High Current Ion Sources at GSI

Part 1

Operation Principles

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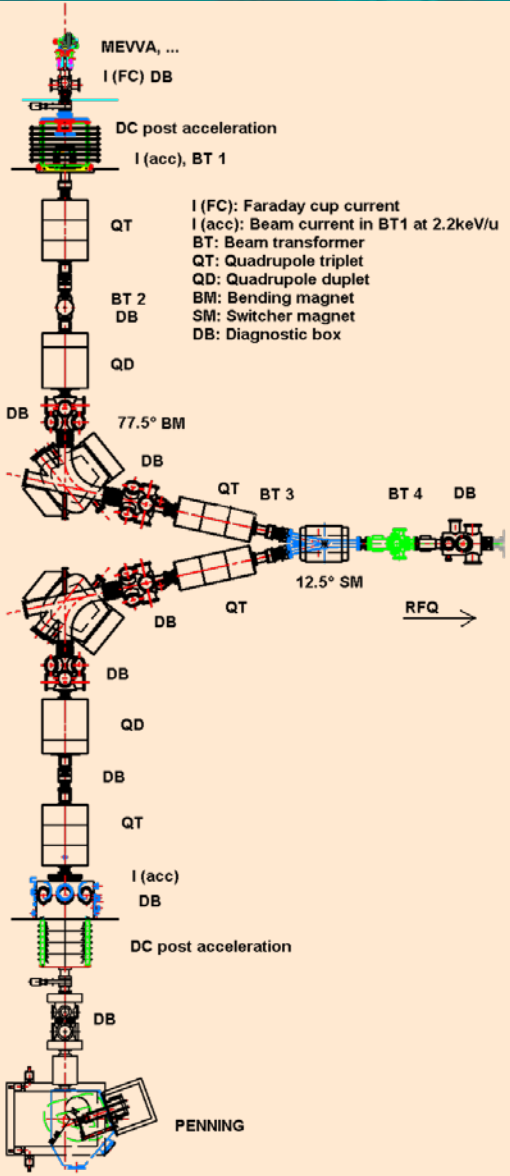
Ion Source Group, GSI

GSI Betriebsworkshop

01. Februar 2016

Terminals and LEBT



	injector NORD	injector SÜD
Extraction Voltage:	up to 35 kV	up to 25 kV
Post Acceleration:	up to 130 kV	
Pulse Length:	0.1 ms ÷ 6 ms	up to 5 ms
Repetition Rate:	up to 5 Hz	up to 50 Hz
Design-Ion:	$^{238}U^{4+}$, $^{130}Xe^{2+}$	
MAX Resolution:	Pb-isotops are resolved	

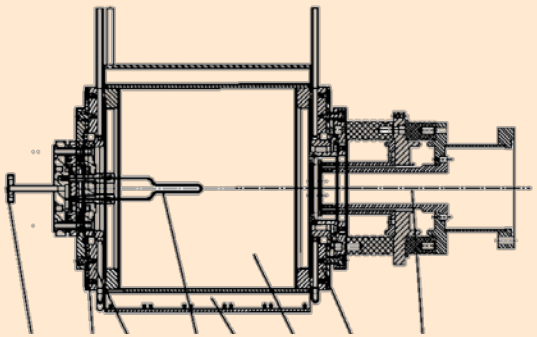
RFQ requirements

Specific Energy:	2.2 keV/u
MAX Mass to Charge (A/ζ):	65
Space-charge limit RFQ:	$0.25 \times A/\zeta$ [mA]
Acceptance RFQ:	$\varepsilon_{x,y}=138\pi$ mm·mrad

Types of High Current Ion Sources

High Current Ion Sources

Filament driven

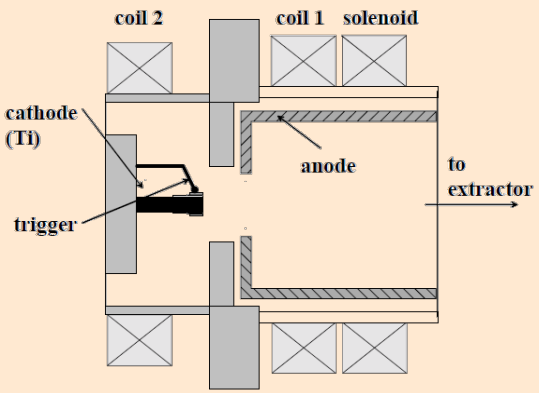


MUCIS, MUCIS New, CHORDIS

Working material:

Gases

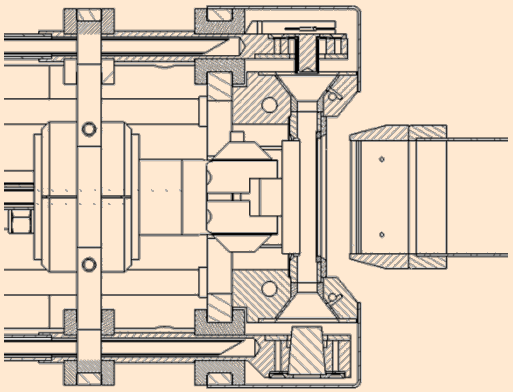
Vacuum Arc driven



MEVVA, VARIS

Metalls and Gases

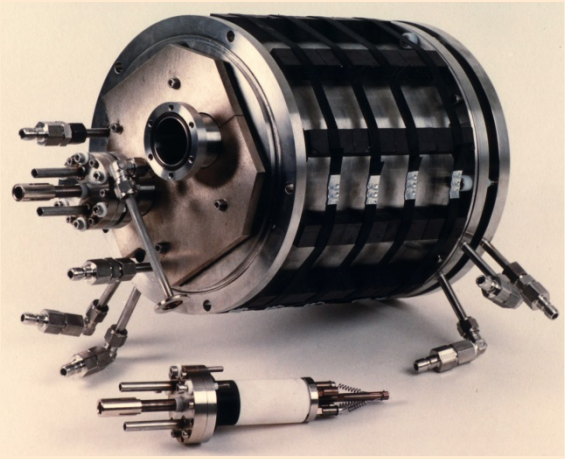
High Duty factor



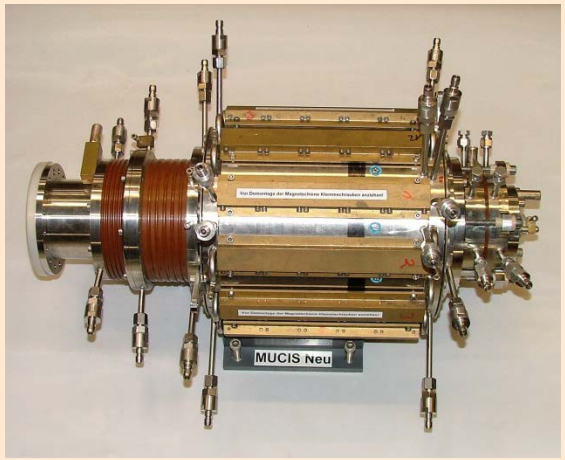
PIG

Metalls and Gases

Filament driven Ion Sources



MUCIS



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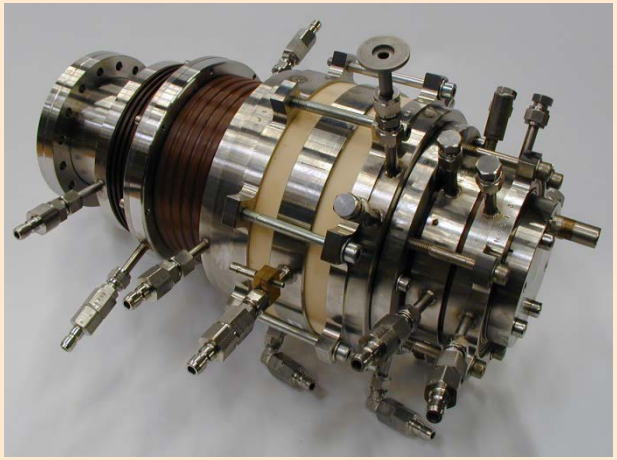
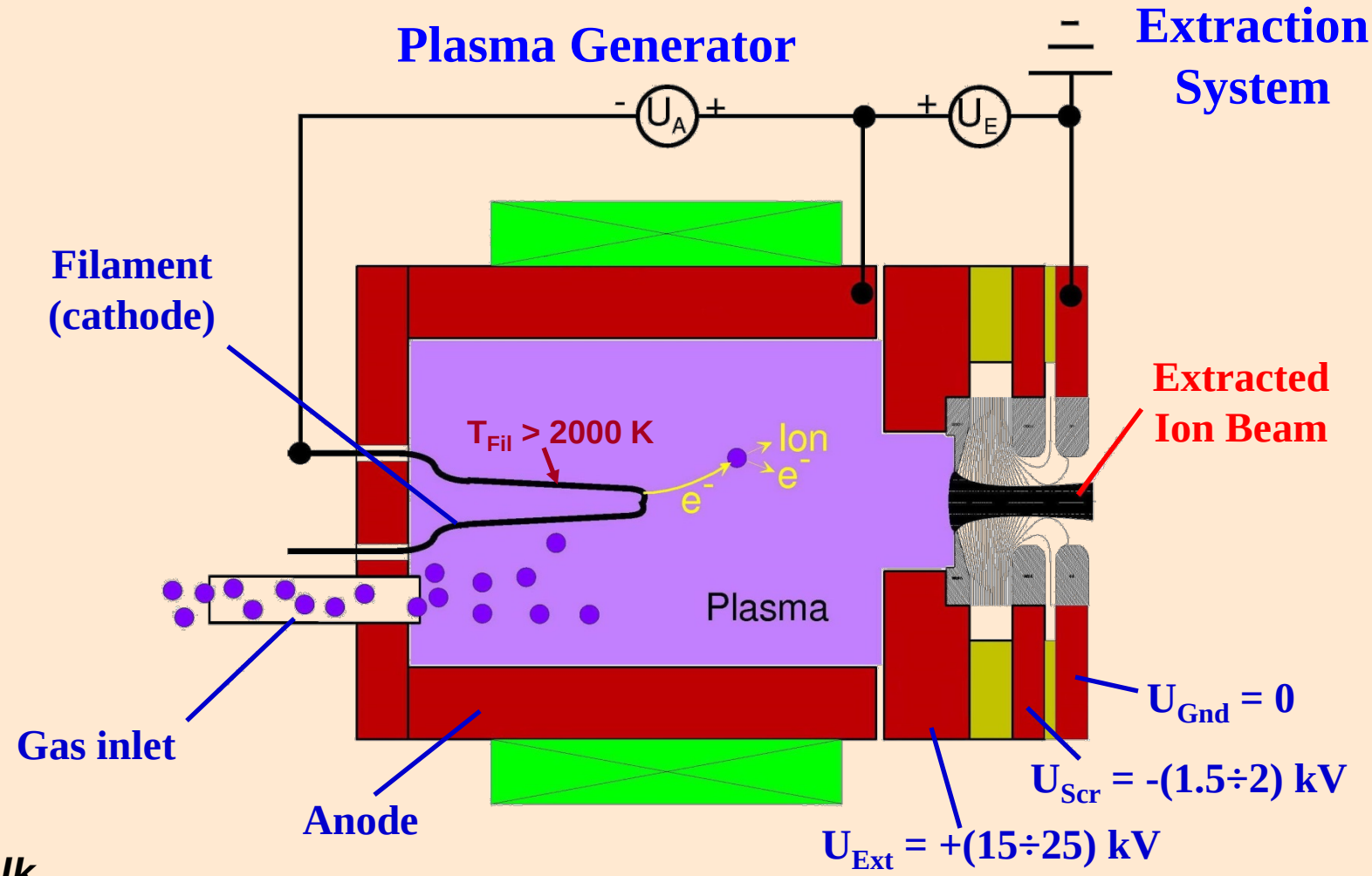


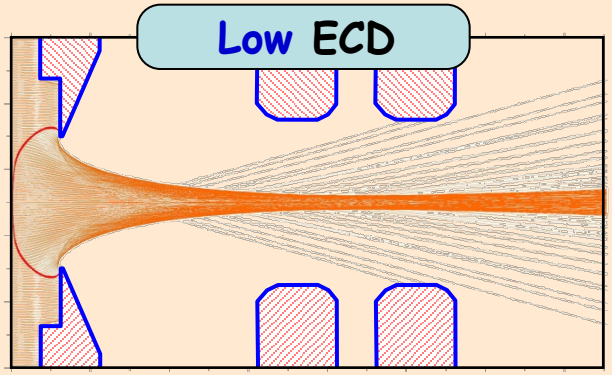
CHORDIS

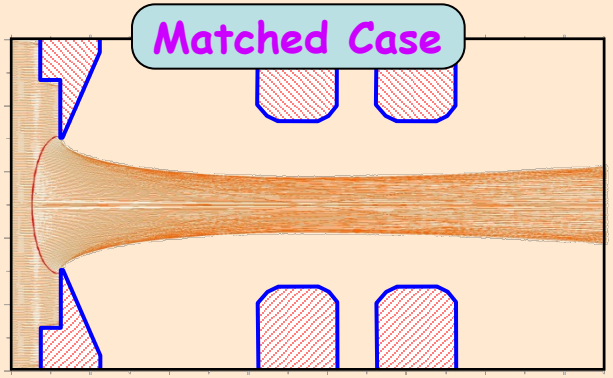
Operation principle (ion production)

