Ion Sources for FAIR

Ralph Hollinger

Status Quo

- Ion Sources for Beam Time Operation

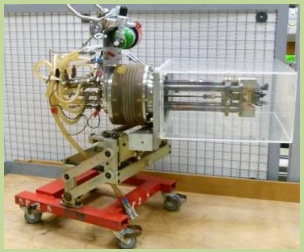
MUCIS

MUCIS New

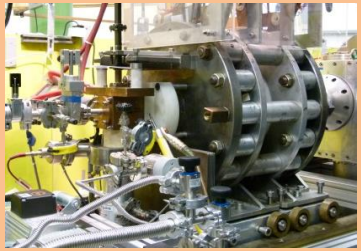
CHORDIS

MEVVA

VARIS



PIG

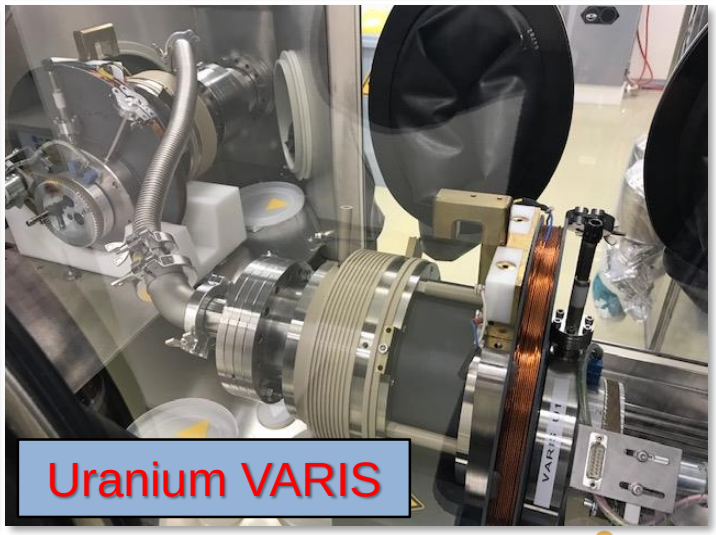


ECR

Terminal North
Terminal South
HLI

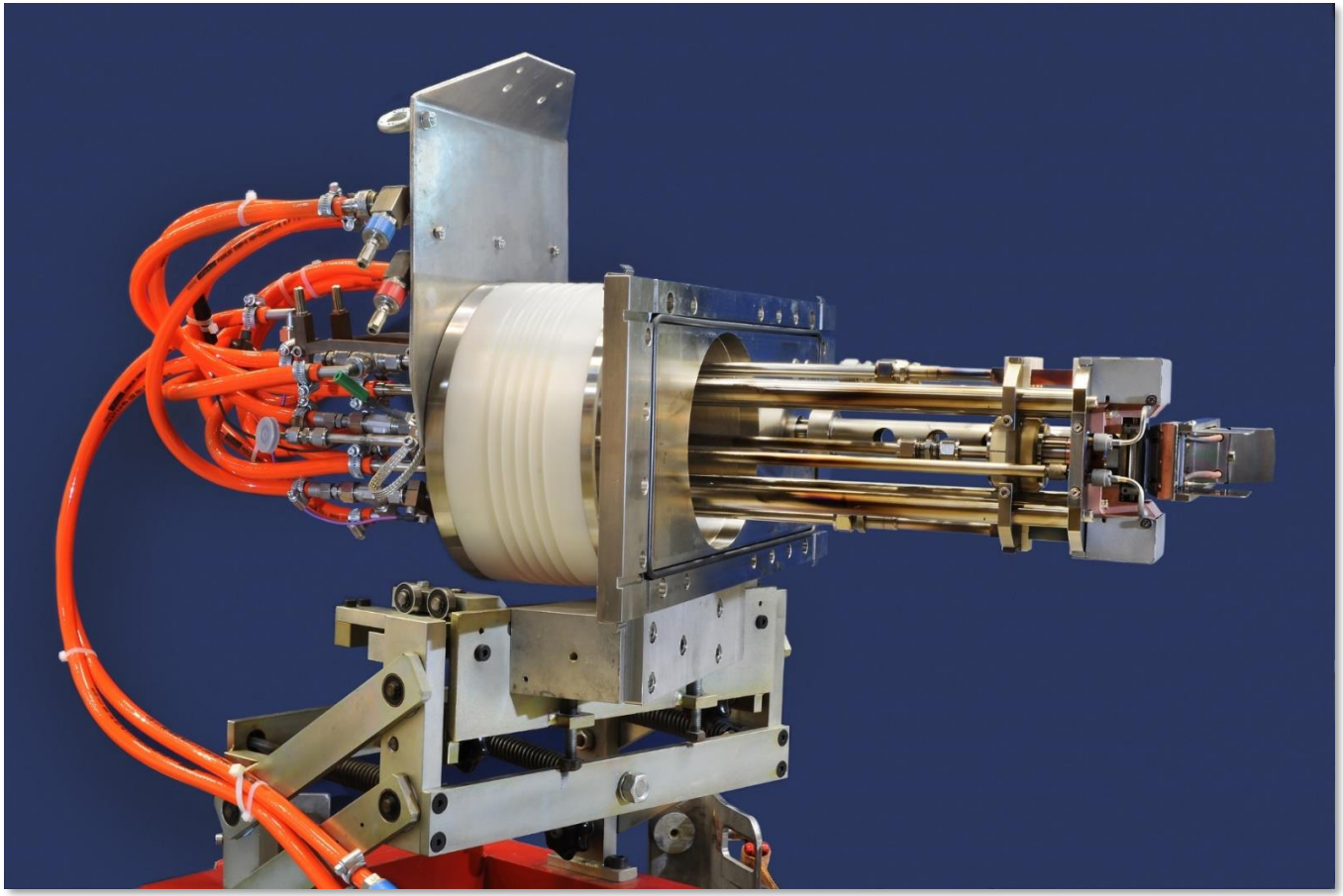
Increas the Number of High Current Ion Sources

	today		future
VARIS:	6	⟹	12
Uranium VARIS:	2	⟹	3+
MUCIS NEW:	2	⟹	6
MUCIS OLD:	2	⟹	3
CHORDIS:	3	⟹	6



Renewing of PIG Sources

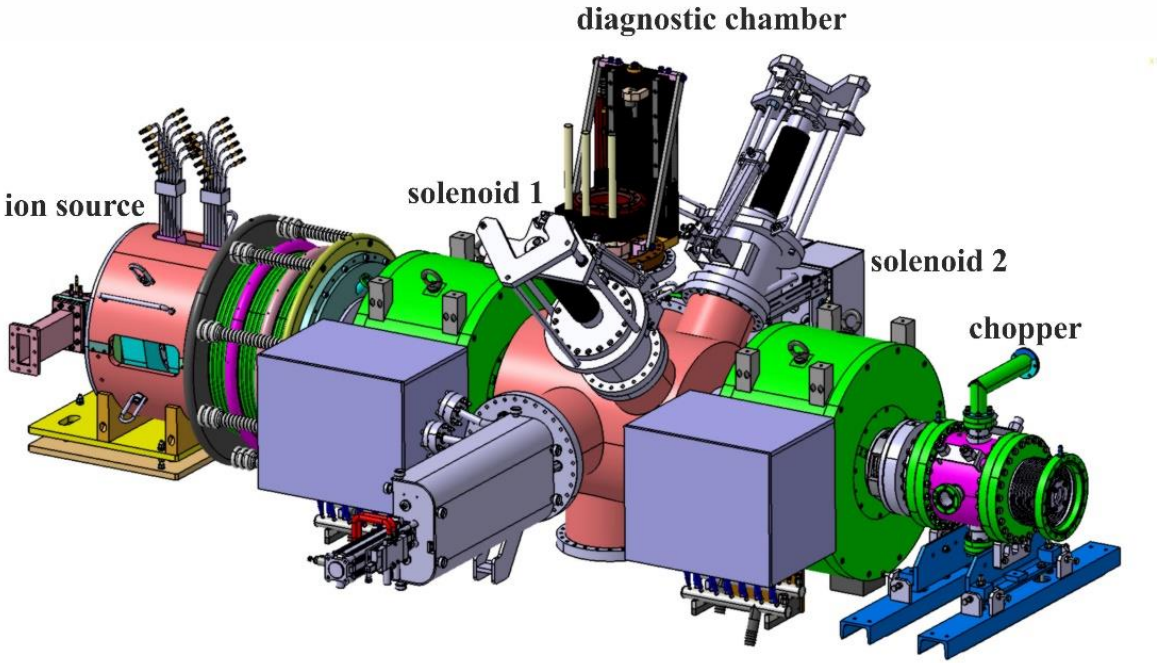
After 5 years and 3500 hrs of work…



…10 PIG sources are completely renewed and ready for operation for the time after more than 40 years of operation.

