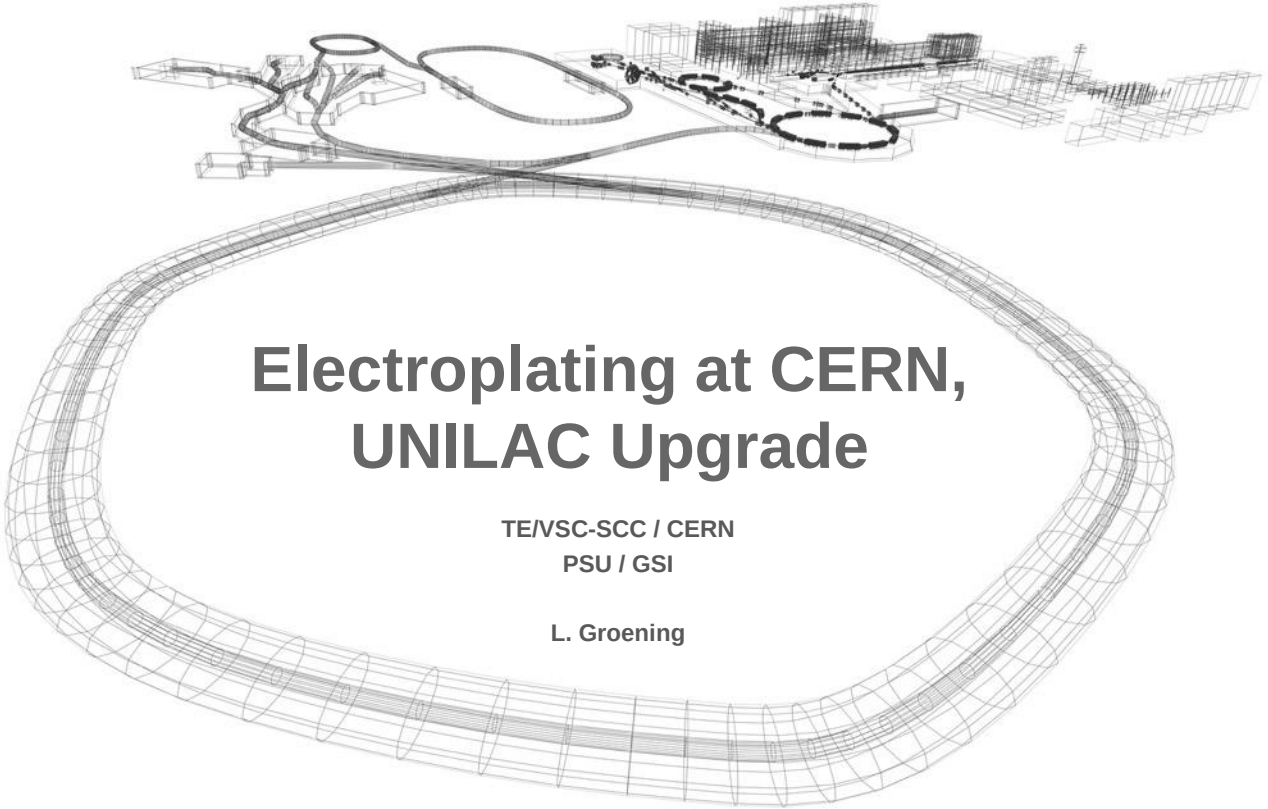

Electroplating at CERN, UNILAC Upgrade

TE/VSC-SCC / CERN
PSU / GSI

L. Groening

Outline

- Introduction
- Scope of work
- Status

ADDENDUM 18 KR5656/TE

TO

COLLABORATION AGREEMENT K 1727/DG (THE "AGREEMENT")

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That the Parties wish to collaborate in the field of copper plating technology of components for rf-linacs on the basis that CERN has unique expertise in providing such activities;

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M. Taborelli, G. Rosaz, L. Ferreira, S. Roupioz, P. Maurin
T. Dettinger, L. Groening, M. Heilmann, S. Mickat, M. Strauch