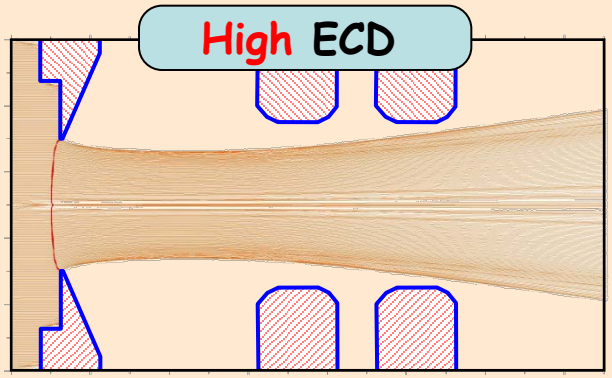


K. Volk

Ion Extraction



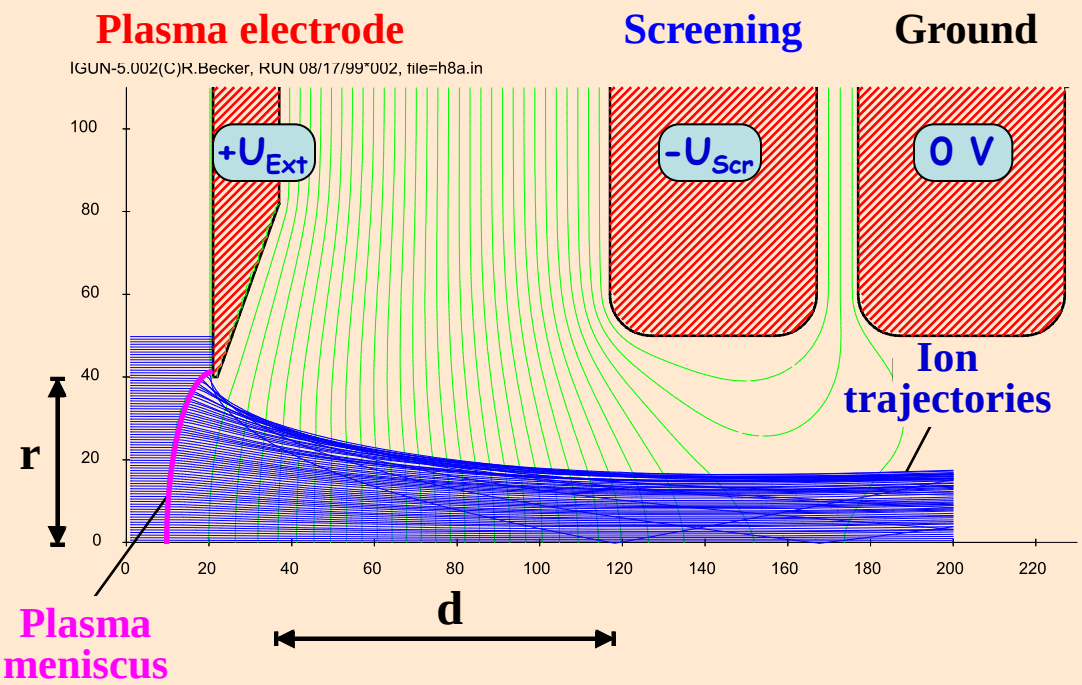




Child-Langmuir Law:

$$j_{CL} = \frac{4}{9}\varepsilon_0 \cdot \sqrt{\frac{2e\zeta}{m}} \cdot \frac{1}{\sqrt{d}} \cdot E^{3/2} \qquad S = \frac{r}{d} \qquad E = \frac{U_{Ext}}{d}$$

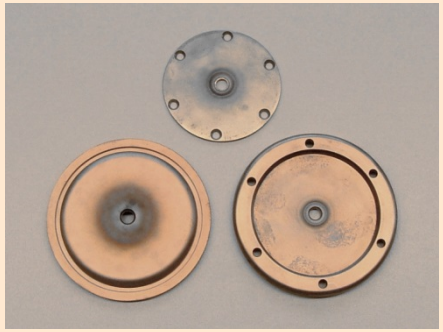
$$I_{CL} = \frac{4}{9}\pi \cdot \varepsilon_0 \cdot \sqrt{\frac{2e\zeta}{m}} \cdot S^2 \cdot U_{Ext}^{3/2}$$

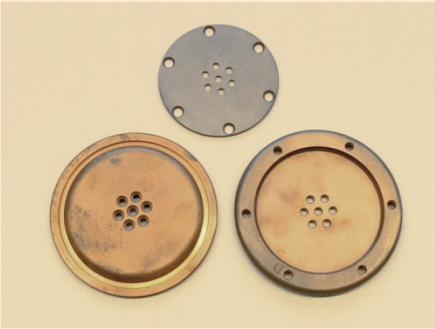


Extraction System

Triode Extraction Systems:

1 hole	7 holes	13 holes	19 holes
ø 4÷8 mm	ø 4÷6 mm	ø 3 mm	ø 2÷3 mm



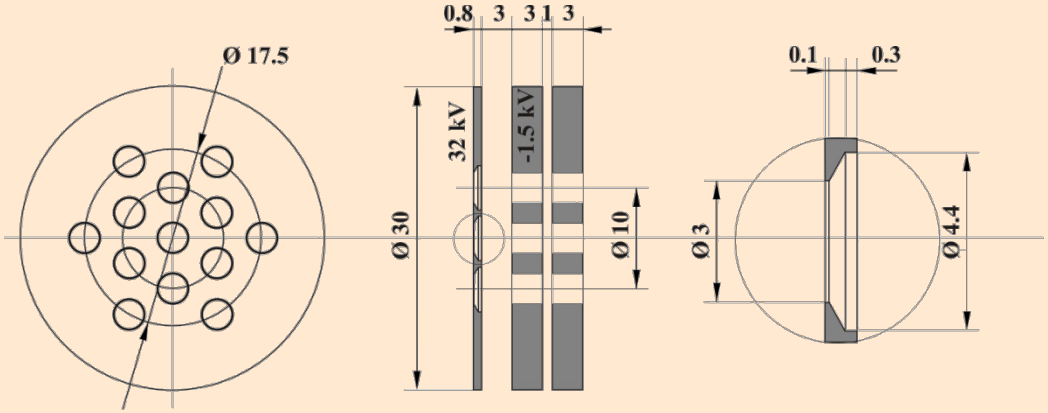


Plasma - Screening distance: r = 3 mm

Aspect Ratio: S = 0.5

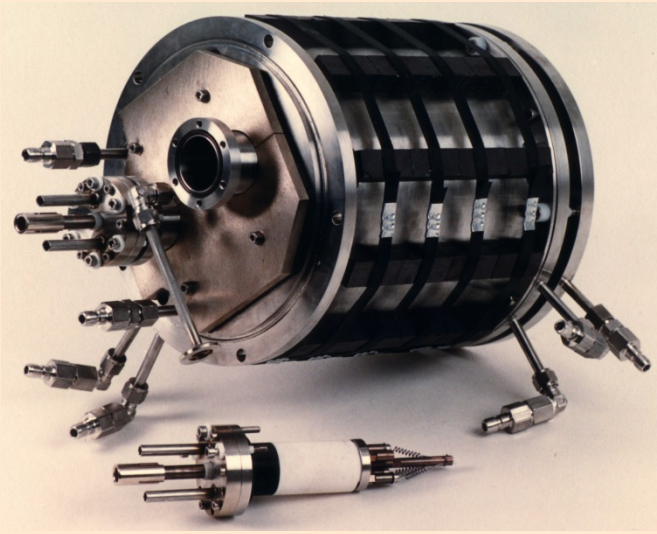
MAX Ext. Voltage: 35 kV

Emission Area: 92 mm^2



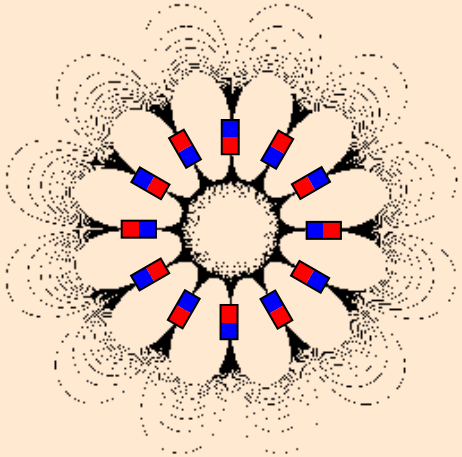
Filament driven Sources

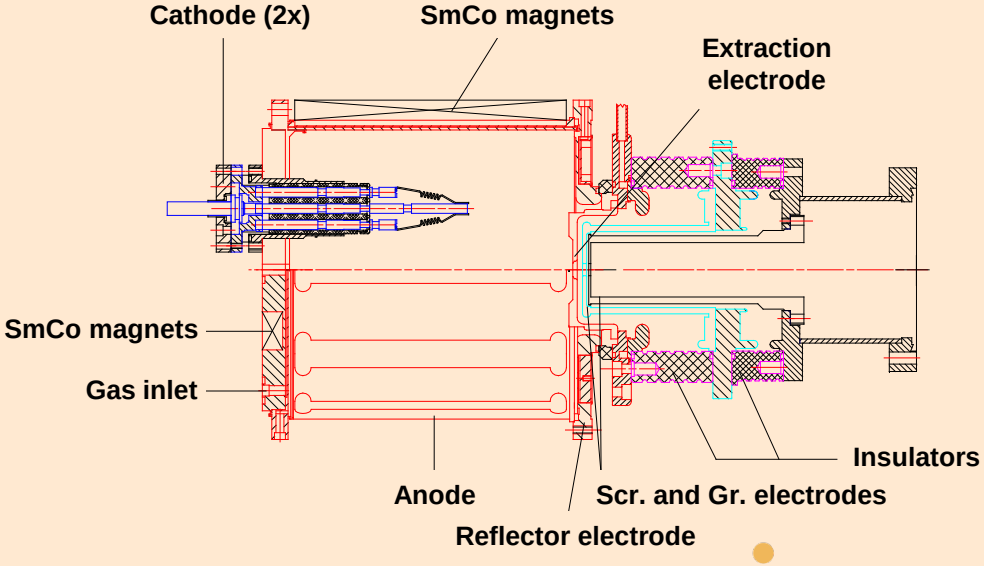
MUCIS (Multi Cusp Ion Source)



60 SmCo-Magnets (2 Tesla)

Solenoid:	0.1 T
6 Filaments:	W / Ta
Duty Cycle:	5 Hz
Pulse Length:	1 ms
Arc Power:	3 kW (I_{arc}=100A)
Emission Current Density:	150 mA/cm^2 (Argon)

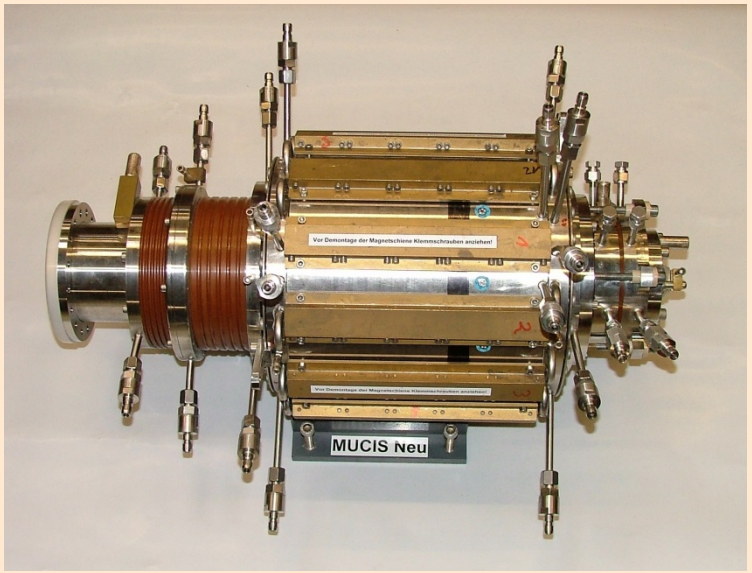


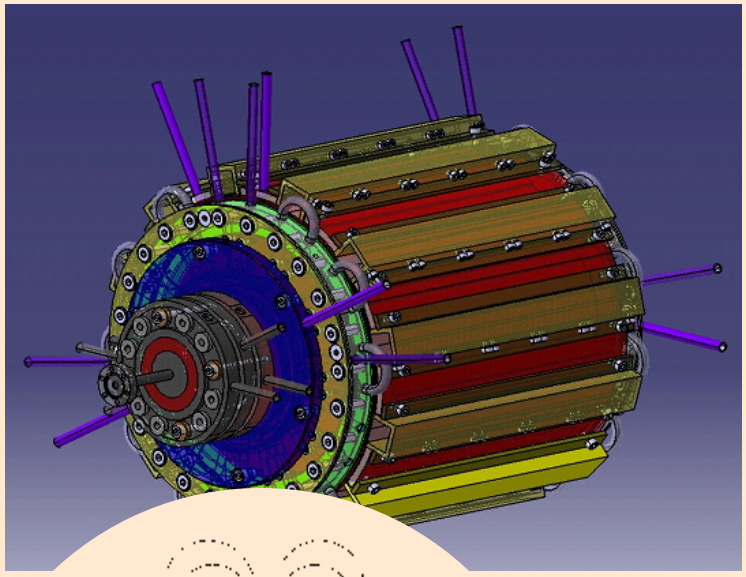


R. Keller

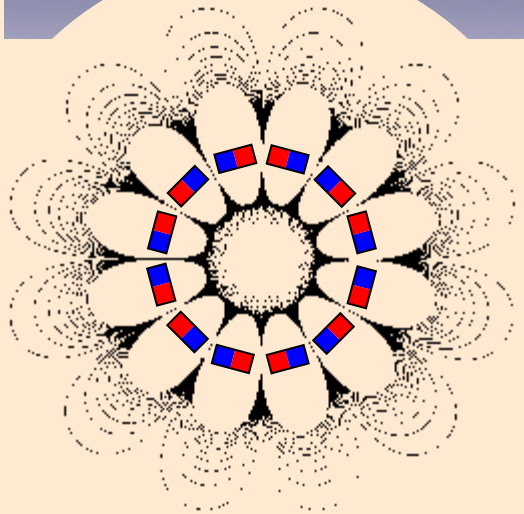
Filament driven Sources

MUCIS New





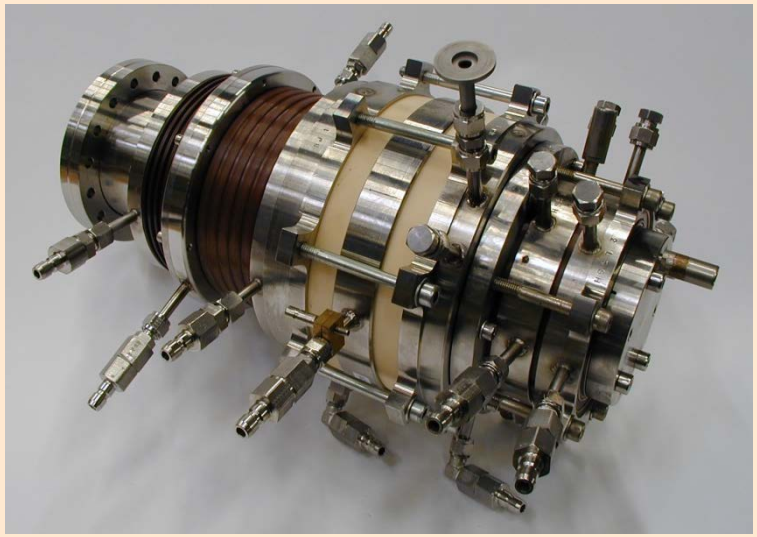
- Bigger Plasma chamber
- Improved Cooling (I_{arc} = 200A)
- Symmetrical Magnet alignment at the ends
- Halbach-alignment of the Magnets
- Optimized for highly-charged ions (Kr^{2+}, Xe^{3+})