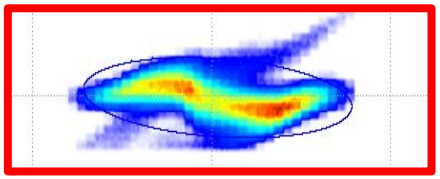
p-LINAC Injector for FAIR

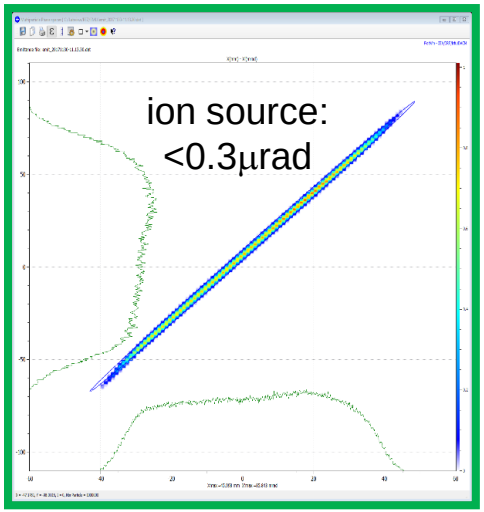
- Collaboration between GSI and CEA/Saclay
- Injector build up and commissioned at CEA (similar to IFMIF)
- 100mA p @ 95keV inside 0.3μrad in front of RFQ, pulse >40μs @ 2.7Hz
- 3GHz RF source with double solenoid focussing LEBT

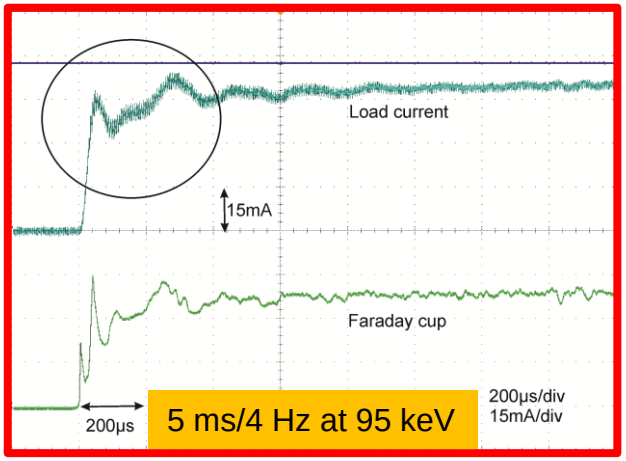


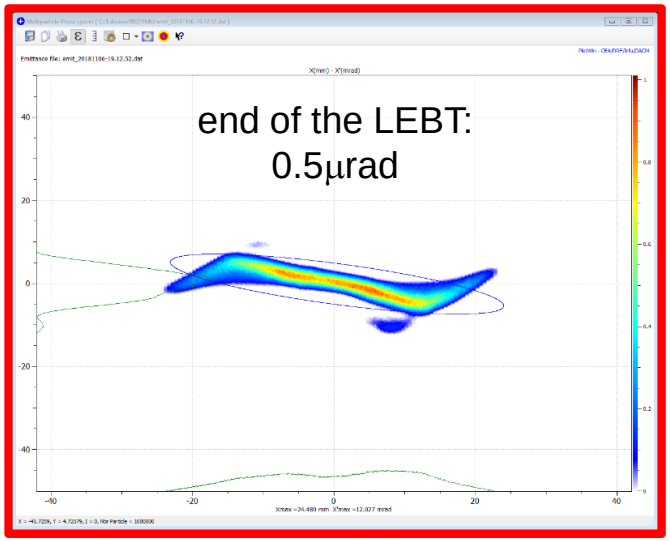
p-LINAC Injector for FAIR

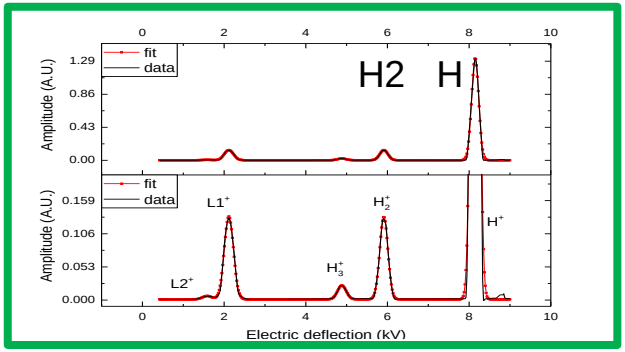
- **Beam quality:**
- Spectrum & proton current: >85% and up to 125mA full beam ✓
- Emittance of the ion source: <0.3µrad, no filamentation ✓
- Pulse shape and duty cycle ✗
- Emittance of the LEBT: 60% higher as expected ✗

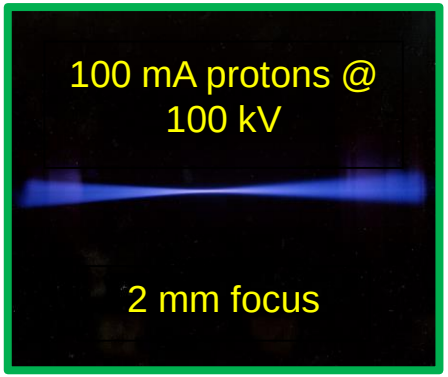










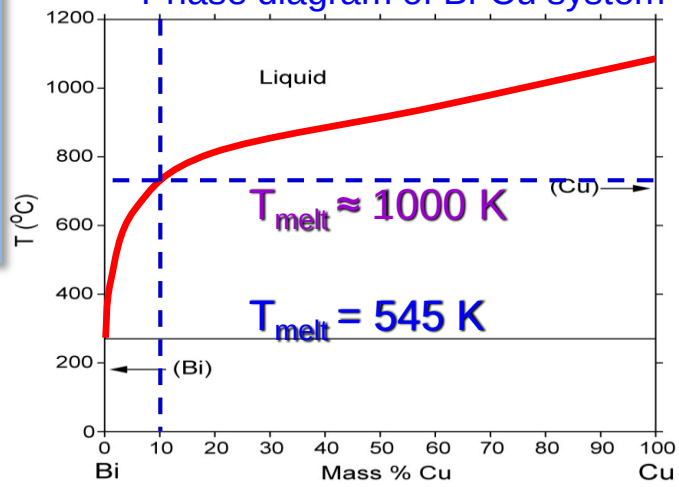


Development of New Elements for High Current Ion Sources

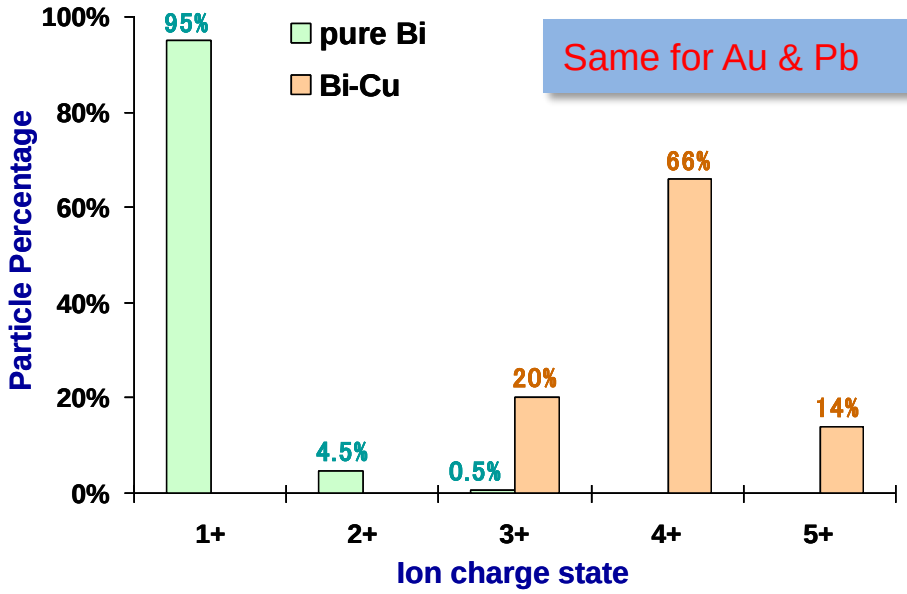
Challenges with Au, Pb and Bi:

- Soft and fusible metals with low melting point
- Operation with low discharge current
- Danger of melting of the cathode material
- High flux of neutrals from the surface

Phase diagram of Bi-Cu system*



*Calculated Phase Diagram from NIST, Metallurgy Division, Material Measurement Laboratory



Same for Au & Pb

Bi-Cu cathodes:

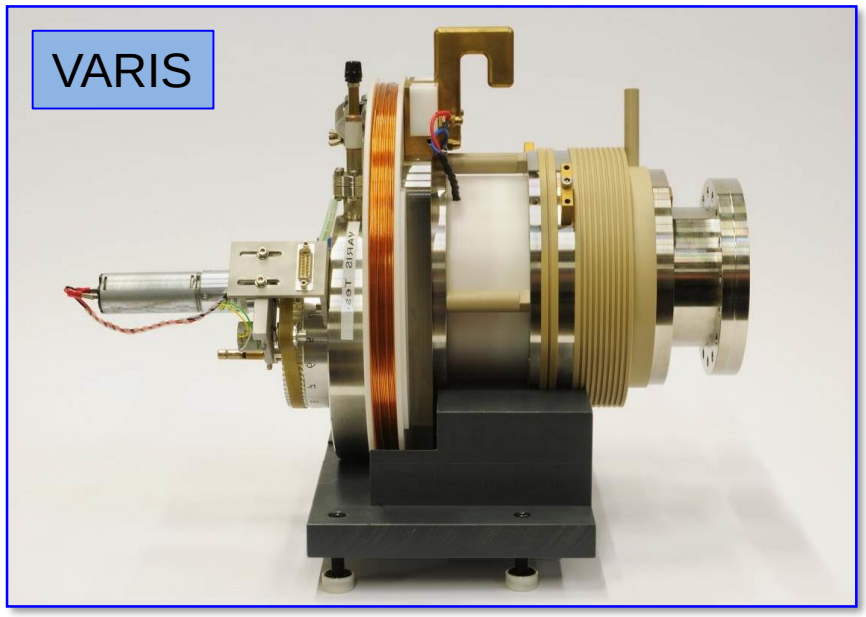
- Cu admixture between 8% and 15%
- Discharge currents up to 900 A
- Stable operation
- Good pulse-to-pulse repetition
- 15 mA of Bi^{4+} in front of the RFQ

