# Linac & Operation Division

# GSI Departments

# External Collaborations

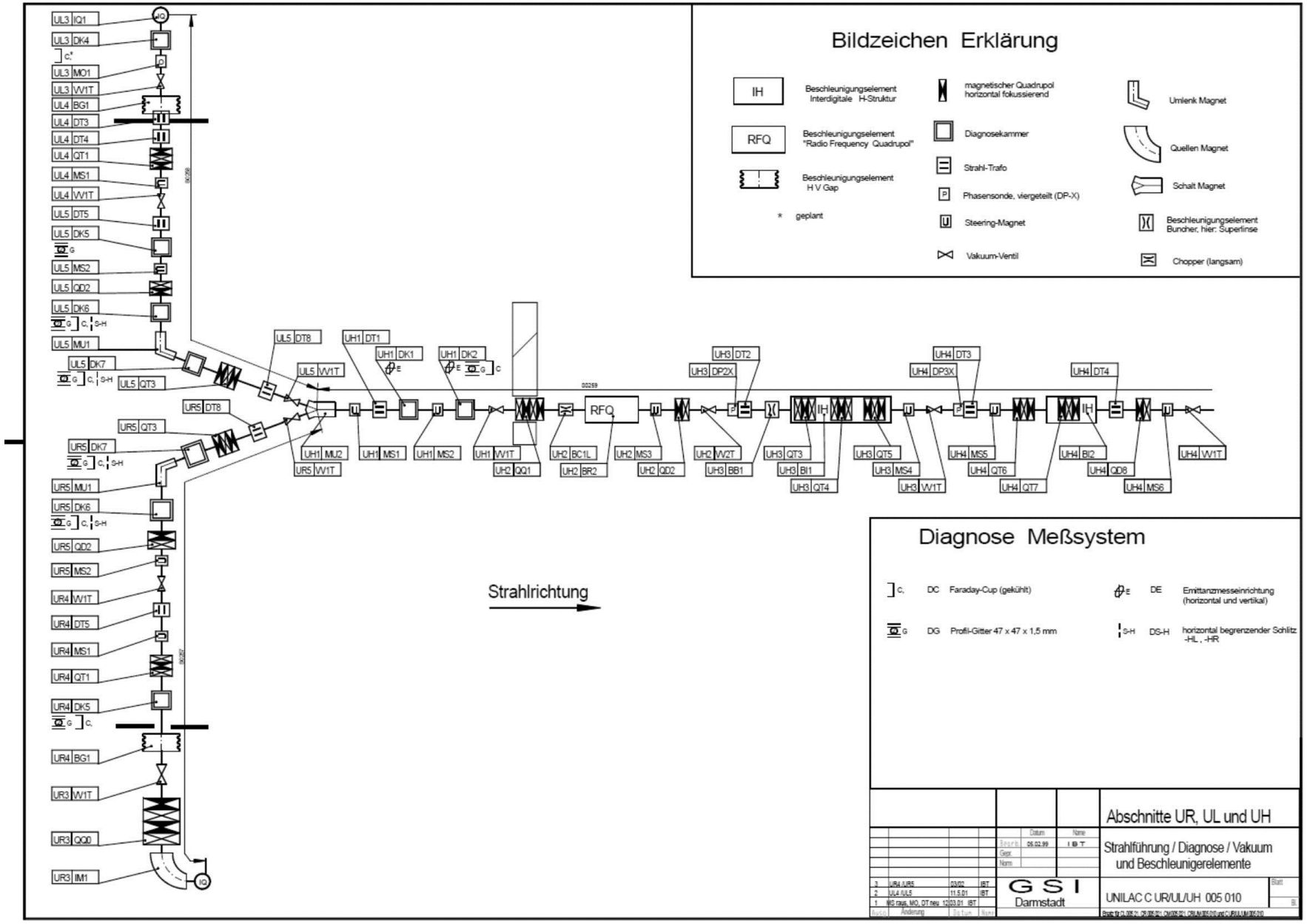
# General stucture of a linac

## Accelerating (and focusing) channels

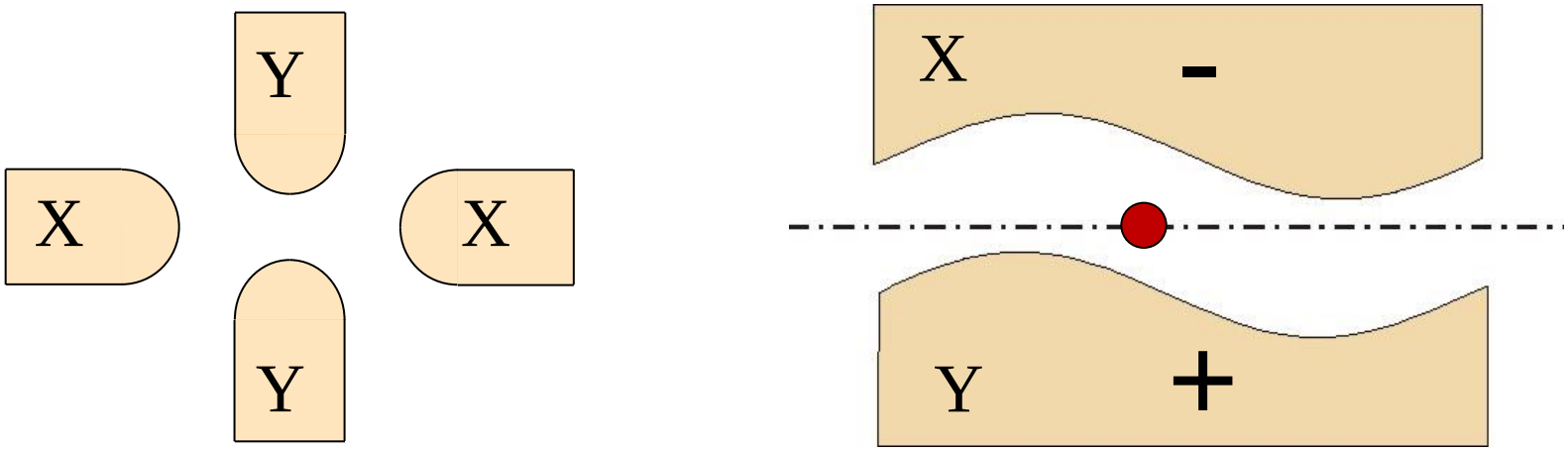
RFQ
DTL

## Transport beam lines

# Transport beam line (North and South Ion Source Terminals)

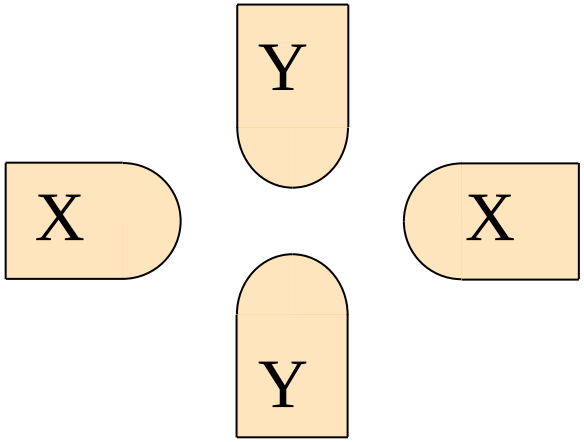


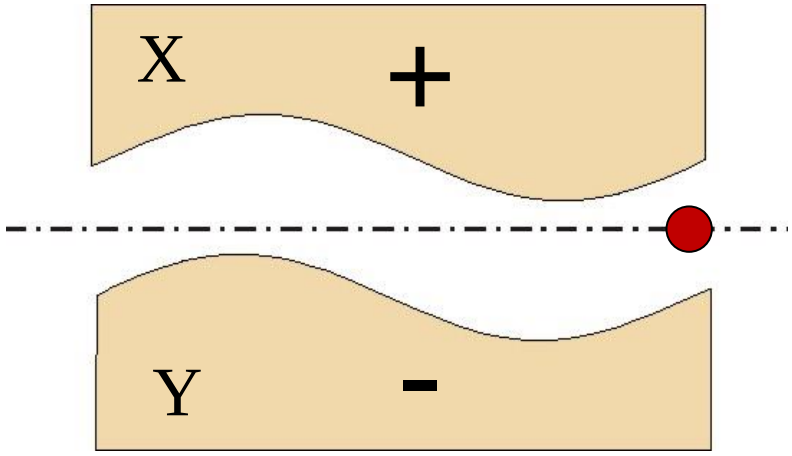
# RFQ (Radio Frequency Quadrupole) Structure