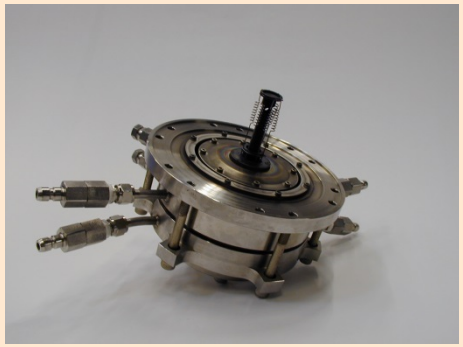


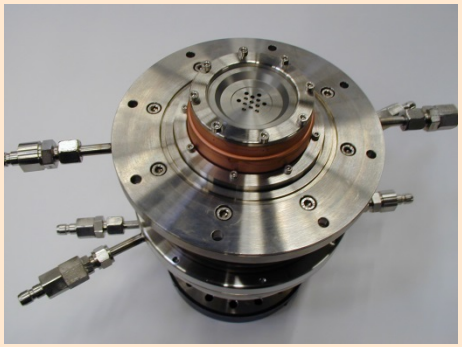
1 - Gas inlet
2 - Cooling system
3 - Cathode flange
4 - Filament
5 - Magnets
6 - Anode
7 - PE flange
8 - Triode system

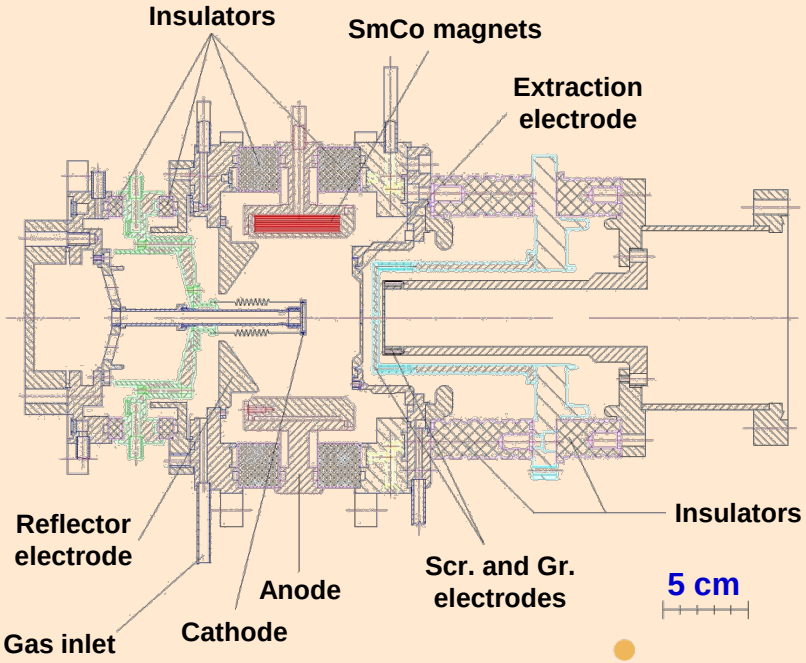
Filament driven Sources

CHORDIS (Cold or Hot Reflex Discharge Ion Source)





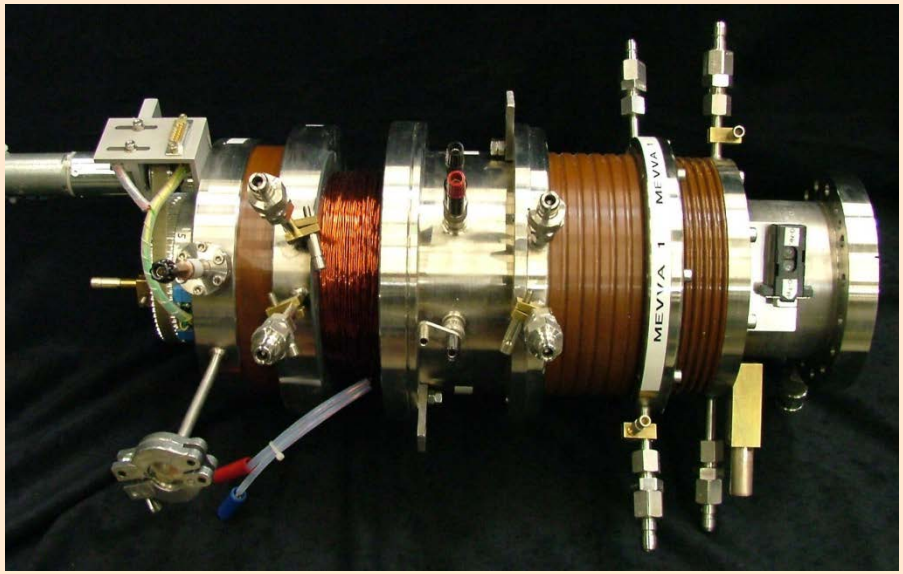




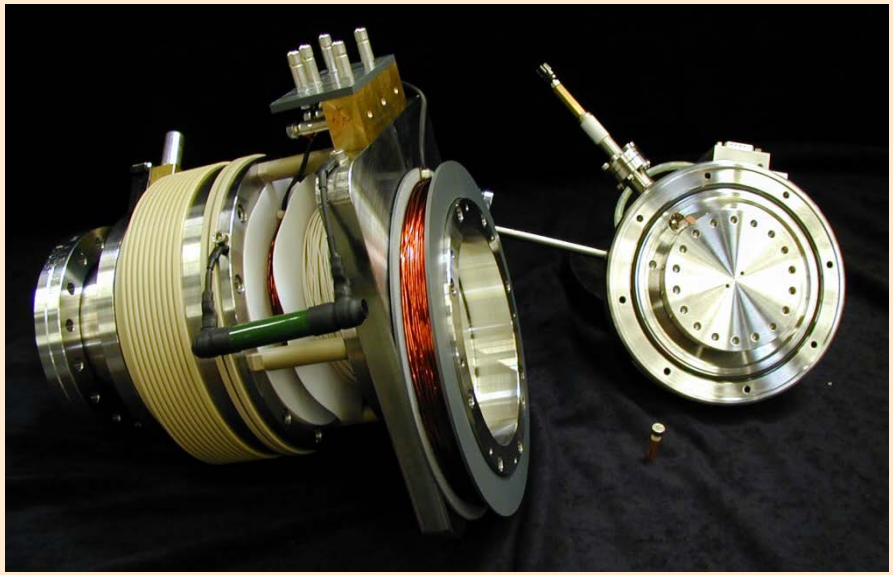
- Smaller Plasma chamber
- 20 SmCo-Magnets (2 Tesla)
- Plasma-Electrode at the Cathode potential
- Optimized for singly-charged ions