Existing UNILAC post-stripper DTL

- design from the 1960ies: high intensity operation of heavy ions not considered
- anticipated life time: 1990 – 2000
- first three cavities in operation since 51 years, aging goes on
- cavities, drift tubes, and magnets partially damaged

  → increased maintenance efforts & operational risks


U N I L A C

Bericht Nr. 5 - 67

Dimensionierung der Quadrupolfokussierung in einem Schwerionen-Linearbeschleuniger

R. Fricke

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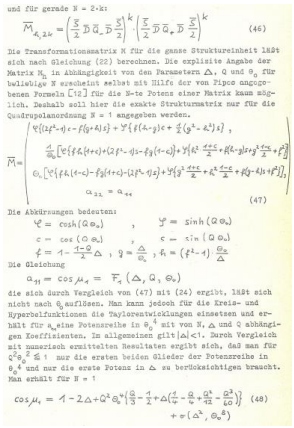
UNIVERSITÄT HEIDELBERG
UNILAC-GRUPPE


und für gerade N = 2·k:

$$\overline{M}_{x,2k} = \left(\frac{\Sigma}{2} D\, \overline{G}_{+} D\, \frac{\Sigma}{2}\right)^{k} \cdot \left(\frac{\Sigma}{2} D\, \overline{G}_{+} D\, \frac{\Sigma}{2}\right)^{k} \qquad (46)$$

Die Transformationsmatrix M für die ganze Strukturreinheit läßt sich nach Gleichung (22) berechnen. Die explizite Angabe der Matrix M_0 in Abhängigkeit von den Parametern Δ, Q und Θ_0 für beliebiges N erscheint selbst mit Hilfe der von Pipco angegebenen Formeln [12] für die N-te Potenz einer Matrix kaum möglich. Deshalb soll hier die exakte Strukturmatrix nur für die Quadrupolanordnung N = 1 angegeben werden.

$$\overline{M}_{1} = \begin{pmatrix} \Psi\{(2f^2-1)c - f(g+k)s\} + \Psi\{f(k-g)c + \frac{f}{2}(g^2-k^2)s\}, & \\ \frac{1}{\Theta_0}\left[\Psi\{fk(c-1) + (2f^2-1)s - fg(1+c)\} + \Psi\{k^2\frac{1+c}{2} + fk(k-g)\frac{1+c}{2} + f^2\frac{s}{2}\}\right], & \\ \Theta_0\left[\Psi\{fk(1+c) - fg(1+c) - (2f^2-1)s\} + \Psi\{g^2\frac{1+c}{2} + k^2\frac{1-c}{2} + fg(g-k)\frac{s}{2}\}\right], & \\ a_{22} = a_{11} \end{pmatrix} \qquad (47)$$

Die Abkürzungen bedeuten:

$\Psi = \cosh(Q\Theta_0)$, $\Psi = \sinh(Q\Theta_0)$

$c = \cos(Q\Theta_0)$, $s = \sin(Q\Theta_0)$

$f = 1 - \frac{1-Q}{2}\Delta$; $g = \frac{\Delta}{\Theta_0}$; $k = (f^2-1)\cdot\frac{\Theta_0}{\Delta}$

Die Gleichung

$$a_{11} = \cos\mu_x = F_x(\Delta, Q, \Theta_0)$$

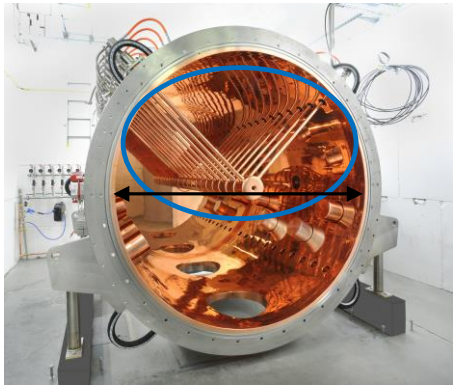
die sich durch Vergleich von (47) mit (24) ergibt, läßt sich nicht nach Θ_0 auflösen. Man kann jedoch für die Kreis- und Hyperbelfunktionen die Taylorentwicklungen einsetzen und erhält für a_{11} eine Potenzreihe in Θ_0^2 mit von N, Δ und Q abhängigen Koeffizienten. Im allgemeinen gilt $|\Delta|<1$. Durch Vergleich mit numerisch ermittelten Resultaten ergibt sich, daß man für $Q^2\Theta_0^2 \leq 1$ nur die ersten beiden Glieder der Potenzreihe in Θ_0^2 und nur die erste Potenz in Δ zu berücksichtigen braucht. Man erhält für N = 1