t = 0

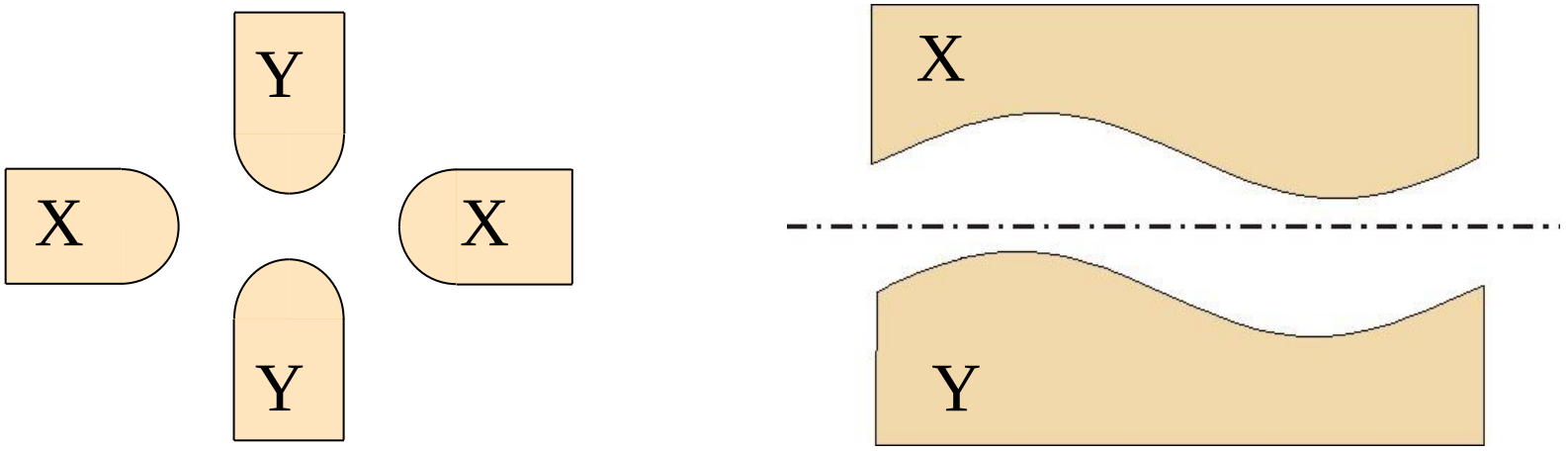
# RFQ (Radio Frequency Quadrupole) Structure




$t = T/2$

# RFQ (Radio Frequency Quadrupole) Structure




*Potential in the regular RFQ cell by Prof. I.Kapchinsky (ITEP)*

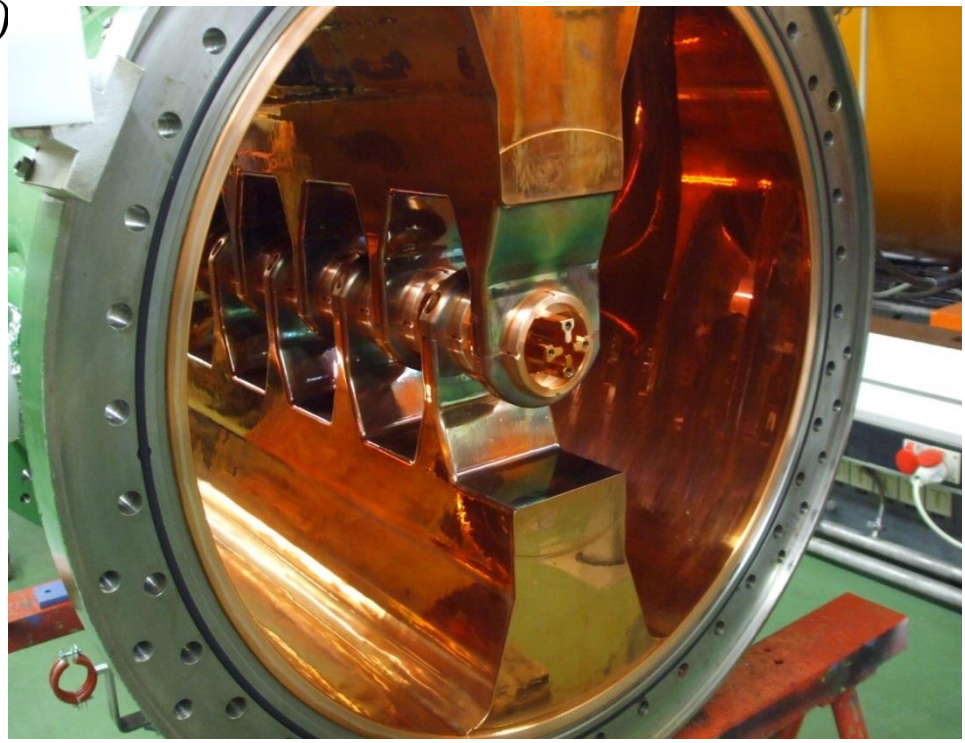
$$U(r,\psi,z) = -\frac{U_l}{2}\left[F_0(r,\psi) + \sum_{n=1}^{\infty} F_n(r,\psi)\sin(2n-1)\,kz\right]$$

$$F_0(r,\psi) = \sum_{s=0}^{\infty} A_{0s}\left(\frac{r}{R_0}\right)^{2(2s+1)}\cos\left(2(2s+1)\psi\right)$$

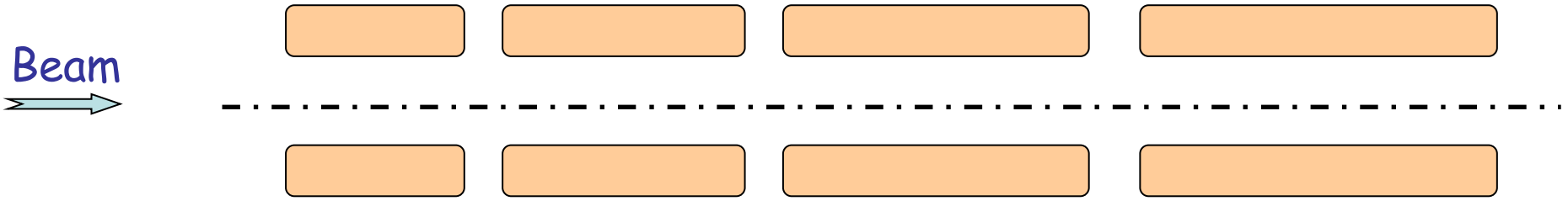
$$F_n(r,\psi) = \sum_{s=0}^{\infty} A_{ns}\, \mathrm{I}_{4s}\left[(2n-1)\,kr\right]\cos 4s\psi$$

DYNAMION solves Laplace equation for the potential in the area, formed by surface of the electrodes

DYNAMION calculates electrical field in an RFQ for electrodes "as fabricated"

