Status Report 03/2011

Project Light – Matching the Laser p-bunch into a CH-DTL

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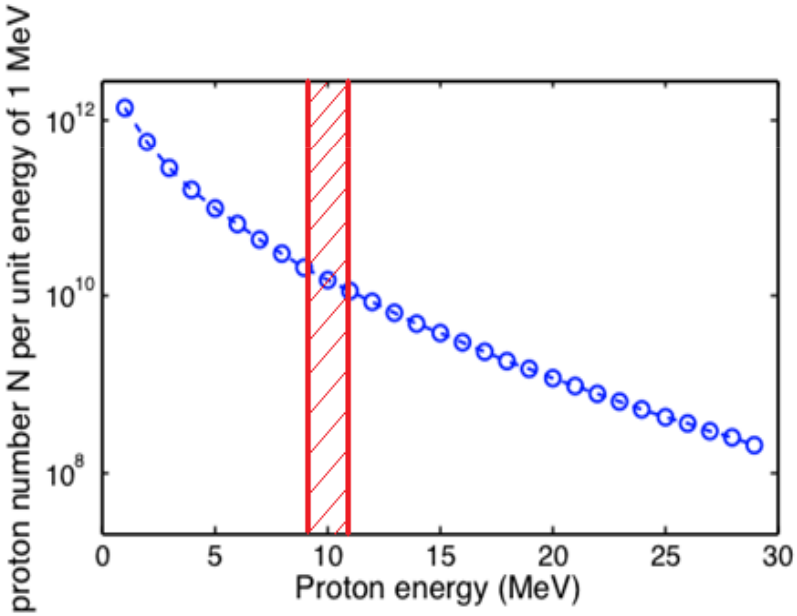
Content

- Introduction
- LASIN – Code Development
  - with space charge
  - with space charge + electrons
- CH-Cavity for postacceleration
  - new proposed cavity
- Outlook and Conclusion

IAP

Proton Beams

- Transverse emittance (rms): < 0.1 mm-mrad.
- Longitudinal emittance (rms): < 0.02 keV-ns.
- Energy spread 0 - 30 MeV
- Source radius: 30 – 60 μm (FWHM),
- Bunch length: ps- range.



Selected bunch parameters:

$$10\,MeV \pm 0.5\,MeV$$

$$\Rightarrow \Delta N \approx 10^{10}$$

$$\equiv 500\,mA \text{ at } 325\,MHz$$

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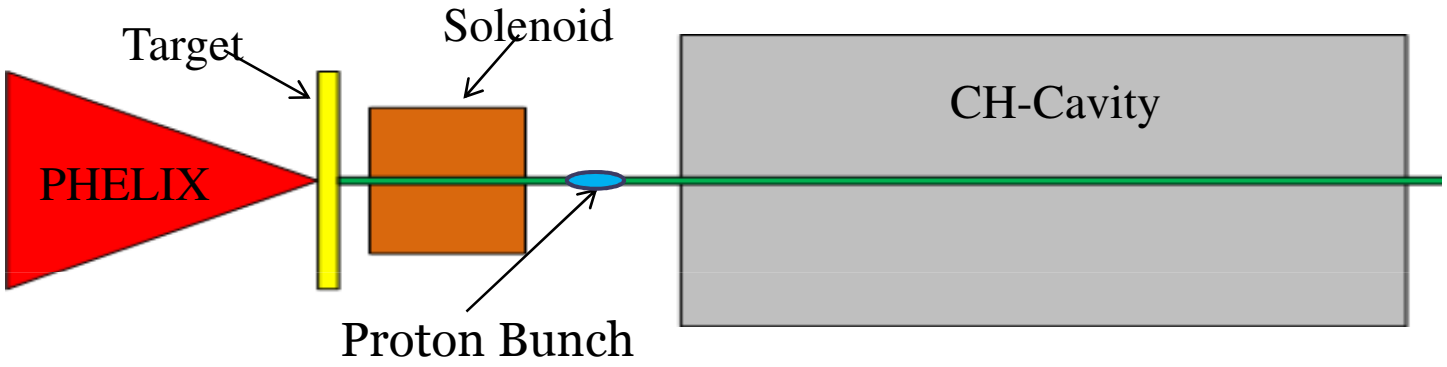
Phase space matching



- Expansion region (space charge, collective phenomena) - LASIN
- Focusing and preparation W~10MeV - LASIN
- Postacceleration - LORASR