R. Keller

Vacuum Arc driven Ion Sources

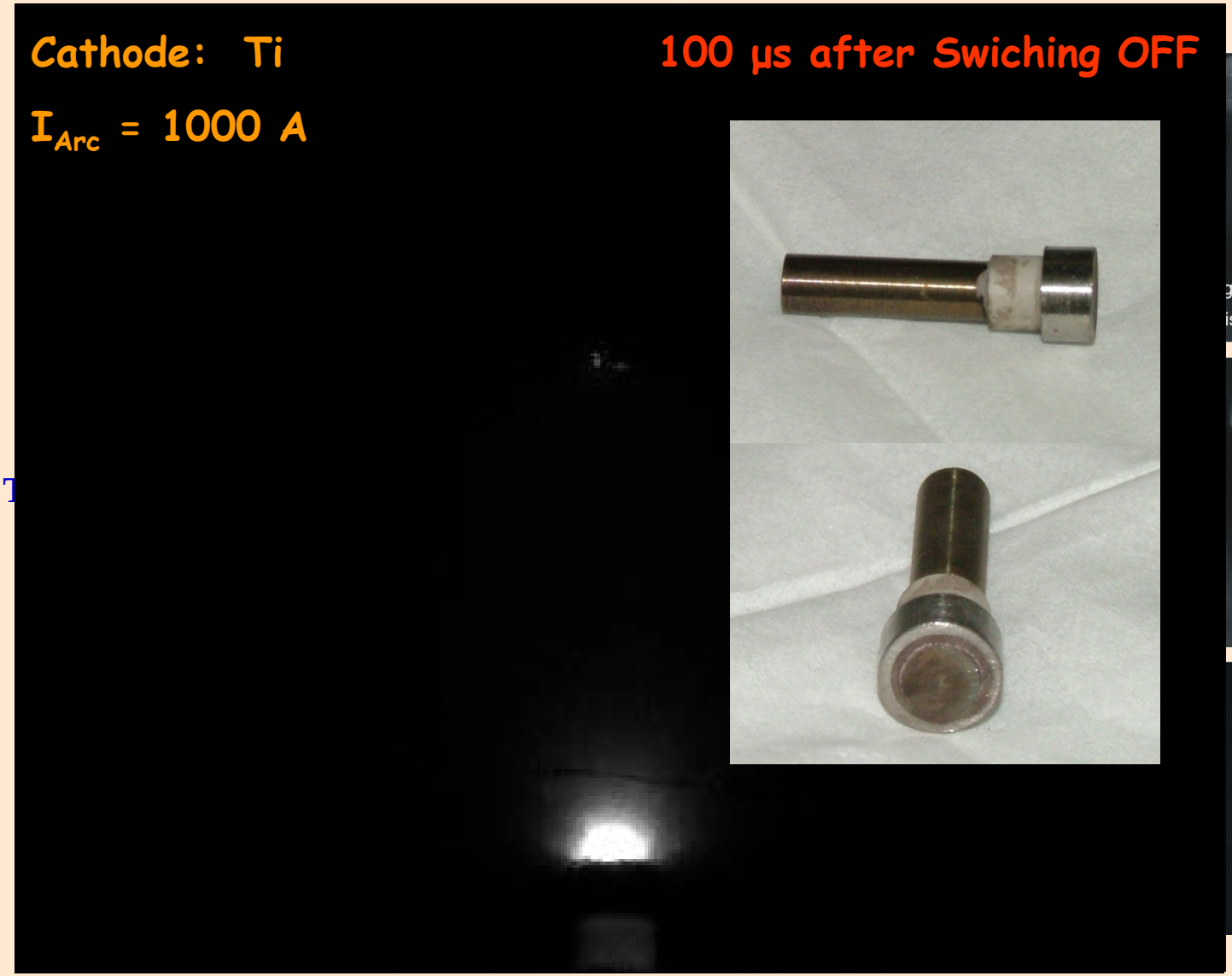


MEVVA

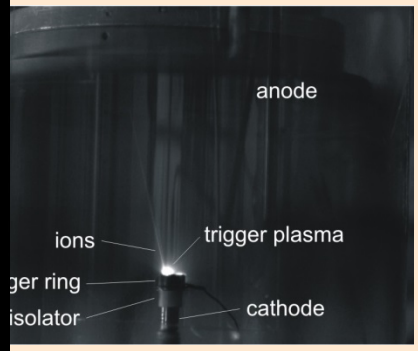


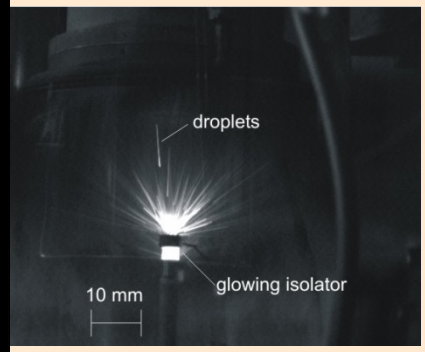
VARIS

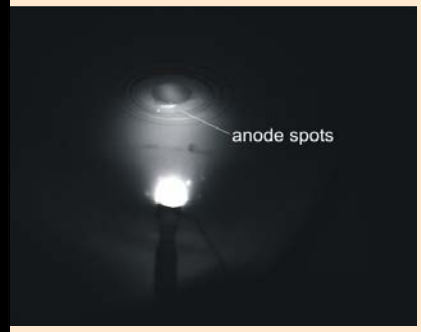
Vacuum Arc driven Sources



R. Hollinger

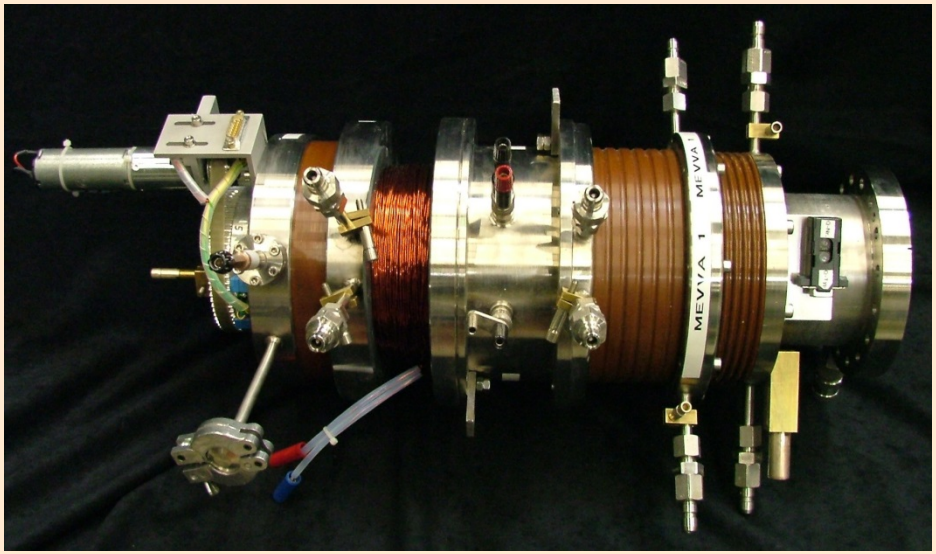


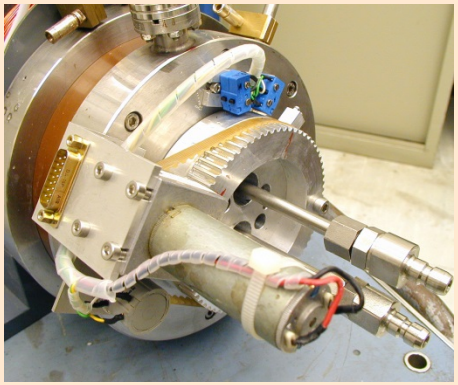


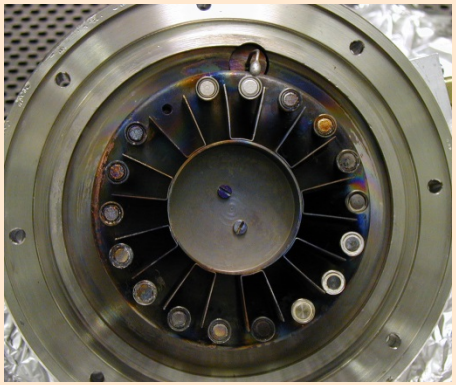


Vacuum Arc driven Sources

MEVVA (Metal Vapor Vacuum Arc Ion Source)

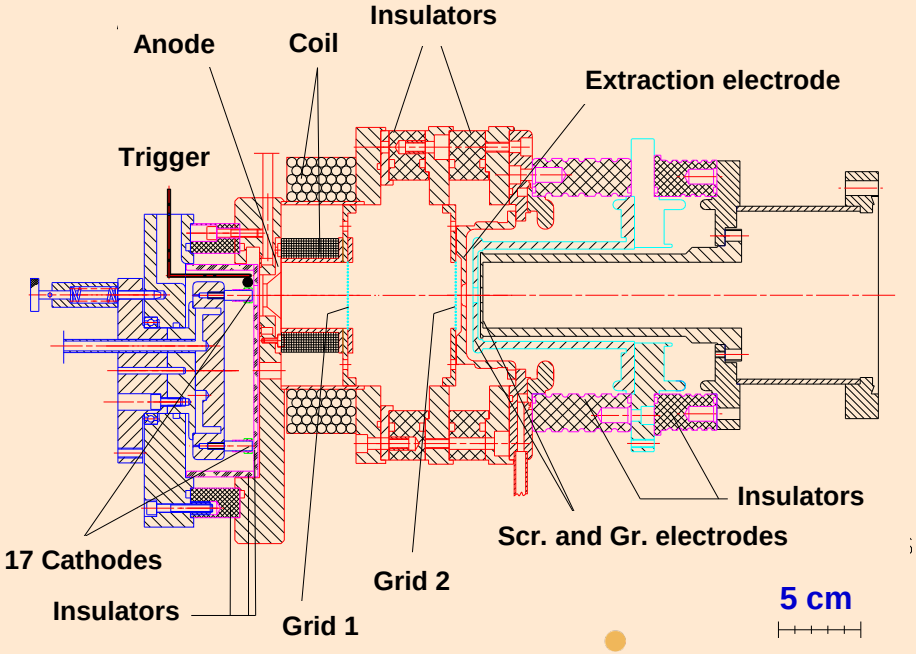






Revolver with 17 Cathodes

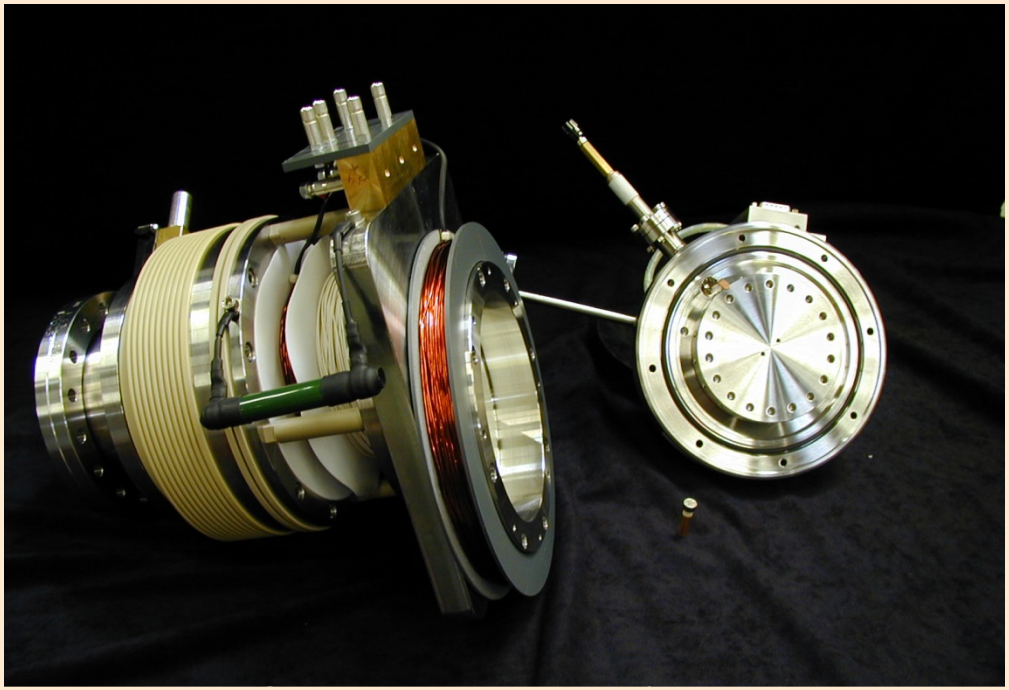
2 Solenoids:	0.1 and 0.2 Tesla
Arc Power:	50 kW (13.3 MW/cm^2)
Arc Current:	~1 kA
Duty Cycle:	typical 1 Hz, 1 ms
Working Material:	ductile Metalls
Life time:	~1 Week (Uranium)

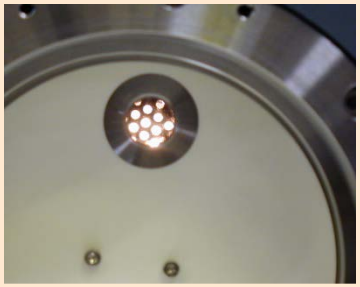


I. Brown

Vacuum Arc driven Sources

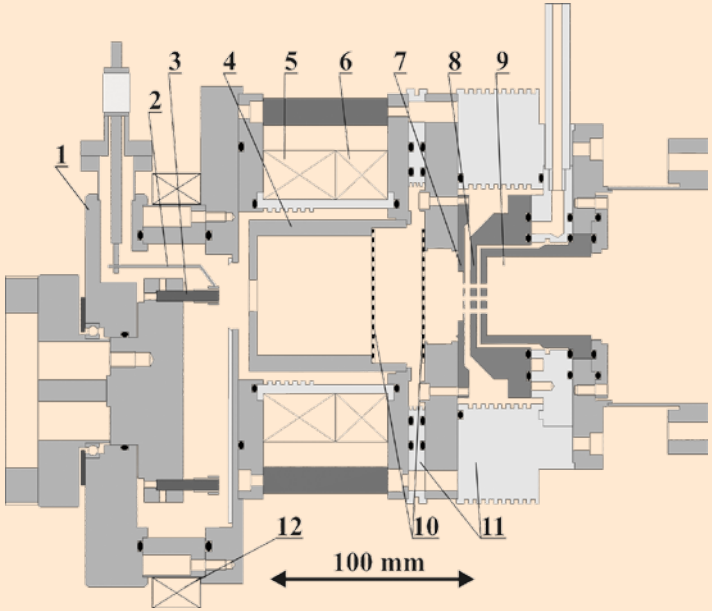
VARIS (Vacuum Arc Ion Source)



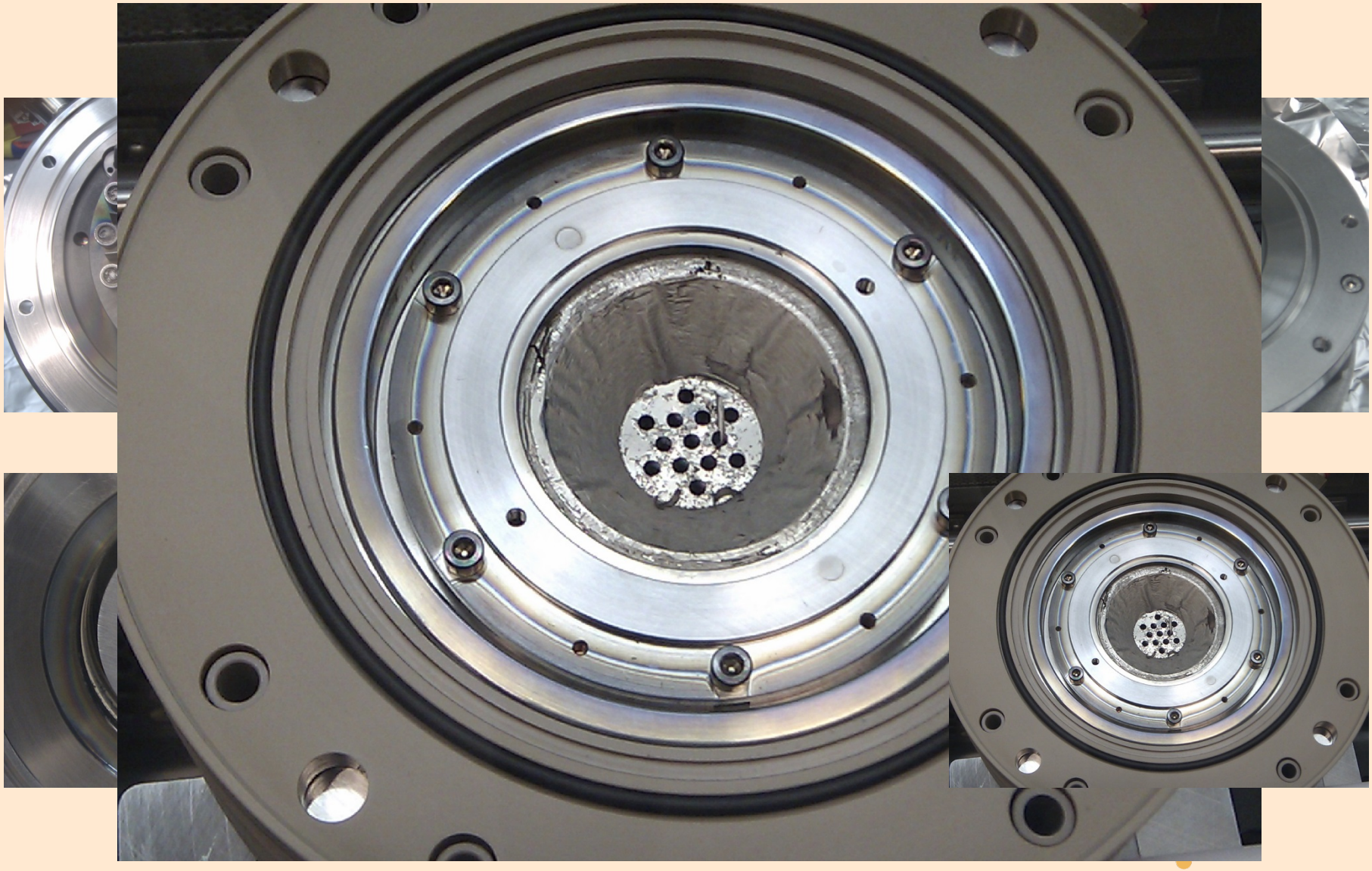


- Optimized for Uranium (67% of $^{238}U^{4+}$)
- NO water cooling necessary
- 170 mA/cm^2; 156 mA @ 32 kV
  55 mA @ 131 kV

