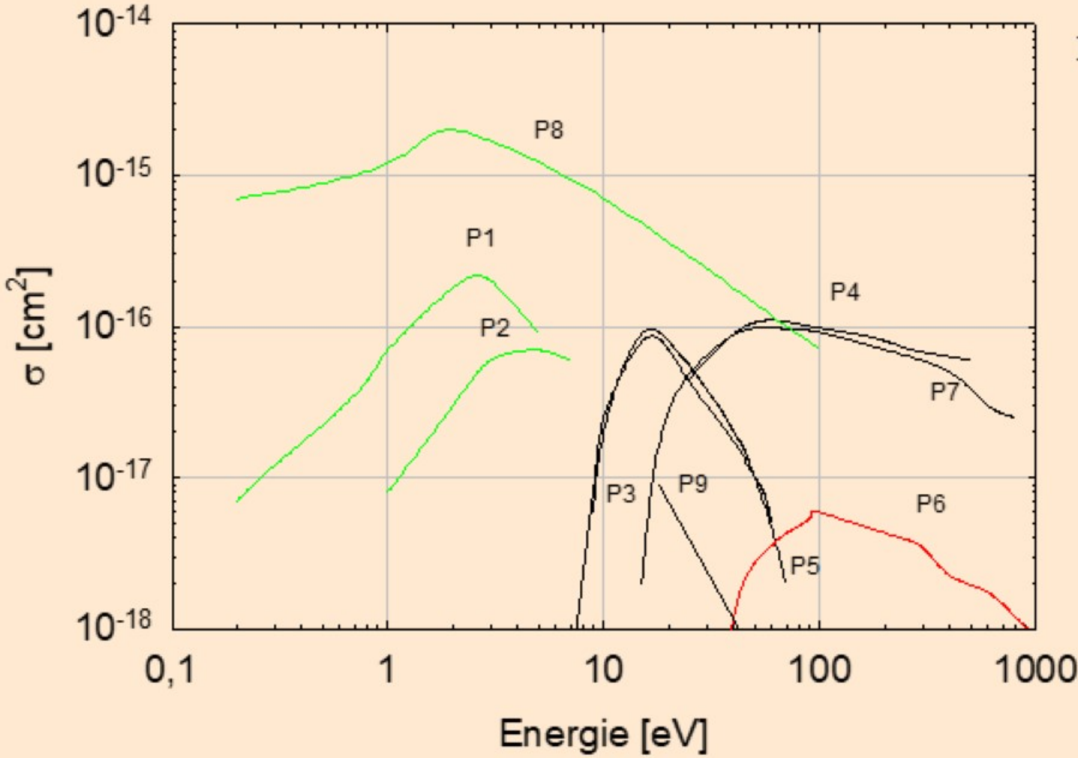
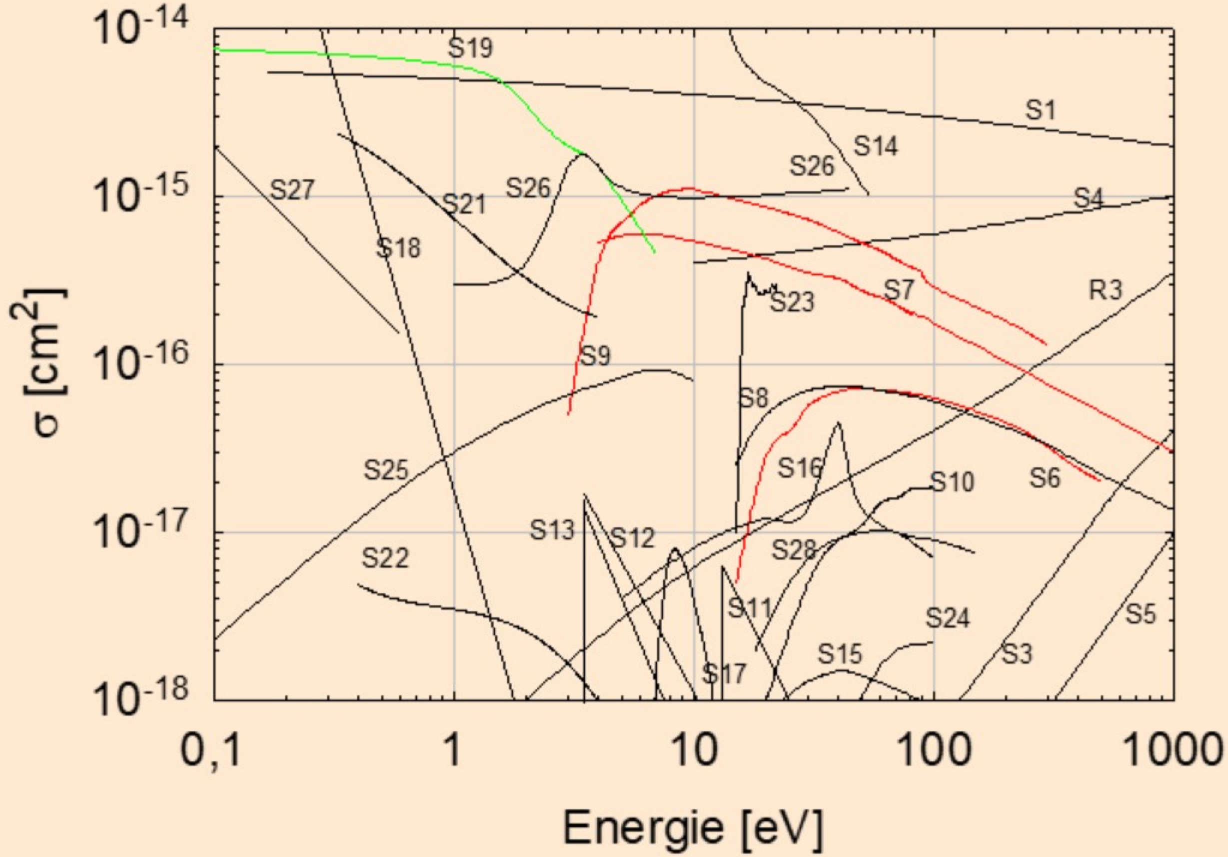
Primärprozesse im Wasserstoffplasma



Primärstoß	Reaktion
P1	$e + H_2 \rightarrow H_2^* (rot) + e$
P2	$e + H_2 \rightarrow H_2^* (vib) + e$
P3	$e + H_2 \rightarrow H_2^* (elec) + e$
P4	$e + H_2 \rightarrow H_2^+ + 2e$
P5	$e + H_2 \rightarrow 2H + e$
P6	$e + H_2 \rightarrow H^+ + H + 2e$
P7	$e + H_2$ (total)
P8	$e + H_2$ (elastic scattering)
P9	$h\nu + H_2 \rightarrow 2H$
P10	$e + H_2 \rightarrow H^- + H$ ($< 10^{-21}$)
P11	$e + H_2 \rightarrow H^- + H^* + e$ ($< 10^{-20}$)

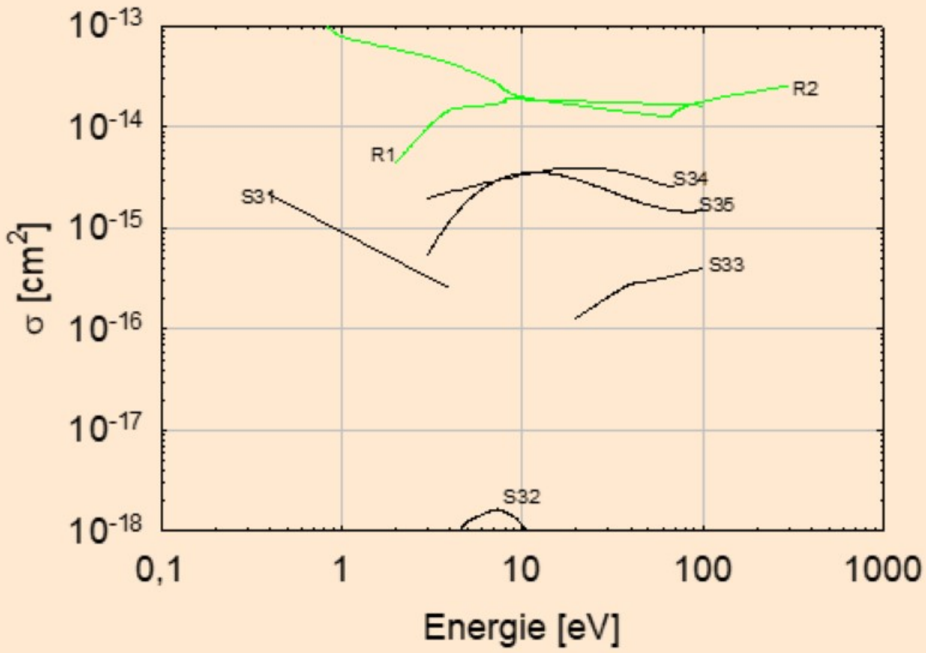
Sekundärprozesse im Wasserstoffplasma



Sekundärprozesse im Wasserstoffplasma

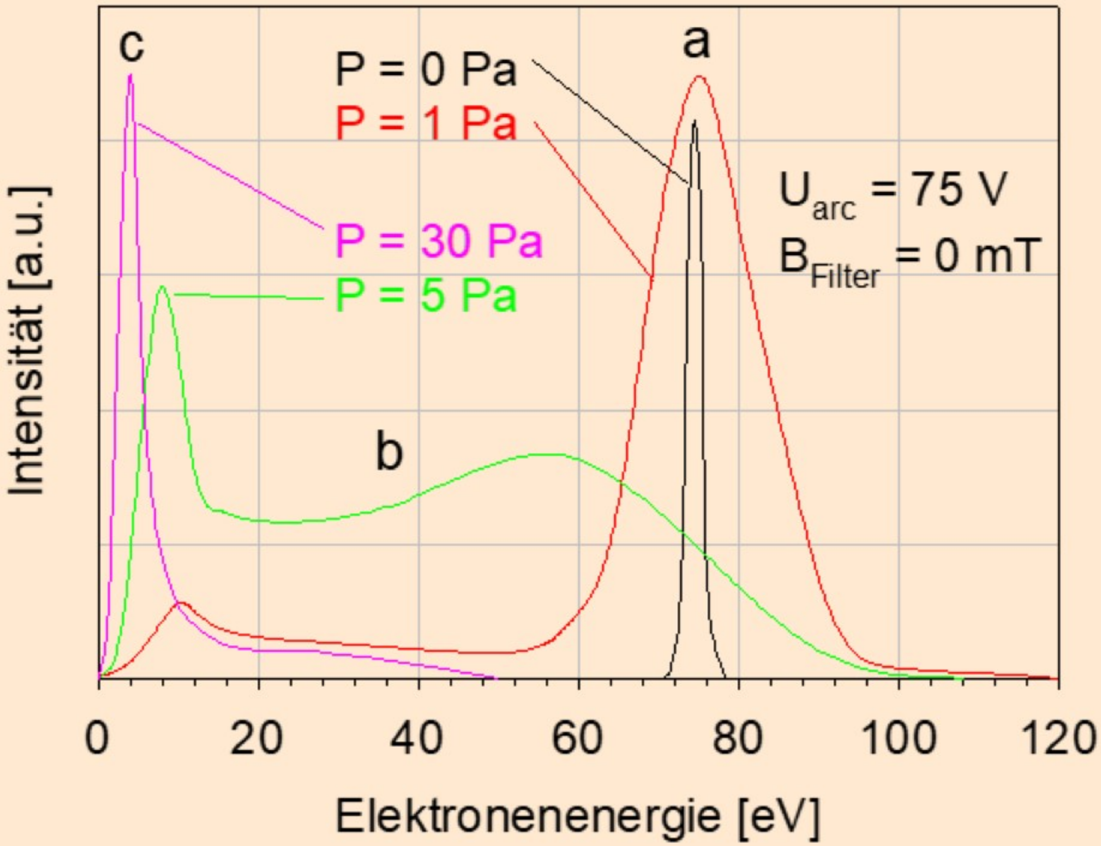
Sekundärstoß	Reaktion	[eV]	Referenz
S1	$H^+ + H \rightarrow H + H^+$	< 0,2	[Taw, Sa]
S2	$e + H_3^+ \rightarrow H_2 + H^+ + e$		[Chan 2]
S3	$H_2 + H \rightarrow H^+$	< 100	[Nak]
S4	$H^- + H_2 \rightarrow H + ...$	< 10	[Nak]
S5	$H^- + H_2 \rightarrow H^+ + ...$	< 300	[Nak]
S6	$e + H \rightarrow H^+ + 2e$	13,6	[Kie, Ch, Taw 2, Chan]
S7	$e + H_2^+ \rightarrow H^+ + H + e$	< 1	[Step, Chan]
S8	$e + H\,(1s) \rightarrow H\,(2p) + e$	< 13,6	[Cou, Cal]
S9	$e + H\,(2s) \rightarrow H^+ + 2e$	< 2	[Taw 2]
S10	$e + H_2^+ \rightarrow 2H^+ + 2e$		[Kie, Step]
S11	$h\nu + H\,(1s) \rightarrow H^+ + e$	13,6	[Cro]
S12	$h\nu + H\,(2p) \rightarrow H^+ + e$	3,5	[Cro]
S13	$h\nu + H\,(2s) \rightarrow H^+ + e$	3,5	[Cro]
S14	$e + H\,(1s) \rightarrow H\,(1s) + e$		[Cal, Kie 2]
S15	$e + H\,(1s) \rightarrow H\,(3s) + e$	< 15	[Cal, Kie 2]
S16	$e + H\,(1s) \rightarrow H\,(3p) + e$	< 3	[Cal, Kie 2]
S17	$h\nu + H_2^+ \rightarrow H^+ + H$	< 6	[Cro]
S18	$e + H_2^+ \rightarrow H + H^*$	< 0,2	[Step]
S19	$H_2^+ + H_2 \rightarrow H_3^+ + H$	< 0,1	[Ale, Chan]
S20	$e + H_2^*\,(vib) \rightarrow H^- + H$		[Wad]
S21	$e + H_2^+ \rightarrow 2H$	< 0,2	[Step, Chan]
S22	$e + H_2^+ \rightarrow H^+ + H^-$	0,3	[Pear 1]
S23	$e + H_3^+ \rightarrow 2H + H^+ + e$	15	[Pear 2]
S24	$H + H_2 \rightarrow H^- + ...$	< 50	[Nak]
S25	$H + H_2 \rightarrow H^+ + H_2 + e$	< 0,1	[Nak]
S26	$H_2^+ + H_2 \rightarrow H_2 + H_2^+$	< 1	[Mor]
S27	$e + H_3^+ \rightarrow H$	< 0,1	[Brian]
S28	$e + H^- \rightarrow H^+ + 3e$		[Det]
S29	$e + H \rightarrow H^*\,(elec)$		[Iti, Bas]
S30	$e + H \rightarrow H^-$	< 8	[Kie]
S31	$e + H_3^+ \rightarrow H_2 + H$	0,3	[Ale]
S32	$e + H_3^+ \rightarrow H_3^*(vib) \rightarrow H^- + H_2^+$	< 2	[Pear 3]
S33	$H^- + H_2 \rightarrow H + H_2 + e$	4,48	[Taw 3]
S34	$e + H^- \rightarrow H + 2e$	< 0,1	[Pear 4]
S35	$H^- + H^- \rightarrow H^- + H + e$	1,1	[unbekannt]
S36	$h\nu + H^- \rightarrow H + e\,(<10^{-18})$		[Gel]
S37	$H^- + H \rightarrow H + H^-(<10^{-18})$		[unbekannt]