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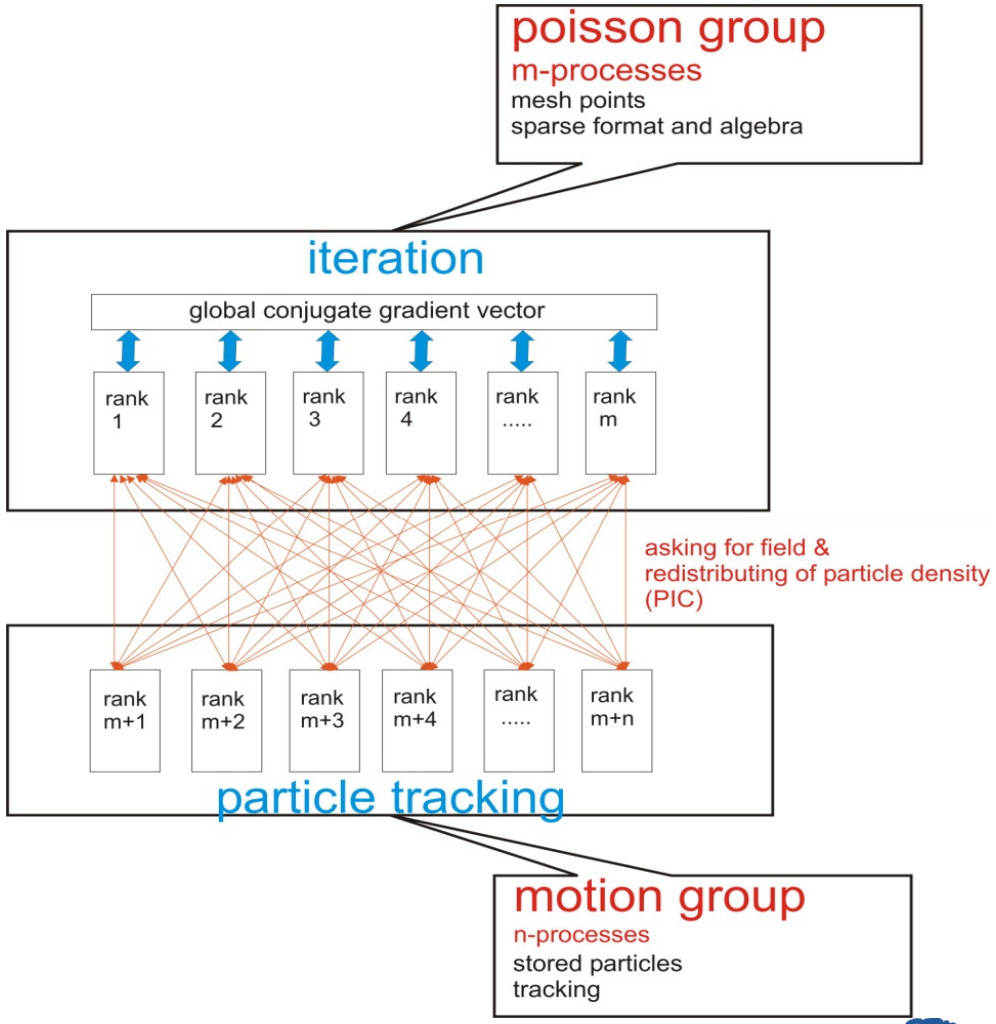
LASIN - Code

- Magnetic field -> Biot-Savart solver or given on mesh
- Parallel PIC-program – implemented on FUCHS (CSC-Cluster)
- Full 3D – calculation
- Cylindrical coordinates
- Distributed memory
- Multispecies tracking (x,y,z)
- Poisson – solver – iterative BiCGSTAB method
- Typically 50 Processors



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LASIN-Development

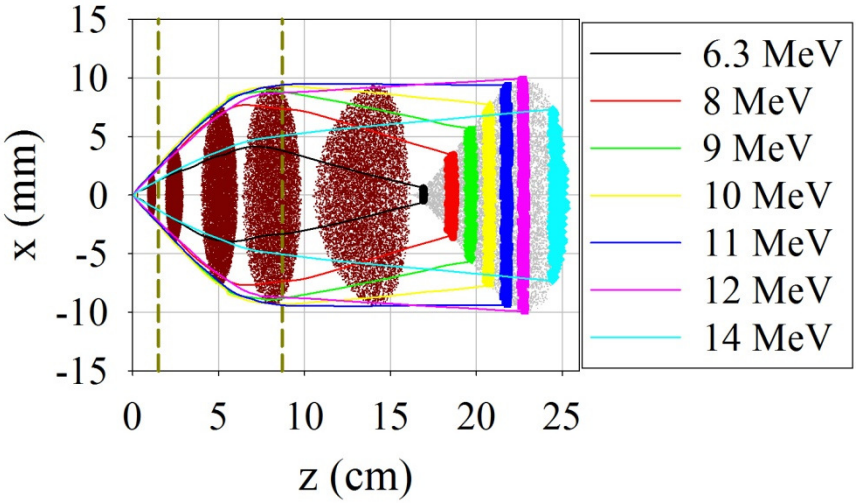
- 2009-2010

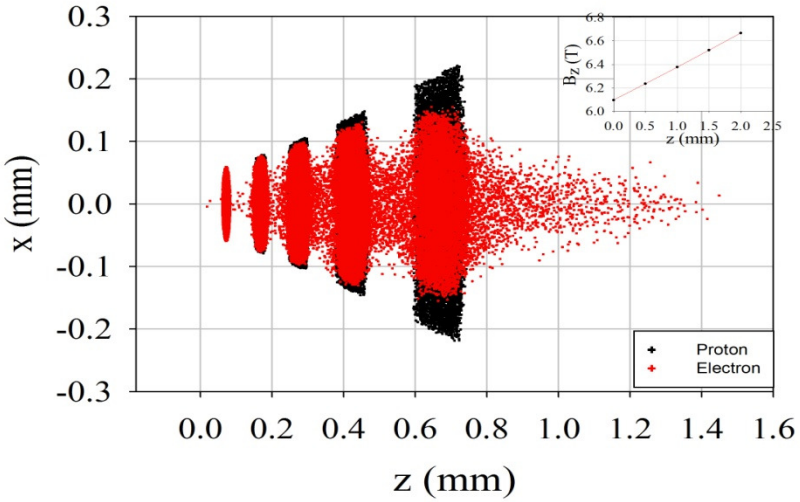
  Simulation without space-charge
  Comparison with DYNAMION, LORASR
  Study of Chromatic and Geometric Aberrations
  (*Workshop Aug.2010 – A.Almomani*)

- 2010-2011

  Space charge simulations
  Boundary conditions
  Energy conservation

LASIN – with space charge





Preliminary studies
with space charge:

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

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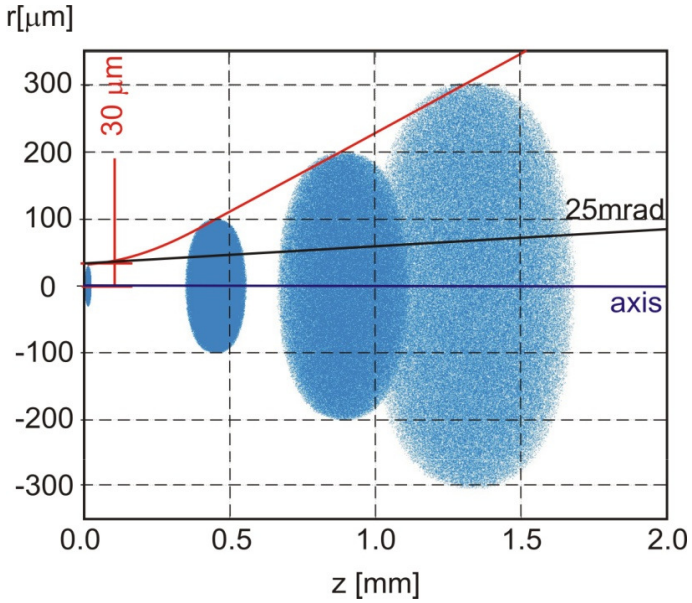
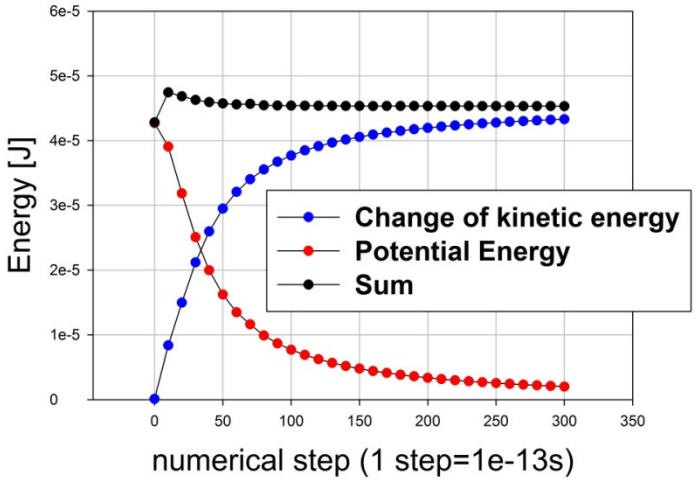
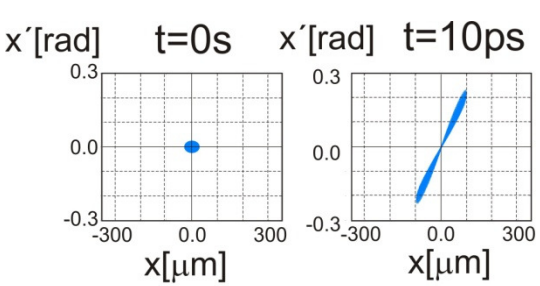
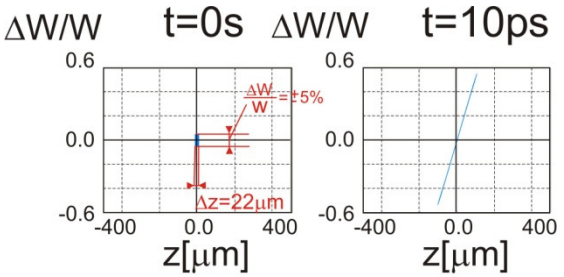
LASIN – with space charge – no electrons

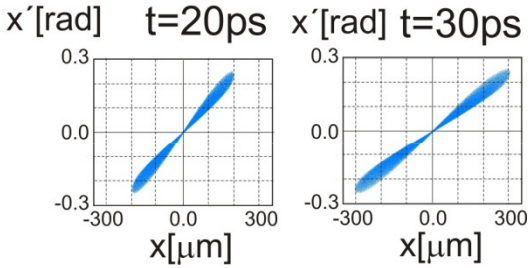


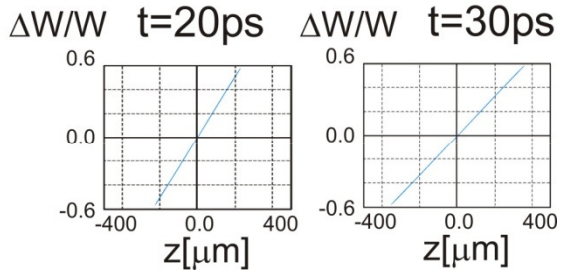
20% of macro-particles











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

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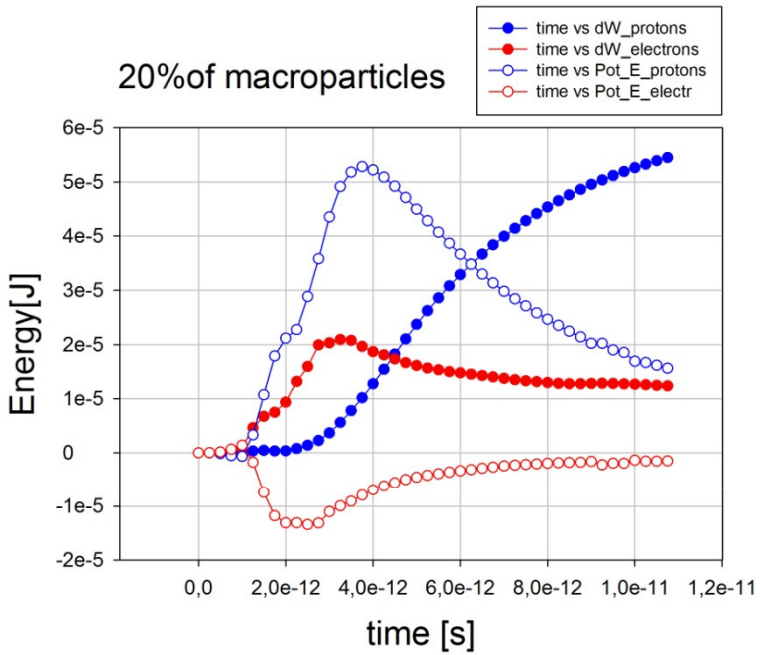
Simulation – Protons&Electrons



