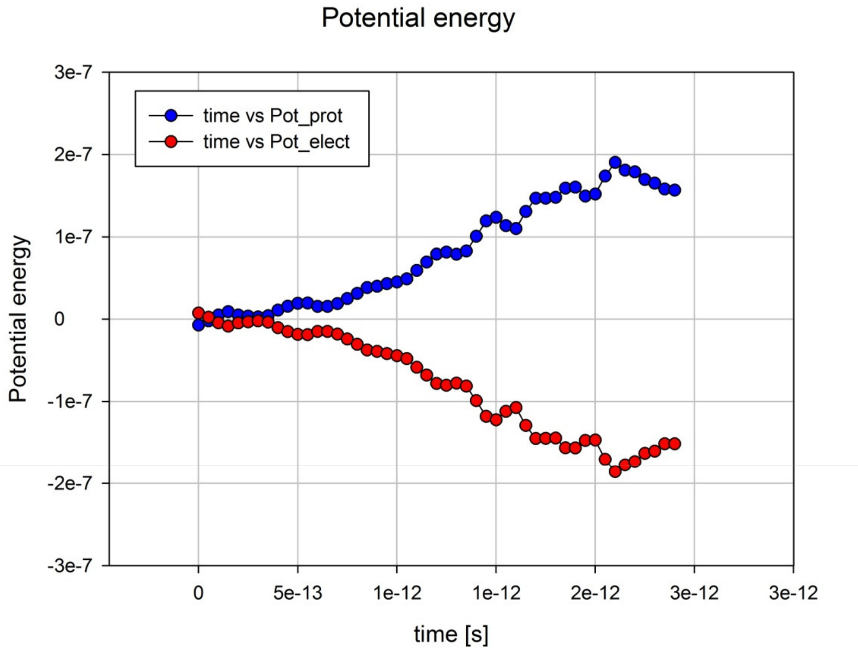




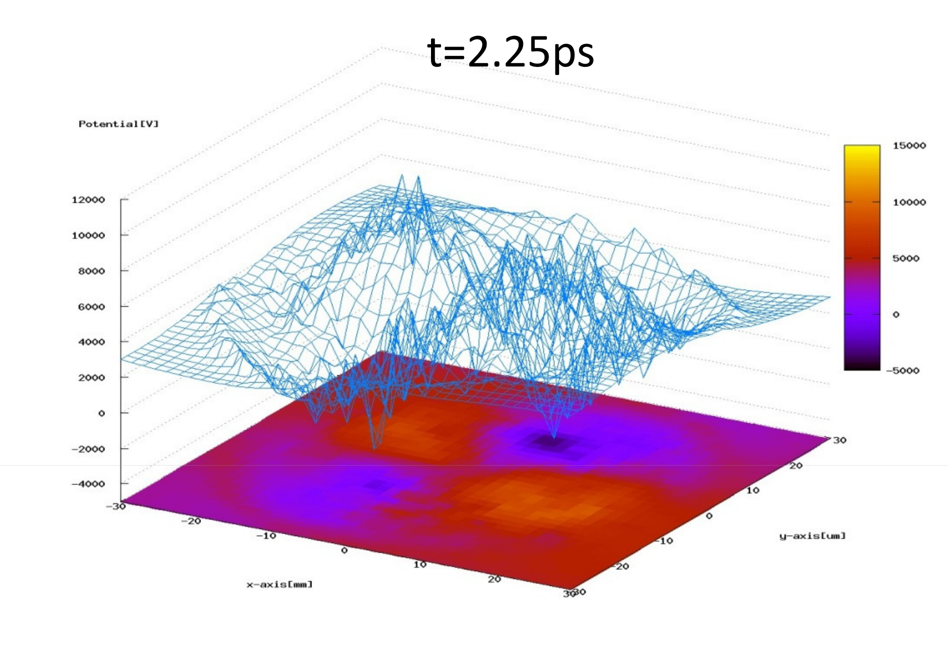


Due to the higher magnetic field in propagation direction
Redistribution of longitudinal momentum
To the transverse direction