Rekombinationen im Wasserstoffplasma

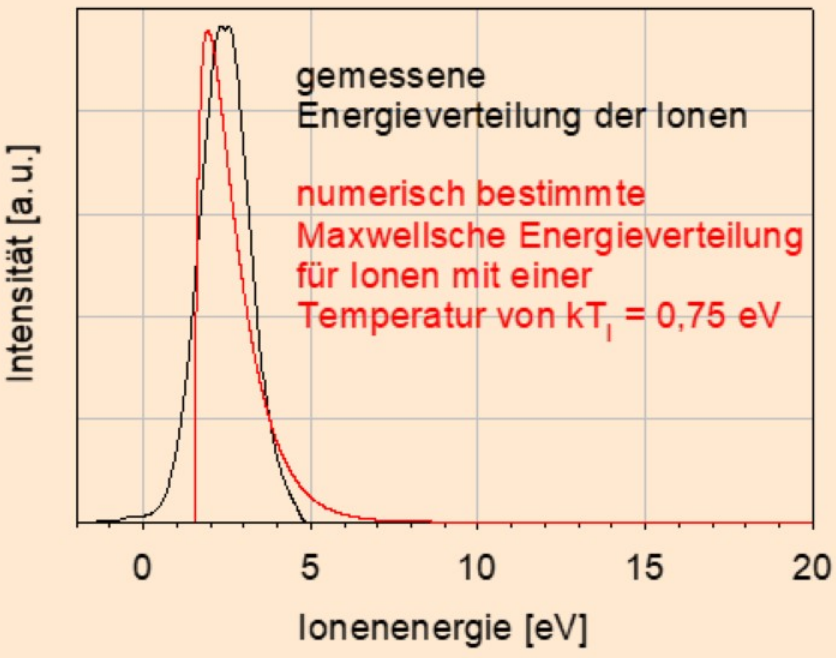


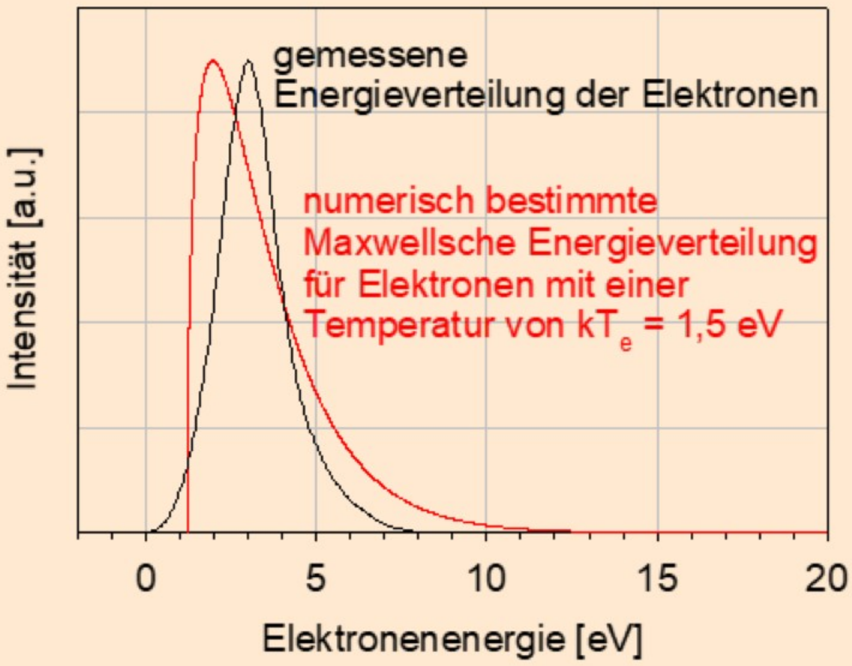
Rekombination	Reaktion	[eV]	Referenz
R1	$H^+ + H^- \rightarrow H^+ + H + e$	0,5	[unbekannt]
R2	$H^+ + H^- \rightarrow 2H$	< 0,1	[Mosley]
R3	$H^+ + H_2 \rightarrow H + H_2^+$	< 1	[Nak]

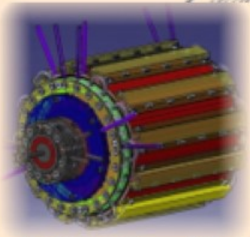
Elektronenenergieverteilung vs. Neutralteilchendichte/Plasmadichte



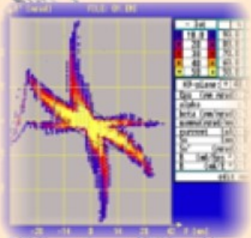
Temperaturen der Teilchen im Wasserstoffplasma



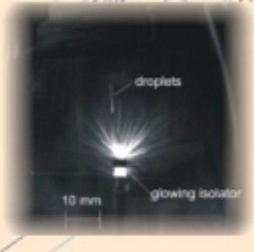




Ion Sources at GSI



Overview & Operation Principles



Aleksey Adonin &

Ralph Hollinger

IOS, GSI

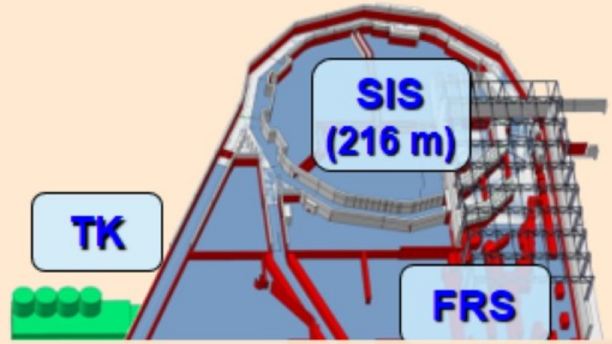
GSI facility

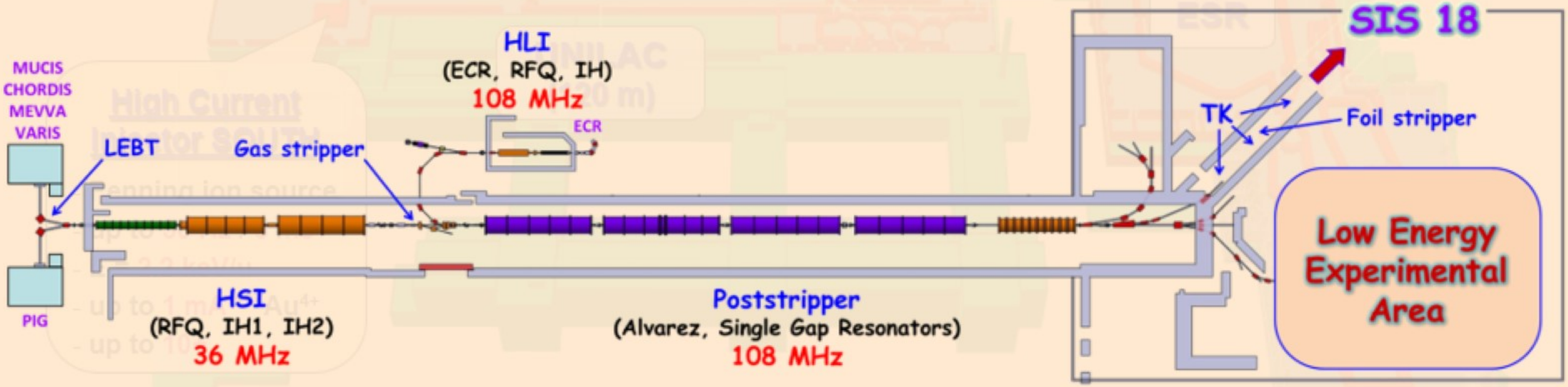
High Current Injector NORTH

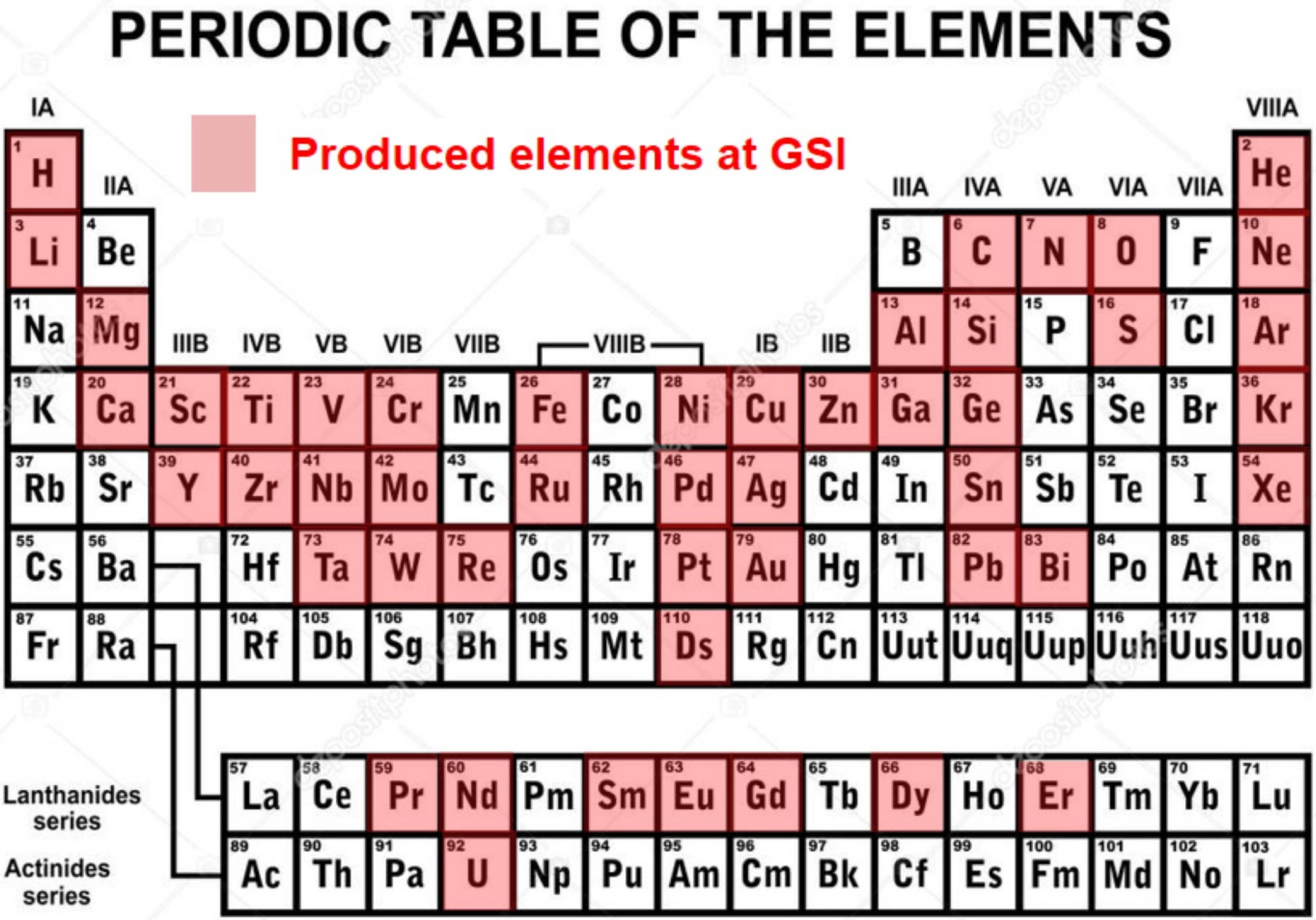
- High current IS
- up to 5 Hz / 2ms
- E = 2.2 keV/u
- up to 20 mA $^{238}U^{4+}$

