Crosscheck & Error Studies in the LEBT Injector Beamline, a Summer Program Summary

요시카 바그너
Joschka Wagner

KIRAMS - Seoul, Republic of Korea
IAP Goethe University - Frankfurt, Germany

September the 2nd, 2014

Outline

1 Overview

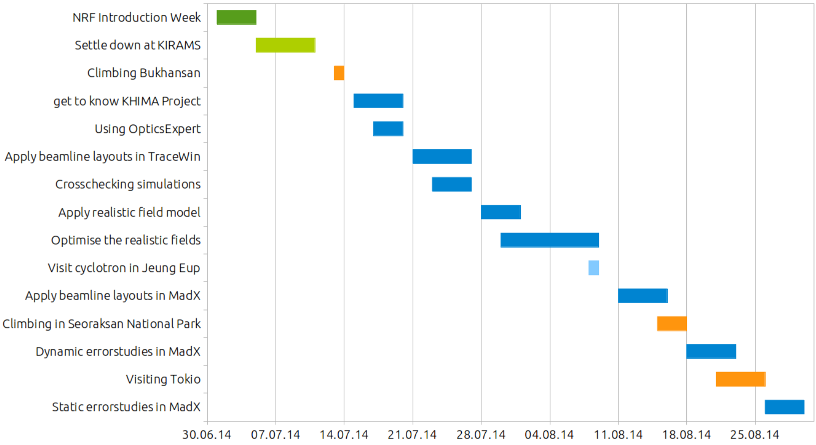
2 Introduction to the Injector

3 Simulations in TraceWin

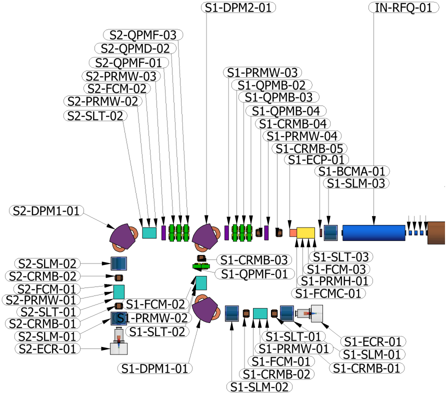
4 Optimisation in the realistic field model