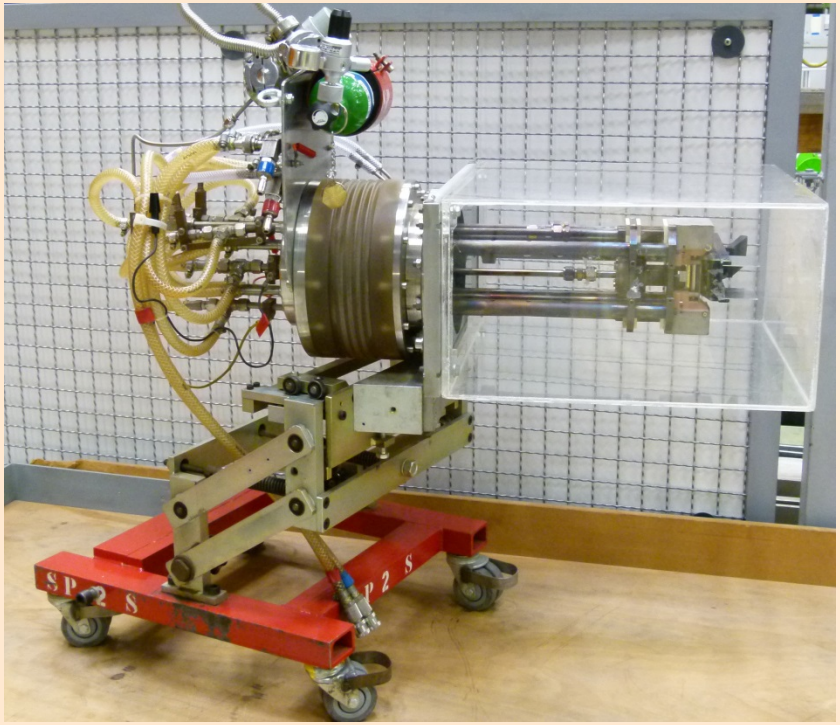
  16 mA in front of the RFQ
  8 mA behind the RFQ



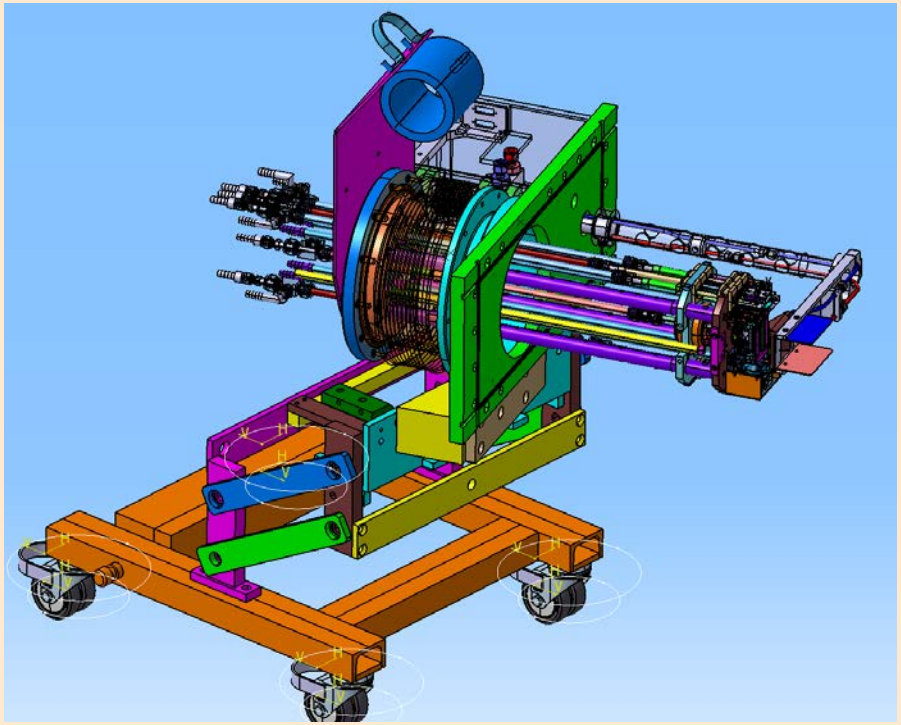
Vacuum Arc driven Sources



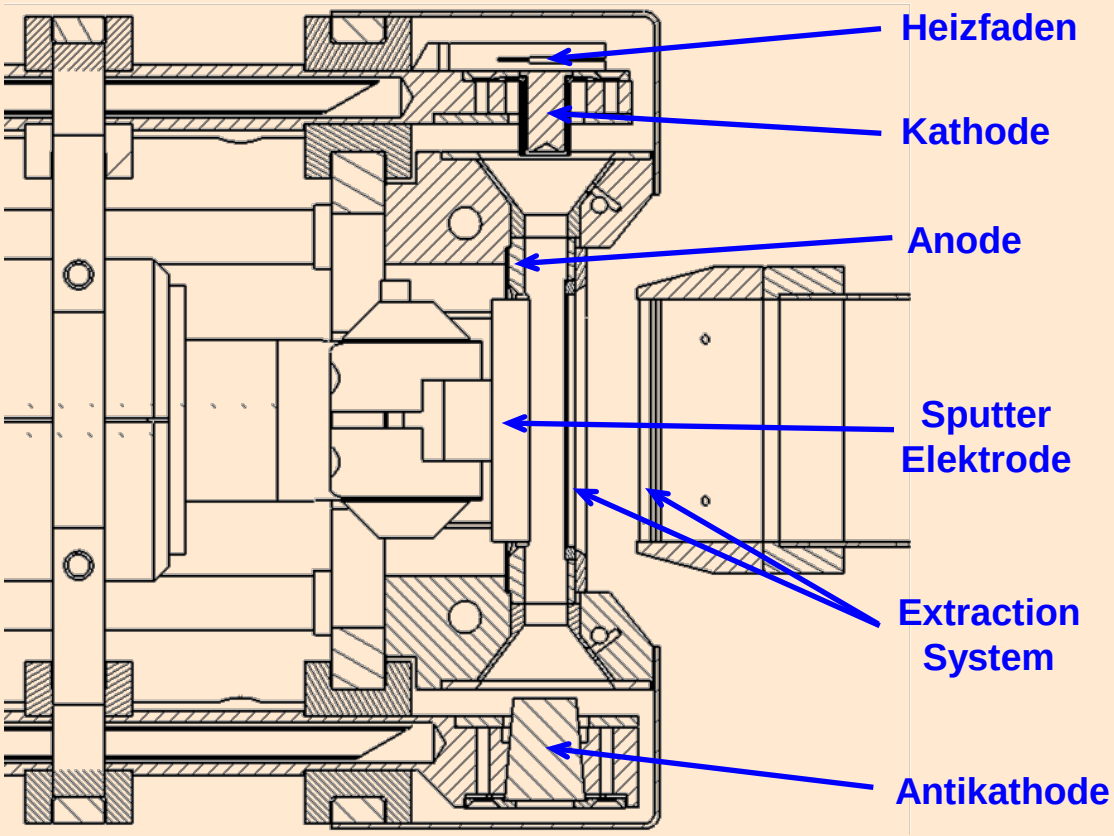
High Duty Factor Ion Source

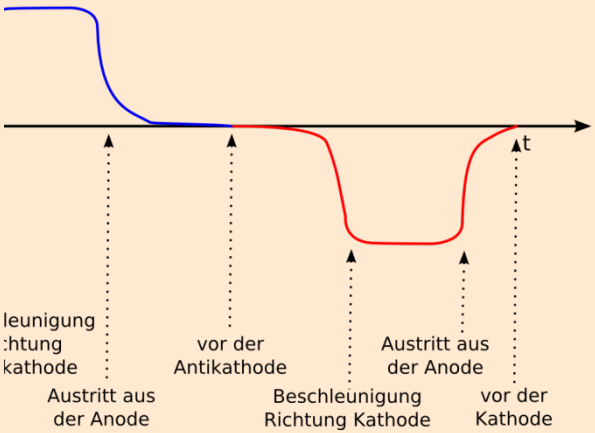


PIG



Operation principle





$I_{Heizfaden} = 65 \div 75$ A

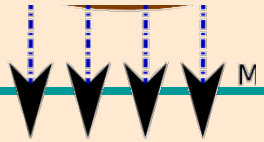
$U_{Besch.} = 500 \div 800$ V

$U_{Pulser} = 1200 \div 2500$ V

$U_{Sputter} = 400 \div 1800$ V

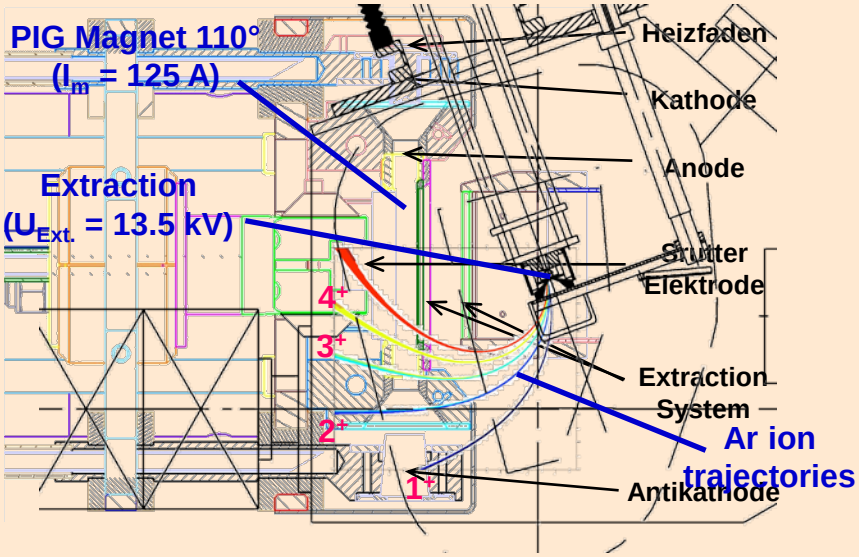
$U_{Exr.}$ up to 23 kV

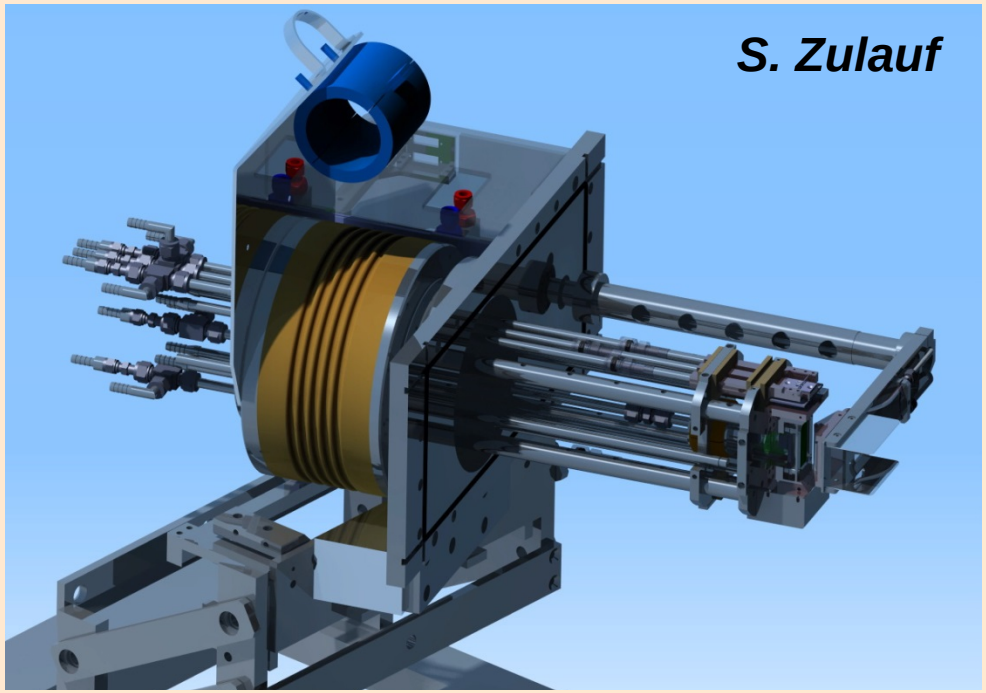
A. Bloch-Späth

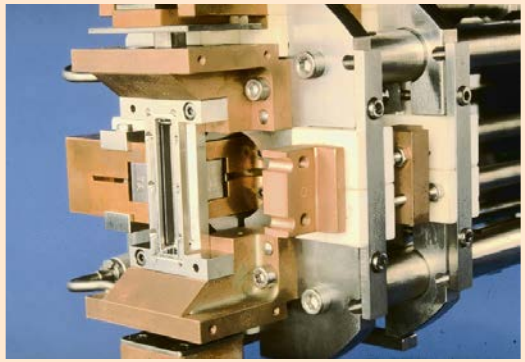


Penning Ion Source

PIG (Penning Ionization Gauge)







- Slit Extraction System
- Working Material:
  Gases and conductive Metals
- Duty Cycle: up to 50Hz / 5ms
- Emission Current Density:
  up to 100 mA/cm^2
- Charge State: 1+...10+