Increase the Offer of Ion Species

Element	Ion Beam	Ion Source	Duty Factor	Beam current in front of the RFQ	Particles in 100 µs pulse	Space-charge limit RFQ
CH_4	$^{12}CH_3^+ \rightarrow$ * p	MUCIS	2 Hz / 1 ms	3 mA → * 3 mA	$1.9 \cdot 10^{12}$	3.8 mA
N_2	$^{14}N_2^+$	CHORDIS	5 Hz / 1 ms	4 mA	$2.5 \cdot 10^{12}$	7 mA
Ar	$^{40}Ar^+$	MUCIS	5 Hz / 1 ms	20 mA	$1.2 \cdot 10^{13}$	10 mA
Ca	$^{40}Ca^{2+}$	PIG	50 Hz / 5 ms	100 µA	$3.1 \cdot 10^{10}$	5 mA
	$^{48}Ca^{10+}$	ECR	DC	100 µA	$6.3 \cdot 10^{9}$	-
Ni	$^{58}Ni^{2+}$	VARIS	1 Hz / 0.5 ms	5 mA	$1.6 \cdot 10^{12}$	7.3 mA
Kr	$^{86}Kr^{2+}$	MUCIS New	5 Hz / 1 ms	7 mA	$2.2 \cdot 10^{12}$	10.8 mA
Ag	$^{107}Ag^{2+}$	VARIS	1 Hz / 1 ms	10 mA	$3.1 \cdot 10^{12}$	13.4 mA
Sn	$^{112}Sn^{15+}$	ECR	DC	25 µA	10^{9}	-
Xe	$^{124}Xe^{3+}$	MUCIS New	5 Hz / 1 ms	4 mA	$8.3 \cdot 10^{11}$	10.3 mA
Au	$^{197}Au^{4+}$	VARIS	0.5 Hz / 0.5 ms	4.5 mA	$7 \cdot 10^{11}$	12.3 mA
Pb	$^{208}Pb^{4+}$	VARIS	0.5 Hz / 0.4 ms	5 mA	$7.8 \cdot 10^{11}$	13 mA
Bi	$^{209}Bi^{4+}$	VARIS	0.5 Hz / 0.5 ms	12 mA	$1.9 \cdot 10^{12}$	13.1 mA
U	$^{238}U^{4+}$	VARIS	1 Hz / 0.5 ms	12 mA	$1.9 \cdot 10^{12}$	15 mA

* behind the gas stripper

2.7 Hz Operation for Uranium

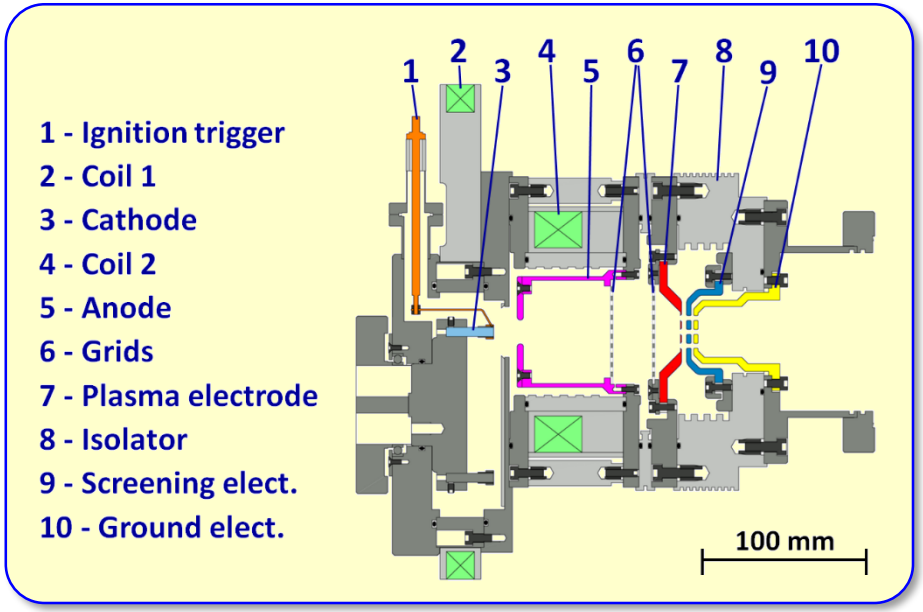


Technical data:

- Revolver with 17 Cathodes
- 2 Solenoids: 0.1 and 0.2 Tesla
- Arc current: up to 2 kA
- Typical duty cycle: 1 Hz / 0.5 ms
- Working Material: ductile Metals
- Life time: ~1 Week (Uranium)

Features:

- Optimized for Uranium: 67% of U^{4+}
- High emission current density: 170 mA/cm^2
- NO water cooling is necessary
- Improved positioning of coils and grids
- Very compact system



2.7 Hz Operation for Uranium

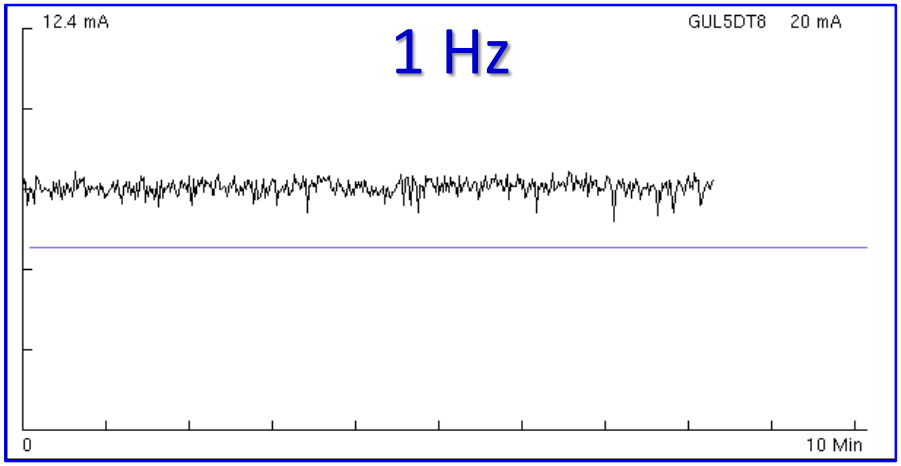
Well established operation with 1 Hz / 0.5 ms

- High production efficiency of U^{4+} ions (67% of U^{4+} in the spectrum)
- Proper beam pulse shape (with a flat top over 120 µs)
- Excellent pulse-to-pulse stability (intensity fluctuations < 12%)
- Beam current in front of the RFQ: up to **15 mA**

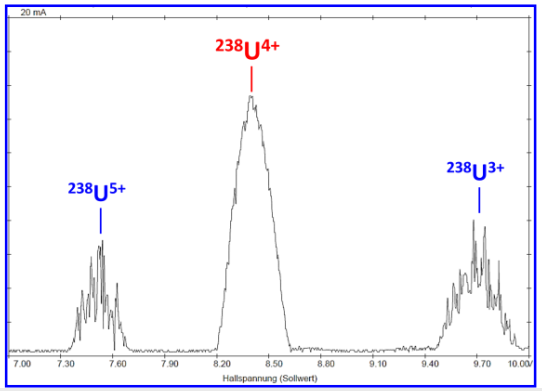
Operation with 2.7 Hz / 0.5 ms

- Ignition failures
- Extraction breaks
- Performance drop

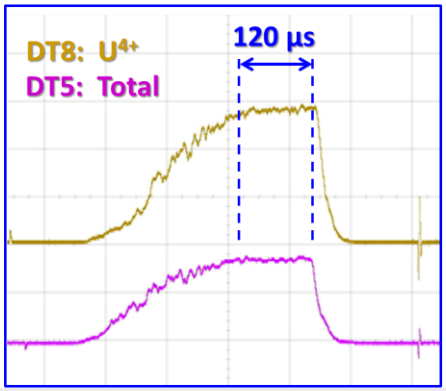
VARIS performance with U by increasing the repetition rate (pulse length = 0.5 ms)