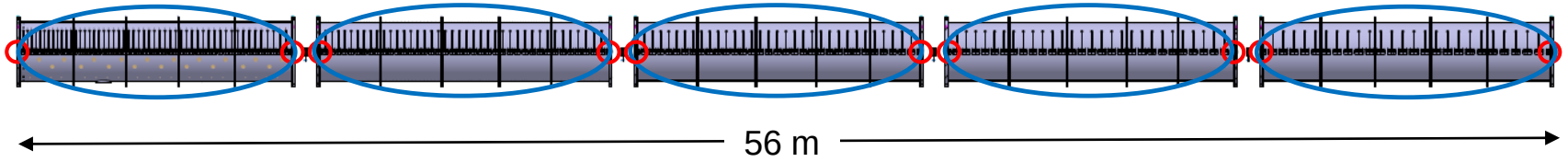
$$\cos\mu_x = 1 - 2\Delta + Q^2\Theta_0^2\left(\frac{Q}{3} - \frac{1}{2} + \Delta\left(\frac{1}{4} - \frac{Q}{6} + \frac{Q^2}{12} - \frac{Q^3}{60}\right)\right) + \varphi(\Delta^2, \Theta_0^4) \qquad (48)$$

UNILAC post-stripper DTL
New design

- shall deal with very intense beams of uranium
- drift tube linac from five Alvarez-type cavities
- pulsed e.m. quadrupole magnets to meet specific ion's A/q
- each drift tube being equipped with one internal quadrupole
- 10 half-size drift tubes and 177 full-size drift tubes including two stems each

1.95 m



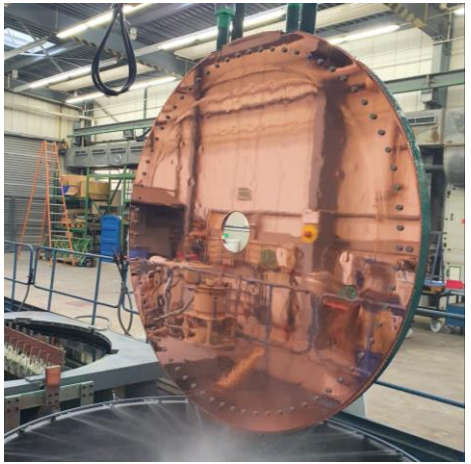


GSI electroplating workshop (est. 1960ies): Retrofitting 2019 - 2023

- meet enhanced requirements from authorities
- replace basins
- renew of technical equipment
- external storage of hazard. materials containers
- hire one more technician and galvanizer, resp.
- total invest of 3.4 M€

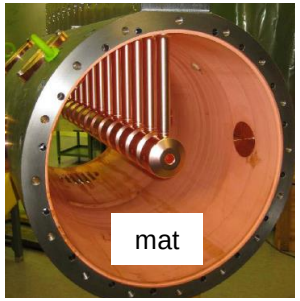
Electroplating with high-bright copper

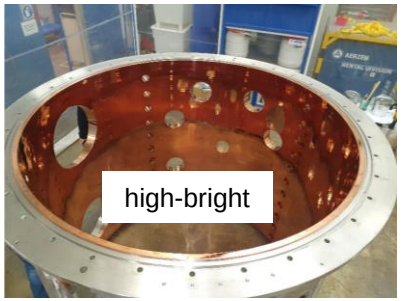
- all surfaces exposed to RF-fields must be Cu-plated with about 150 µm
- GSI has the expertise to do this plating in-house
- however, GSI's plating shop is fully loaded with the 25 cavity mantles and 10 end-plates