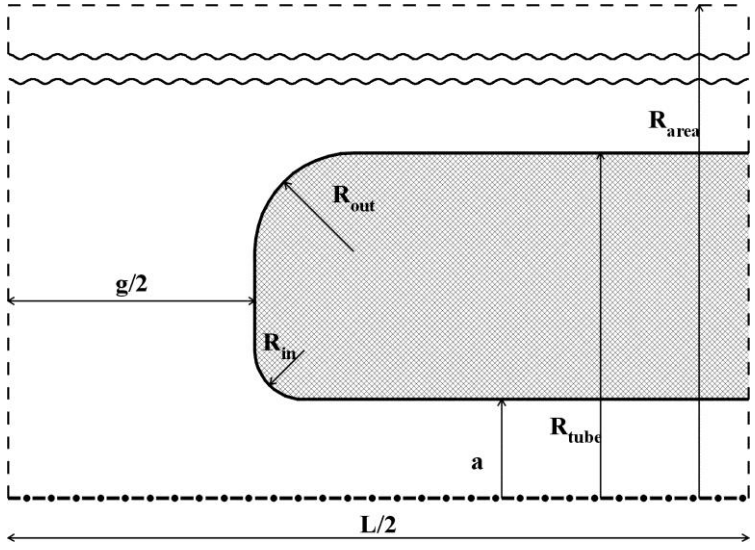


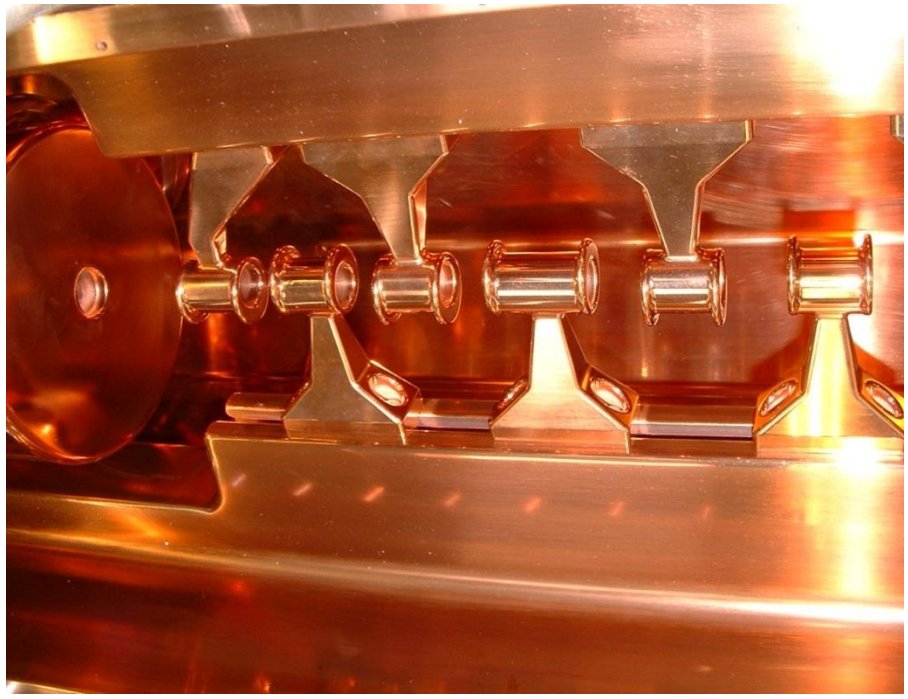
# DTL (Drift Tube Linac) Structure




Potential and field approximation with 30-term series :

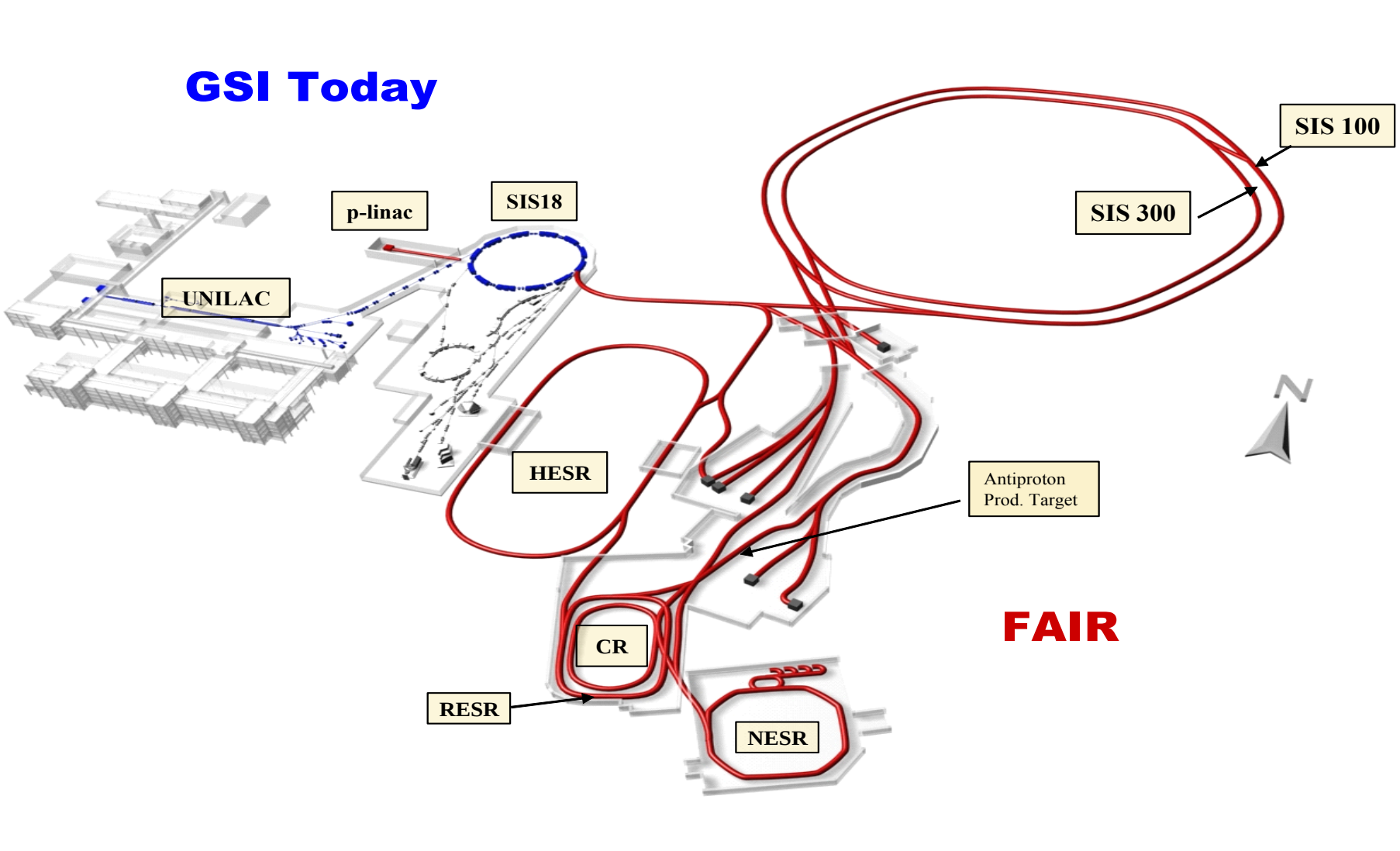
$$U(r,z) = -V\left[\frac{z}{l} + \sum_{n=1}^{\infty} A_n \cdot \sin(2nkz) \cdot I_0(2nkr)\right], \qquad k = \frac{\pi}{l}$$



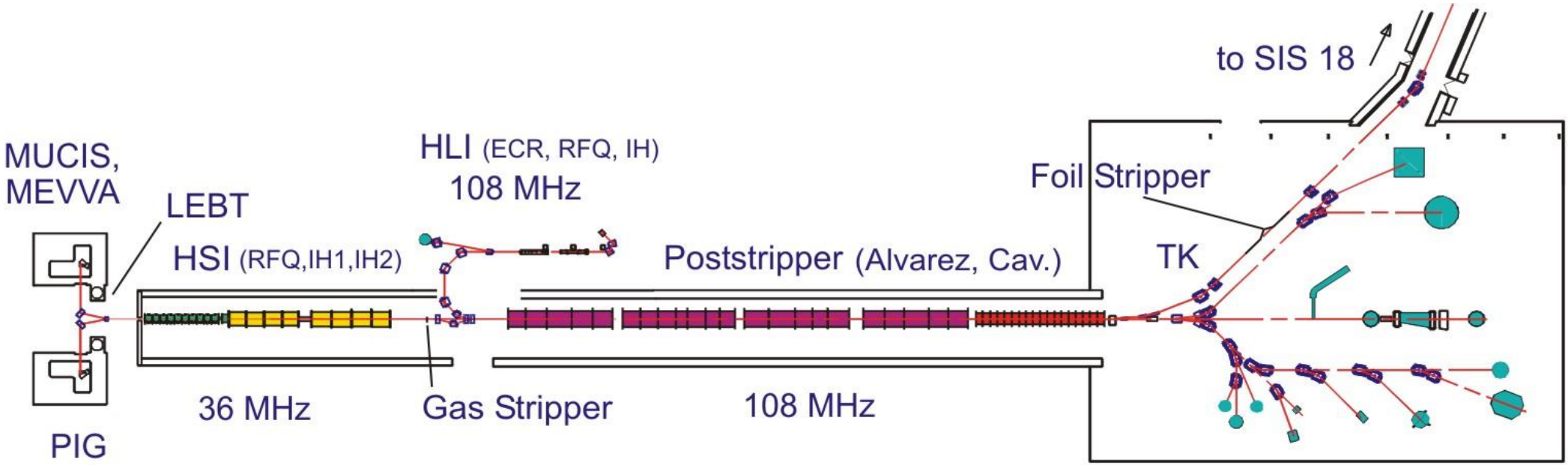



DYNAMION solves Laplace equation for the potential in the area, formed by surface of the drift tubes