5 Errorstudies in MadX

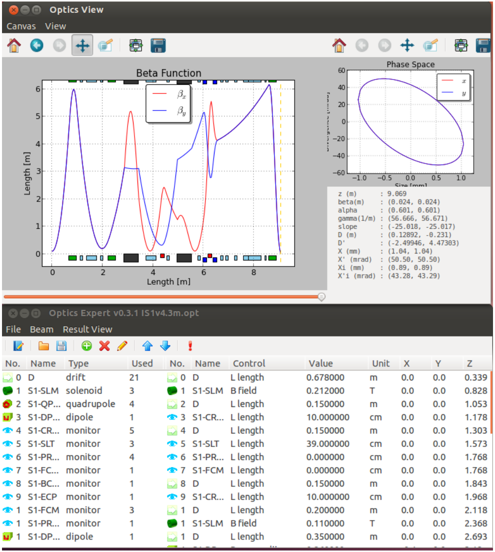
Timetable Overview



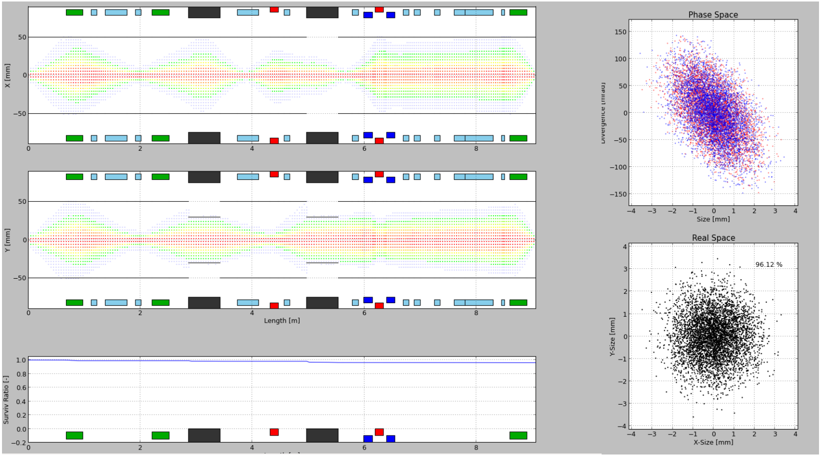
Introduction to the Injector Layout



- ECRIS Ion Sources for $^{12}C^{4+}$ and H_3^+
- beam energy $96\,\mathrm{keV}$ and $24\,\mathrm{keV}$
- extraction voltage $24\,\mathrm{kV}$
- extracted currents $122 - 765\,\mu\mathrm{A}$
- $\epsilon_{4\mathrm{rms}} < 180\pi\,\mathrm{mm.mrad}$



learning how to use the beam optics code OpticsExpert by Garam Hahn (hard edge model, transport matrix simulations)



Output at the entrance of the RFQ:

transmission: 96.12 %

emittance:

$\epsilon_{4\text{rms}} < 280\pi\,\mathrm{mm.mrad}$

$\alpha_{xx'} = \alpha_{yy'} = 0.601$

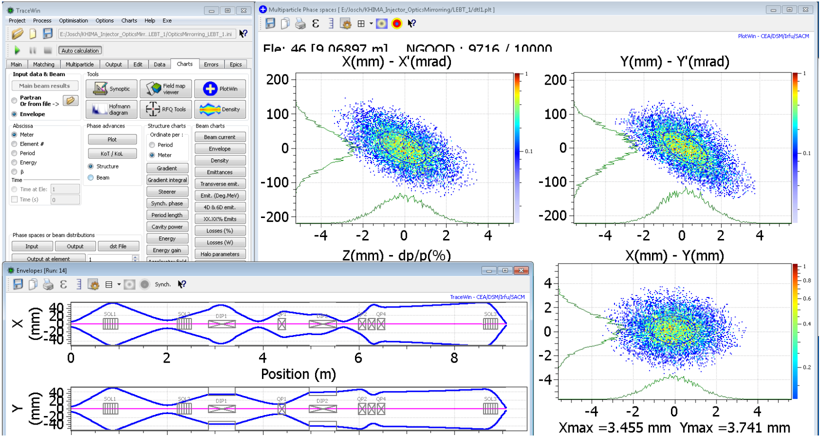
$\beta_{xx'} = \beta_{yy'} = 0.024$

$x = y = 1.04\,\mathrm{mm}$

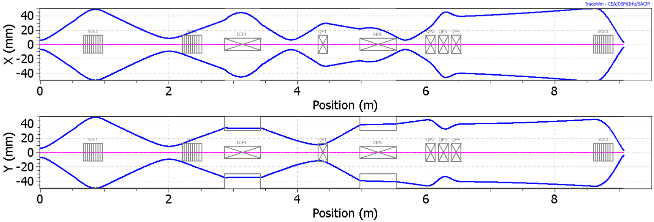
Simulations in TraceWin

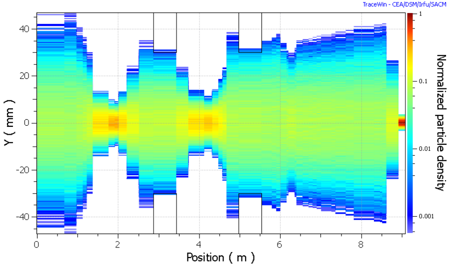
-Construct the Injector Beamlines in Tracewin