Hochstromionenquellen und LEBT

Teil 2

Betrieb und Problemlösung

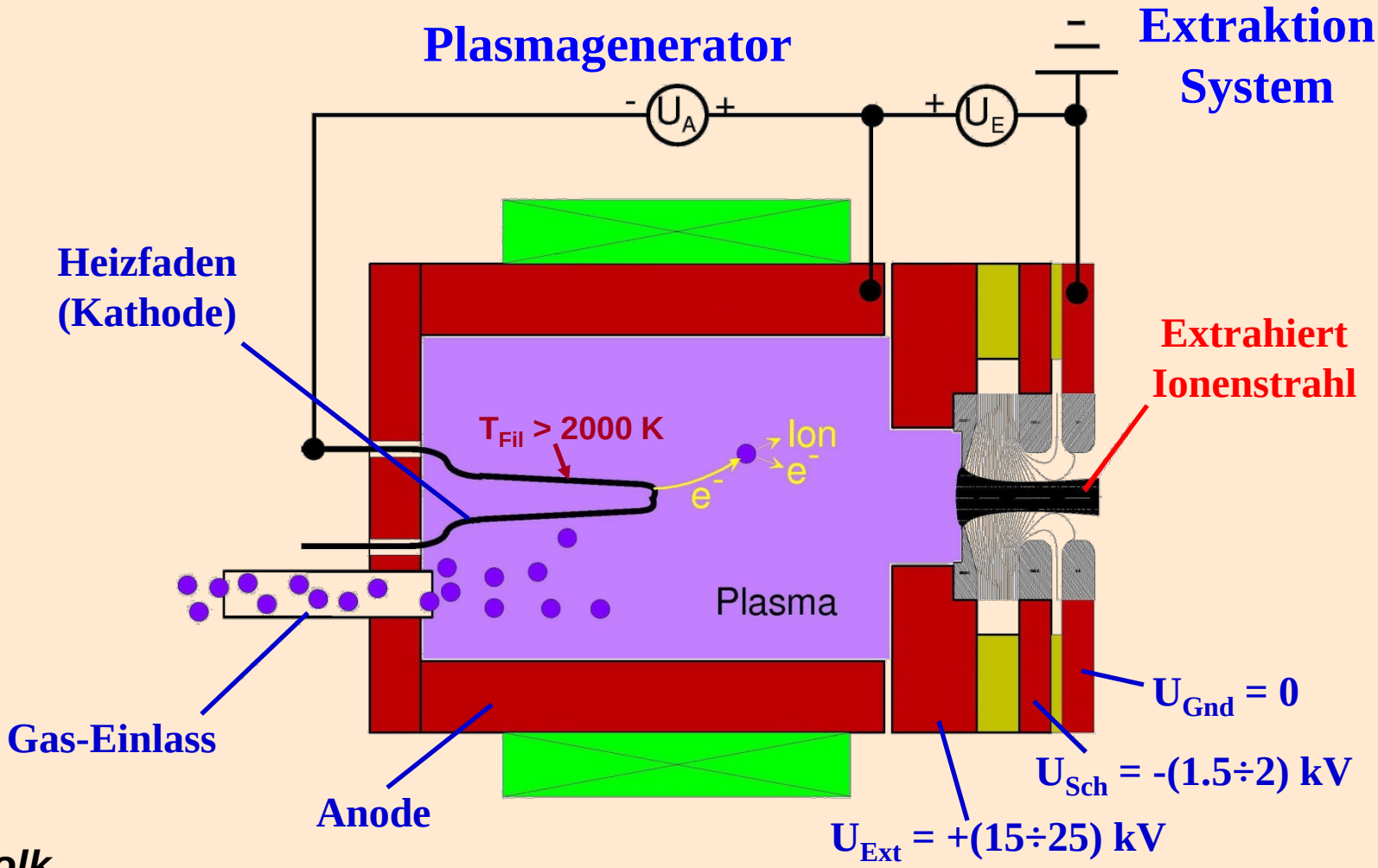
Ralph Hollinger & Aleksey Adonin

Ion Source Group, GSI

GSI Betriebsworkshop

01. Februar 2012

filamentbetriebene Volumen-Quelle



K. Volk

Überwachung ein

7-SEP-2010 06:19

U03 UL-TKG | U06 UL-US3 | U07 UL-TKG | U11 UL-TKU

Süd | Nord | HLI

Operating News | Help | Programmende | Info | Bildschirmcopy

Geleistete Arbeit = 113.14 MJ

Pulse = 2.06E+06 Entladewider. = 0.25 Ohm

U07 UNILAC 40AR 1+ Quellentiming: angefordert 2.00 Hz, 1.00 ms, 5.00 ms Vorlauf B-Feld (Chordis 2 19-AUG-2010 15:05) UL - TKG

Gasventil (UL3IQ1G) Reset Auf Ab + -

Status

P-Einlass (8.51 Pa) 3.372 V

P-Quelle (UL3VV0T) 1.180E-03 Pa

P-BRohr (UL3VV1T) 2.721E-04 Pa

Extraktion (UL3IQ1E) Reset Auf Ab + -

Status HV Ein

17991 V

100.1 mA

Gap (UL3IQ1MG) Auf Ab + -

Status Rechnersteuerung

40.83 mm

Terminal-HV (UL3IQ1H) Reset Auf Ab + -

Status HV Ein Beta=.00217

2.200 keV/u 69910 V

94.96 mA

Bogenng. (UL3IC1E) Reset Auf Ab + -

Status Abw.Soll/Ist >27.5V

144.5 V

0.002 A

Schirm 1 (UL3IQ1S) Reset Auf Ab + -

Status Anlage Ein

-1693 V

0.031 mA

Schirm 2 (UL3IQ2S) Reset Auf Ab + -

Status Anlage Ein

-3195 V

0.010 mA

Röntgenpegel (UL4IX1)

1.003E-02 ct/S

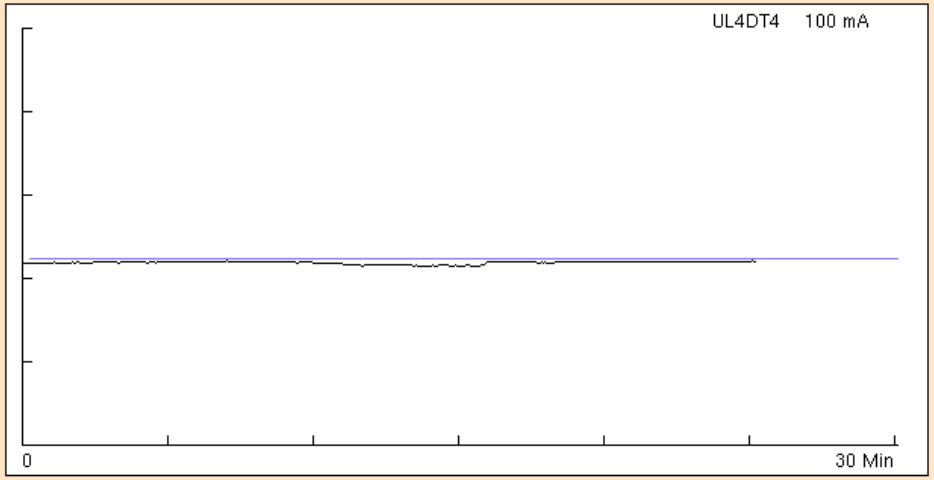
UHall 5.60 V

Filament (UL3IC1K) Reset Auf Ab + -

Status Ein

7.875 V

194.2 A



Powerrack (UL3IQ1P) | Powerrack Ein

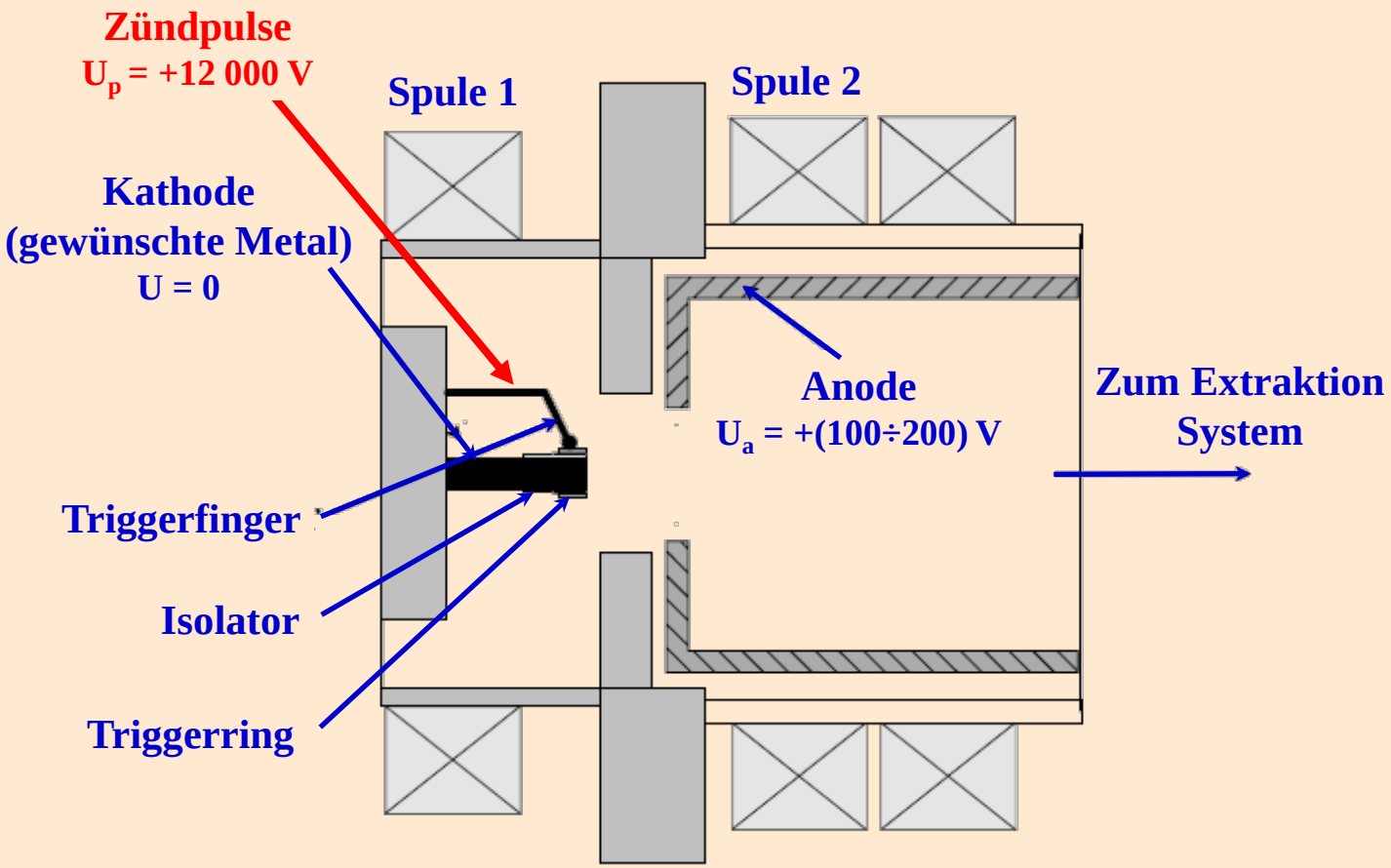
FC (UL3DC4) / Ventil (UL3VV0T) | FC Aus

Auto Extraktion ein !

VFahr langsam

Referenzwerte Überwachung eingeblendet

Vakuumbogenentladungs-Quelle



Überwachung ein

25-MAY-2010 22:06

U06 UL-UM3 | U07 UL-UH1 | U10 UL-TKU | U12 UL-TKU

Operating News | Help | Programmende | Info | Bildschirmcopy

Süd | Nord | HLI | PIG-Test | EIS-Test | Hosti-Test

Geleistete Arbeit = 26.72 MJ

Pulse = 4.30E+05 Entladewider. = 0.25 Ohm

U12 UNILAC 238U 4+ Quellentiming: angefordert 1.00 Hz, 0.50 ms, 5.00 ms Vorlauf B-Feld (Varis U1 23-MAY-2010 08:24) UL - TKU

Gasventil (UL3IQ1G) Reset Auf Ab + -

Status

P-Einlass (0.00 Pa) -10.00 V

P-Quelle (UL3VV0T) 9.305E-06 Pa

P-BRohr (UL3VV1T) 2.719E-05 Pa

Extraktion (UL3IQ1E) Reset Auf Ab + -

Status HV Ein

27145 V

166.1 mA

Gap (UL3IQGM) Auf Ab + -

Status Rechnersteuerung

52.81 mm

Terminal-HV (UL3IQ1H) Reset Auf Ab + -

Status HV Ein Beta=.00217

2.201 keV/u 103835 V

93.00 mA

Bogenng. (UL3IC1E) Reset Auf Ab + -

Status Abw.Soll/Ist >27.5V

184.8 V

-0.004 A

Schirm 1 (UL3IQ1S) Reset Auf Ab + -

Status Anlage Ein

-1847 V

0.031 mA

Schirm 2 (UL3IQ2S) Reset Auf Ab + -

Status Anlage Ein

-3311 V

0.011 mA

Röntgenpegel (UL4IX1)