# Facility for Antiproton and Ion Research at Darmstadt



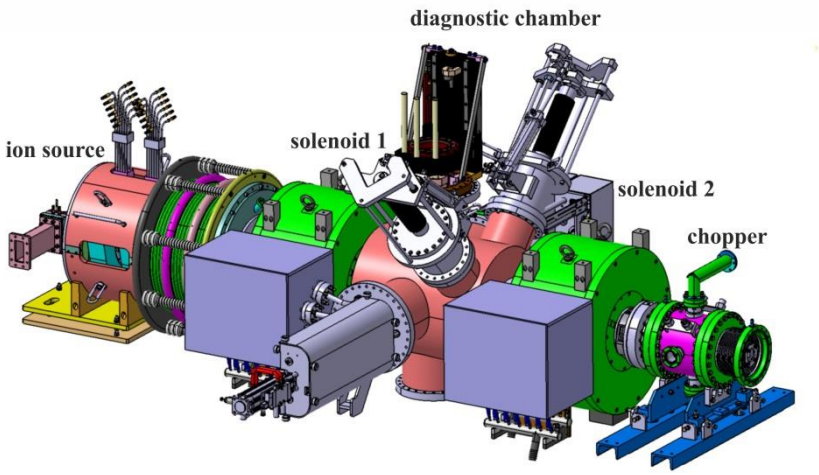
# UNIversal Linear ACcelerator

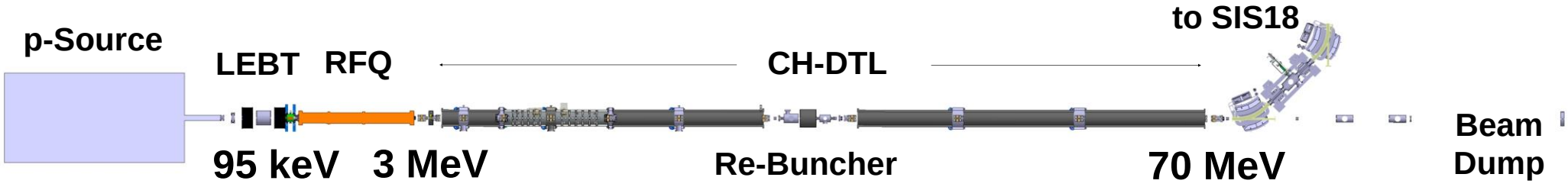


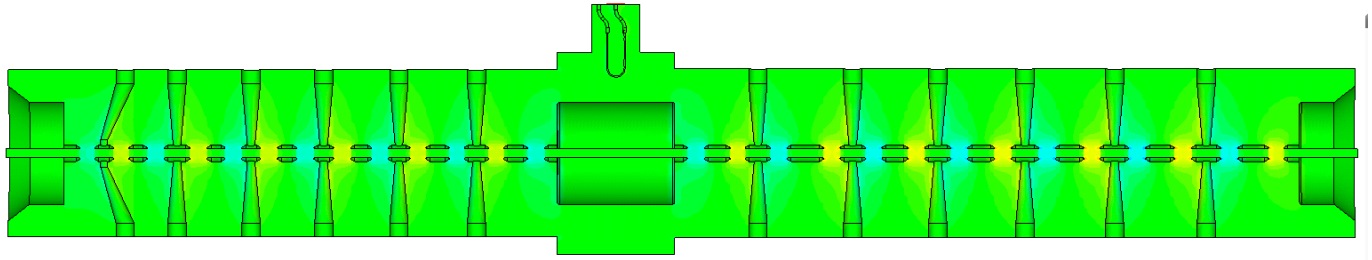

protons to uranium

11.4 Mev/u

# GSI Proton Linac



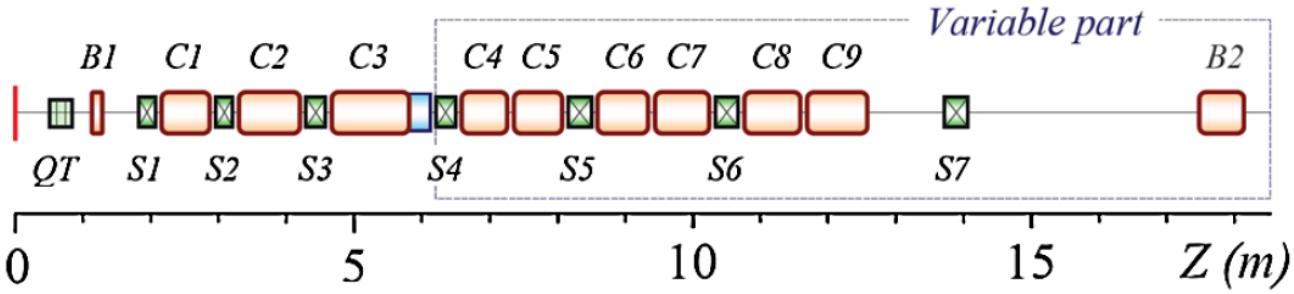



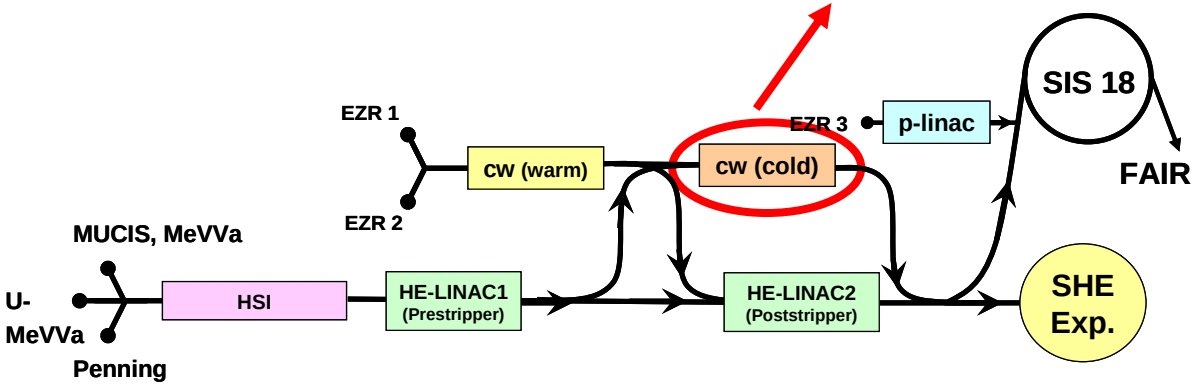
# GSI sc-cw-LINAC-project

## General parameters

| | | |
|---|---|---|
| Mass/Charge | | 1/6 |
| Frequency | MHz | 217 |
| max. beam current | mA | 1 |
| Injection Energy | MeV/u | 1.4 |
| Output energy | MeV/u | 3.5 – 7.5 |
| Output energy spread | keV/u | +- 3 |
| Length of acceleration | m | 12.7 |
| Sc CH-cavities | | 9 |
| Sc solenoids | | 7 |