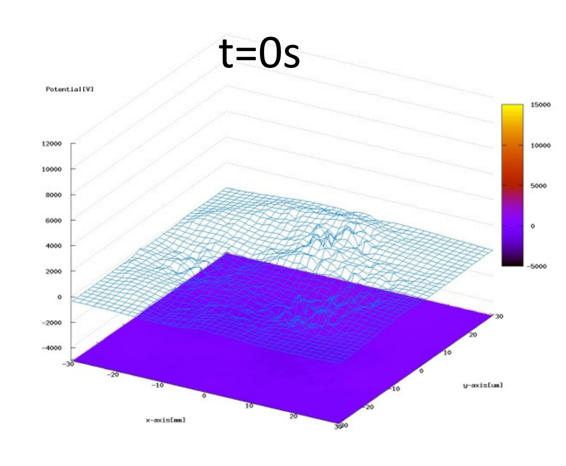
Potential



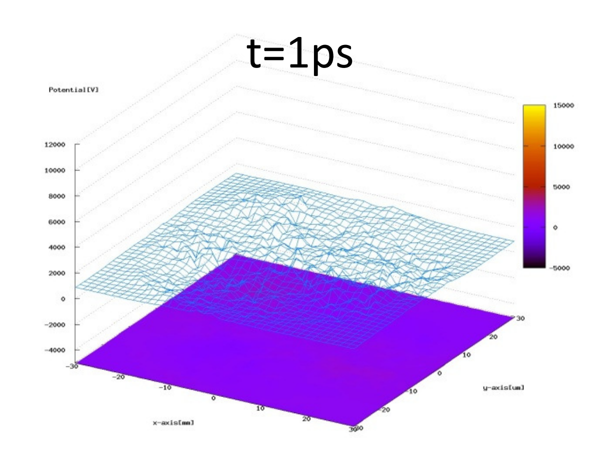
Potential energy
time vs Pot_prot
time vs Pot_elect
Potential energy
time [s]



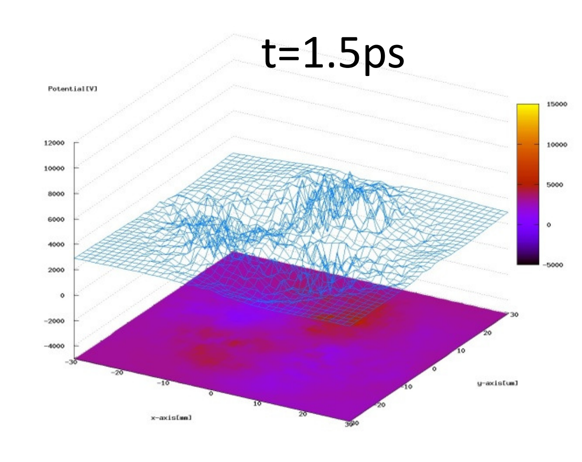
t=2.25ps



t=0s



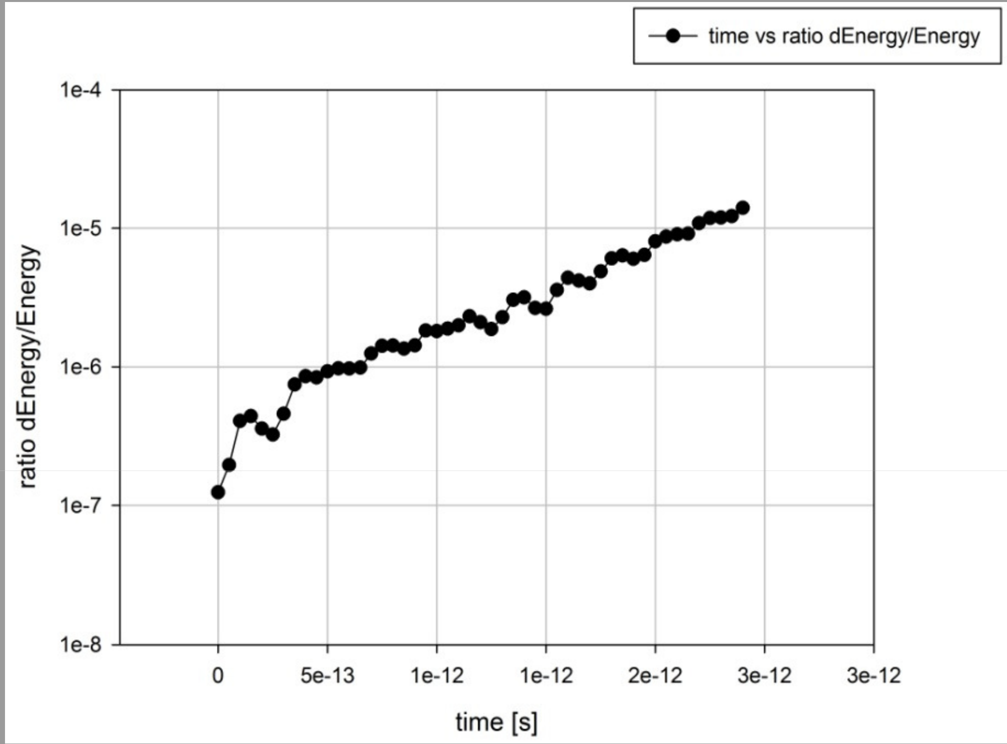
t=1ps



t=1.5ps

LASIN - Energy

Ratio – variation of total energy/energy (~ 1e-5 @ 3ps)



-Less comparing with previous case 6%

-Due to the variation of magnetic field ?

-Using different type of integrators

-Longer simulation needed

-Cyclotron frequency ->characteristic time τ_c=6e-12s

-Plasma frequency -> characteristic time τ= 3.5e-13s

-Debye length λ_D=0.2μm

New strategy -> finer mesh
dual mesh

Conclusion & Outlook

- Dynamic in strong magnetic field (Solenoids, Toroids & Fringing fields+ magnetic coupling)
- Collective phenomena (Gabor Lens, electrons&ions)
- Correction coils
- Space-charge effects & Aberrations
- Experience -> Development of efficient simulation and design tools for future Linacs

- Thank you for your attention