dt=25fs

R=30µm, L=22µm

Protons W=10MeV

Electrons W=5.5keV

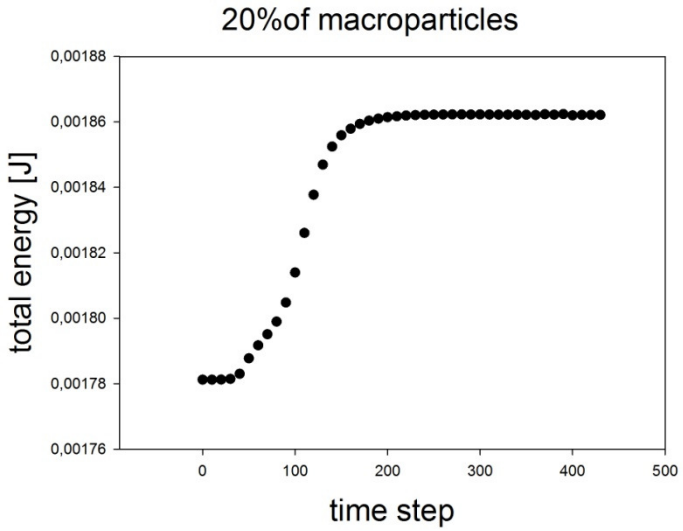
Particles/1 Macroparticle=4444 =>4.5Mio Macroparticles

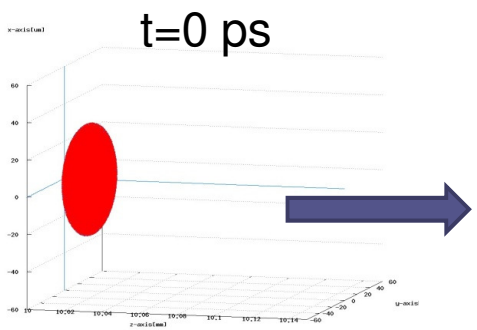
Mesh:

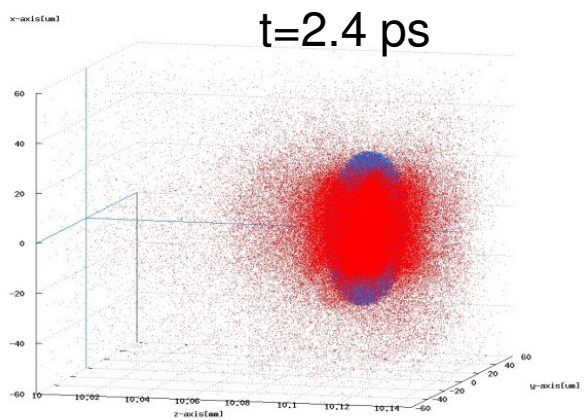
dr=6µm

dϕ=0.2rad

dz=2µm







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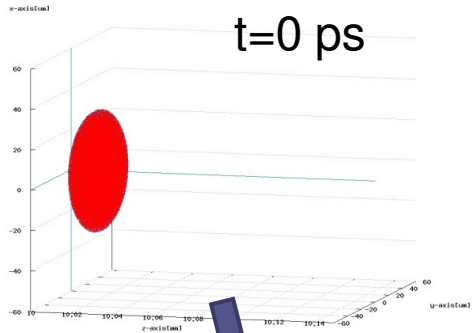
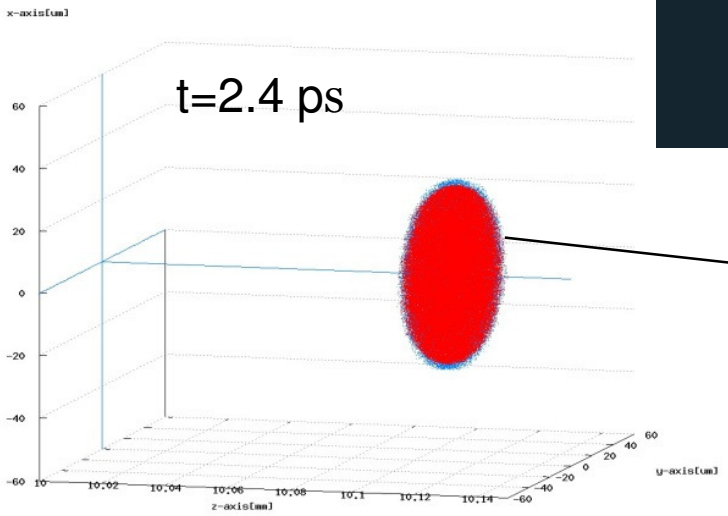
Simulation - Improvements