**conceptual layout of the cw-LINAC**

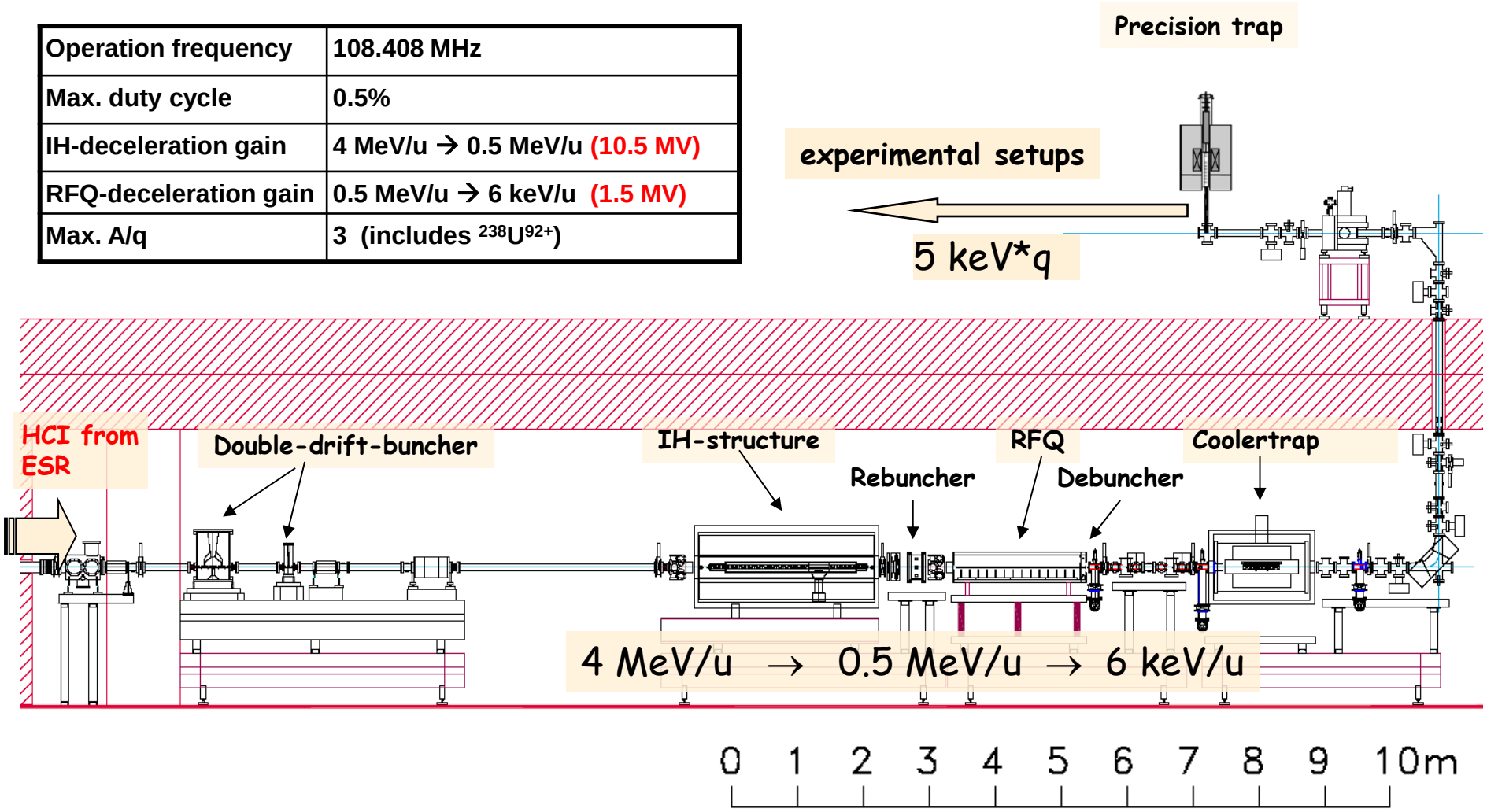



**Future GSI-injector environment**

# Schematic View of the HITRAP Decelerator

| | |
|---|---|
| Operation frequency | 108.408 MHz |
| Max. duty cycle | 0.5% |
| IH-deceleration gain | 4 MeV/u → 0.5 MeV/u (10.5 MV) |
| RFQ-deceleration gain | 0.5 MeV/u → 6 keV/u (1.5 MV) |
| Max. A/q | 3 (includes $^{238}U^{92+}$) |

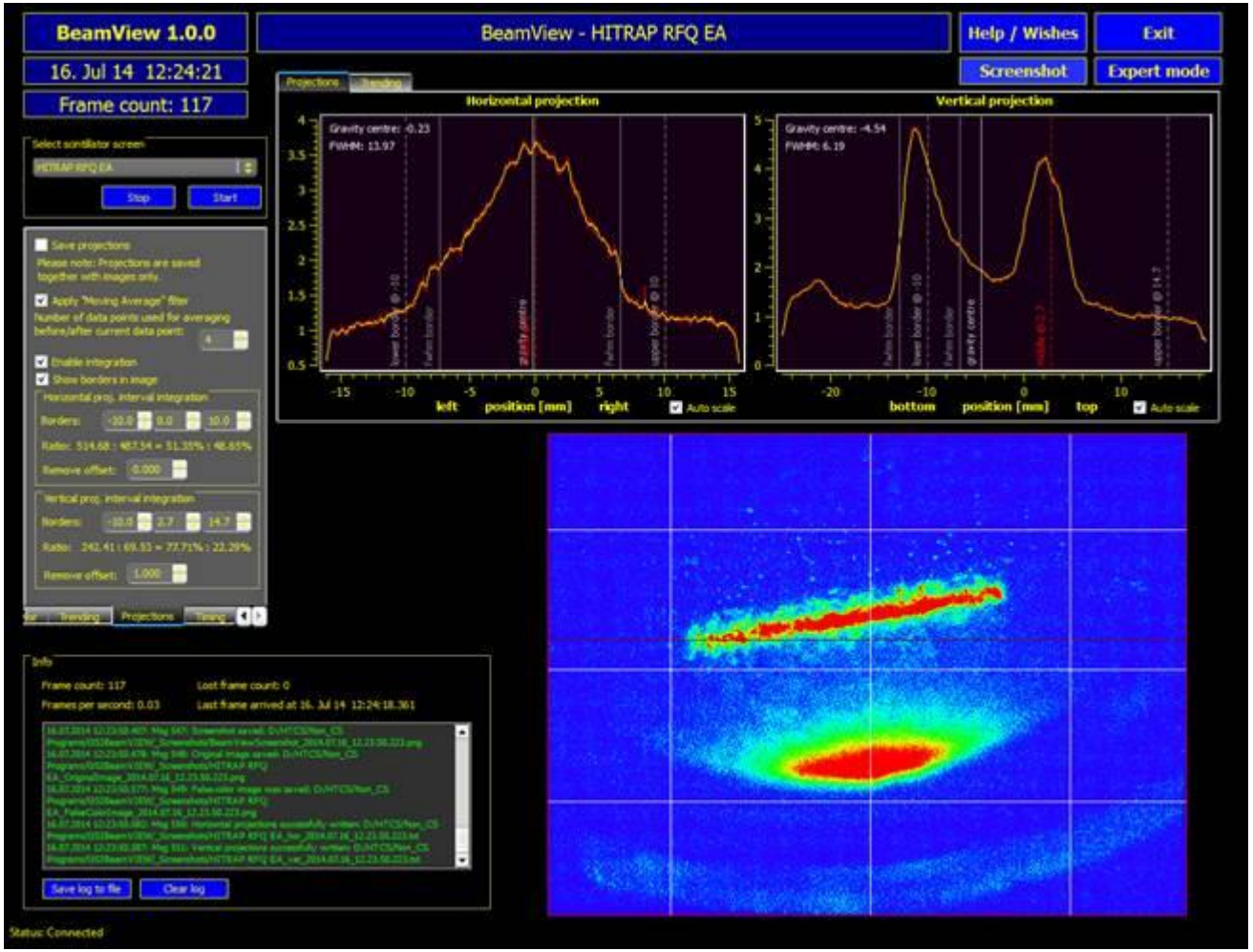


# Linac design, upgrade and optimization

*Beginner*
*Advanced*
***Expert***

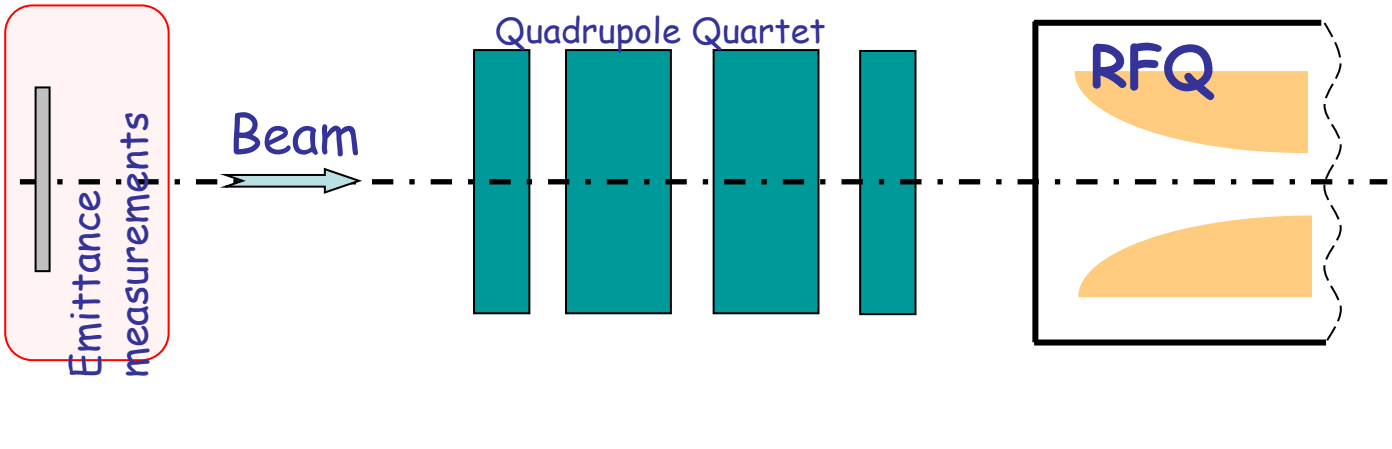
- complicate structure
- realistic model
- proper approaches
- acceptable Simplifications