-crosscheck simulations for the hard edge model

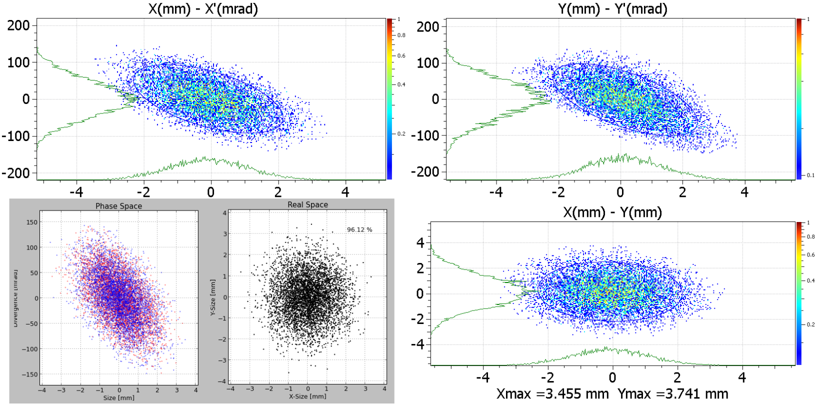


Hard Edge Crosscheck Simulation Beamline 1





Hard Edge Crosscheck Simulation Beamline 1



Hard Edge Crosscheck Simulation Beamline 1

	Optics Expert	TraceWin
$\alpha_{xx'}$	0.601	0.6592
$\beta_{xx'}$	0.024	0.0287
$\alpha_{yy'}$	0.601	0.7881
$\beta_{yy'}$	0.024	0.0299
norm $\epsilon^{x}_{\text{rms}}$ [π mm.mrad]	0.2085	0.1786
$\epsilon^{x}_{\text{rms}}$ [π mm.mrad]	50.5	43.3
norm $\epsilon^{y}_{\text{rms}}$ [π mm.mrad]	0.2085	0.1875
$\epsilon^{y}_{\text{rms}}$ [π mm.mrad]	50.5	45.5
losses	3.88 %	2.8%

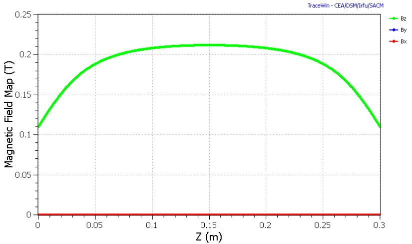
Hard Edge Crosscheck Simulation Beamline 2

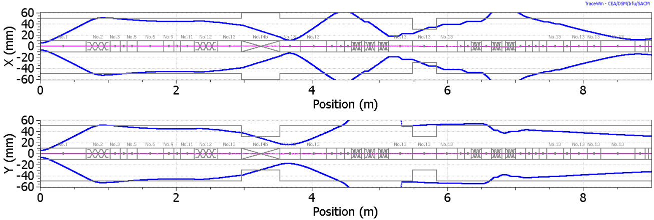
	Optics Expert	TraceWin
$\alpha_{xx'}$	0.599	0.7407
$\beta_{xx'}$	0.024	0.0270
$\alpha_{yy'}$	0.599	0.7736
$\beta_{yy'}$	0.024	0.0265
norm $\epsilon^{x}_{\text{rms}}$ [π mm.mrad]	0.2085	0.1853
$\epsilon^{x}_{\text{rms}}$ [π mm.mrad]	50.5	44.9
norm $\epsilon^{y}_{\text{rms}}$ [π mm.mrad]	0.2085	0.1852
$\epsilon^{y}_{\text{rms}}$ [π mm.mrad]	50.5	44.9
losses	2.6 %	1.6%

- the beam transport, concerning losses and matching gave similar results

Realistic Field Model Crosscheck Simulations in TraceWin

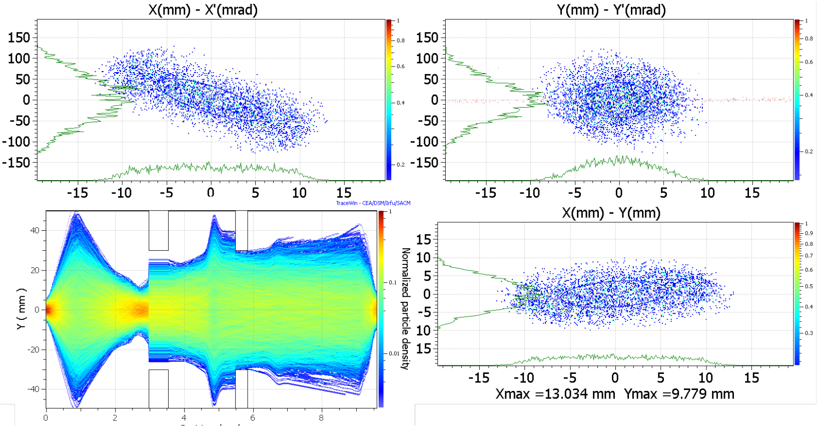
To get a more meaningful result the realistic field model was implementet. Especially important concerning the solenoids