High Charge State Injector

- ECR ion source
- CW operation
- E = 2.5 keV/u
- up to 0.2 mA







PERIODIC TABLE OF THE ELEMENTS
Produced elements at GSI
IA
IIA
IIIA IVA VA VIA VIIA
VIIIA
IIIB IVB VB VIB VIIB VIIIB IB IIB
1 H
2 He
3 Li 4 Be 5 B 6 C 7 N 8 O 9 F 10 Ne
11 Na 12 Mg 13 Al 14 Si 15 P 16 S 17 Cl 18 Ar
19 K 20 Ca 21 Sc 22 Ti 23 V 24 Cr 25 Mn 26 Fe 27 Co 28 Ni 29 Cu 30 Zn 31 Ga 32 Ge 33 As 34 Se 35 Br 36 Kr
37 Rb 38 Sr 39 Y 40 Zr 41 Nb 42 Mo 43 Tc 44 Ru 45 Rh 46 Pd 47 Ag 48 Cd 49 In 50 Sn 51 Sb 52 Te 53 I 54 Xe
55 Cs 56 Ba 72 Hf 73 Ta 74 W 75 Re 76 Os 77 Ir 78 Pt 79 Au 80 Hg 81 Tl 82 Pb 83 Bi 84 Po 85 At 86 Rn
87 Fr 88 Ra 104 Rf 105 Db 106 Sg 107 Bh 108 Hs 109 Mt 110 Ds 111 Rg 112 Cn 113 Uut 114 Uuq 115 Uup 116 Uuh 117 Uus 118 Uuo
Lanthanides series
57 La 58 Ce 59 Pr 60 Nd 61 Pm 62 Sm 63 Eu 64 Gd 65 Tb 66 Dy 67 Ho 68 Er 69 Tm 70 Yb 71 Lu
Actinides series
89 Ac 90 Th 91 Pa 92 U 93 Np 94 Pu 95 Am 96 Cm 97 Bk 98 Cf 99 Es 100 Fm 101 Md 102 No 103 Lr

a) MEVVA, b) MUCIS, c) CHORDIS, d) PENNING, e) VARIS
f) auxiliary gas/material
g) enriched material
h) Synchrotron mode
i) other tuning of the ion source
j) life time of the filament for MUCIS, CHORDIS, PENNING, and life time of the plasma grids for MEVVA and VARIS
k) life time given by the volume of the gas bottle
m) generation of CH3+ from the ion source for H+ or C+ behind the poststripper

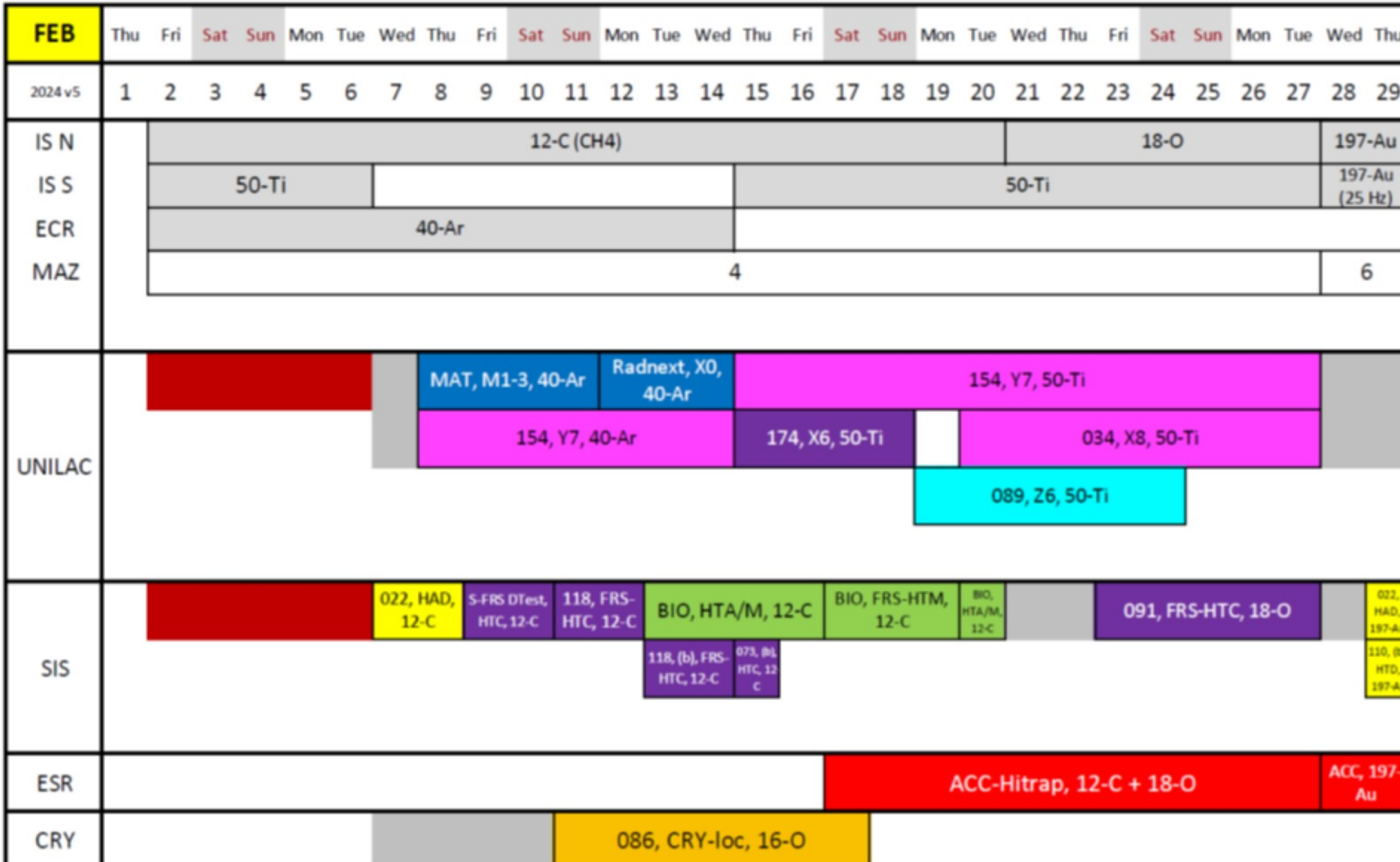
Operating

n) sputter gas
p) full beam current at extraction potential
q) full beam current at 2.2 keV/u
r) ion beam current in front of the RFQ
s) 90 % 4rms emittance behind extraction / in front of the RFQ
t) space charge limit for the RFQ (0.25 [mA]·A/ζ)
u) for PENNING arc current, the maximum arc voltage is 2.5 kV
v) drain current

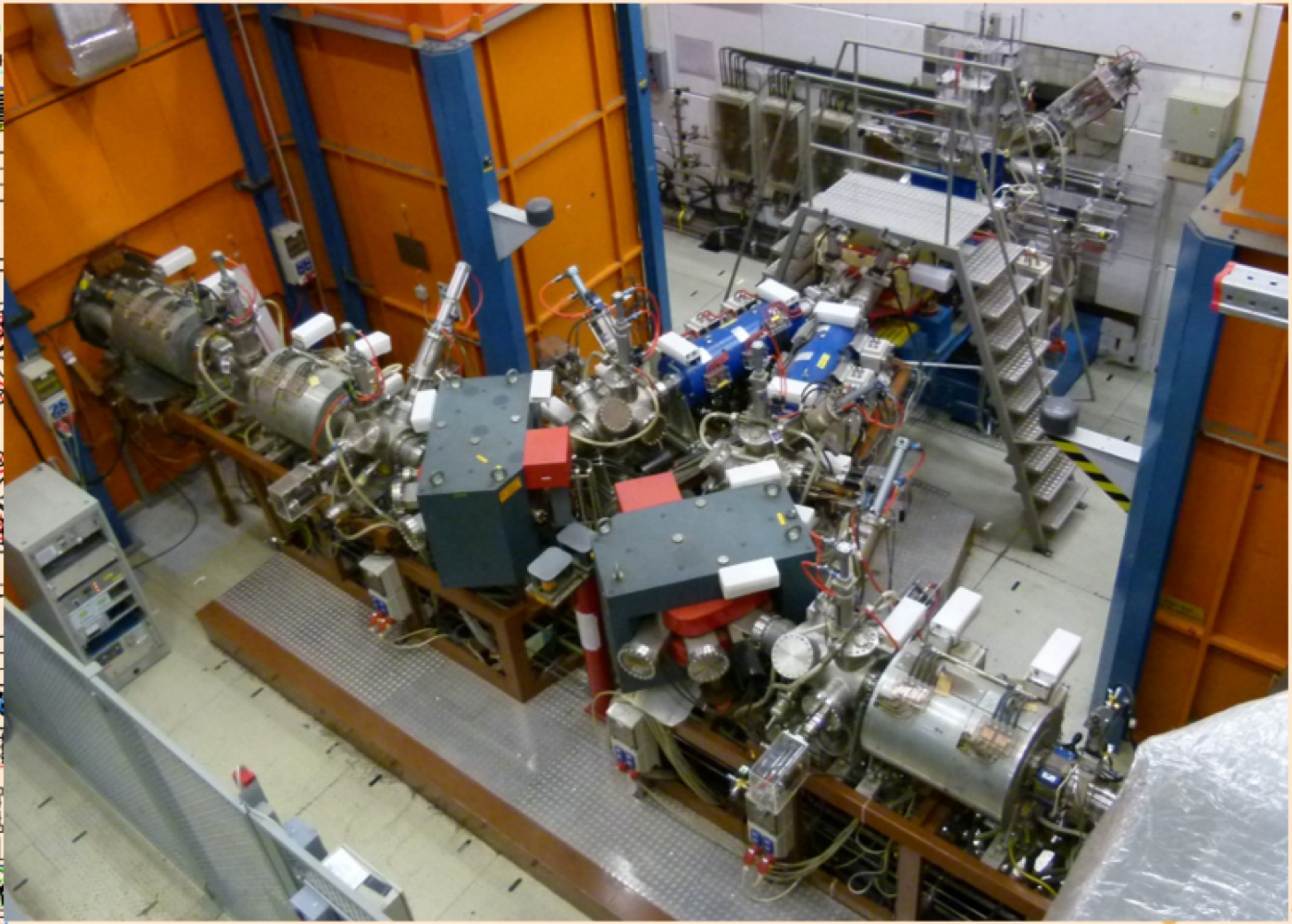
ions	I_{FC} [p] [mA/kV]	I_{ACC} [q] [mA]	I_{RFQ} [r] [mA]	SCL [t] [mA]	duty factor [Hz/ms]	$\varepsilon_{IS}/\varepsilon_{RFQ}$ [s] [πmmmrad]	life time [d] [j]	current fraction [%] 1+/2+/3+/4+/…	other, aux. gas	arc power [u] [kW]	type of IS
$^{1}H_3^+$	40/6.6	15	1	0.75	5/1	~320/~110	7[k]	H_1^+: 37, H_2^+: 8, H_3^+: 55		2	b
$^{2}H_3^+$	90/13.2	50	2	1.5	5/1	~320/~110	7[k]	D_1^+: 30, D_2^+: 5, D_3^+: 65,		4	b
$^{12}C^+$	9[v]/15	0.6	0.3	3	10/2	<500/~90	2		CO_2[f]	2	d
$^{12}C^{2+}$	7[v]/13.2	0.3	0.06	1.5	10/2	<500/~90	2		CO_2[f]	2	d
$^{12}C^+$	15/6	9	0.5	3	5/1	~320/~110	2	divers (C, H, CH, …)	CH_4[f]	2	b
$^{14}N^+$	20/10	12	2.5	3.5	5/1	~320/~110	7	N_2^+: 31, N^+: 69		1	b
$^{12}CH_3^+$	30/8	12	1.2	3.75	5/1	~320/~110	2	divers (C, H, CH, …)	CH_4[f]	2	h,m
$^{14}N_2^+$	40/14	35	4	7	5/1	~320/~110	7	N_2^+: 31, N^+: 69		2	b
$^{14}N_2^+$	35/13	25	5.5	7	5/1	~320/~110	3	N_2^+: 50, N^+: 50		1.5	c
$^{16}O_2^+$	30/13	15	3.5	8	0.24/0.4[h]	~650/~150	7	O^+: 21, O_2^+: 35	Mg[f]	5	a
$^{18}O_2^+$	30/13	15	3.5	9	0.24/0.4[h]	~320/~110	7	O^+: 21, O_2^+: 35	Mg[f]	5	a,g
$^{20}Ne^+$		0.15	0.09	5	50/6	<500/~90	5				d
$^{20}Ne^{3+}$		0.035	0.02	1.6	50/5.5	<500/~90	2				d
$^{22}Ne^+$		0.4	0.2	5.5	50/6	<500/~90	3				d
$^{24}Mg^+$	80/18	28	2	6	0.25/0.4[h]	~650/~150	7	24/62	O, O_2[f]	6.5	a
$^{40}Ar^+$	65/20	42	20	10	5/1	~320/~110	5	80/20		3	b
$^{40}Ar^+$	50/19	33	22	10	5/1	~320/~110		90/10		1	c
$^{40}Ar^+$	8[v]/10	0.09	0.02	10	12/2	<500/~90		23/77		2	d
$^{40}Ar^{2+}$	8[v]/10	0.8	0.25	5	50/5	<500/~90	6	23/77		2	d
$^{40}Ar^{2+}$	50/16	16	1.5	5	5/1	~320/~110	5	65/35		3	b
$^{40}Ca^{2+}$	40/15	15	5	5	0.25/0.6	~650/~150	2	6/94		15	a
$^{40}Ca^+$		0.08	0.08	10	10/2	<500/~90	2		Xe[n]		d
$^{40}Ca^{2+}$		0.3	0.1	5	50/5	<500/~90	2		Xe[n]		d
$^{40}Ca^{3+}$		0.15	0.05	3.3	10/2	<500/~90	2		Ne[n]		d
$^{46}Ti^{2+}$		0.075	0.02	5.75	50/5	<500/~90	2	9/46/45	Ar[n]		d
$^{50}Ti^{2+}$		0.35	0.07	6.25	50/6	<500/~90	3	9/46/45	Ar[n]		d
$^{51}V^{2+}$		0.02	0.02	6.38	50/6	<500/~90	5		Ar[n]		d
$^{52}Cr^{2+}$	11[v]/11	0.2	0.07	6.5	50/5	<500/~90	2		Ar[n]	4	d
$^{56}Fe^{2+}$	10[v]/14	0.4	0.2	7	10/1	<500/~90	4		Ar[n]		d
$^{56}Fe^{3+}$	10[v]/14	0.15	0.06	4.7	50/5	<500/~90	2		Ar[n]	6	d
$^{58}Ni^+$	60/22	40	8	14.5	1/0.6	~650/~150	4	72/22/5	N_2[f] O_2[f]	25	a
$^{58}Ni^{2+}$	60/18	17	5	7.25	1/0.6	~650/~150	4	8/76/16		25	a
$^{58}Ni^{2+}$		0.4	0.1	7.25	50/6	<500/~90	1		Ar[n]		d
$^{58}Ni^{3+}$	16[v]/15	0.6	0.2	4.8	50/5.5	<500/~90	2		Ar[n]	4	d
$^{74}Ge^{4+}$		0.25	0.02	4.6	10/2.5	<500/~90	1		Ar[n]		d