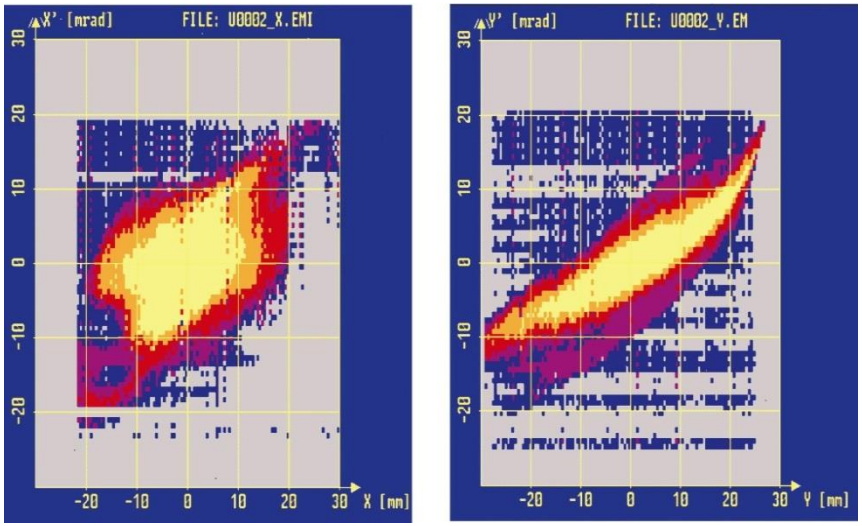
# HITRAP linear decelerator commissioning (July 2014)



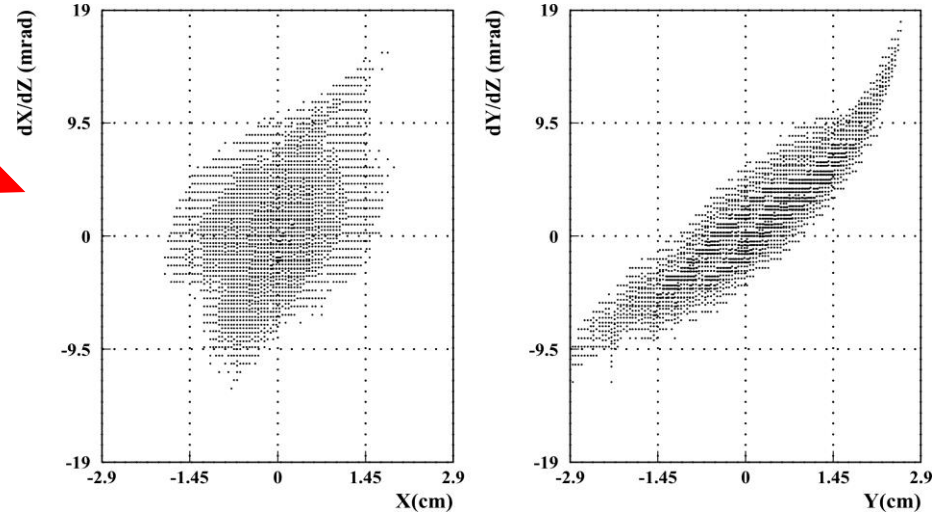
# Input particle distribution (GSI-HSI-LEBT)

Emittance measurements in the LEBT were used for the generating of the particle distribution.



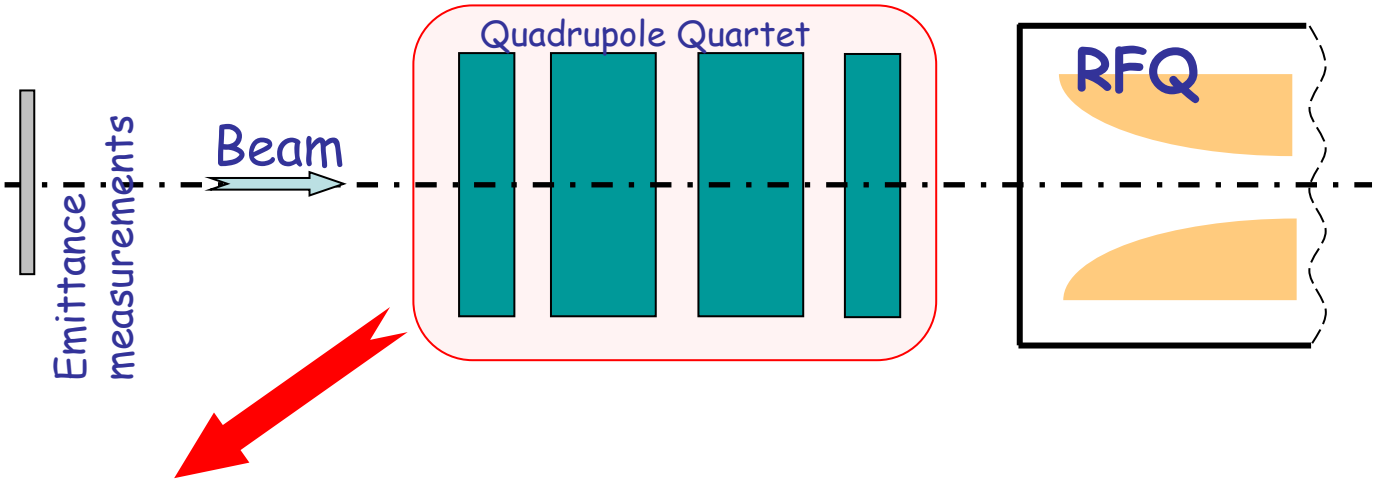

Number of particles in each bin is proportional to the measured intensity

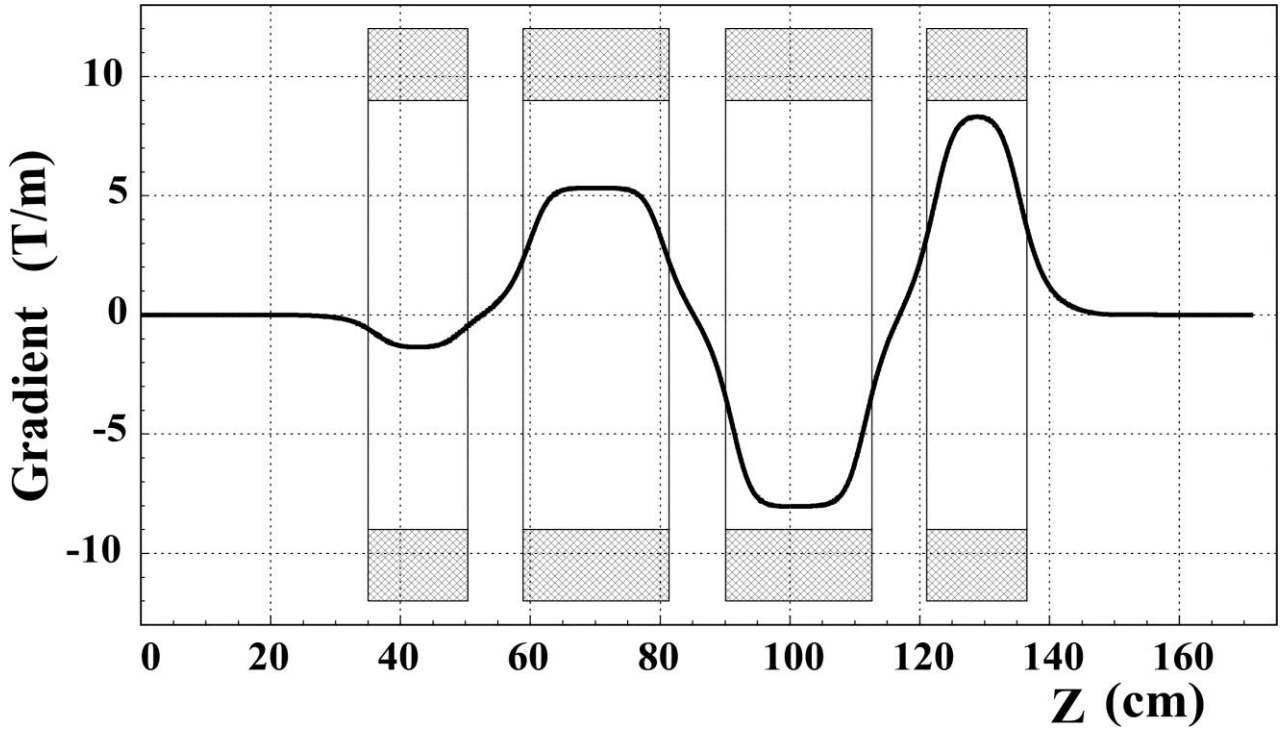



Measured beam emittance is significantly higher (up to 50%) than design value (1999)