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

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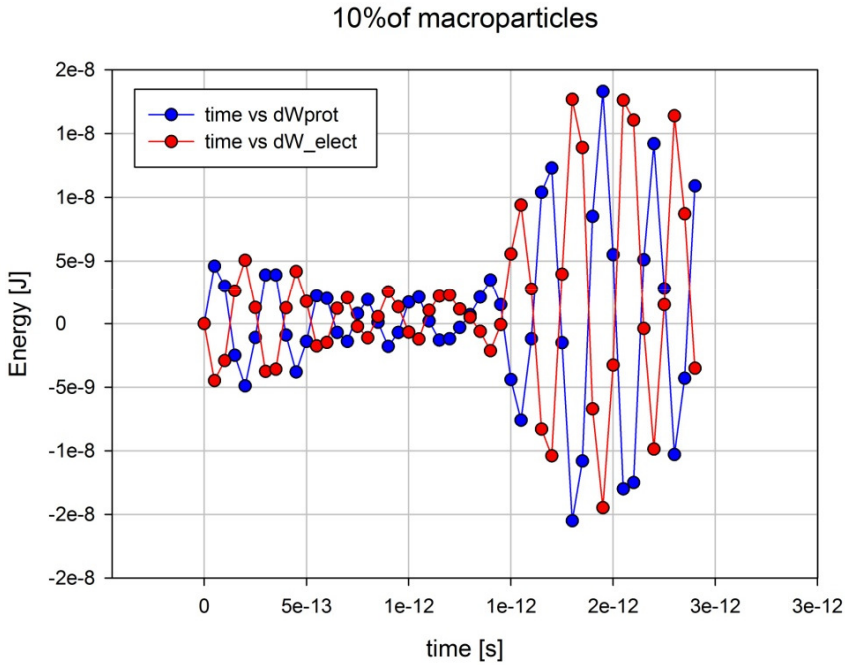
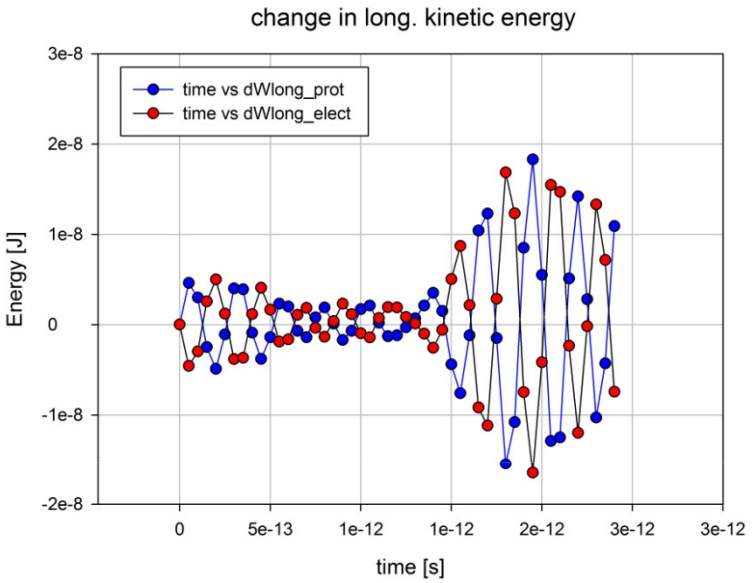
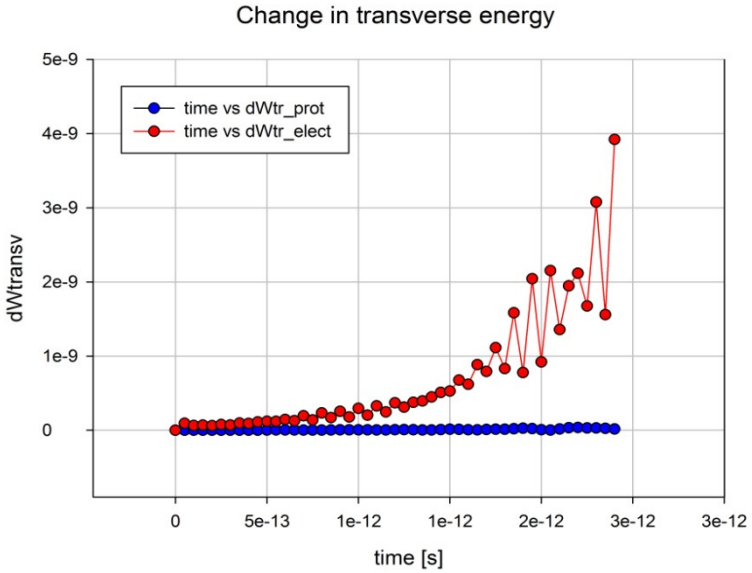
LASIN – Kinetic Energy