Operating

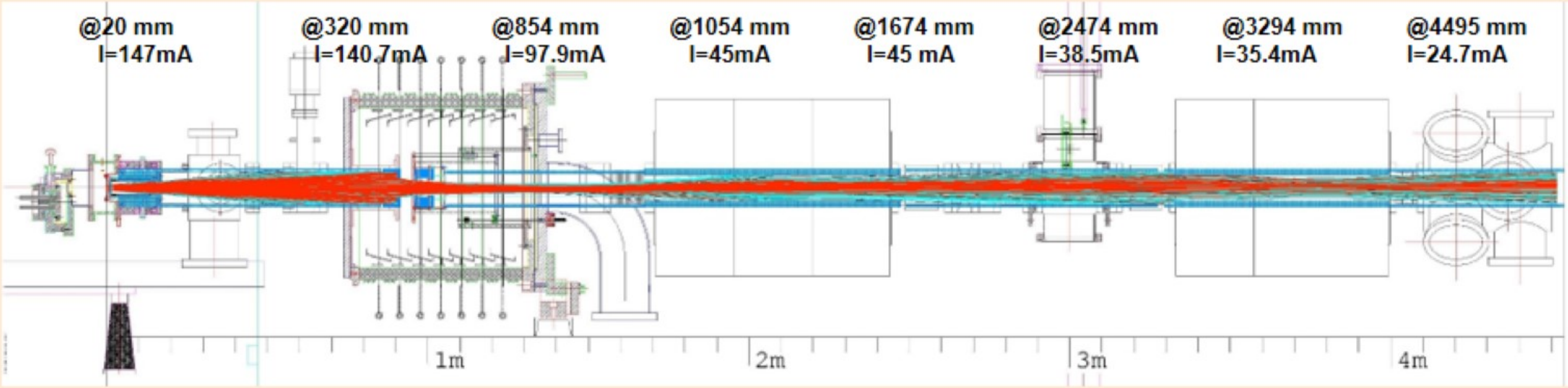
$^{80}Kr^{2+}$	60/22	28	0.15	10	5/1	~320/~110	3	17/53/29		6	b
$^{84}Kr^{3+}$		0.2	0.04	7	10/2	<500/~90					d
$^{86}Kr^{2+}$	80/23	34	9	10.75	5/1	~320/~110	3	48/45/7		4	h,g
$^{86}Kr^{2+d}$		0.8	0.02	10.75	10/2	<500/~90	3				d
$^{86}Kr^{3+}$		0.4	0.2	7.2	50/6	<500/~90	3				d,g
$^{94}Mo^{2+}$	50/18	19	0.5	11.75	0.1/0.6[h]	~650/~150	10	6/56/28	N_2[f]	20	a
$^{97}Mo^{4+}$		0.1	0.006	6.1	50/5	<500/~90	1		Ar[n]		d
$^{98}Mo^{4+}$		0.2	0.003	6.1	50/5	<500/~90	1		Ar[n]		d
$^{100}Mo^{2+}$	50/18	19	0.5	12.5	0.1/0.6[h]	~650/~150	10	6/56/28	N_2[f]	20	a
$^{107}Ag^{2+}$	40/18	23	3	13.4	0.25/0.4[h]	~650/~150	4	13/81/6	N_2[f]	20	a
$^{124}Sn^{5+}$	14/15	0.2	0.008	6.2	20/2	<500/~90		7/20/62/11	Ar[n]	8	d
$^{132}Xe^{3+}$	25/18	17	0.02	11	5/1	~320/~110	11	79/18/3		1	b
$^{132}Xe^{6+}$	20[v]/15	0.2	0.03	11	25/4	<500/~90	2	1/9/24/29/25/12		5	d
$^{136}Xe^{3+}$	40/21	18	0.8	11.3	5/1	~320/~110	6	78/21/1		2.5	h,g
$^{136}Xe^{3+}$	40/21	18	0.07	11.3	5/1	~320/~110	6	78/21/1		2.5	b
$^{136}Xe^{3+}$	20[v]/15	0.3	0.25	11.3	25/3	<500/~90	2	1/9/24/29/25/12			d,g
$^{136}Xe^{4+}$	20[v]/15	0.3	0.006	8.5	25/2	<500/~90	2	1/9/24/29/25/12			d
$^{142}Nd^{3+}$	80/28	32	1.5	11.8	0.25/0.4[h]	~650/~150	10	0/4/87/9 or 0/55/45[i]		15	a
$^{150}Nd^{3+}$	80/28	32	0.4	12.5	0.25/0.4[h]	~650/~150	10	0/4/87/9 or 0/55/45[i]		15	a
$^{152}Sm^{3+}$	20[v]/12	0.2	0.06	12.7	10/4	<500/~90	3		Ar[n]	2	d
$^{181}Ta^{3+}$	75/24	31	7	15.1	0.25/0.6[h]	~650/~150		0/0/56/35/8	Ar[f]	40	a
$^{181}Ta^{4+}$	80/24	34	8	11.3	0.25/0.6[h]	~650/~150		0/0/35/51/13		40	a
$^{197}Au^{4+}$	60/24	20	1	12.3	1/1	~650/~150	3	0/43/47/10			c
$^{197}Au^{4+}$	20[v]/15	0.6	0.5	12.3	10/2	<500/~90		2/14/19/26/24/12/3/1	Xe[n]		d
$^{197}Au^{8+}$	20[v]/15	0.05	0.02	6.2	10/2	<500/~90	3	2/14/19/26/24/12/3/1	Xe[n]	5	d
$^{208}Pb^{4+}$	17[v]/12	0.3	0.1	13	15/2	<500/~90	2	4/24/40/33	Xe[n]	4	d
$^{208}Pb^{5+}$	17[v]/12	0.08	0.01	10.4	50/2	<500/~90	2	4/24/40/33	Ar[n]		d
$^{208}Pb^{9+}$	17[v]/12	0.4	0.02	5.8	50/5	<500/~90	2	4/24/40/33	Ar[n]		d
$^{209}Bi^{4+}$		0.3	0.2	13.1	10/1	<500/~90	2		Ar[n]		d
$^{209}Bi^{5+}$		0.4	0.3	10.45	8/3	<500/~90	2		Ar[n]		d
$^{238}U^{4+}$	100/30	40	12	15	0.25/0.6[h]	~650/~150	7	0/0/22/65/13		40	a
$^{238}U^{4+}$	150/35	55	20	15	0.25/0.6[h]	~650/~150	7	0/0/18/67/15		50	c
$^{238}U^{4+}$	36[v]/12	0.3	0.3	15	10/2	<500/~90	2	0/0/5/15/21/24/25/7	Xe[n]	4	d
$^{238}U^{5+}$	36[v]/12	0.5	0.4	12	10/2	<500/~90	2	0/0/5/15/21/24/25/7	Xe[n]		d
$^{238}U^{6+}$	36[v]/12	0.7	0.35	10	10/2	<500/~90	3	0/0/5/15/21/24/25/7	Xe[n]	4	d
$^{238}U^{8+}$		0.25	0.1	7.4	50/3	<500/~90	2	0/0/5/15/21/24/25/7	Xe[n]		d
$^{238}U^{10+}$		0.15	0.05	6	50/3	<500/~90	2	0/0/5/15/21/24/25/7	Xe[n]		d