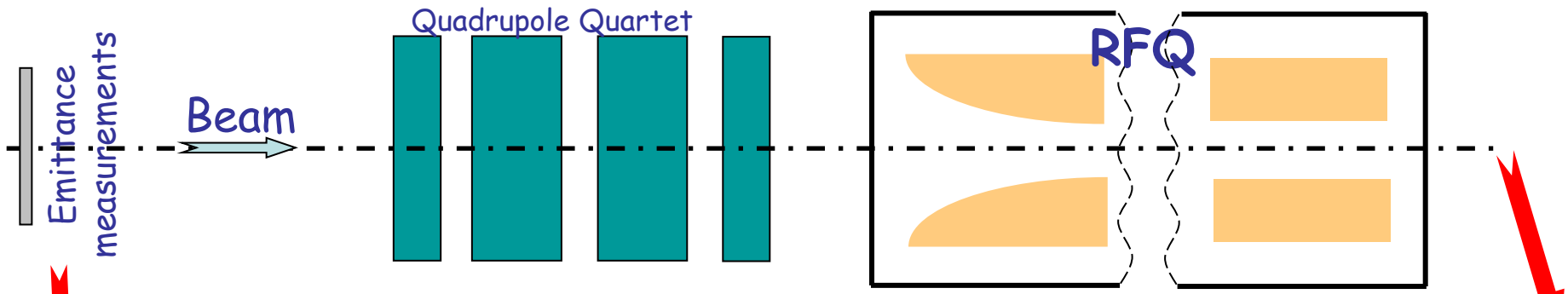
# Measured external fields

Distribution of magnetic field, measured for each quadrupole lens, was introduced as input data (with machine settings during operation).



# Status of the HSI front-end before upgrade in 2004




measured $U^{4+}$ beam current 15 mA

- particle distribution: measured emittance
- measured gradients in quadrupoles
- realistic electrical field in the RFQ
- measured voltage in the RFQ
- measured misalignments