Realistic Field Model Crosscheck Simulations in TraceWin

beamline 2

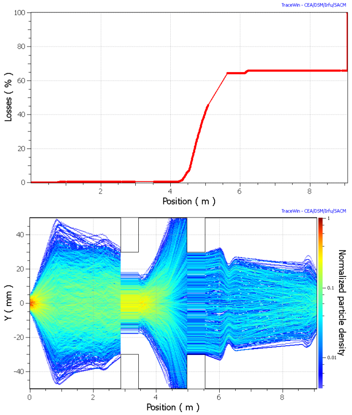


	beamline 1	beamline 2
losses	60.0%	14.8 %

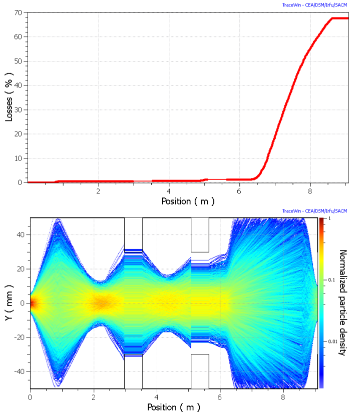
Optimisation of Beamline 1 in the realistic field model

The results obviously showed that one has to focus on the realistic field model to fit the beam envelope

As a first approach: optimising the fieldstrengths and gradients via adjustment and monitoring commands



OpticsExpert fields



optimised fields

Optimisation in the realistic field model

- optimisation studies took much calculation time
- yet there is no satisfying result
- one has to find the same mapping condition as in the hard edge model to change to more realistic fields
- or: setting up the beamline in the realistic model step by step

For time reasons we switched the objective to get some errorstudies in the hard edge model

$\rightarrow$ Calculations with MadX

Errorstudies in MadX

Which error types had to be investigated?

- dynamic errors: field errors due to the current ripple of the magnet power supplies (not correctable)
- static errors: due to misalignment of the beamline components (correctable with kickers)

type	$\Delta x/mm$	$\Delta y/mm$	$\Delta s/mm$	$\Delta\Phi/mrad$	$\Delta\Theta/mrad$	$\Delta\Psi/mrad$	stability
Dipole	±0.5	±0.5	±0.3	±0.2	±0.2	±0.2	50 ppm
Quadrupole	±0.3	±0.3	±0.5	±0.2	±0.2	±0.2	200 ppm
Solenoid	±0.3	±0.3	±0.5	±0.2	±0.2	±0.2	200 ppm

Errorstudies in MadX

What is the purpose of the errorstudies?

- all errors influence the quality of matching into the RFQ
- the dynamic errorstudie shall determine the accuracy of the magnet power supplies
- in case of static errors the goal is to find a strategy how to use corrector magnets and beam monitors

Dynamic Error in MadX

- current beamline layouts were applied at first
- implementation of the dynamic error assignment for specific multipole orders (dipole,quadrupole) was debugged

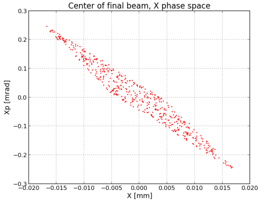
→ the error of the quadrupole field has almost no influence, compared to the dipole
→ stability turns out to generate a linear behaviour of beam center dislocation (beamline 1, beamline 2)

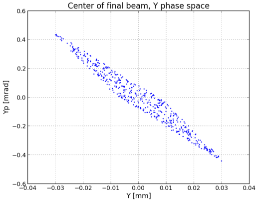
QPM stability DPM stability	200 ppm 50 ppm	400 ppm 100 ppm	800 ppm 200 ppm	2000 ppm 500 ppm	200 ppm 50 ppm
dx/mm	±0.02	±0.034	±0.063	±0.17	±0.008
dy/mm	±0.03	±0.06	±0.12	±0.32	±0.015
$dx'/mrad$	±0.26	±0.49	±0.93	±2.47	±0.33
$dy'/mrad$	±0.45	±0.87	±0.174	±4.66	±0.60

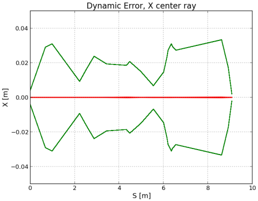
Dynamic Error in MadX

→the power supply stabilty constraints in the KHIMA Handbook are fully sufficient