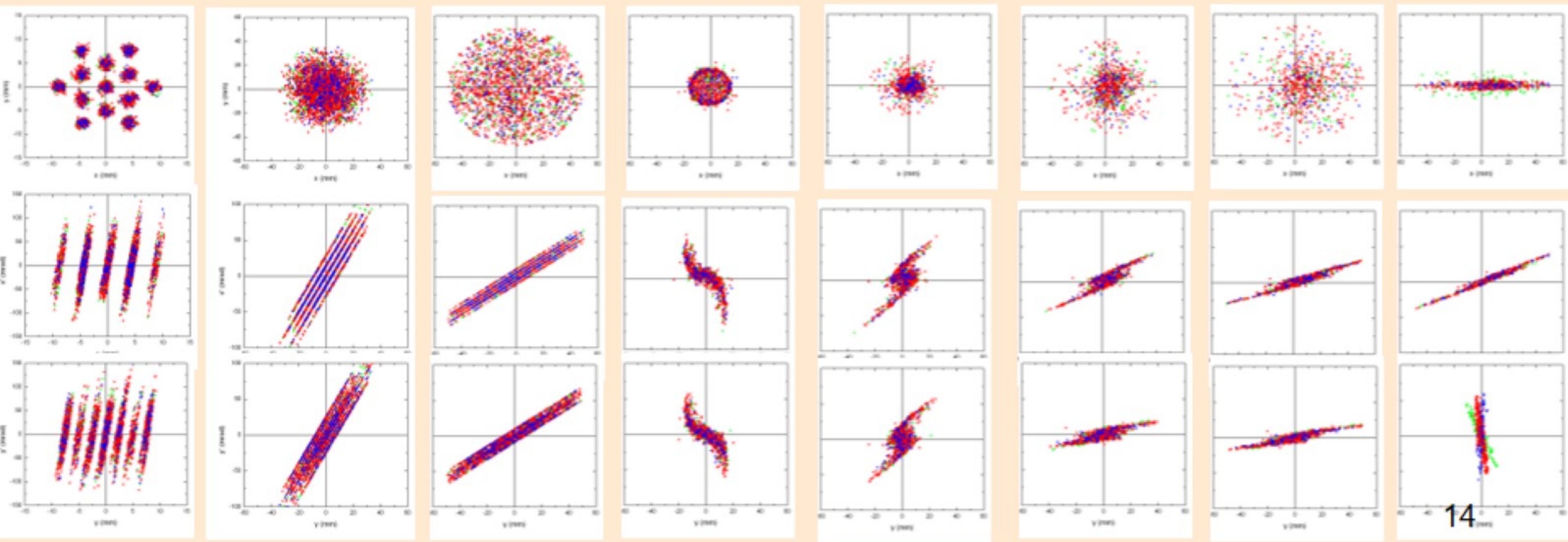

FEB
Thu Fri Sat Sun Mon Tue Wed Thu Fri Sat Sun Mon Tue Wed Thu Fri Sat Sun Mon Tue Wed Thu Fri Sat Sun Mon Tue Wed Thu
2024 v5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
IS N
12-C (CH4)
18-O
197-Au
IS S
50-Ti
50-Ti
197-Au (25 Hz)
ECR
40-Ar
MAZ
4
6
UNILAC
MAT, M1-3, 40-Ar
Radnext, X0, 40-Ar
154, Y7, 50-Ti
154, Y7, 40-Ar
174, X6, 50-Ti
034, X8, 50-Ti
089, Z6, 50-Ti
SIS
022, HAD, 12-C
S-FRS DTest, HTC, 12-C
118, FRS-HTC, 12-C
BIO, HTA/M, 12-C
BIO, FRS-HTM, 12-C
BIO, HTA/M, 12-C
091, FRS-HTC, 18-O
118, (b), FRS-HTC, 12-C
ESR
ACC-Hitrap, 12-C + 18-O
ACC, 197-Au
CRY
086, CRY-loc, 16-O

Terminals and LEBT



Post Acceleration, Kobra3-INP

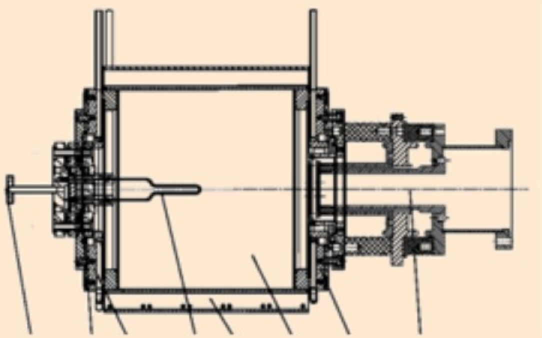




Types of High Current Ion Sources

High Current Ion Sources

Filament driven

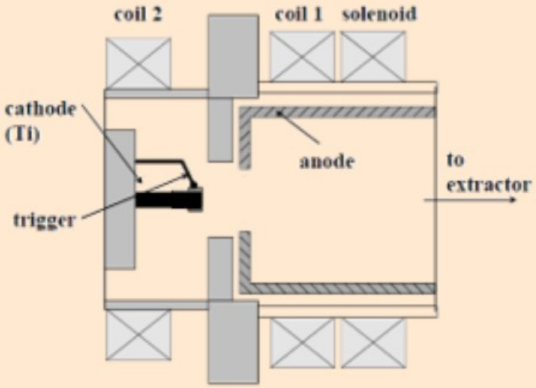


MUCIS, MUCIS New, CHORDIS

Working material:

Gases

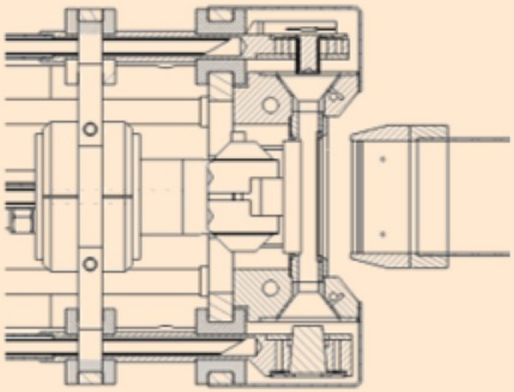
Vacuum Arc driven



MEVVA, VARIS

Metalls and Gases

High Duty factor

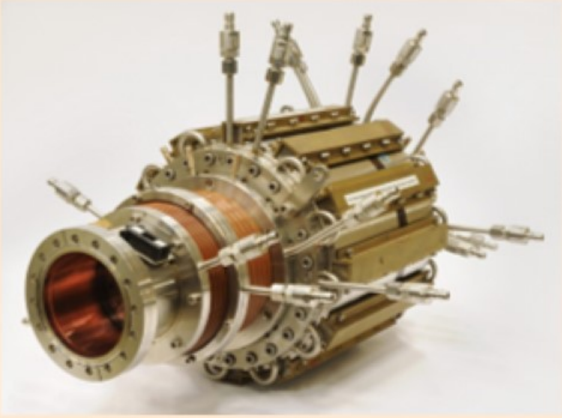


PIG

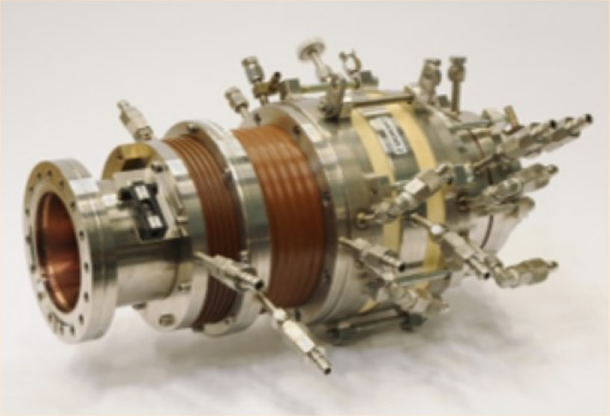
Metalls and Gases

Filament driven Ion Sources

MUCIS

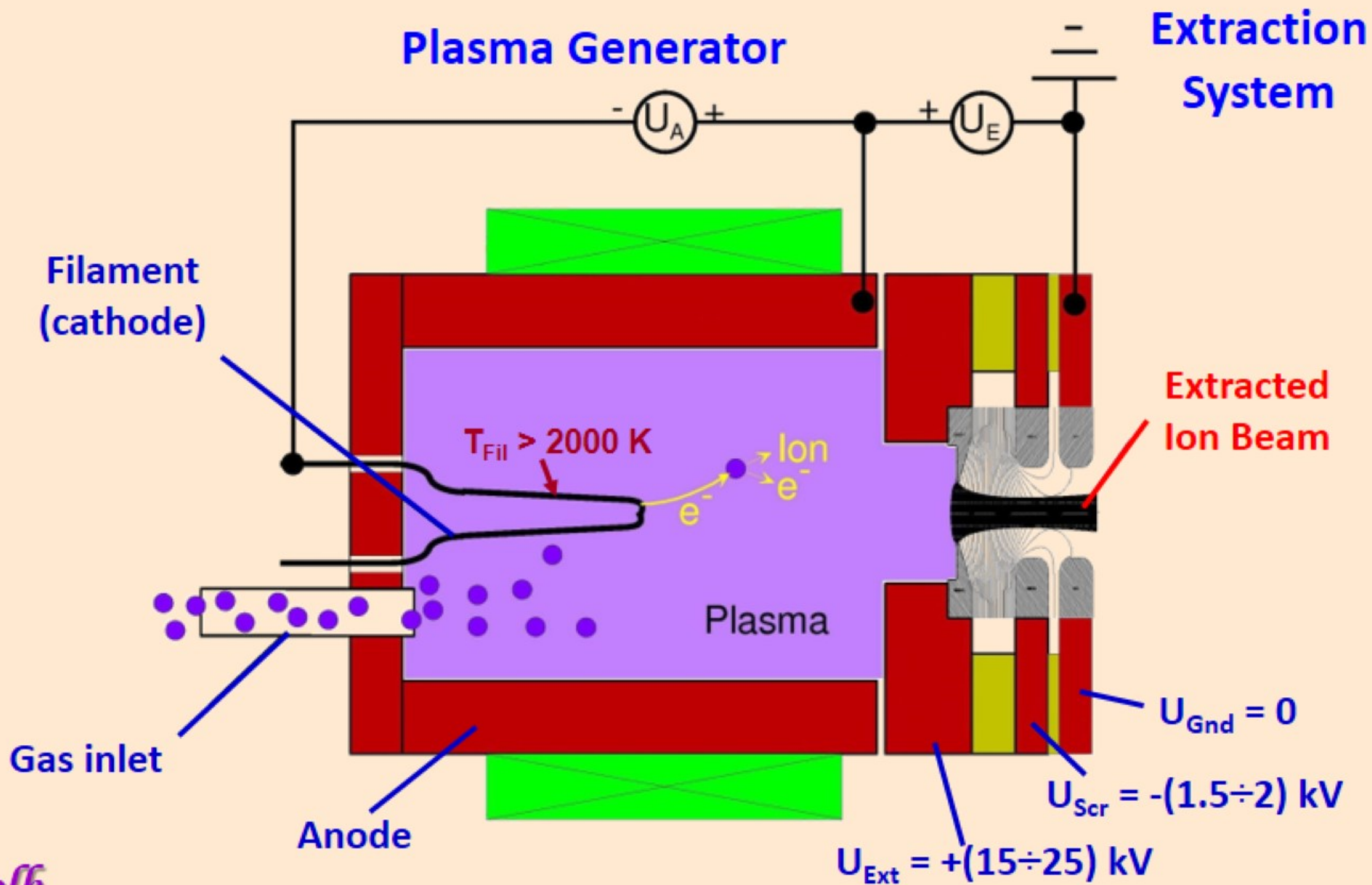


MUCIS New



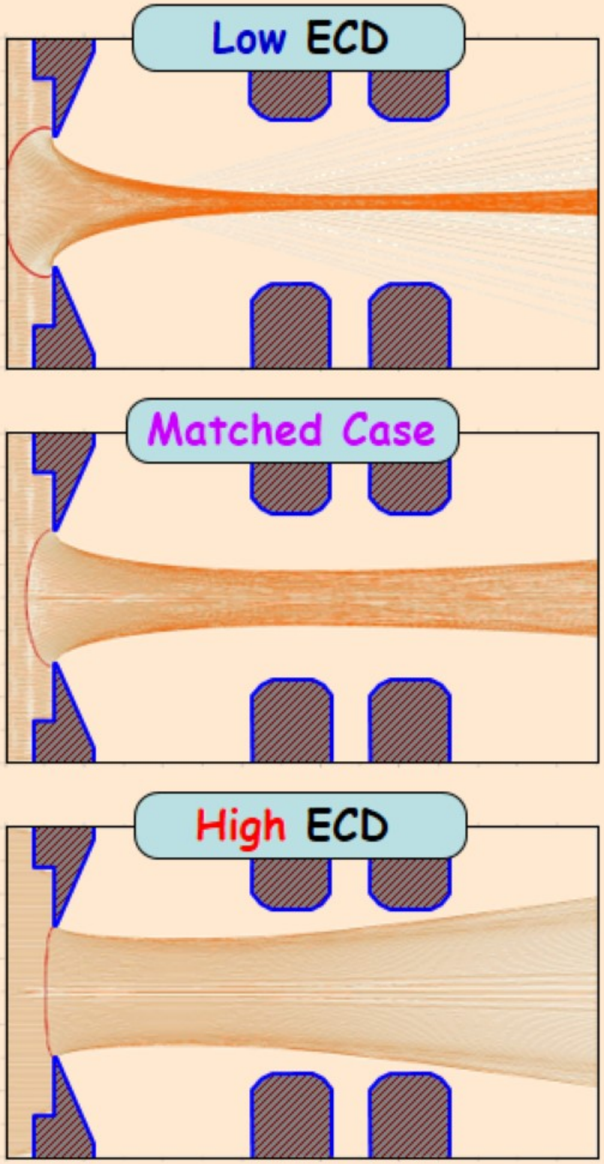
CHORDIS

Operation principle (ion production)