Ion charge state distribution for U



Temporal profile of U^{4+} beam



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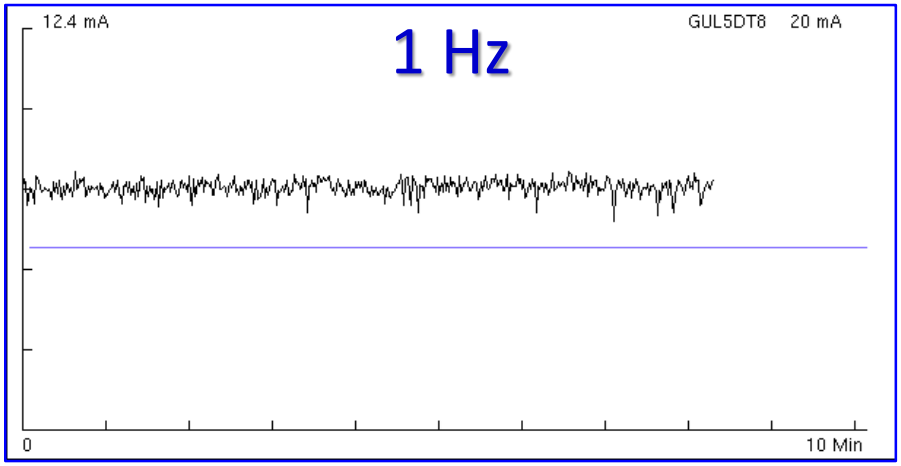
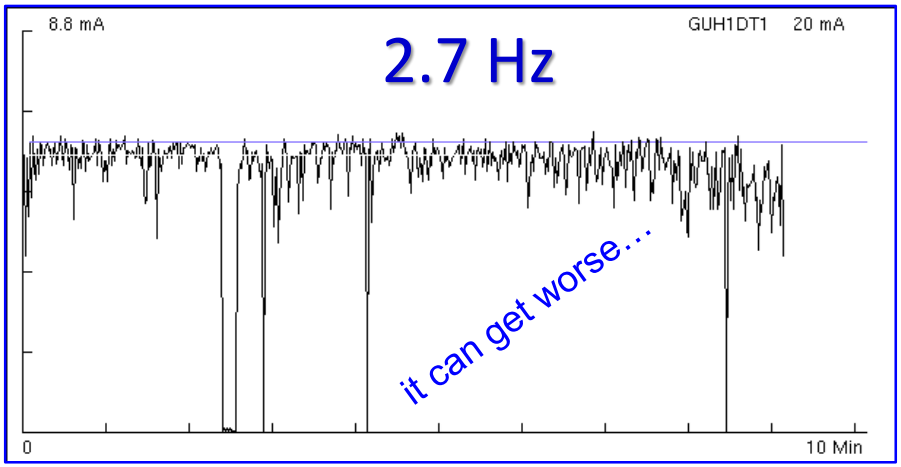
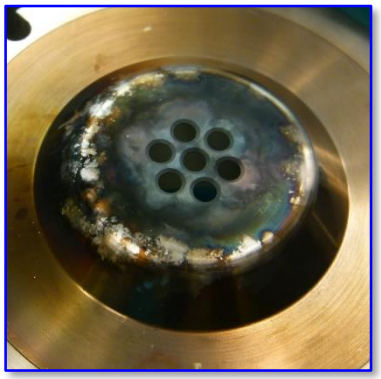




2.7 Hz Operation for Uranium

Inhibiting factors:

- Increased $T_{surface}$ of the cathode
  ⟹ short circuit bridges ⟹ arc ignition failures
- Higher flux of neutrals from the surface
  ⟹ shifting the spectrum to the lower charge states
- Increased T of extraction electrodes
  ⟹ increased breakdown prob. ⟹ sparking in the extr. sys.
- Reduce discharge current (as a consequence)
  ⟹ reduced plasma density ⟹ lower beam current



2.7 Hz Operation for Uranium (work together with framatome & HMW Hauner GmbH & Co. KG Metallische Werkstoffe ...für Forschung und Entwicklung)

Possible Solutions:

-Reduce of total pulse length by zero L resistances - done, positive effect observed

-Using U-W alloy to increase the melting temperature - no significant improvement

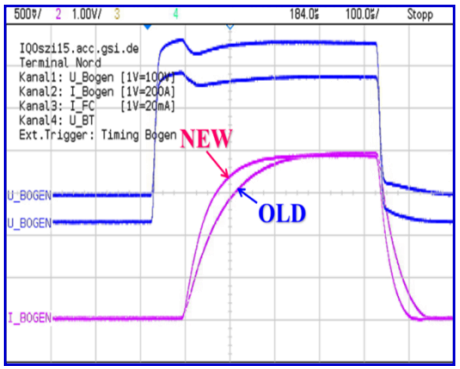
-Using U-Zr alloy to increase the melting temperature - in preparation (new oven needed)

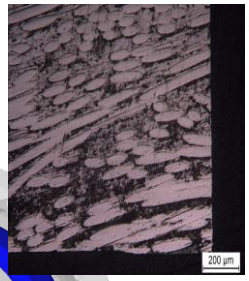
-Cooling the of the electrodes - in preparation

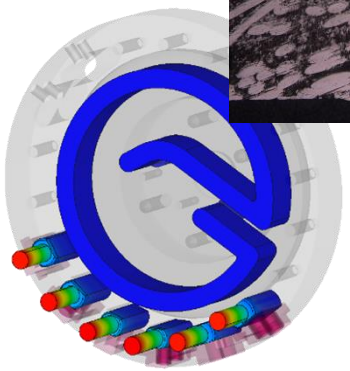
-Use of threaded electrodes - in preparation

U-W15 electrodes

100 µs faster rise time

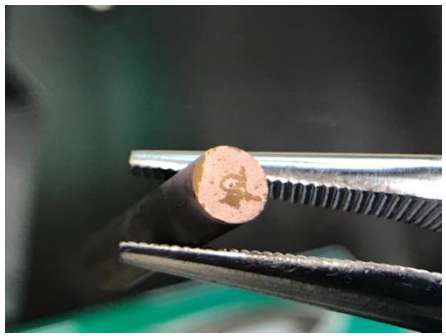


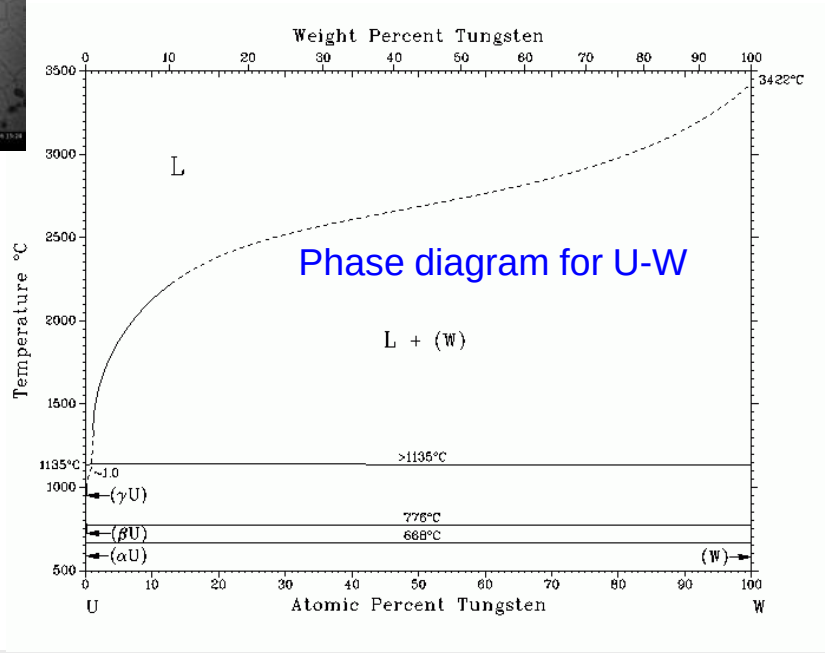




cooled electrode holder

Cu sputtered U electrode;
Goal: Soldering of U on Cu





Phase diagram for U-W

2.7 Hz Operation for Uranium (U-W15) Electrodes

Actual problems:

- "Bad phases" in cathode operation:

→ ignition failures (> 50% of beam pulses are failed even with P_{ZG} = MAX)

→ very unstable arc discharge => => very noisy beam pulse (intensity fluctuations up to 70%)

→ no pulse-to-pulse stability

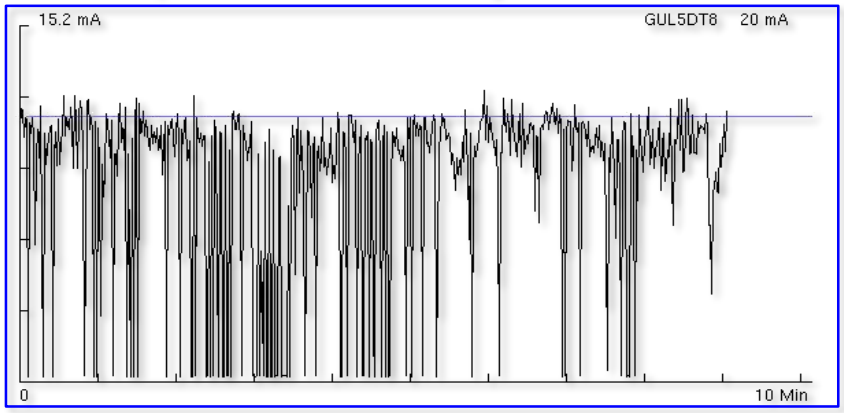
→ tuning the IS parameters doesn't help => it burns out by itself