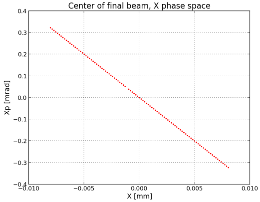
uniformly errors in beamline 1

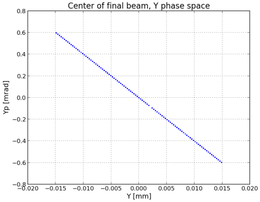


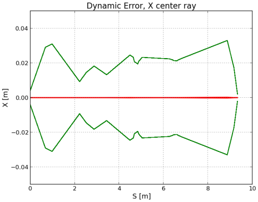




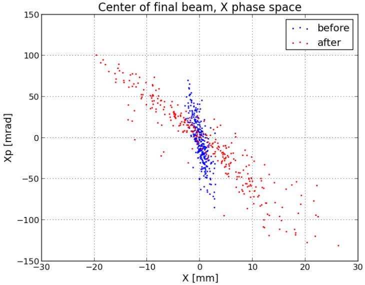
uniformly errors in beamline 2

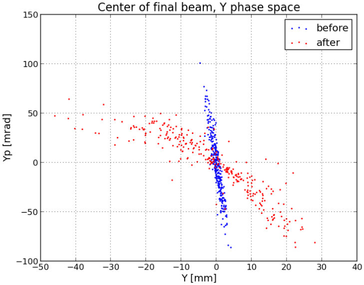


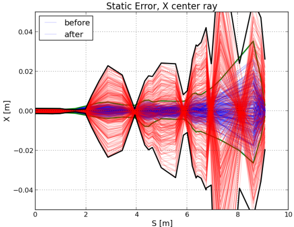


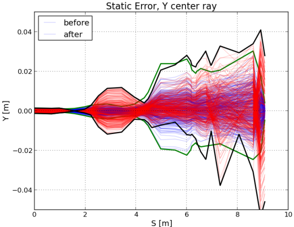


Static Error in MadX gaussian errors in beamline 1, correction with single monitors

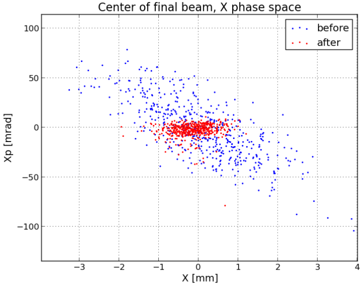


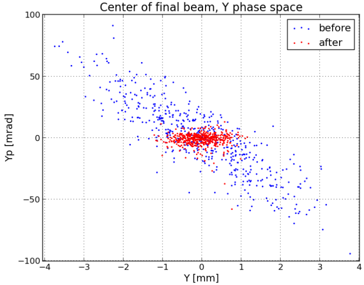


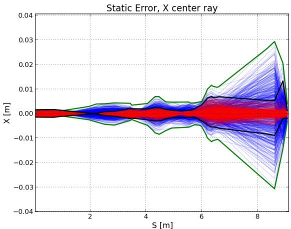


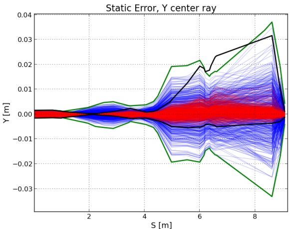


Static Error in MadX gaussian errors in beamline 1, first optimising approach with double monitors









What I have learned

- writing codes like OpticsExperts by themself gives a deeper insight than any documentation of existing codes
- it also provides a good tool to make fast layout estimation and quickly explain to your colleagues
- in this program I really applied the beam transport matrix theory I learned at university
- I got to know TraceWin much better than before, but it still needs practise for simulation strategies
- I learned MadX which gave me a good first introduction to relatively quick error estimations

여러분의 관심에 감사드립니다

Thank you for your attention and hospitality!

Acknowledgement

The team of KHIMA
and especially
Dr.Nam, Goni Jung, Garam Hahn, Dr.Kim, Prof.Dr.Podlech, Dr. Marcus Iberler, Daniel Noll, Malte Schwarz .....