K. Volk

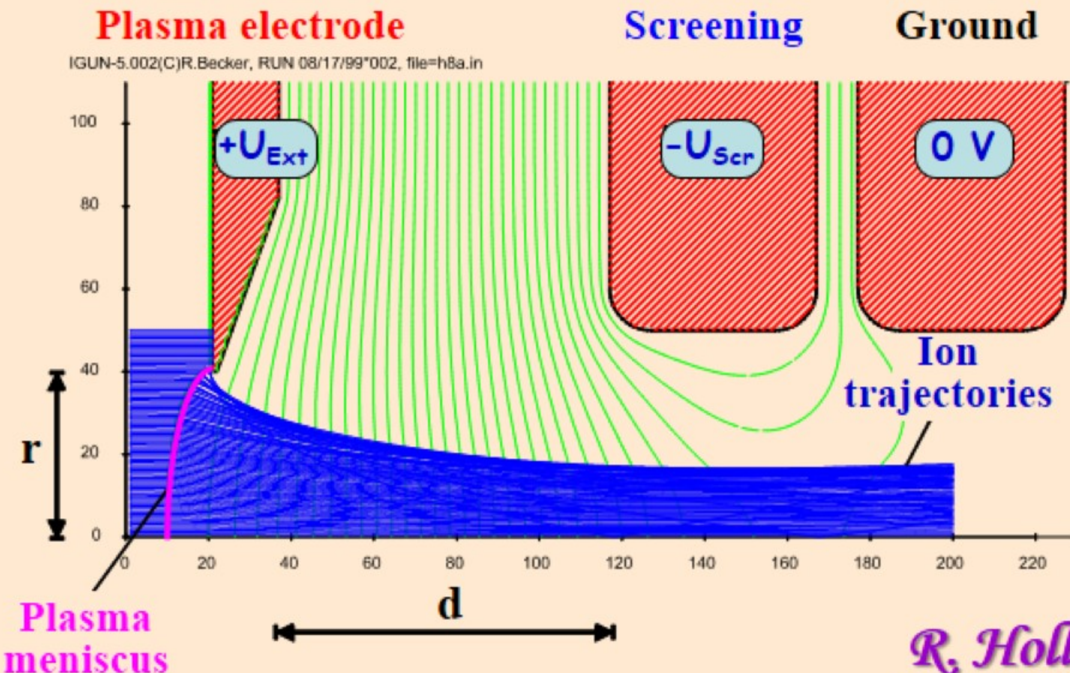
Ion Extraction



Child-Langmuir Law:

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

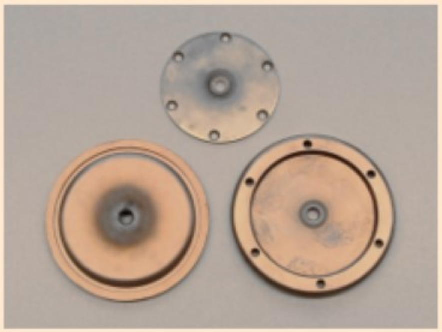
$$I_{CL} = \frac{4}{9}\pi \cdot \varepsilon_0 \cdot \sqrt{\frac{2e\zeta}{m}} \cdot S^2 \cdot U_{Ext}{}^{3/2}$$



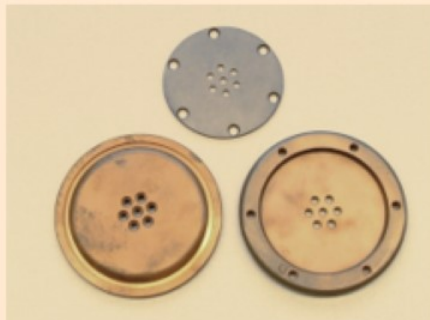
Extraction System

Triode Extraction Systems:

1 hole
ø 4÷8 mm



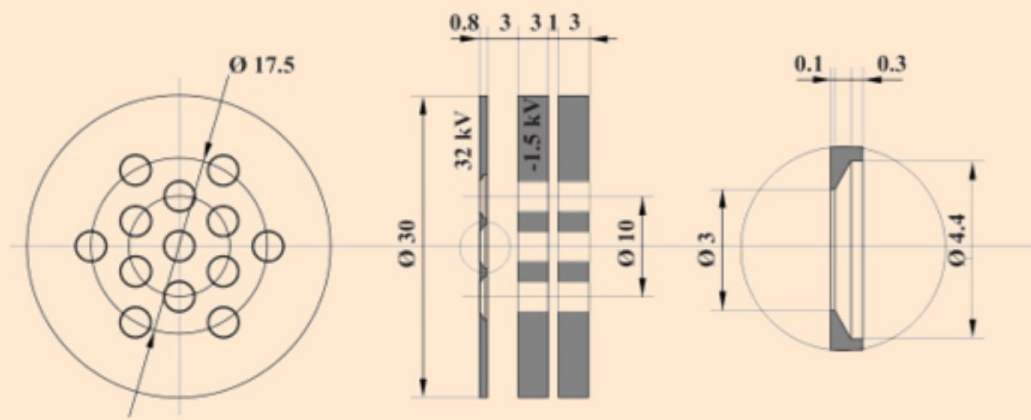
7 holes
ø 4÷6 mm



13 holes
ø 3 mm

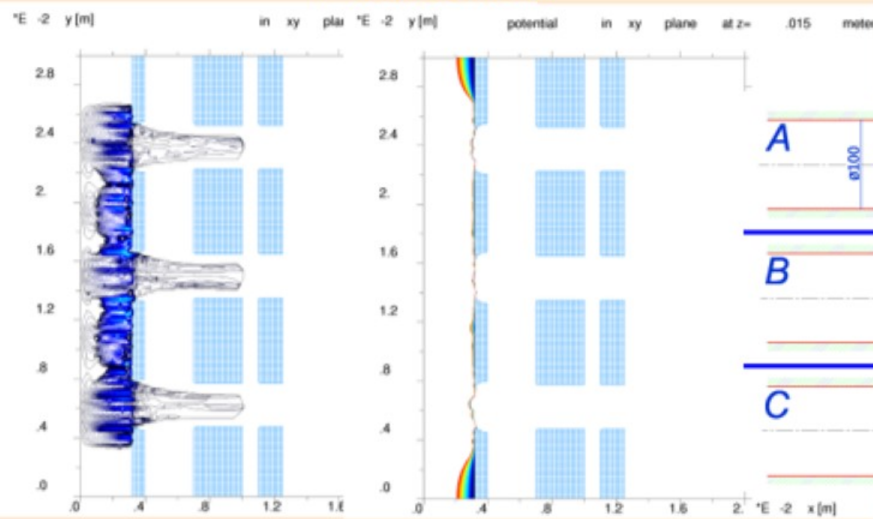
19 holes
ø 2÷3 mm

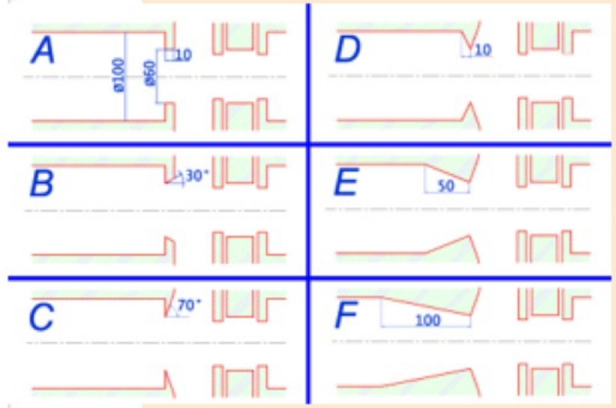
Plasma - Screening distance:	r = 3 mm
Aspect Ratio:	S = 0.5
MAX Ext. Voltage:	35 kV
Emission Area:	92 mm²