→ "bad phase" can take from 5 to 30 min

- Lifetime of cathodes:

→ up to 7 hours with 2.8 Hz incl. total time of "BPh" ~1.5 hours

Operation "instability" over 10 min



2nd Supplier for Uranium:

MSC Manufacturing Sciences Corporation

framatome

FAIR GSI

BUDGETARY QUOTATION DATE: 9/8/2015

MSC Manufacturing Sciences Corporation
A GMS Company

FROM: Manufacturing Sciences Corporation
804 South Illinois Avenue
Oak Ridge, TN 37830

GSI Helmholtzzentrum für Schwerionenforsch

TELEPHONE +49 6159 71 2691
TELEFAX +49 6159 71 2166
e-mail B.Lommel@gsi.de

TELEPHONE
TELEFAX (865)481-3142
e-mail

FQ NUMBER

MSC QUOTATION # 15-78

ITEM	QUANTITY	DESCRIPTION	UNIT PRICE	TOTAL PRICE
1	250	DEPLETED URANIUM ELECTRODES 5.7 MM X 30 MM. CHEMISTRY AND ISOTOPIC DATA INCLUDED	$353	$88,250

ALL WORK IN ACCORDANCE WITH MSC STANDARD COMMERCIAL TERMS

MSC NOT LIABLE FOR DAMAGE OR LOSS OF CUSTOMER SUPPLIED MATER

INVOICE - 100% UPON COMPLETION
TERMS - NET 30 DAYS, 1.5% INTEREST ON BALANCES OVER 30 DAYS PAST DUE

PRICES VALID FOR 30 DAYS UNLESS OTHERWISE SPECIFIED.

DELIVERY IS 8 WEEKS AFTER RECEIPT OF A PURCHASE ORDER

THANK YOU FOR THE OPPORTUNITY TO PROVIDE A QUOTATION FOR THIS WORK. PLEASE CONTACT US IF WE MAY BE OF FURTHER ASSISTANCE.

Menge Uran-Elektroden je Bestellung bzw. Lieferung von ... (in Stück)	Preis in EUR je Stück
mindestens 100	EUR 338,--
mindestens 200	EUR 325,--

framatome

Framatome GmbH, FDM-G, Postfach 11 09, 91001 Erlangen, Germany

GSI
Helmholtzzentrum für Schwerionenforschung GmbH
z.Hd. Herrn Dr. Ralph Hollinger
Planckstraße 1
64291 Darmstadt

Name	Dr. Wolfgang SCHMID / Iullia SYNOVA
Abteilung	FDM1-G / FK1-G
Telefon	+49 9131 900 -95321 / -94685
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E-Mail	Wolfgang.Schmidt@framatome.com / Iullia.Synova.ext@framatome.com
Ihr Schreiben	
Unser Zeichen	FDM/2018/133
Datum	08. Oktober 2018

Angebot Nr.
FDM/2018/133

Angebot von
Framatome GmbH (FRA)

Helmholtzzentrum für Schwerionenforschung GmbH (GSI)

über einen

Mehrjahresvertrag zur Herstellung und Lieferung von Uran-Elektroden

Dieses Angebot besteht aus 7 Seiten einschließlich Deckblatt, sowie einer Anlage 1: „Grüne Lieferbedingungen" (Stand Juni 2011)