1.003E-02 ct/S

Magnetfeld I (UL3IM1B) Reset Auf Ab + -

Status Ein

34.77 V

0.003 A

Zündgenerator (UL3IM1T) Reset Auf Ab + -

Status Ein

U(Prim) 448.4 V 12369 V

I(Prim) 0.0 A 0.000 A

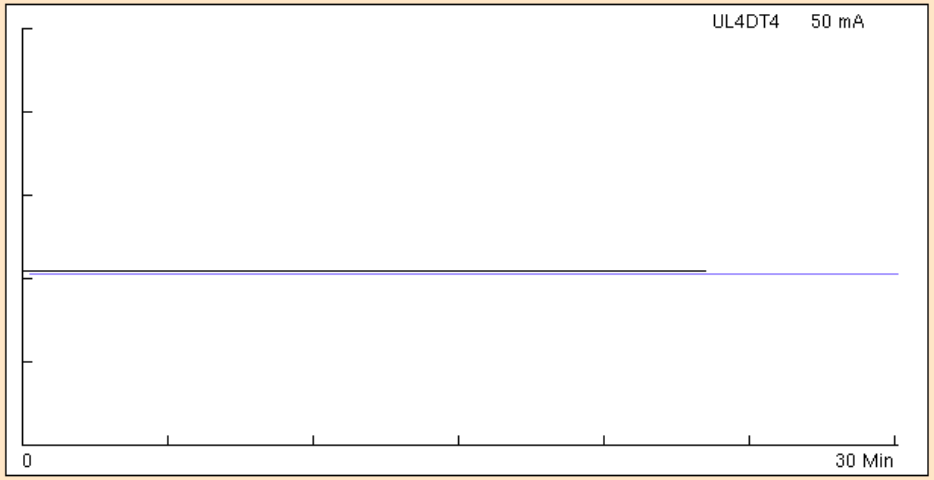
UHall 8.39 V

Magnetfeld II (UL3IM1K) Reset Auf Ab + -

Status Abw.Soll/Ist > 7.5V

39.39 V

0.005 A



Powerrack (UL3IQ1P) | Kühlanlage Aus

FC (UL3DC4) / Ventil (UL3VV0T) | FC Aus

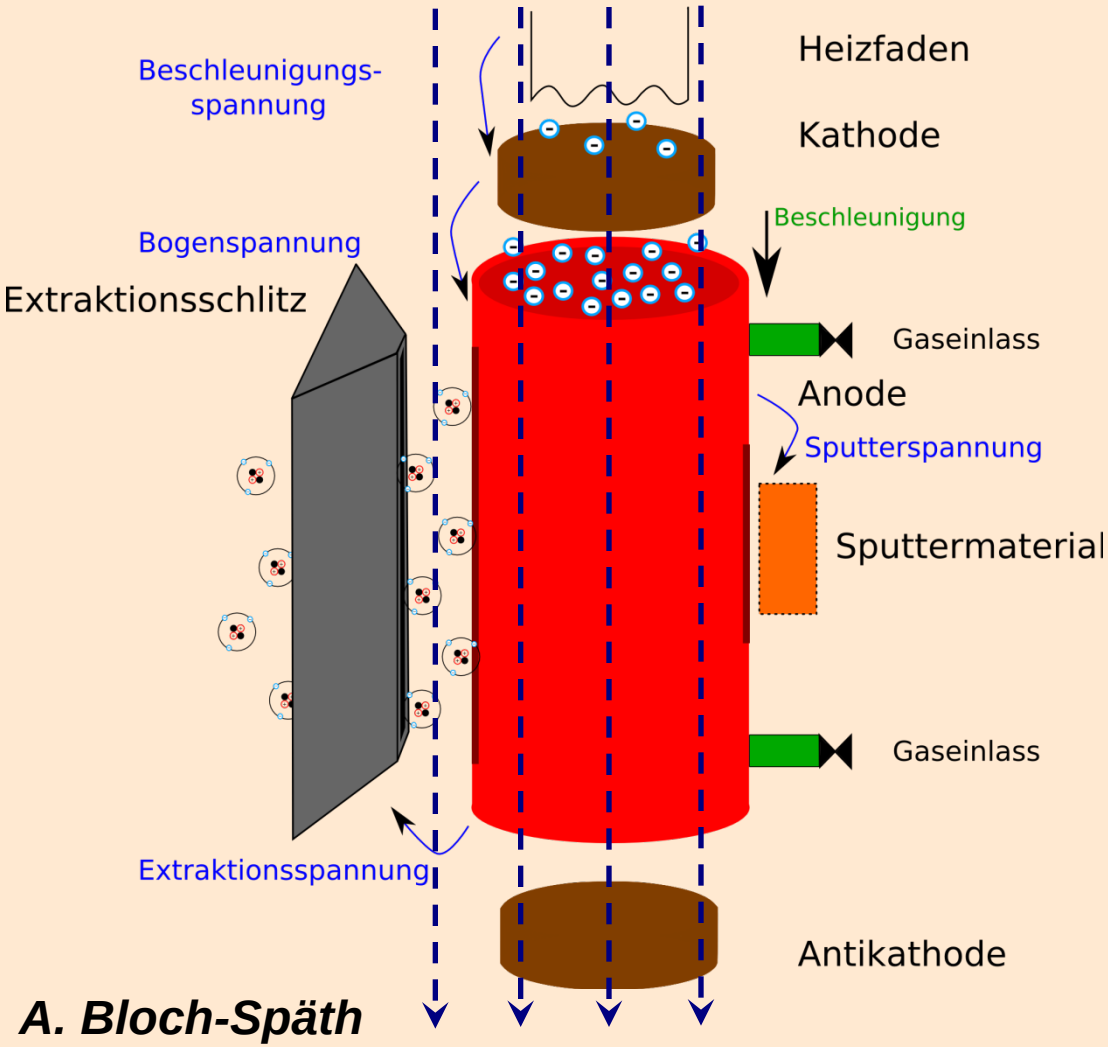
Kathode (UL3IM1KD) | Nr. 4

Auto Extraktion ein !

VFahr mittel

Referenzwerte Überwachung eingeblendet

PIG Quelle



- $I_{Heizfaden} = 65 \div 75$ A
- $U_{Besch.} = 500 \div 800$ V
- $U_{Pulser} = 1200 \div 2500$ V
- $U_{Sputter} = 400 \div 1800$ V
- $U_{Exr.}$ up to 23 kV

A. Bloch-Späth

Inj. Betrieb

30-AUG-2011 08:42

U01 UR-UZ6 | U03 UR-UX8

Süd | Nord | HLI

Operating News | Help | Programmende | Info | Bildschirmcopy

U03 UNILAC 50TI 2+ Quellentiming: periodisch 50.00 Hz, 5.00 ms, 0.20 ms Vorlauf (Sputter 3 28-AUG-2011 20:25) UR - UX8

Kathodenheizung (UR3IP1K) — Re-set
Status: Regelung Ein
3.025 V
70.25 A

Quellenmagnet (UR3IM1)
Status: Ein
156.1 A

Extraktion (UR3IQ1E) — Re-set
Status: HV Ein
16388 V
20.56 mA

Hochspannung (UR3IQ1H) — Re-set
Status: HV Ein — Beta=.00217
2.199 keV/u
38464 V
0.157 mA

Beschleuniger (UR3IP1B) — Re-set
Status: Regelung Ein
494.2 V
0.798 A

Gasventil (UR3IQ1G) — Re-set
Status
P-Einlass (60.25 Pa) 5.184 V
P-Quelle (UR3VV0T) 3.719E-04 Pa

Schirm 2 (UR3IQ2S) — Re-set
Status: Anlage Ein
-19.53 V
0.034 mA

Hauptnetzgerät (UR3IP1E) — Re-set
Status: Abw.Soll/Ist > 150V
2522 V
-0.002 A

Sputter (UR3IP1S) — Re-set
Status: Regelung Ein
1771 V
0.068 A

Gap (UR3IQ1MG)
Status: Rechnersteuerung
62.80 mm

HV-Kopplung ein !

Röntgenpegel (UR4IX1)
0.000E+00 ct/S

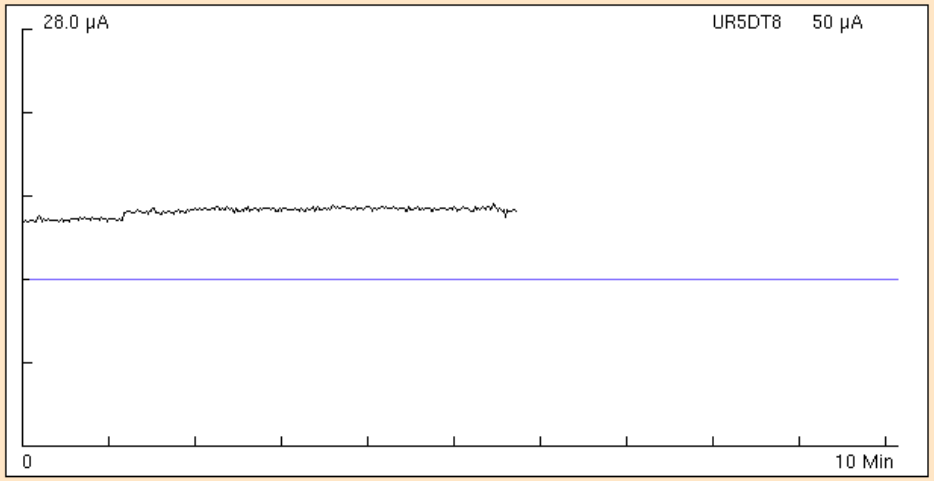
UHall 3.50 V

Schirmgitter (UR3IP1G) — Re-set
Status: Regelung Ein
983.0 V
0.016 A

Elektrode re/li (UR3IP1X)
Status
-0.191 mm

Elektrode vor/rück (UR3IP1X)
Status
4.212 mm

Pulser Netzgerät (UR3IP1P) — Re-set
Status: Ein
Sollwert 1425 V
-20.00 A



Powerrack (UR3IQ1P) | Powerrack Ein

FC (UR3DC4) / Ventil (UR3VV0T) | FC Aus

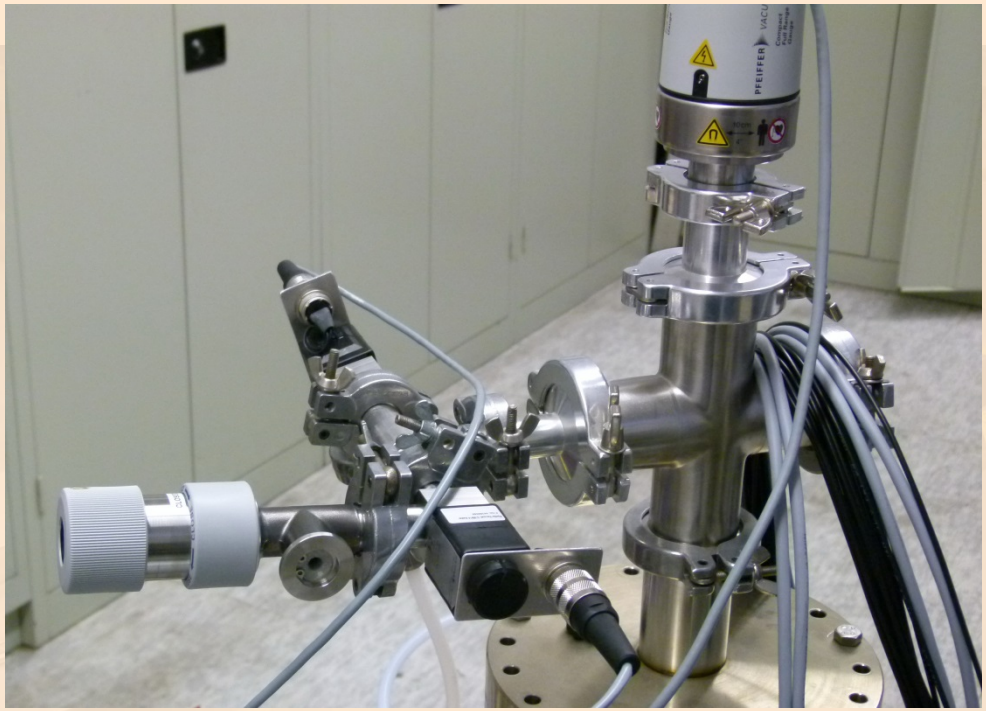
VFahr mittel

Referenzwerte Überwachung eingeblendet

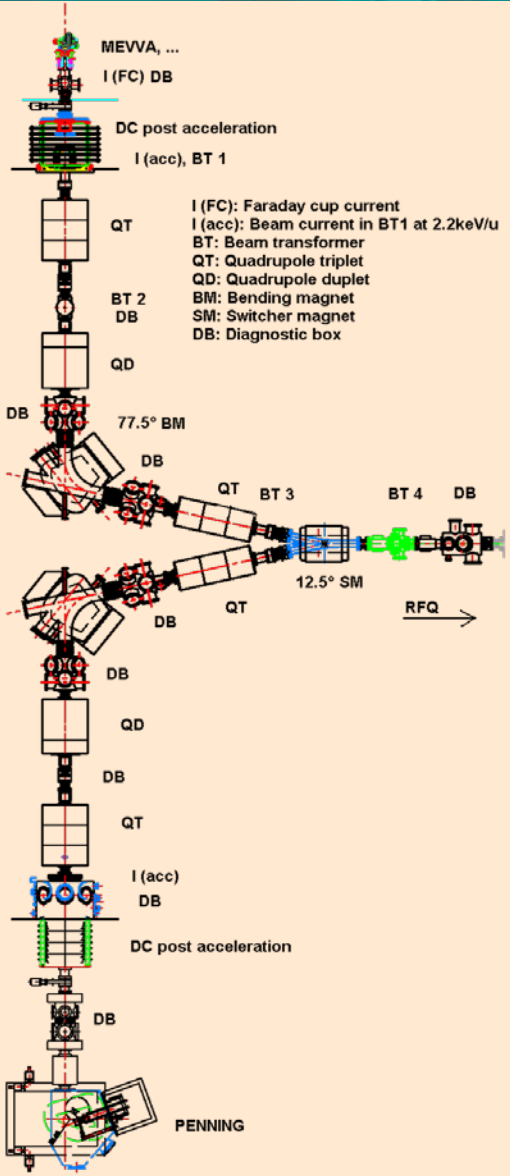
Verbesserungen

- IQ-Programm
  - reagiert verzögert...
- Terminal Süd
  - Intergrale geleistete „Quellenarbeit" (in Bearbeitung)
  - Strahlrohr kontaminationsfrei
  - Ölfreie Vorpumpe
  - 5 von 6 Sputterquellen neu aufgebaut
- Terminal Nord
  - Autom. Belüftung
  - Bogenstrom und Spulenstrom werden digital angezeigt