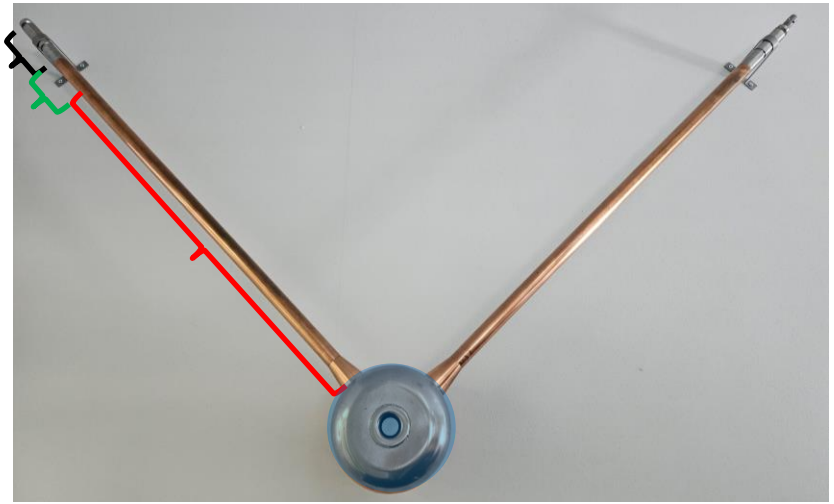


Requirements to plating

- high-bright plating with dedicated chemistry recipe
- copper of purity larger than 96% IACS
- plated surface ready for operation at ≤ 10^{-8} mbar
- defined thickness profile (thickness d in µm):
  - d = 0
  - 50 ≤ d ≤ 120
  - 50 ≤ d ≤ 300
  - 100 ≤ d ≤ 140
- 177 pieces
- each with individual length of drift tube







Electroplating with high-bright copper

- dedicated and rigorous market survey revealed that:
  - there are some few commercial shops that can deal with add-on parts as flanges, bellows, plungers, etc.
  - but there is no shop that can deal with 177 drift tubes

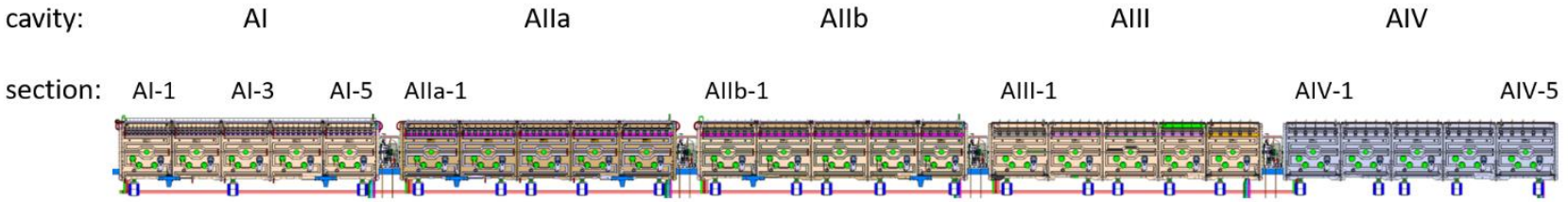
- a collaboration with CERN has been forged with mutual benefits:
  - GSI: plating of the drift tubes
  - GSI: a fully working plating line (GSI may take it over afterwards) →
  - CERN: expertise in high-bright copper plating
  - both: merge expertise
  - both: increase independence from very restricted commercial market

- collaboration is on the high-bright Cu-plating of 177 drift tubes (DT)

Workpackages and schedule as agreed and signed (Dec. 2023)

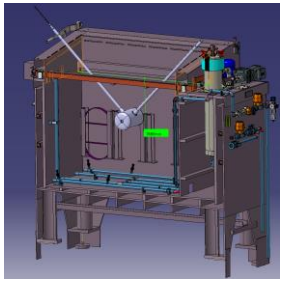
WP	Scope	Cavity	# of DTs	timeline	payment [CHF]
1	Design of plating line & tools			01/23 - 05/23	25000
2	Purchasing plating line & tools			01/23 - 09/24	331875
3.0	Recruitment of CERN staff			09/23 - 06/24	81000
3.1	Plating DTs	AI	52	01/25 - 08/25	104720
3.2	*Plating DTs*	*AIIa + AIIb*	*72*	*04/26 - 02/27*	*277632*
3.3	*Plating DTs*	*AIII + AIV*	*53*	*04/27 - 09/27*	*218752*
			177		***1038979***