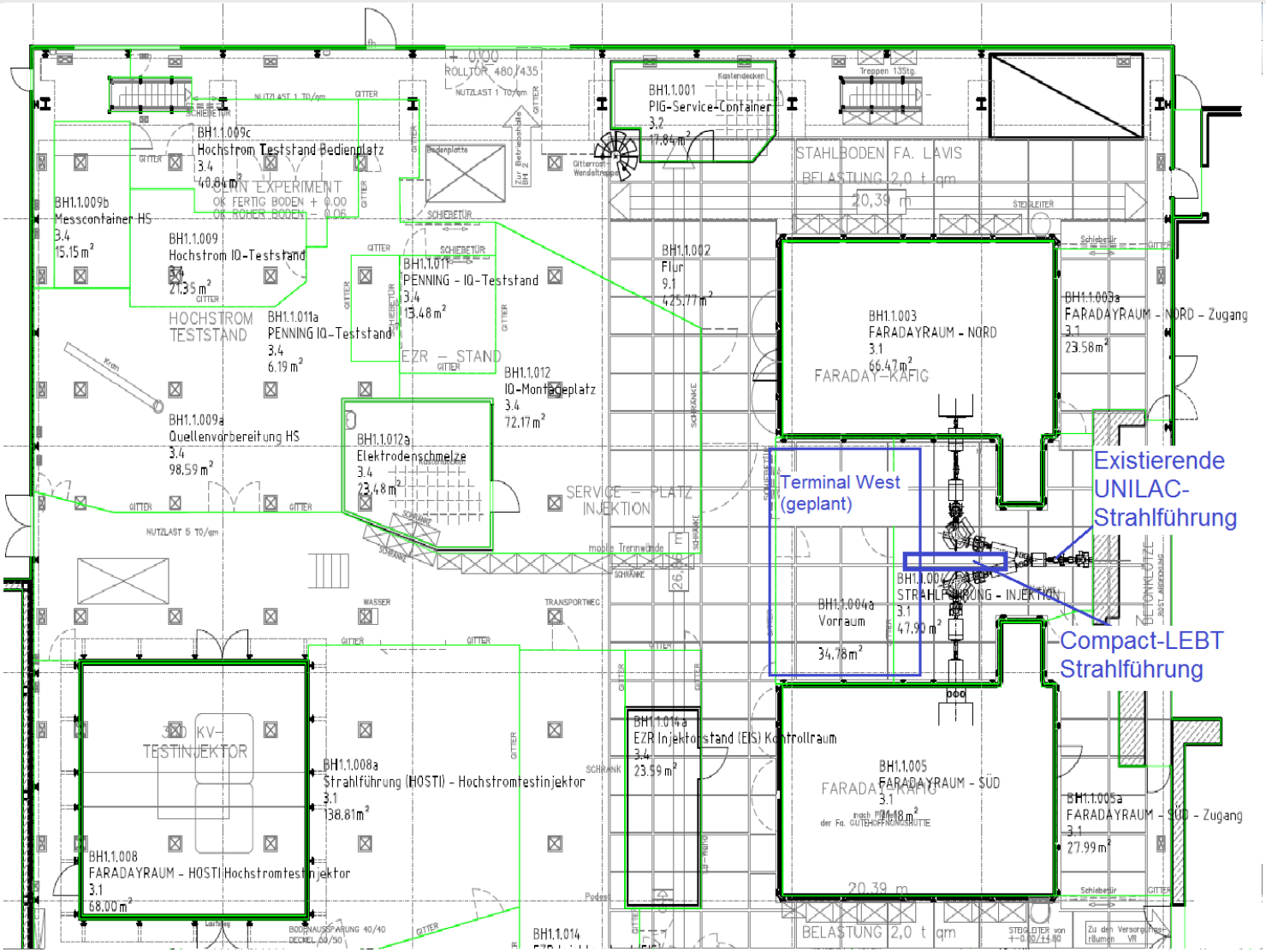
Mit freundlichen Grüßen,

Framatome GmbH

i. V. P. Hoffmann
Dr. Petra-Britt HOFFMANN

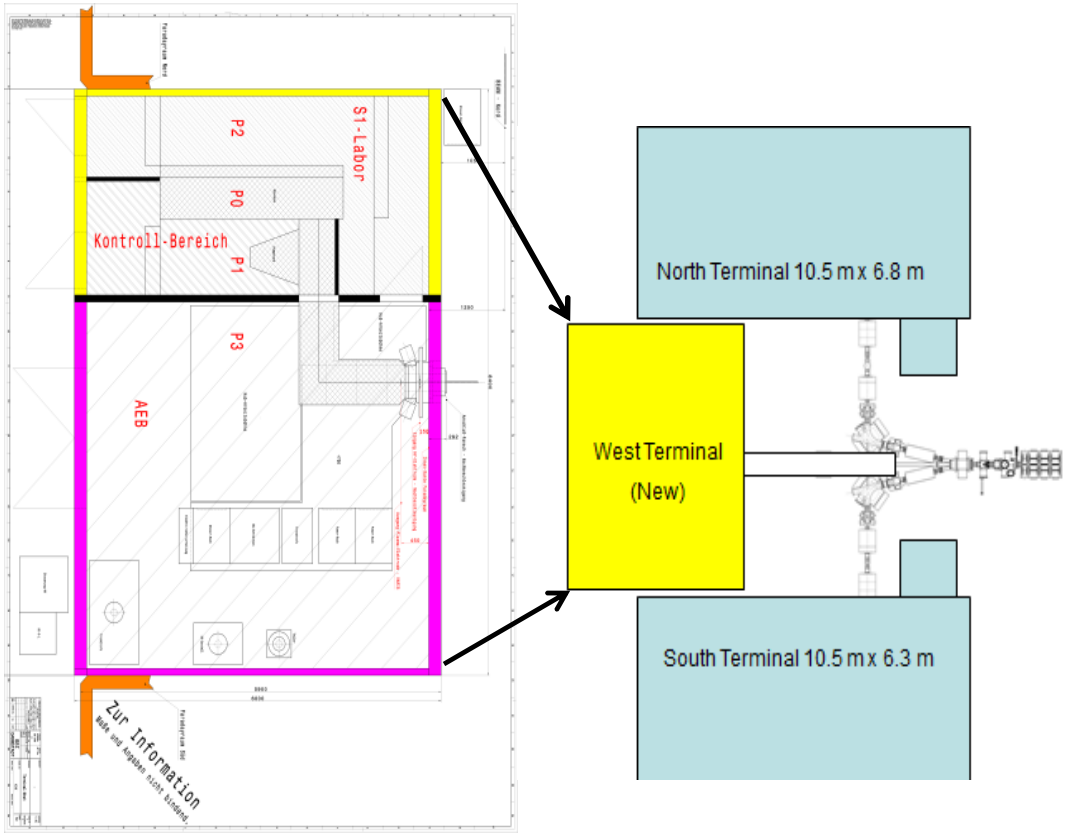
i. V. Otto
Annette OTTO

Terminal West & Compact LEBT: PRIDE

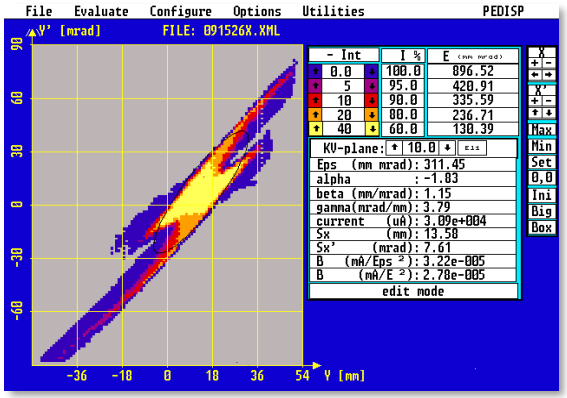


Terminal West

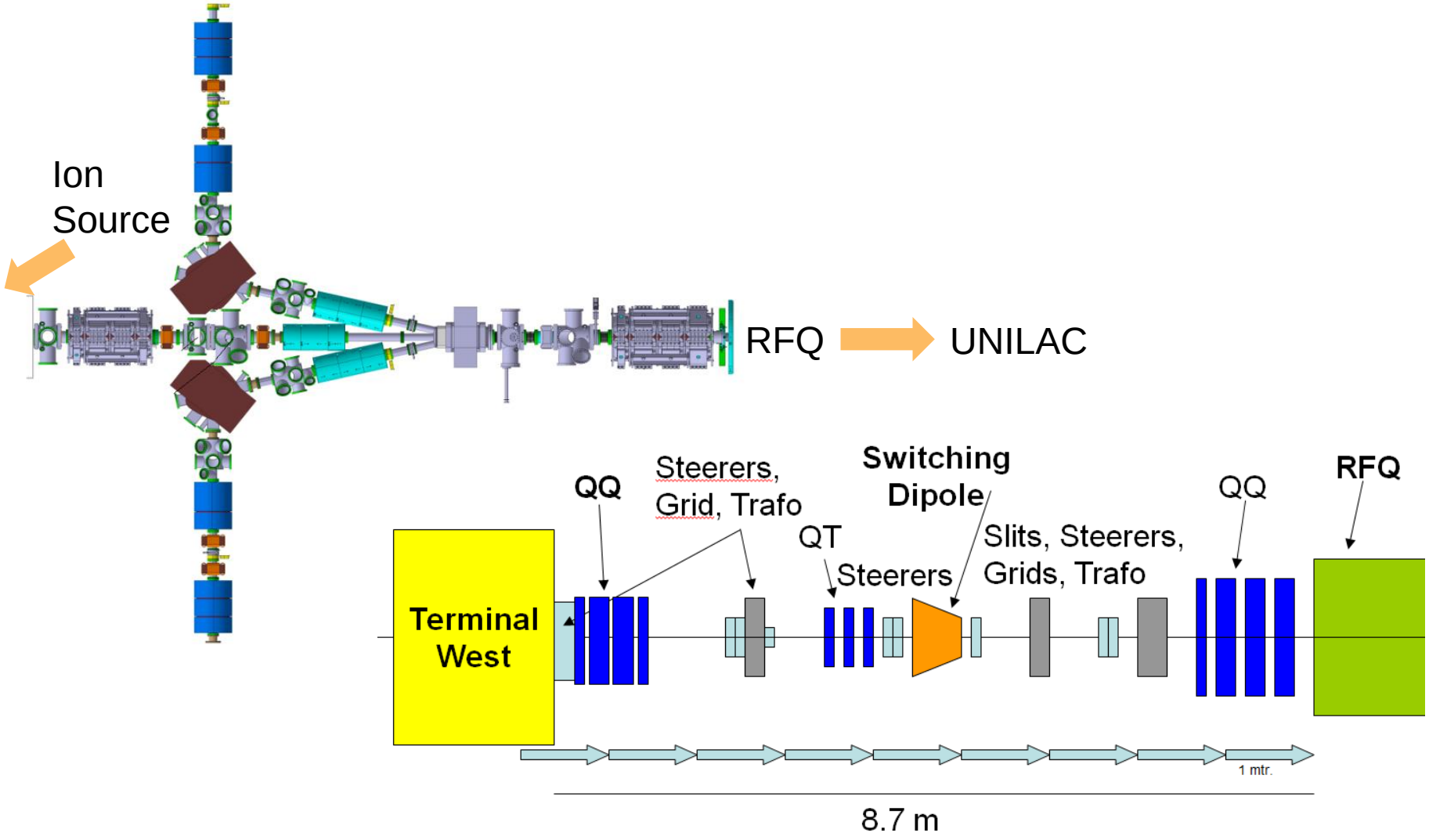
FAIR requirements:
25 mA inside 250π mm mrad



- New uranium Injector for VARIS ion sources between existing Terminals
- Included control area for ion source service and operation
- Straight beamline without charge state separation
- LEBT design with QT, QQ, steerers,

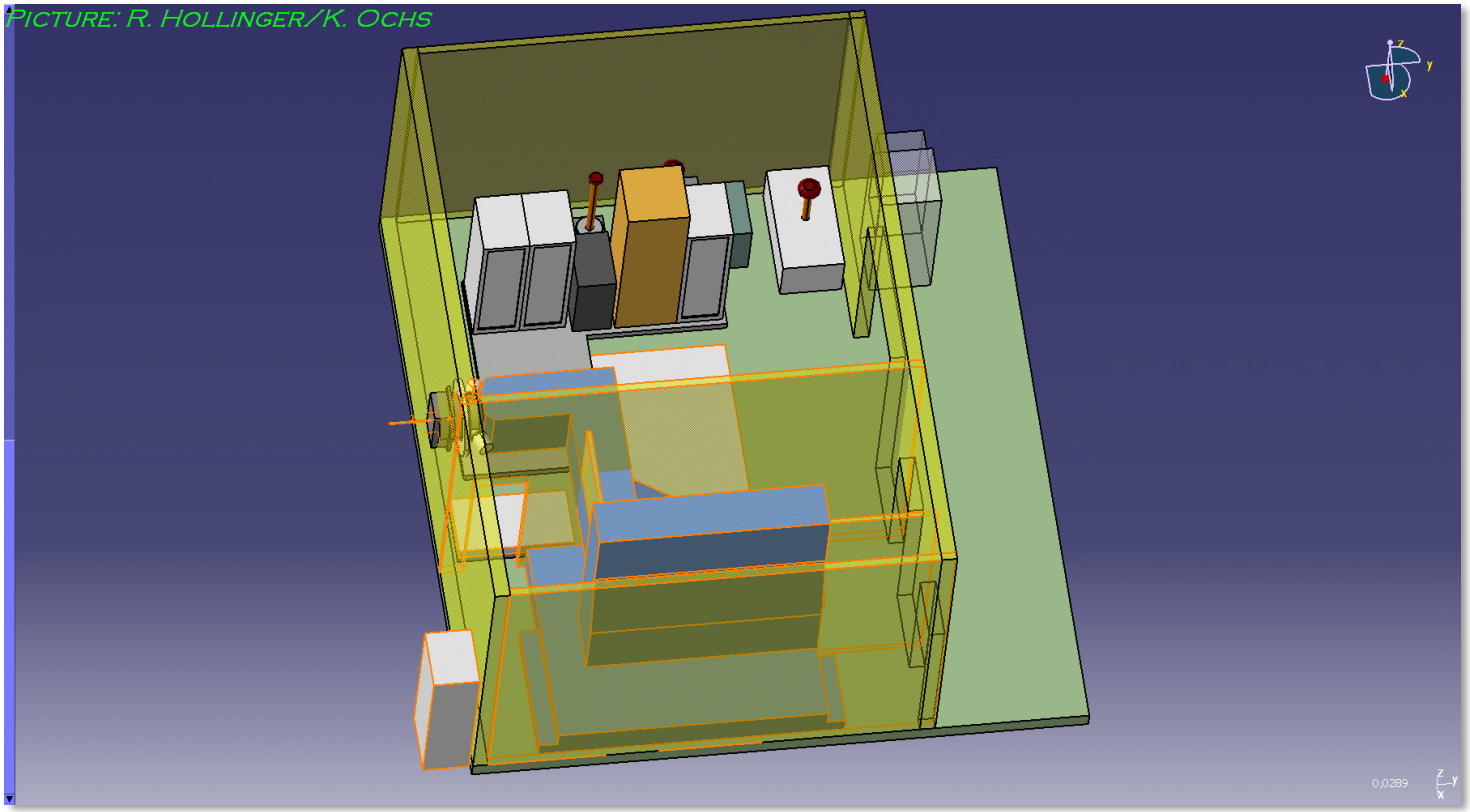


Terminal West (LEBT)