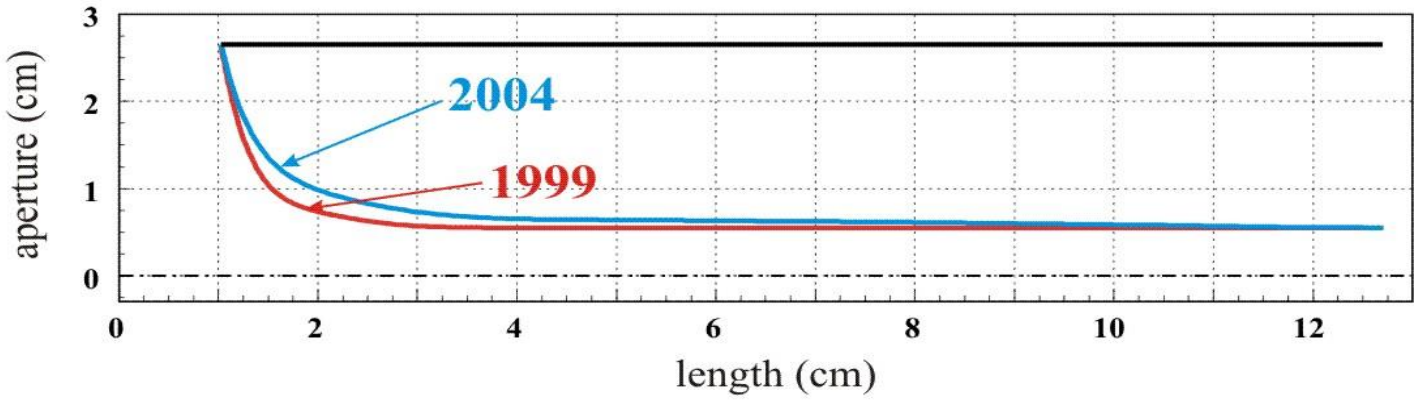
**Measured** beam current behind RFQ

**8.3 mA**

**Calculated** beam current behind RFQ

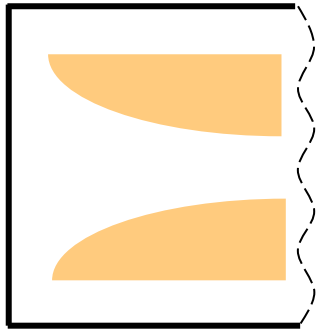
**8.7 mA**

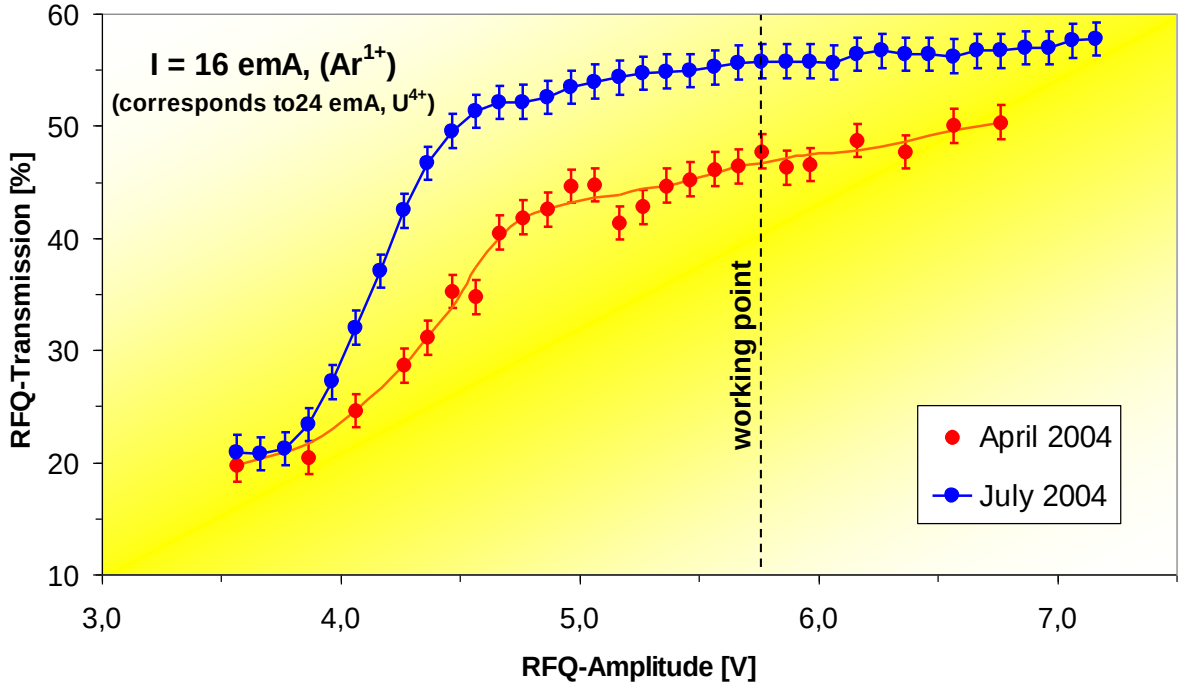
≈10 cm *(HSI-RFQ length is 9.3 m)*




Heavy Ion
High Current
GSI-HSI-RFQ
*Upgrade 2004*

Shape of the Input Radial Matcher






Simulated results and measurements after upgrade are in a good coincidence

# New design of the HSI-RFQ electrodes *Upgrade **2009***

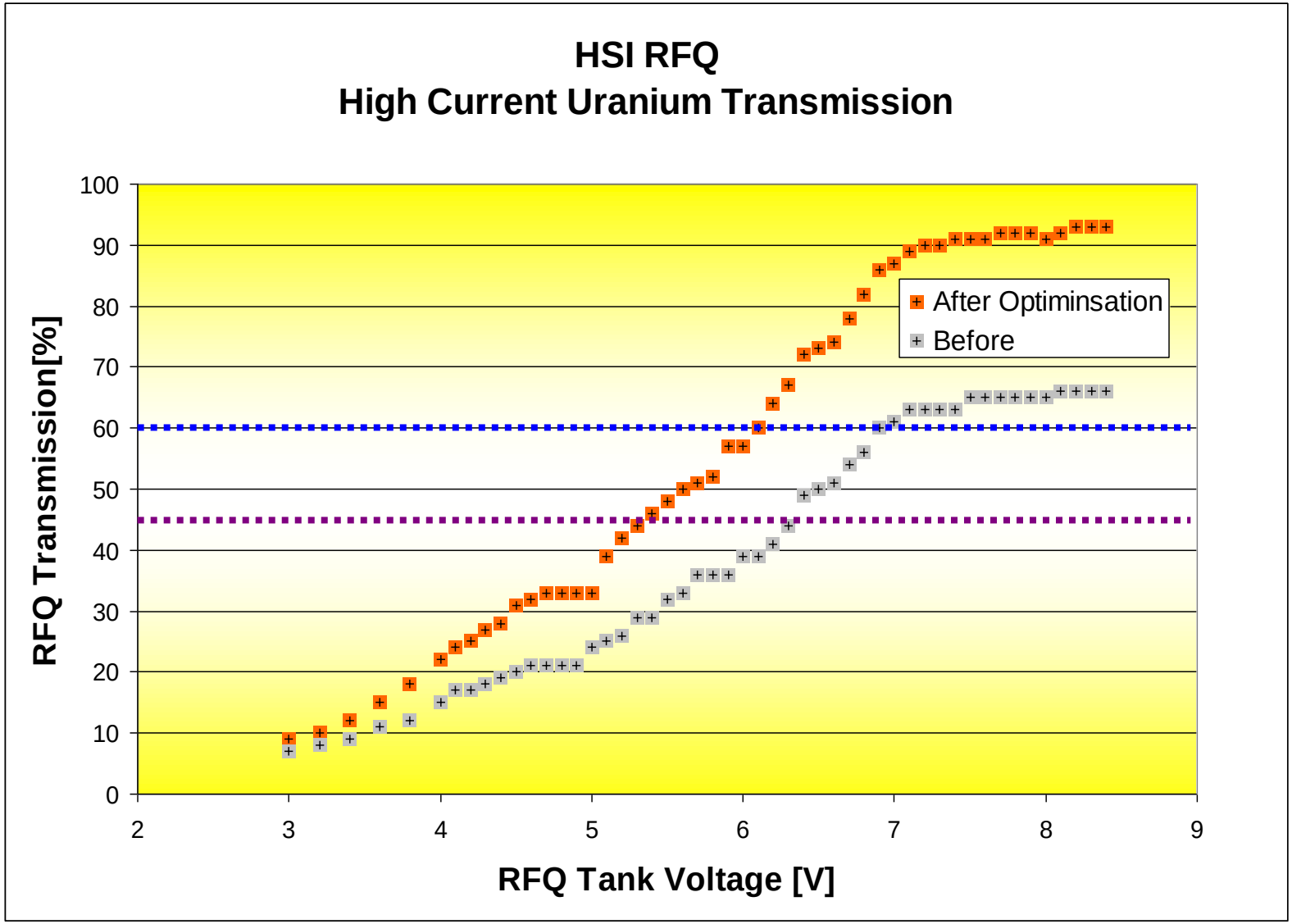
A. Kolomiets,
S. Minaev
*ITEP (Moscow)*

## UNILAC Department & GSI Workshop

DYNAMION family
code for an RFQ design

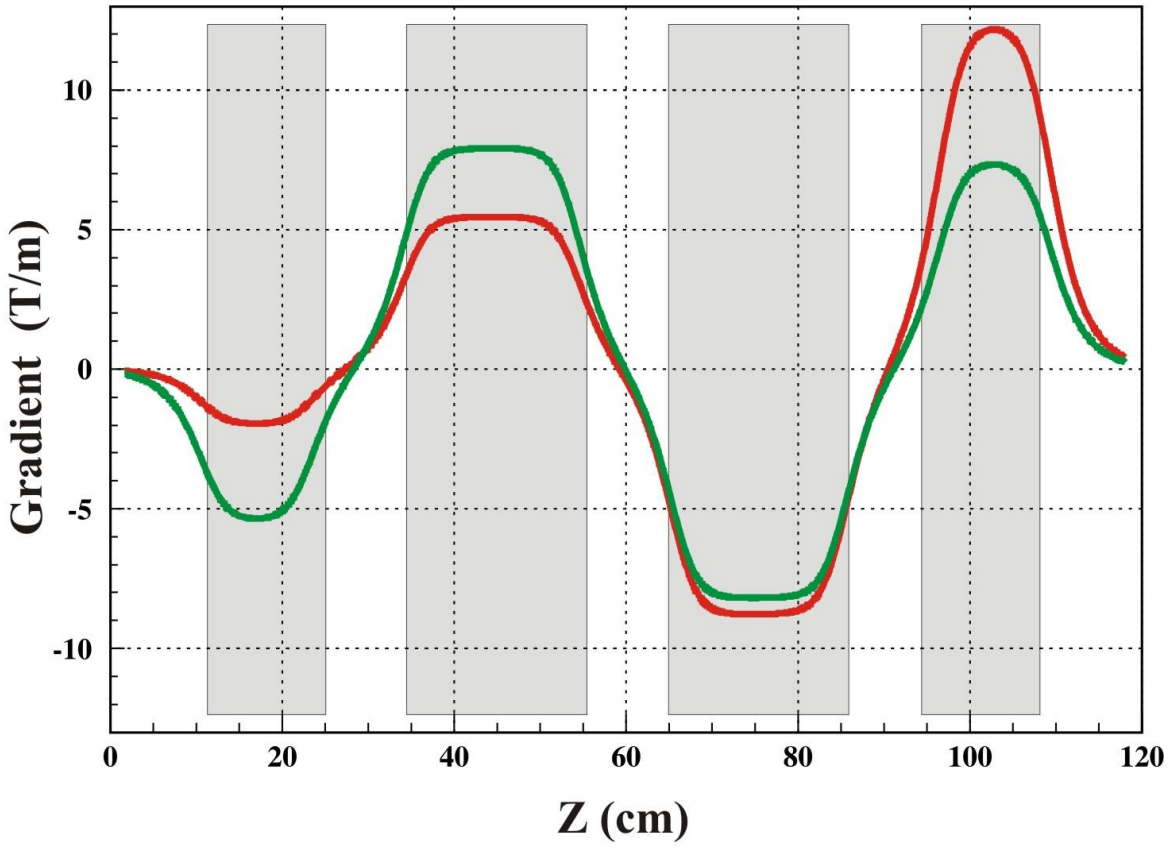
**DESRFQ**

- advanced
- interactive
- object-oriented
- visualized
- ...



# Beam matching to the RFQ with Quadrupole Quartet

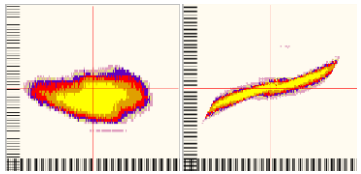
*proposed in advance*



## Beam experiments / 4 mA $Ta^{4+}$ at UH1DT1 / *February 2014*

TRAFO **UH1DT1**

Emittance meter



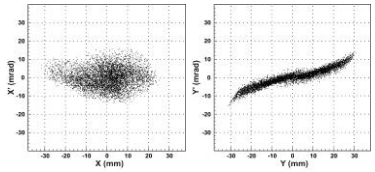
Quadrupole Quartet (QQ)

RFQ

TRAFO **UH3DT2**

## DYNAMION simulation using machine settings *(100% neutralization inside QQ)*

Generated particle distribution



Measured magnetic field

Realistic external field, space charge, real Voltage

| QQ settings | Transmission | |
|---|---|---|
| | *measured* | *calculated* |
| *standard* | 48% | 53% |
| *new* | 71% | 74% |