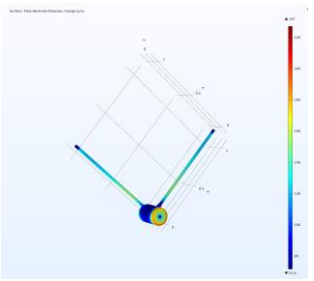
} optional in view of progress

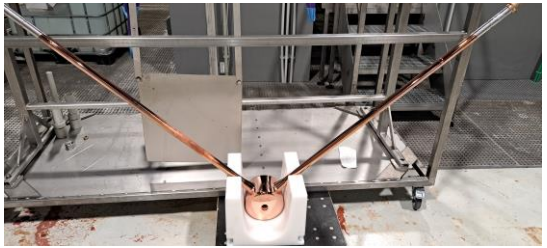


Successful commissioning of plating line at CERN

- 2022 - 23: design works, simulation of plating process
- Oct. 2024: FAT of plating line @ GALVO Service / Italy
- Dec. 2024: delivery, installation and SAT
- Mar 2025: dummy drift tube plated and stripped several times to optimize process







Workpackages and schedule as currently executed and planned

WP	Scope	Cavity	# of DTs	timeline	payment [CHF]	status
1	Design of plating line & tools			01/23 - 05/23	25000	done
2	Purchasing plating line & tools			01/23 - 09/24	331875	done
3.0	Recruitment of CERN staff			09/23 - 06/24	81000	done
3.1	Plating DTs	AIIa	40	05/25 - 09/26	135843	starting soon
3.2	*Plating DTs*	*AI*	*52*	*04/26 - 02/27*	176596	*open*
3.3	*Plating DTs*	*AIIb*	*32*	*10/26 - 02/27*	108674	*open*
3.4	*Plating DTs*	*AIII + AIV*	*53*	*03/27 - 09/27*	179992	*open*
			177		***1038979***	

104720 CHF (billed & paid)

optional in view of progress

- unchanged:
  - overall scope and benefits
  - final termination date
  - overall payment
- adapted to progress of DT production
  - pulling AIIa in advance of AI (AI production meets issues at supplier)
  - splitting WP (AIIa + AIIb) into two separate WPs

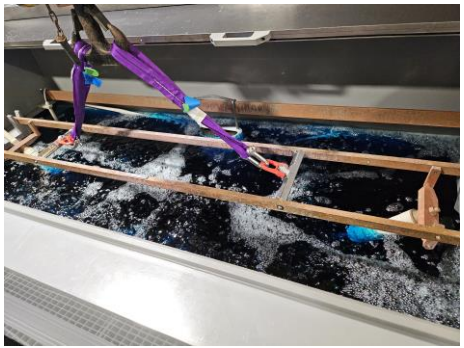
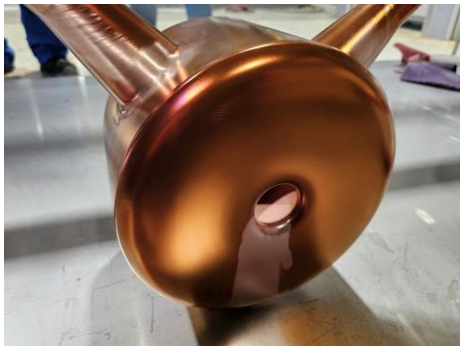
this is how we live it; there is no formal re-agreement yet

Defining the plating process prior to series

- last week: dummy DT provided by GSI has been used to commonly finalize the process
- two joint complete plating processes have been performed
- results meet specifications in all aspects
- few tools (increase efficiency of handling) will be re-designed and series plating starts on May 19th

collaboration is on track w.r.t. timeline, budgets, results



Thank you for your attention!