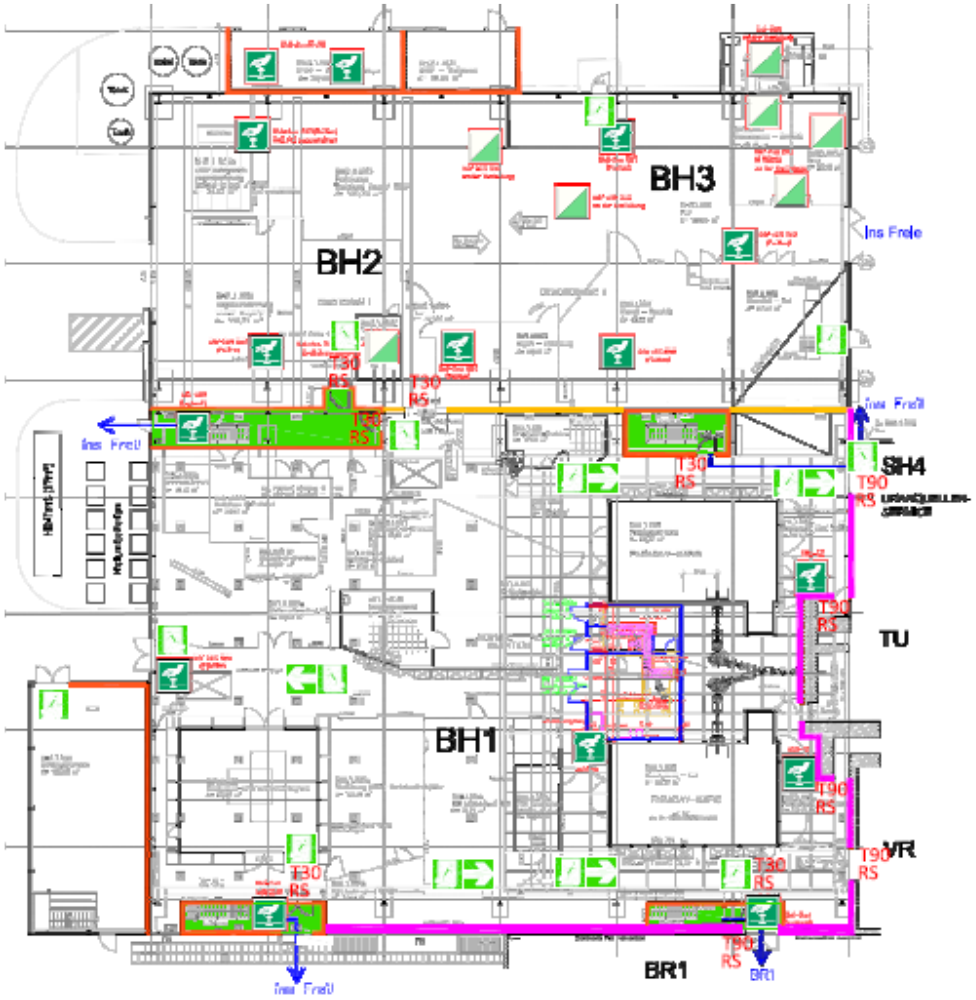
Terminal West

- Dedicated Terminal exclusively for uranium beam
- General layout exists (IOS)
- Integrated service area
- All power supplies integrated in the Faraday room (except high voltage)
- No extension within the basement, only ground floor (plus lifting platform)



Terminal West

Fire protection issus



DAS INGENIEURBÜRO FÜR BAULICHEN BRANDSCHUTZ GBR
Dipl.- Ing. Franz Hoffmann / Dipl.-Ing. Katrin Hoffmann
- Von der Obersten Bauaufsicht Rheinland-Pfalz anerkannter Prüfsachverständiger für Brandschutz
- Von der Architektenkammer Hessen anerkannte Prüfsachverständige für Brandschutz gem. HPPVO

BRANDSCHUTZ HOFFMANN

Ingenieurbüro für baulichen Brandschutz Hoffmann GbR · Uhlandstraße 16 · 65189 Wiesbaden

Aktenzeichen	Index	Datum	Bearbeitung durch
25-23/10	A	29.01.2018	Hoffmann (kh-dg)
	B	03.06.2018	Hoffmann (kh)
	C	01.10.2018	Hoffmann (kh)

Brandschutzkonzept für die Bestandsgebäude BH 1 + BH 2 + BH 3

GSI Helmholtzzentrum für Schwerionenforschung GmbH

Planckstraße 1
64291 Darmstadt

Projekt:	**GSI** Helmholtzzentrum für Schwerionenforschung GmbH Darmstadt
Baumaßnahme:	Brandschutzkonzept für die Bestandsgebäude BH1 + BH2 + BH3
Grundstück:	Planckstraße 1 64291 Darmstadt
Bauherr:	**GSI** Helmholtzzentrum für Schwerionenforschung GmbH Standort Wixhausen Planckstraße 1 64291 Darmstadt
Entwurfsverfasser:	---
Genehmigungsbehörde:	Der Magistrat der Stadt Darmstadt

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www.brandschutz-hoffmann.com

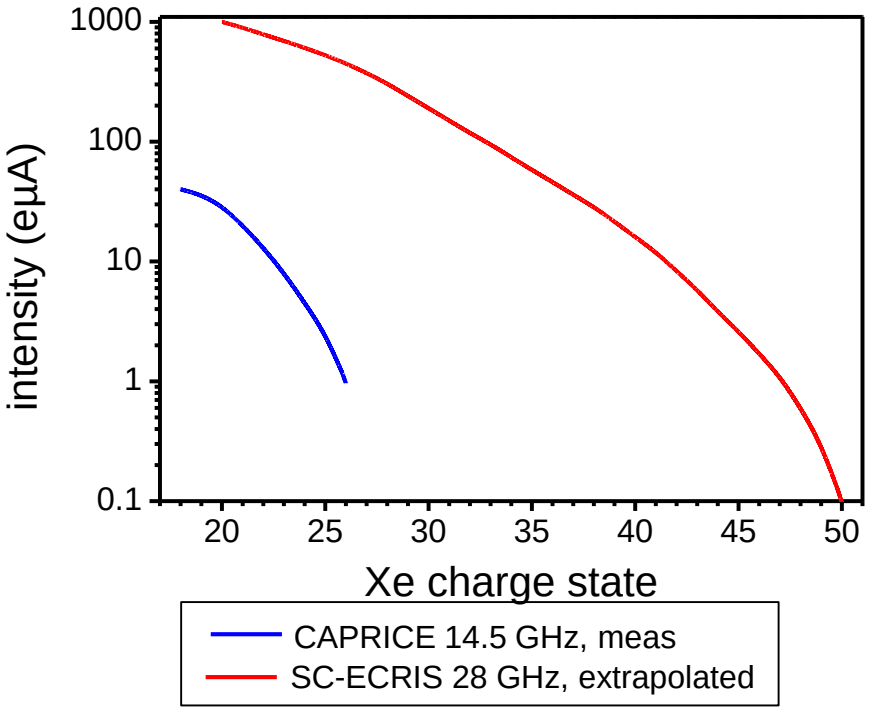
18 GHz ECR

- Higher intensity in higher charge states

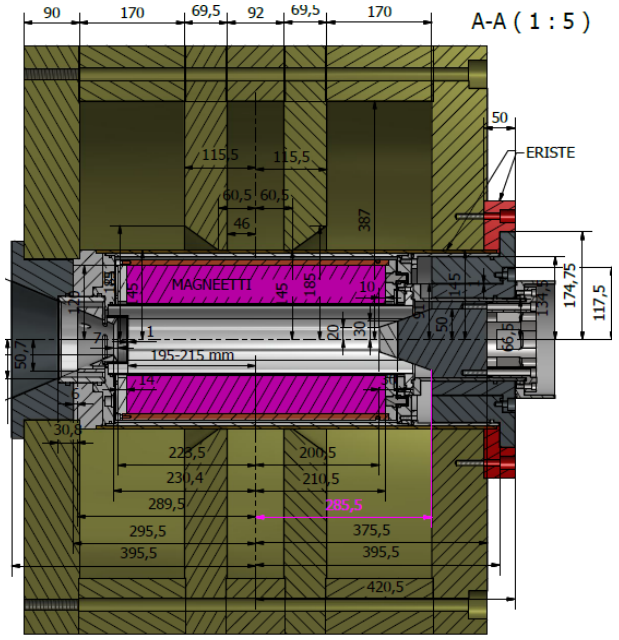
Semiempirical scaling law: $I(A^{q+}) \sim \omega_{ECR}^{2}$