Verbesserungen



Diagnostik in LEBT

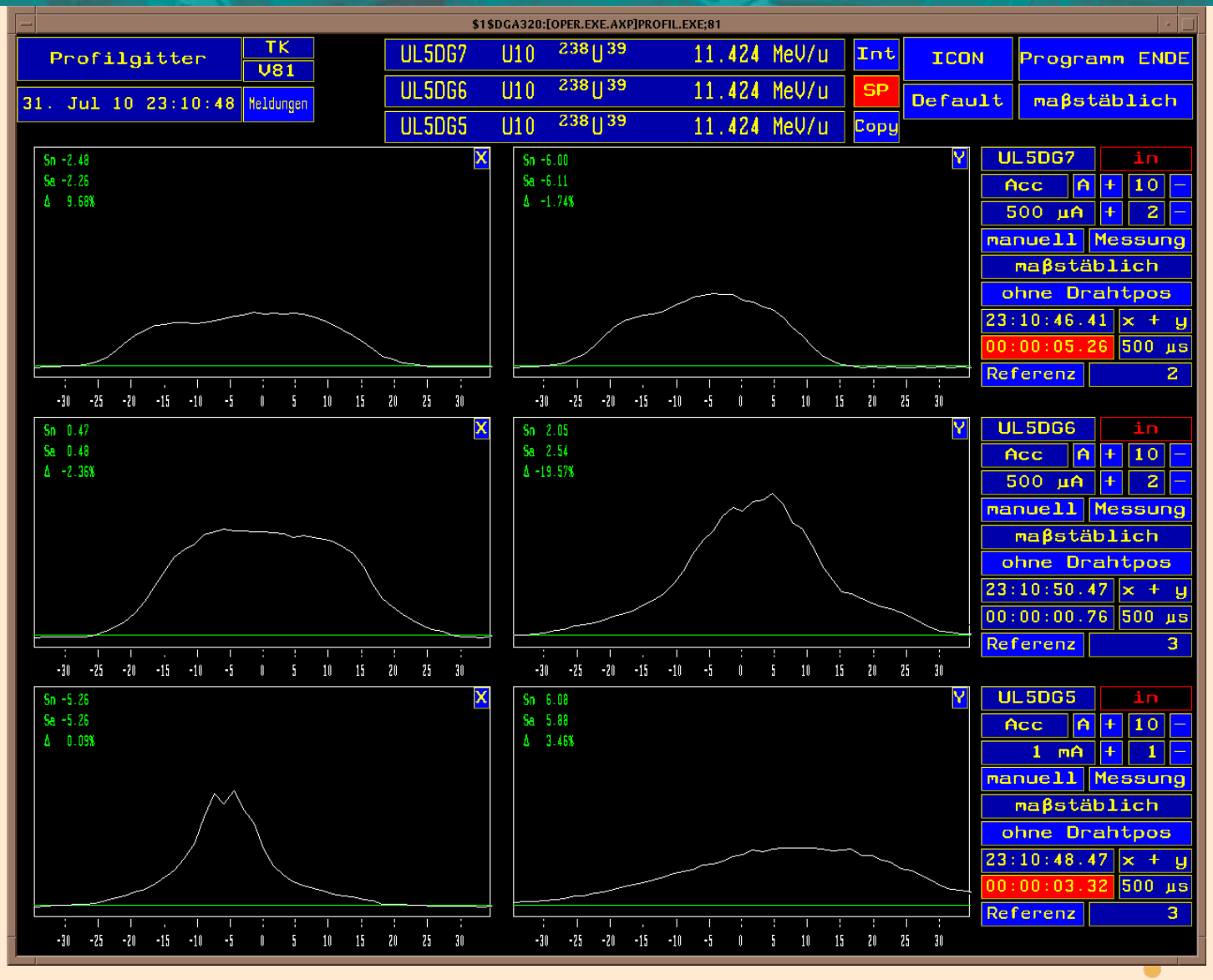


	injector NORD	injector SÜD
Extraction Voltage:	up to 35 kV	up to 25 kV
Post Acceleration:	up to 130 kV	
Pulse Length:	0.1 ms ÷ 6 ms	up to 5 ms
Repetition Rate:	up to 5 Hz	up to 50 Hz
Design-Ion:	$^{238}U^{4+}$, $^{130}Xe^{2+}$	
MAX Resolution:	Pb-isotops are resolved	

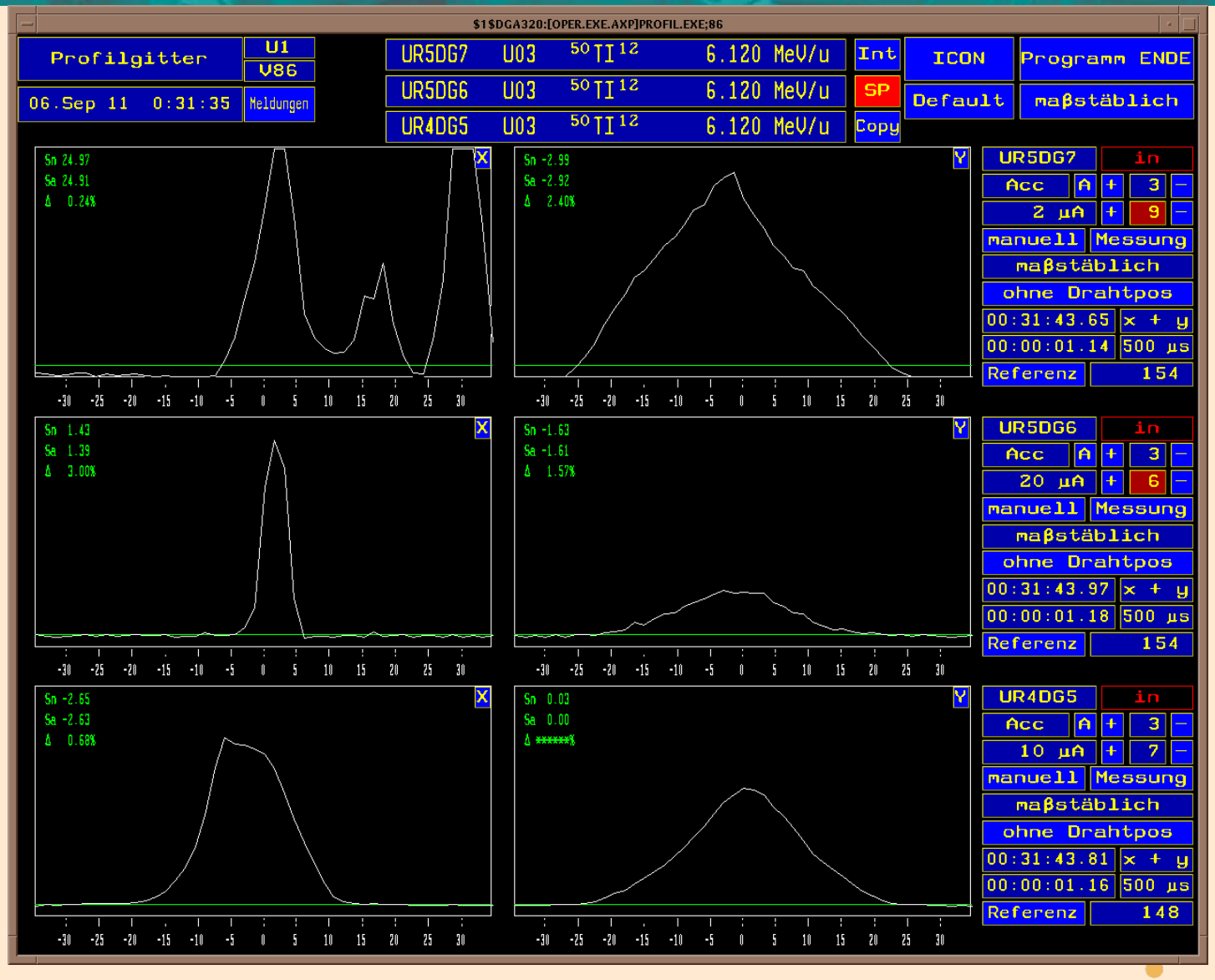
RFQ requirements

Specific Energy:	2.2 keV/u
MAX Mass to Charge (A/ζ):	65
Space-charge limit RFQ:	$0.25 \times A/\zeta$ [mA]
Acceptance RFQ:	$\varepsilon_{x,y}=138\pi$ mm·mrad

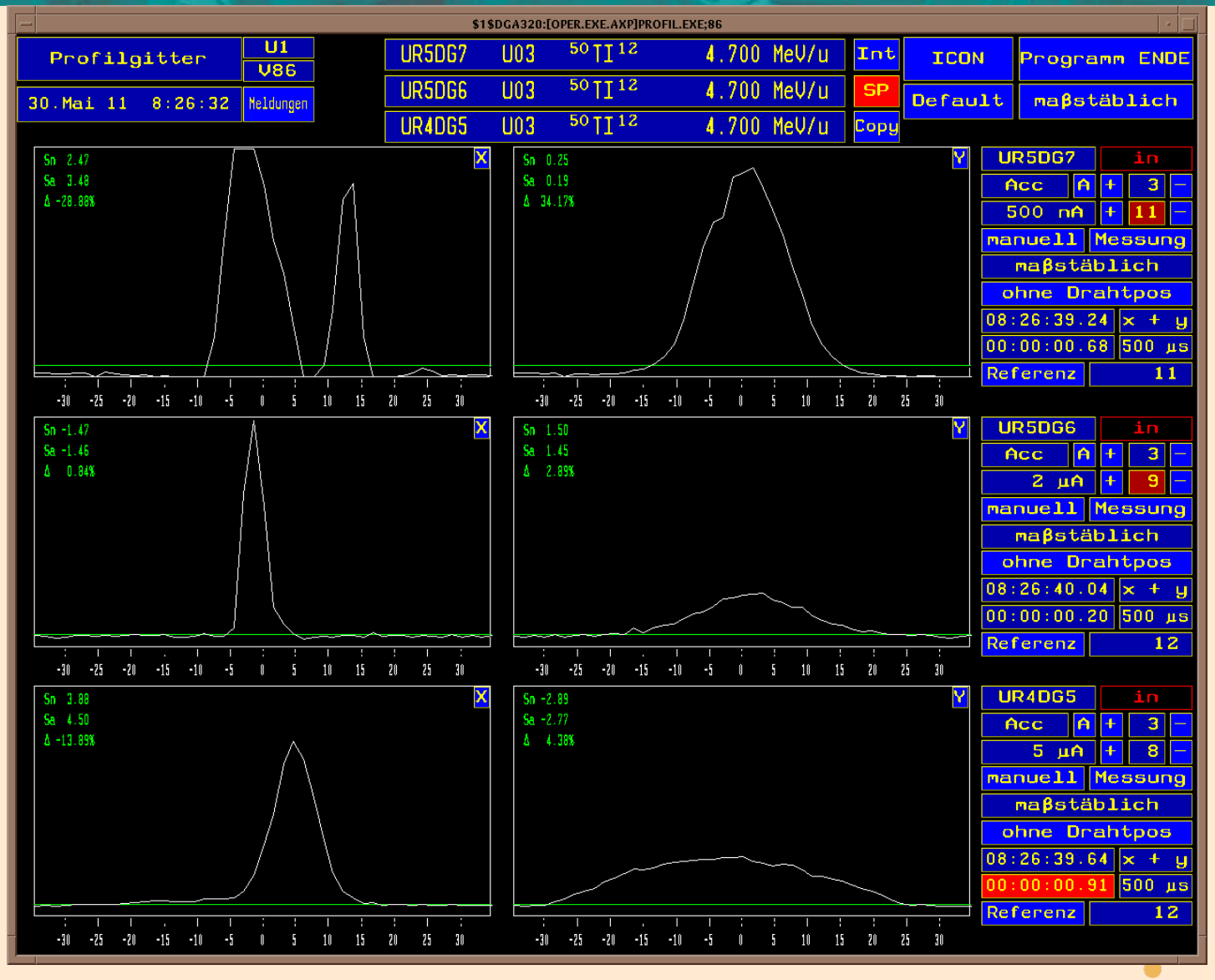
Diagnostik in LEBT



Diagnostik in LEBT



Diagnostik in LEBT



Rufbereitschaften

HSI Quellenoperating (SO): Adonin, Berezov, Heymach, Hollinger

HLI Quellenoperating (LO): Lang, Mäder, Maimone, Tinschert

Quellenelektronik (QE): Gutermuth, Patchakui, Rossbach, Schäffer P.

Quellenservice Nord (QN): Ochs, Schäffer S., Vierheller

Quellenservice Süd (QS): Brühl, Wesp, Schäffer S., Zulauf

Rufbereitschaften

Grundsätzlich gilt:

Immer zuerst die RB „Operating“ anrufen

Ausnahme: PIG Quellenservice

HSI Quellenoperating (SO): Fehleranalyse und –behebung z.T. unter Zuhilfenahme von QE, QS und QN, Filamentwechsel, Gasflaschenwechsel, Wechsel NG, Quellenwechsel, etc.

HLI Quellenoperating (LO): Fehleranalyse und –behebung z.T. unter Zuhilfenahme von QE, Ofenwechsel, etc.

Quellenelektronik (QE): Unterstützung von SO

Quellenservice Nord (QN): Unterstützung von SO

Quellenservice Süd (QS): PIG Quellenservice

Am Ende…

Vielen Dank für die Aufmerksamkeit !!!