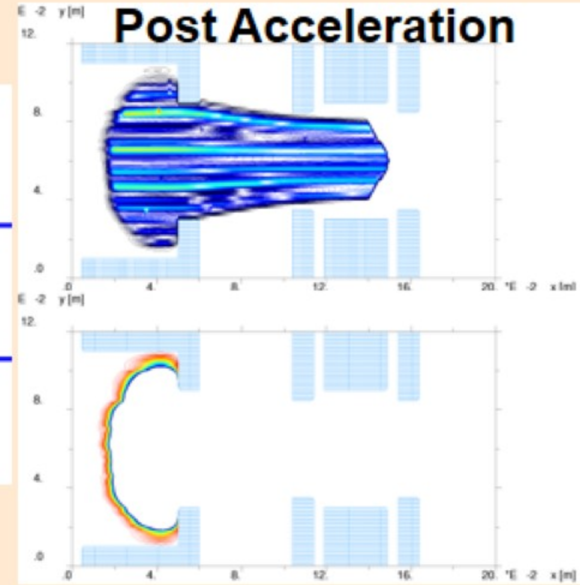
Post Acceleration, Kobra3-INP

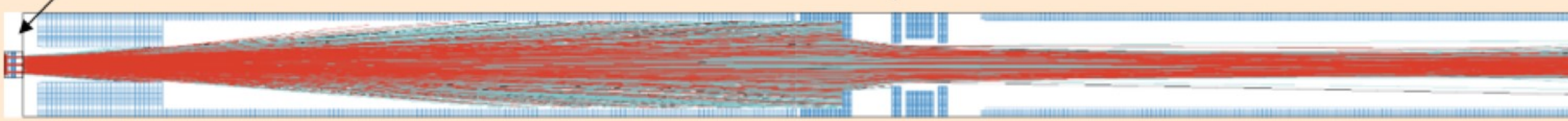
Extraction



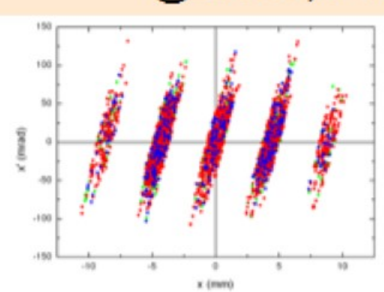


Post Acceleration

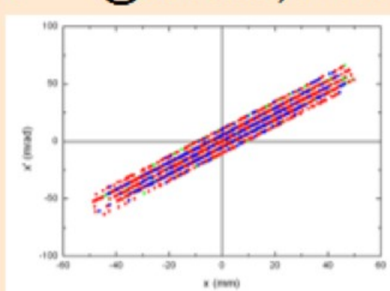




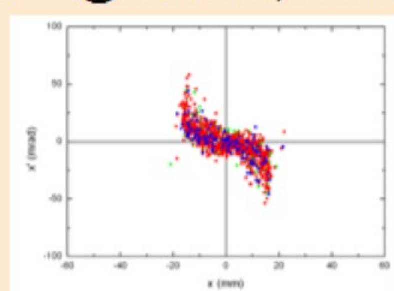
@20 mm, I=159 mA



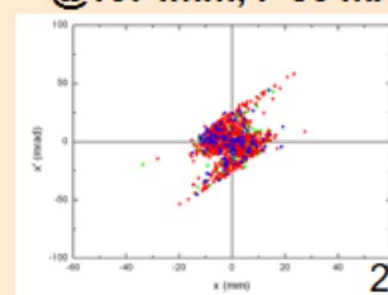
@854 mm, I=117 mA



@1054 mm, I=56 mA

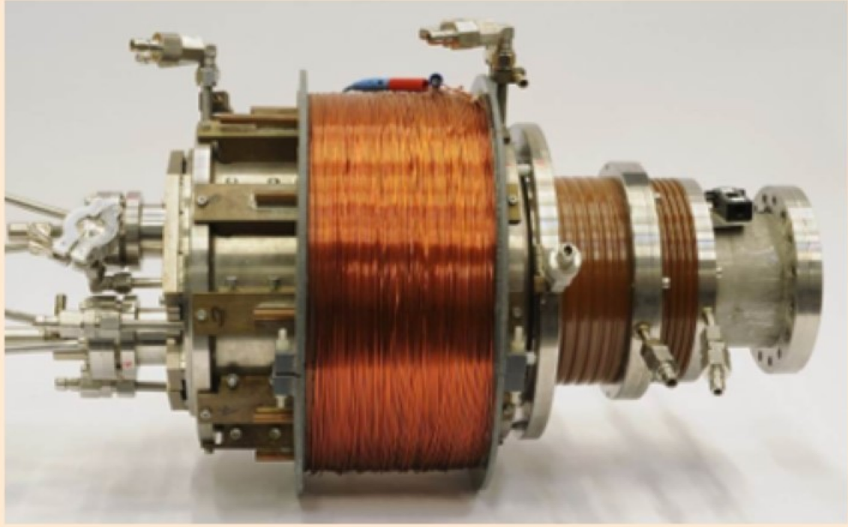


@1674mm, I=56 mA



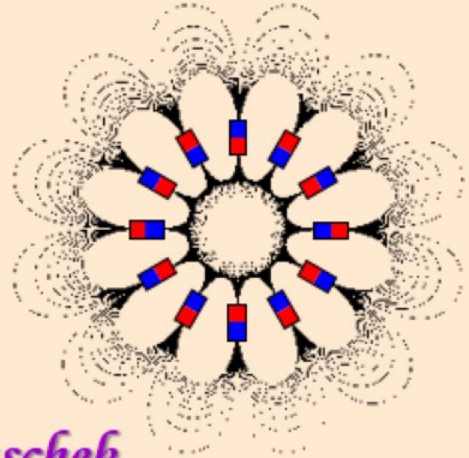
Filament driven Sources

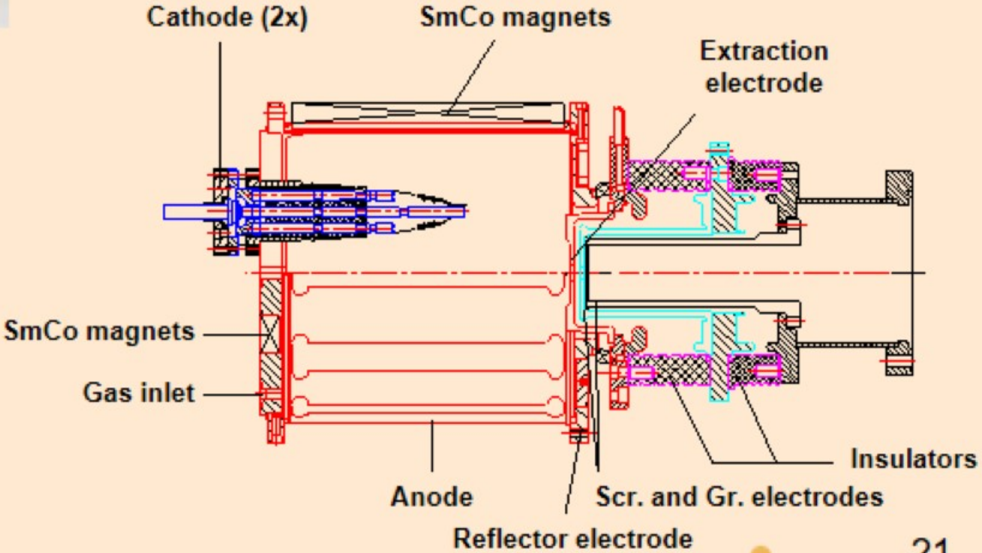
MUCIs (Multi Cusp Ion Source)



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/cm² (Argon)



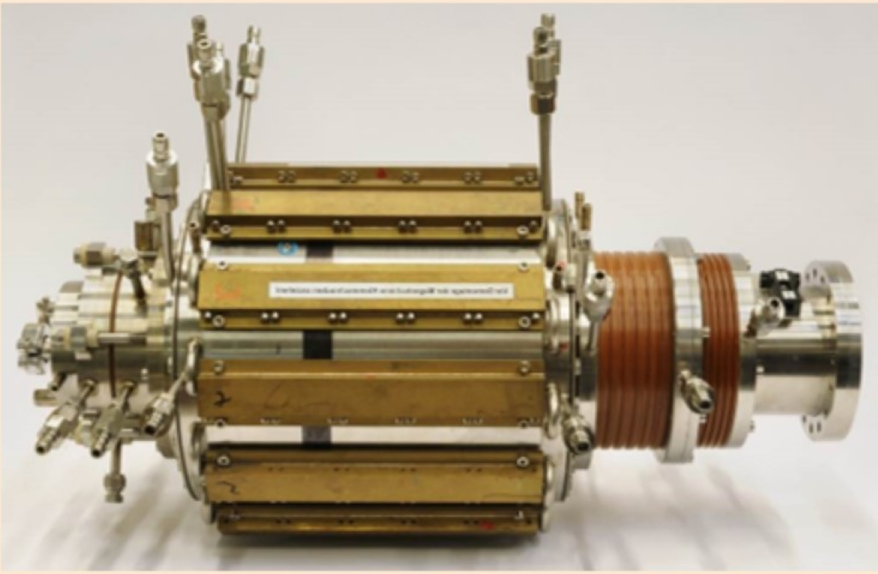


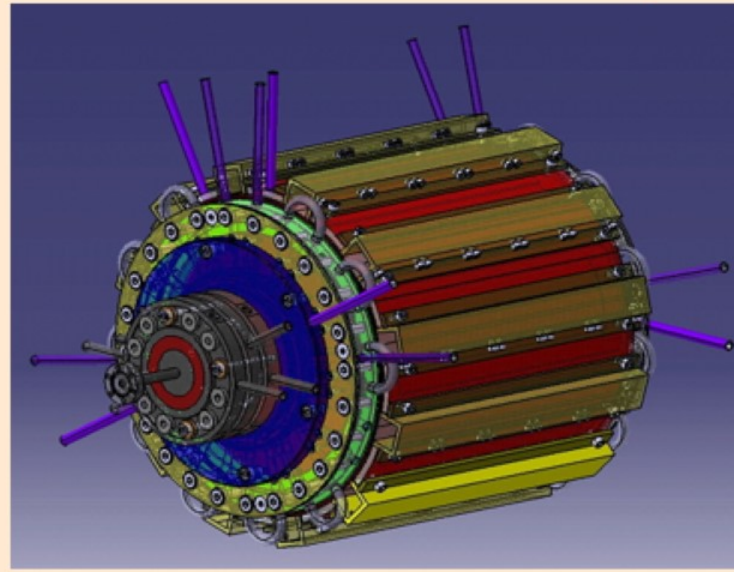
H. Wituschek

Filament driven Sources

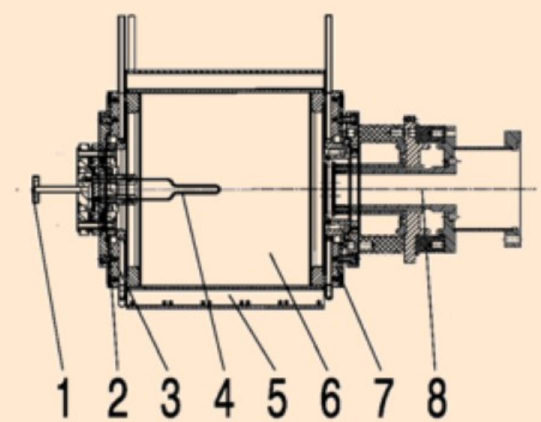
MUCIS New

R. Hollinger





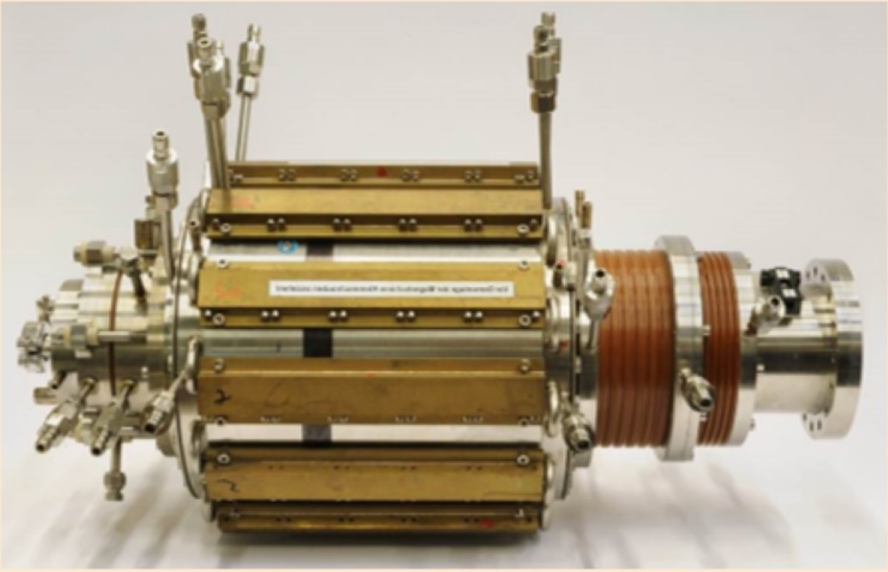
- Bigger Plasma chamber
- Improved Cooling (I_{arc} = 200A)
- Symmetrical Magnet alignment at the ends
- Halbach-alignment of the Magnets
- Optimized for highly-charged ions (Kr^{2+}, Xe^{3+})

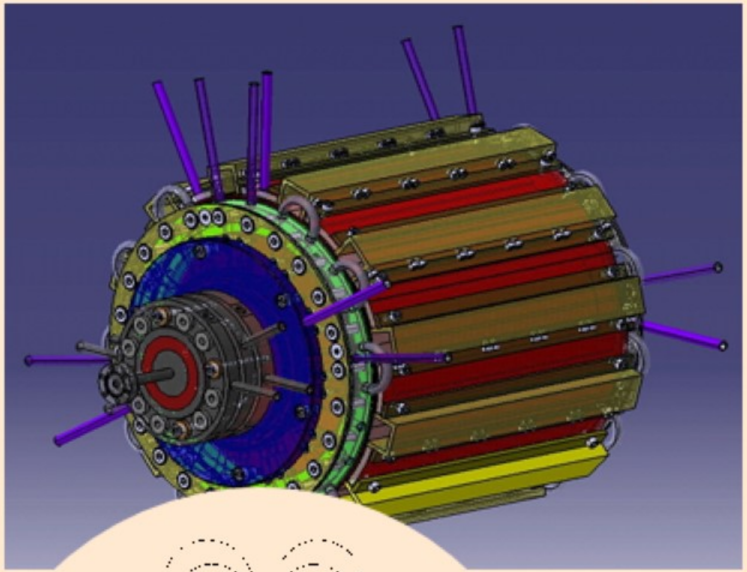


1 - Gas inlet
2 - Cooling system
3 - Cathode flange
4 - Filament
5 - Magnets
6 - Anode
7 - PE flange
8 - Triode system

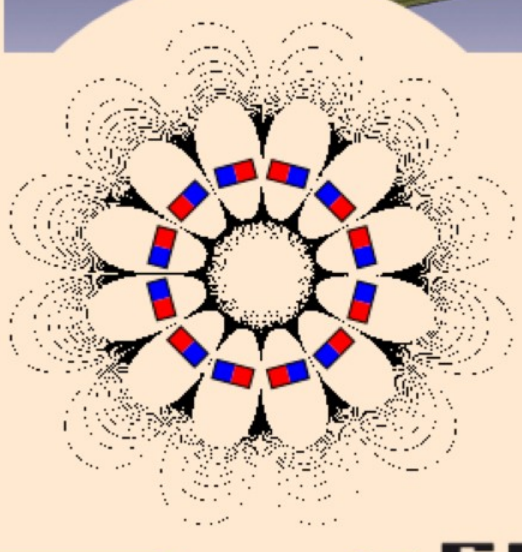
MUCIS New

R. Hollinger



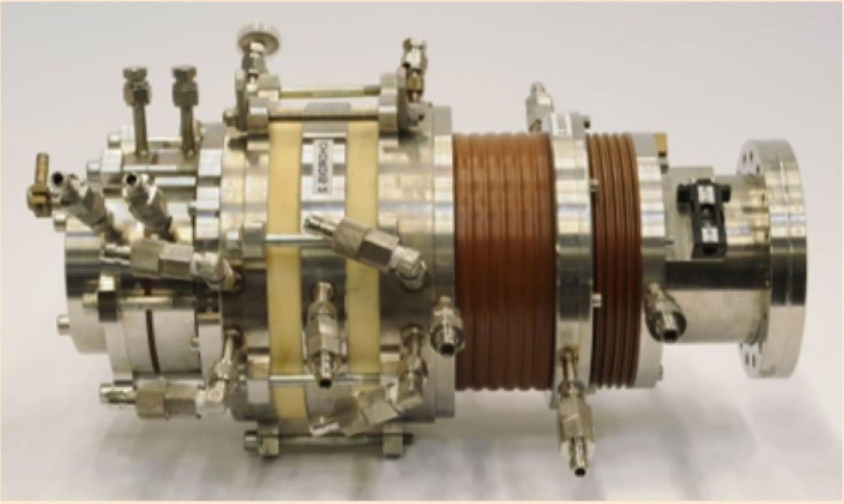


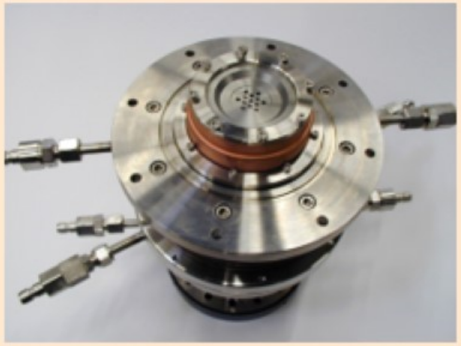
- Bigger Plasma chamber
- Improved Cooling (I_{arc} = 200A)
- Symmetrical Magnet alignment at the ends
- Halbach-alignment of the Magnets
- Optimized for highly-charged ions (Kr^{2+}, Xe^{3+})