➔increase of microwave frequency: $\omega_{RF} = \omega_{ECR} \sim B$

➔higher magnetic flux density



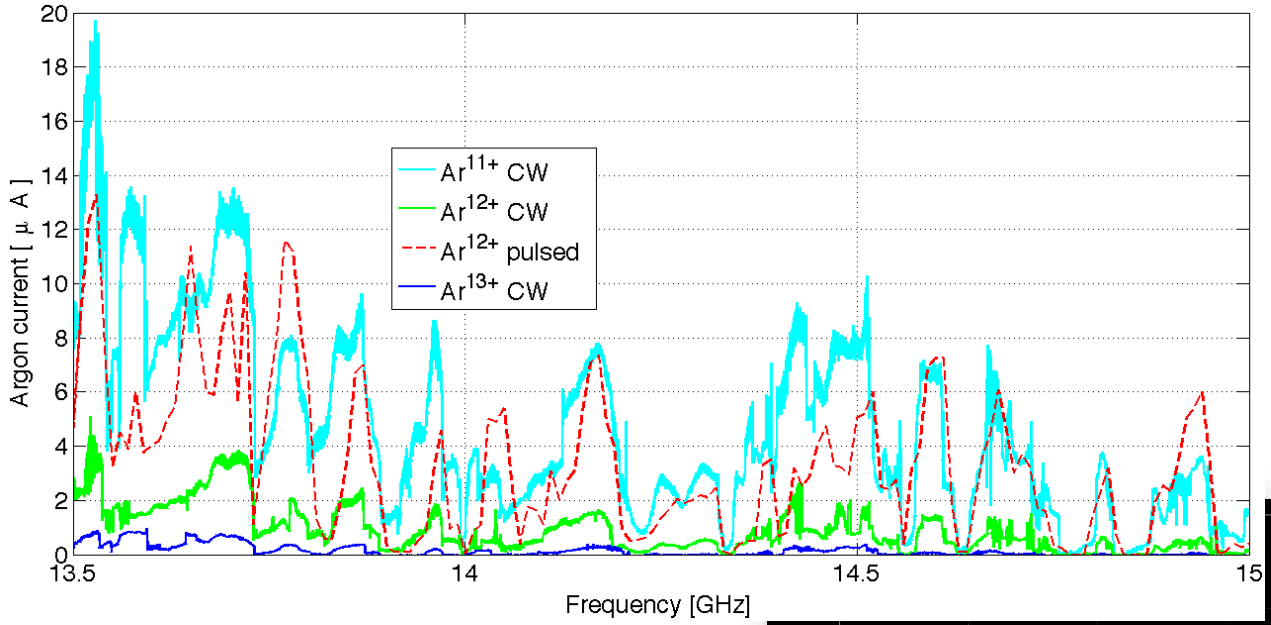
HIISI (University of Jyväskylä)



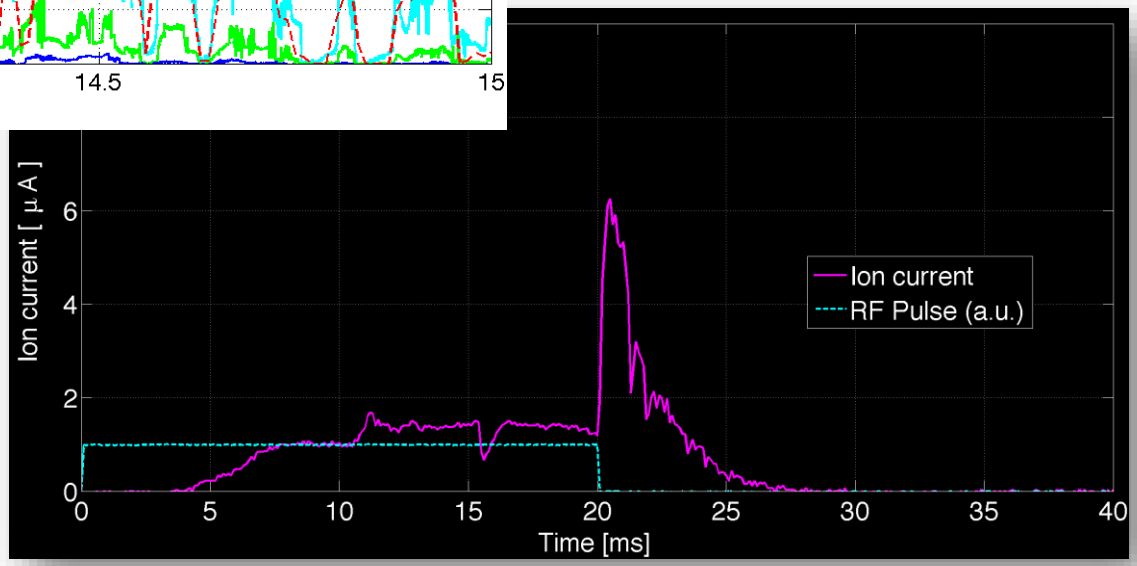
- Available charge states and intensities increase with operating frequency (e. g. 14 ➔18 ➔28 GHz)
  e. g. Xe^{20+} 25 µA – CAPRICE@14.5GHz ➔200 µA – PKISIS@18GHz = factor 8
  and Xe^{27+} 80 µA – PKISIS@18GHz ➔800 µA – SECRAL@28GHz = factor 10

ECR topics

Frequency tuning

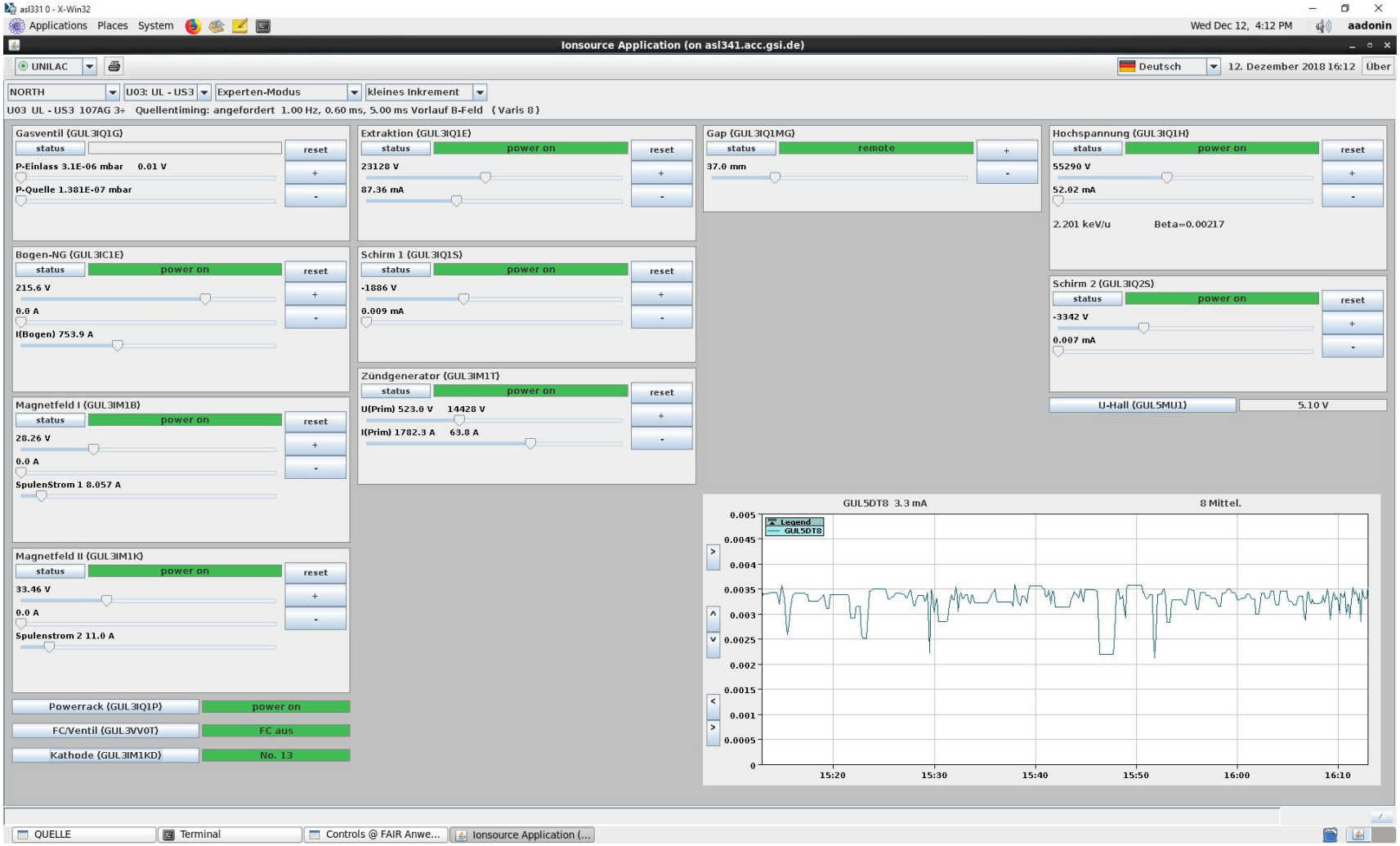


After glow mode



New Ion Source Program…

…we are working on



Savety Topics and more

Glove box for service of heavy metal ion sources

Electrode melting area for PIG and VARIS


POWER

Thank you for your attention

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