Plasma oscillation longitudinally
Along magnetic field







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

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LASIN - Energy

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

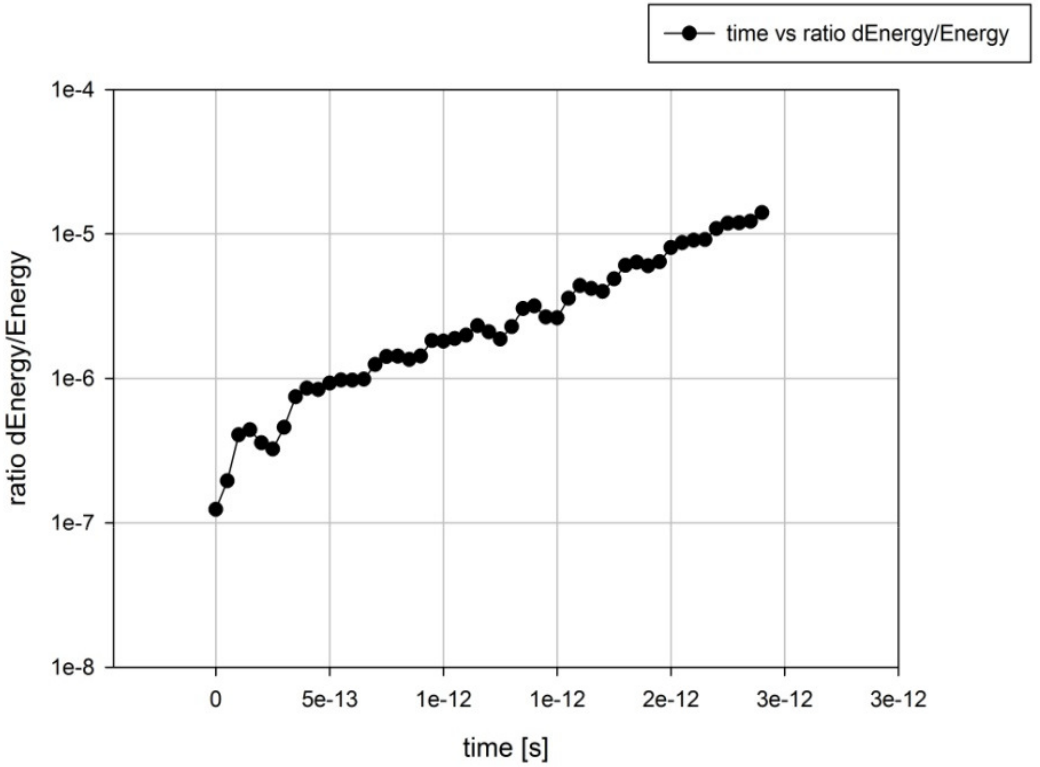
-Less comparing with previous case 6%

-Longer simulation needed

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

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

-Debye length @ Target λ_D=0.2µm



New strategy -> finer mesh
dual mesh
higher order SI (symplectic integrator)

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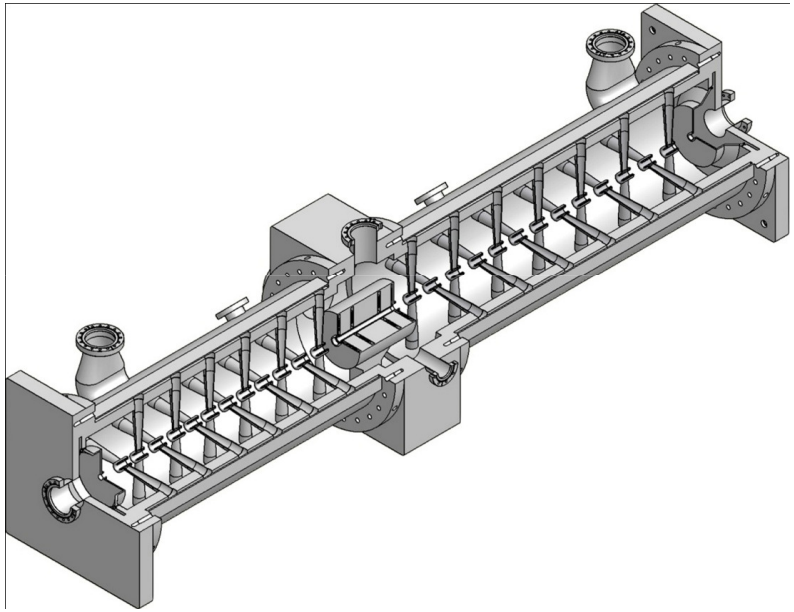
CH- DTL for High Intensity Proton Acceleration

- Current = 500 mA
- Frequency = 325 MHz
- **Energy: 11.69 – 23.57 MeV**

(FAIR prototype cavity, under production)

Emittance values for the input and output distribution at 500mA		
Beam Parameters	Input	Output
ε_{tr}	0.69	0.84 *mm·mrad*
ε_{long}	7.25	10.42 *keV·ns*



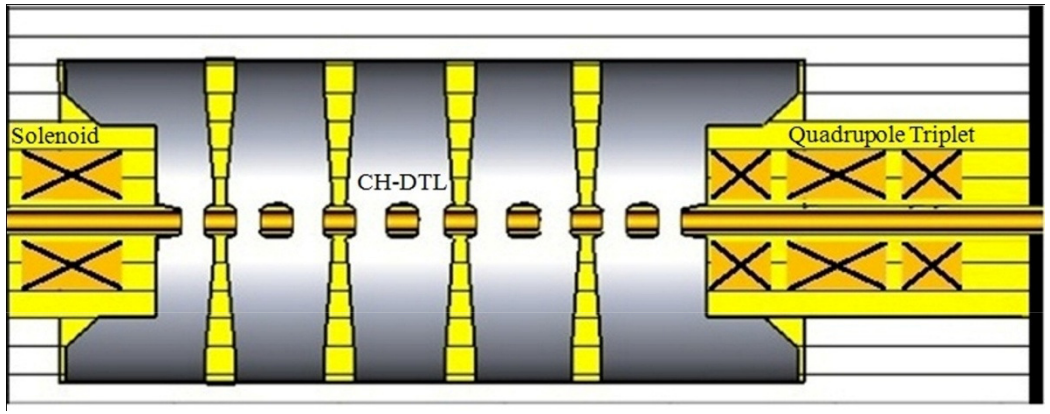
IAP and GSI Cooperation

After testing the coupled cavity with UNILAC-beam at Z4 area it might be installed next to Z6 area for tests with TNSA proton beams.

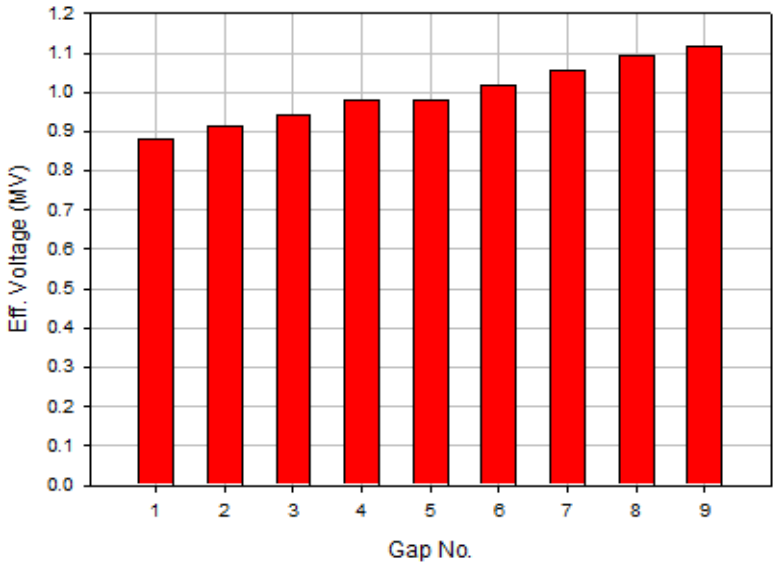
Design for a dedicated CH - DTL

- Current = 500 mA.
- Frequency = 325 MHz.
- **Energy: 10.05 – 17.37 MeV.**
- No. of Gaps = 9
- Magnetic Solenoid is Part of the Design.

Schematic



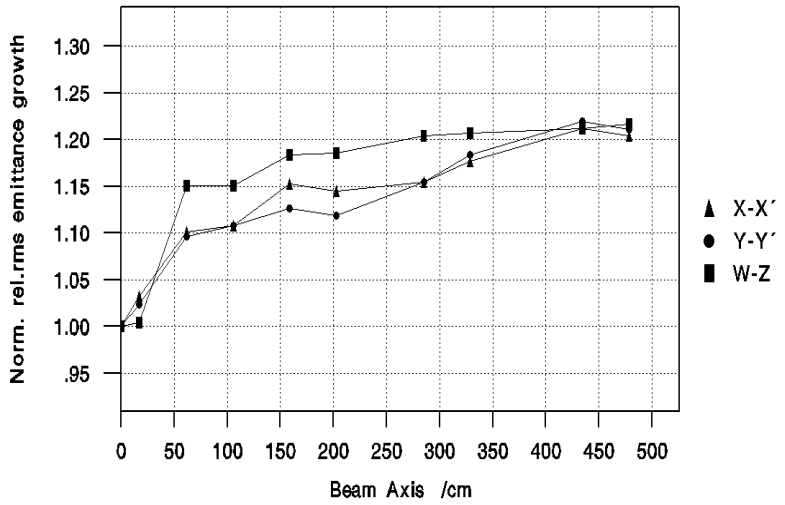
Emittance values for the input and output distribution at 500mA		
Beam Parameters	Input	Output
ε_{tr}	0.33	0.53 *mm·mrad*
ε_{long}	3.22	4.08 *keV·ns*



Study further acceleration - 4 CH - Cavities

Matched parameters used

- Current = 500 mA.
- Frequency = 325 MHz.
- **Energy: 10.05 – 39.6 MeV.**
- No. of Gaps = 33
- Magnetic Solenoid is Part of the Design.



Input:
Trans. emitt. (rms): 0.82 mm.mrad
Long. emitt. (rms): 3.21 keV.ns

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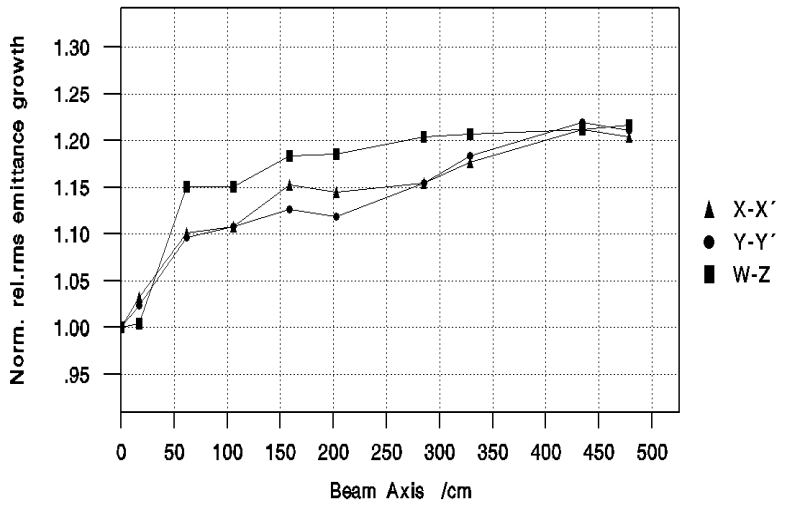

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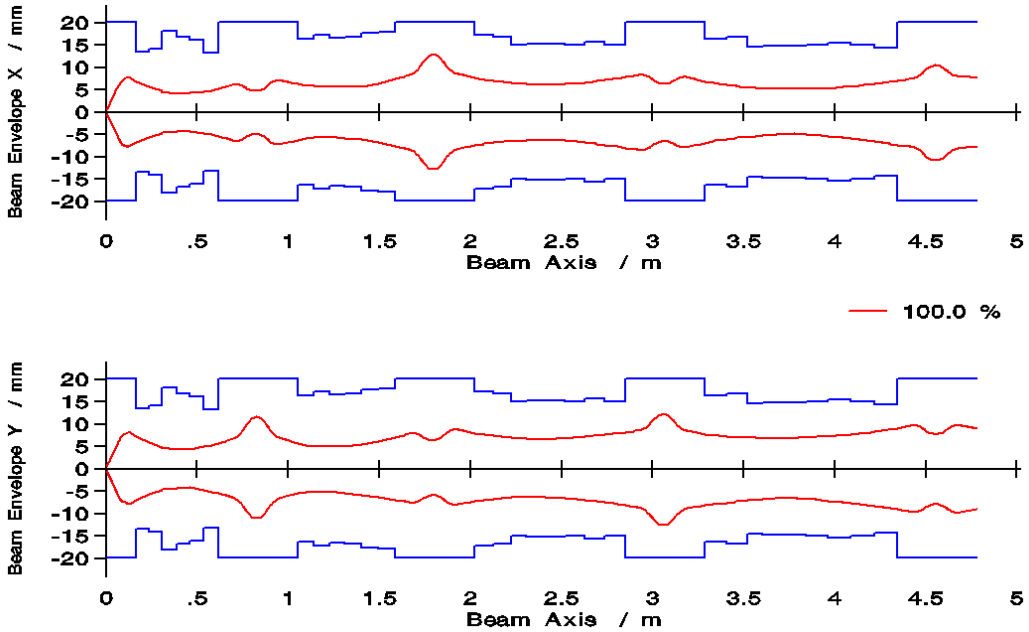

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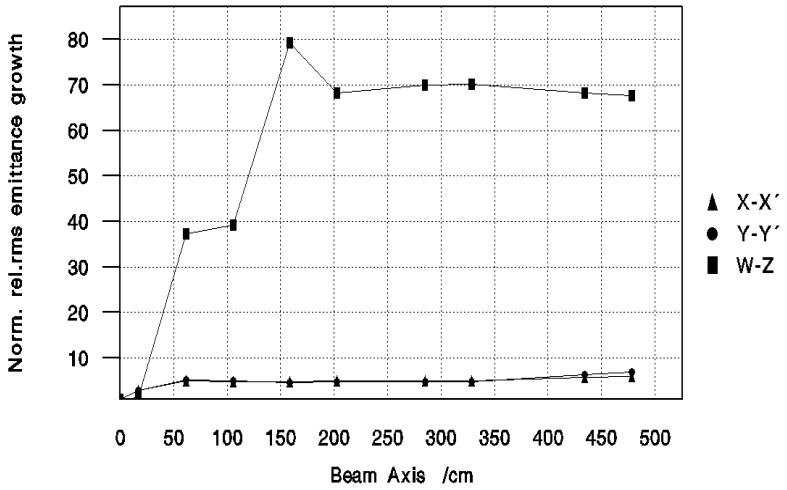
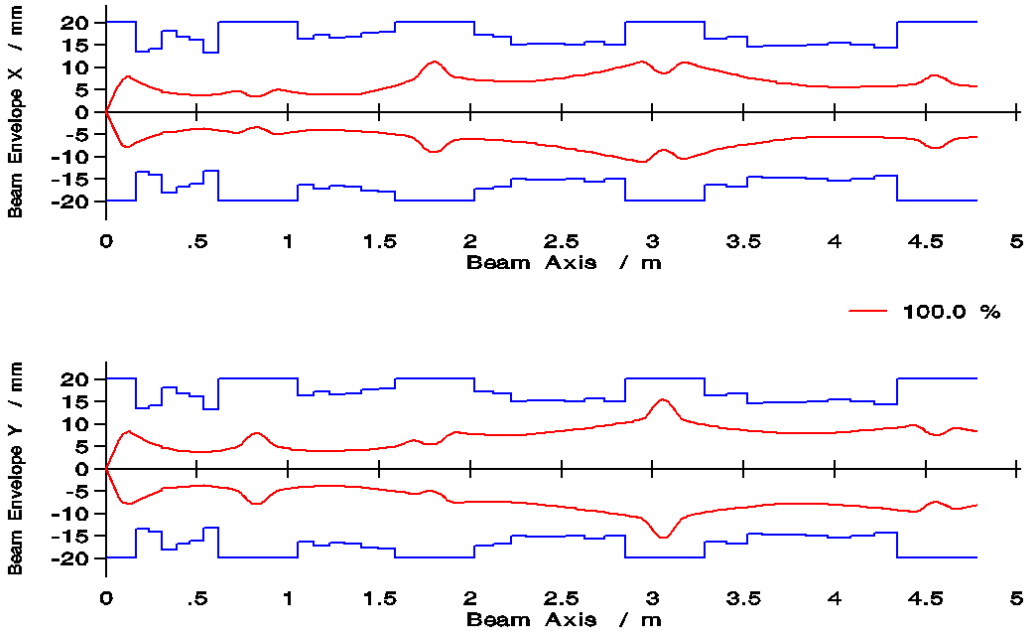


Laser generated p-bunch parameters



Input:

Trans. emitt. (rms): 0.08 mm.mrad

Long. emitt. (rms): 0.03 keV.ns

Outlook and Conclusion

- Mesh adaption along the beam path
- Realistic distribution – electrons? (input from measurements and simulations)
- Improvement of calculation speed
- Transport of whole spectrum through the solenoid
- Injection of realistic distribution into CH
- MWS – Simulation
- Heat Power Calculations