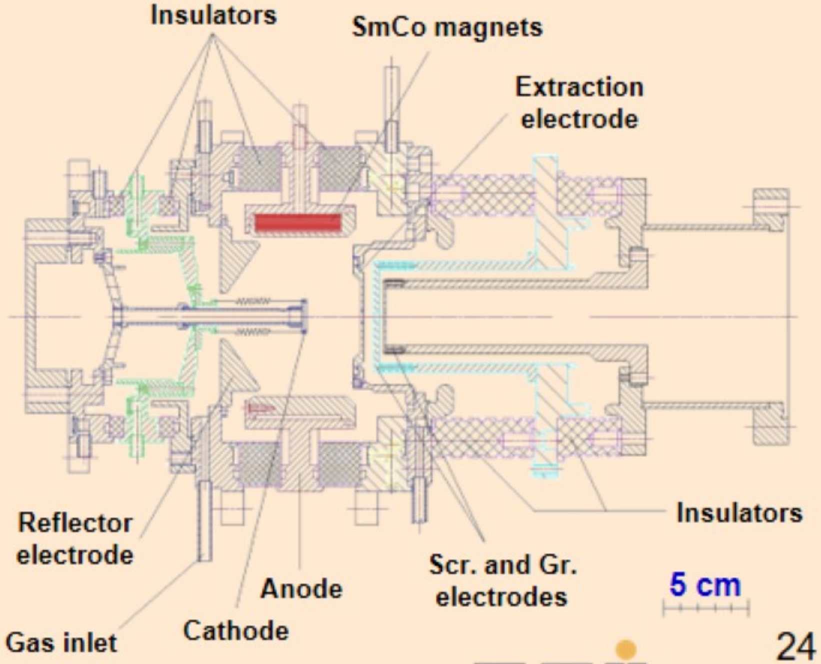


Filament driven Sources

CHORDIS (Cold or Hot Reflex Discharge Ion Source)



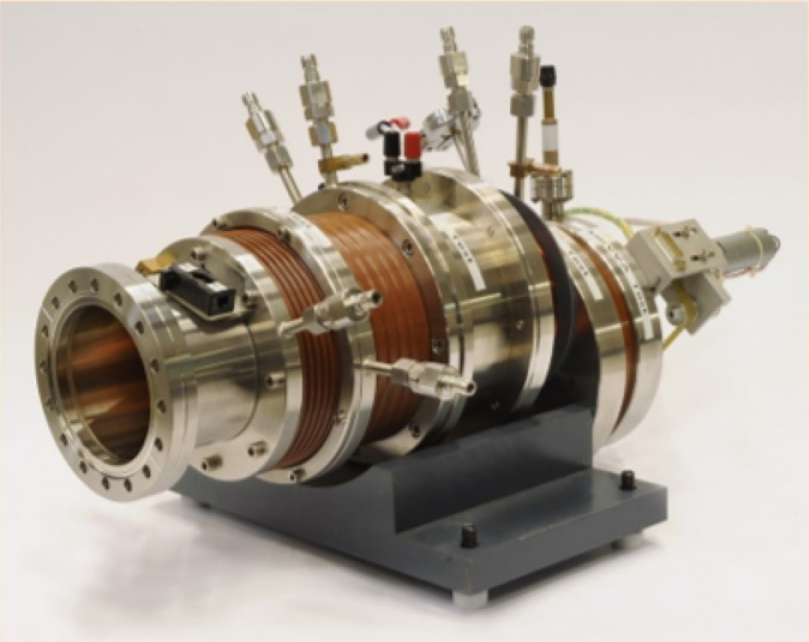




- Smaller Plasma chamber
- 20 SmCo-Magnets (2 Tesla)
- Plasma-Electrode at the Cathode potential
- Optimized for singly-charged ions

R. Keller

Vacuum Arc driven Ion Sources



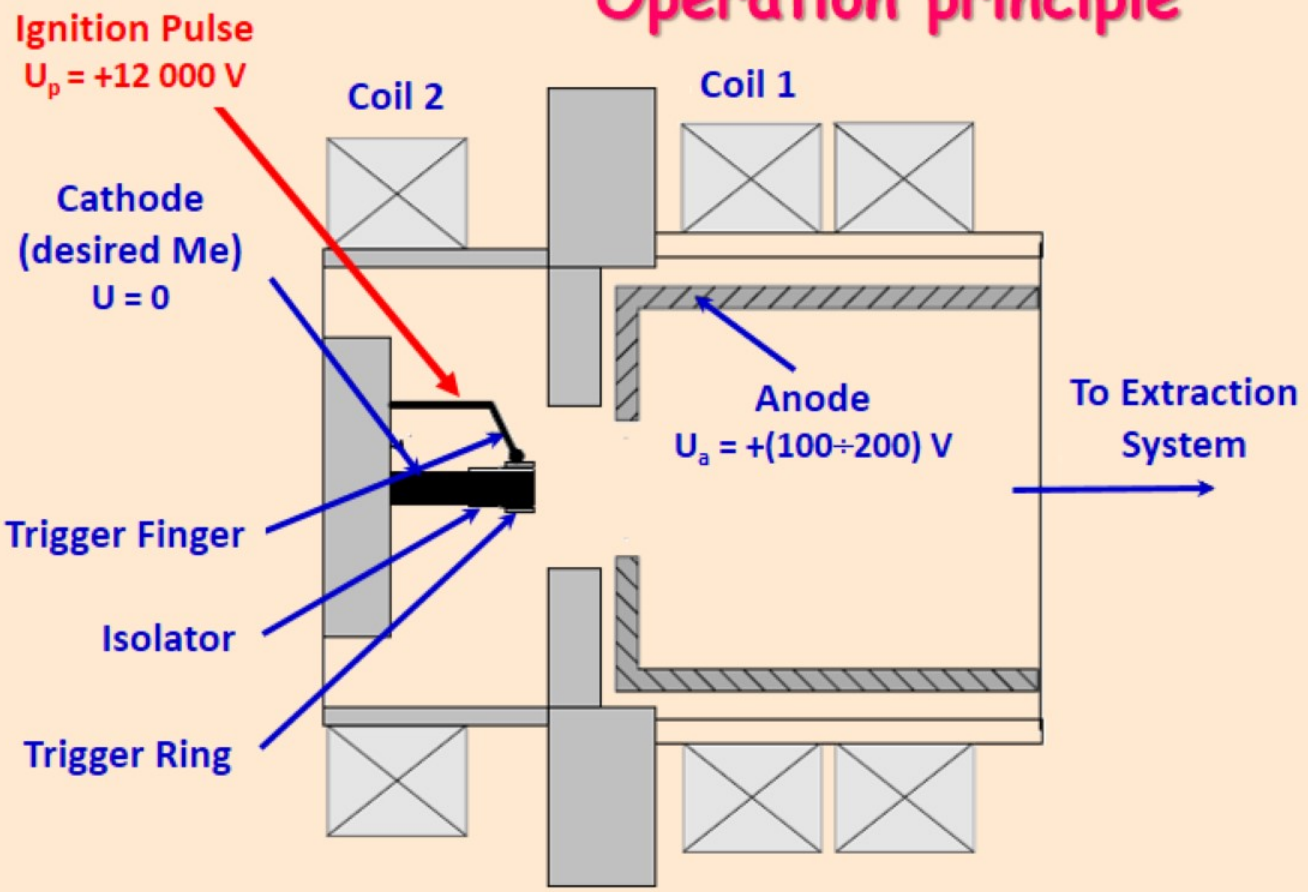
MEVVA

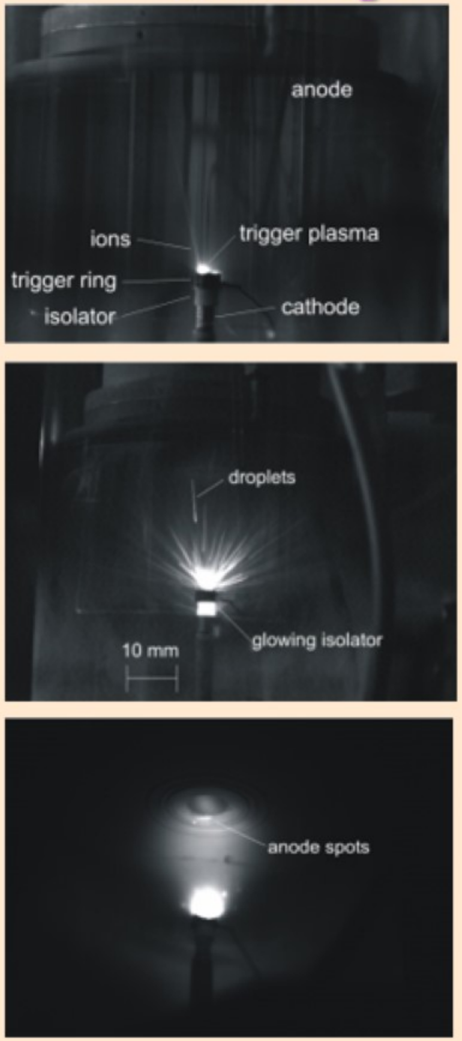
VARIS

Vacuum Arc driven Sources

Operation principle

R. Hollinger

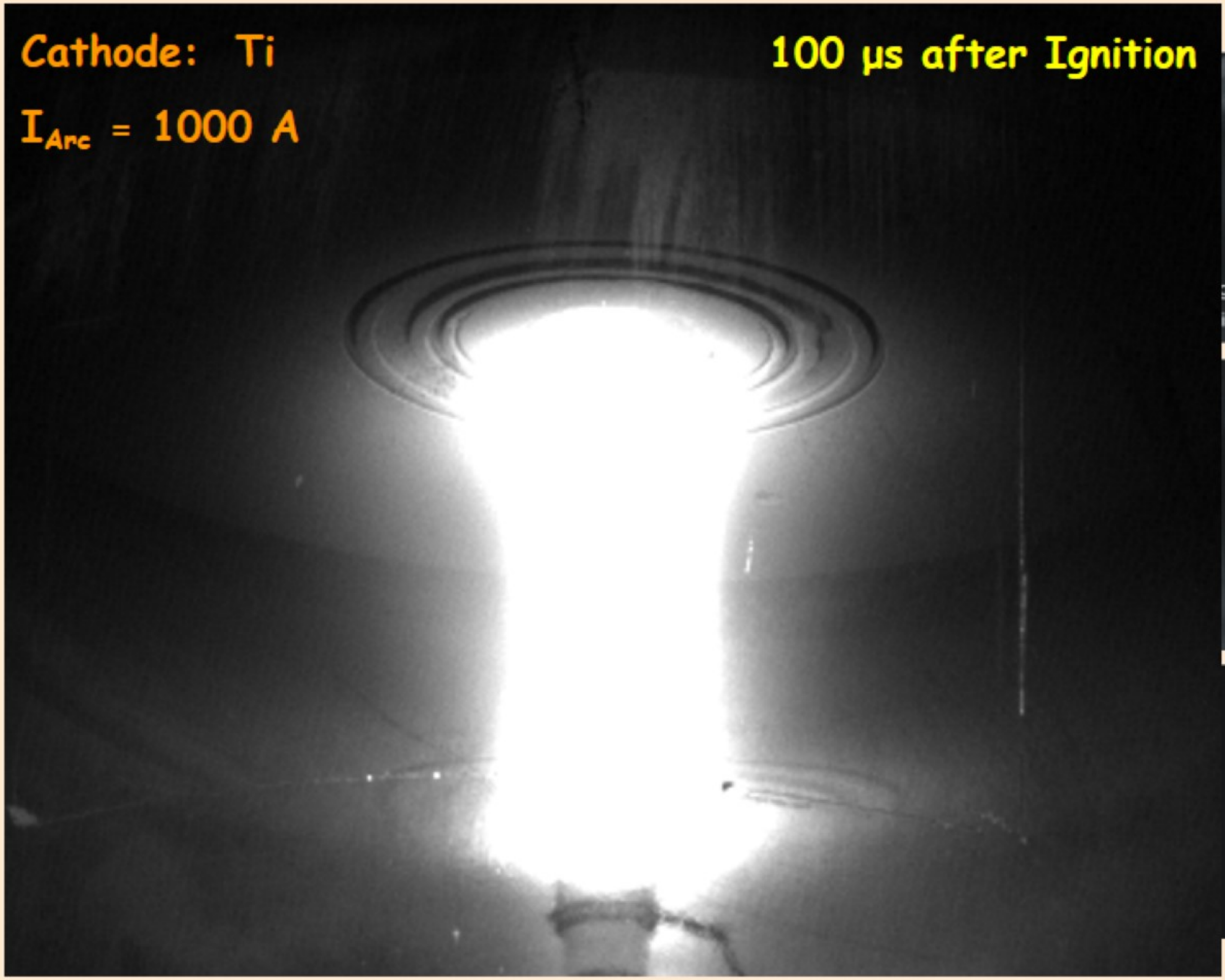




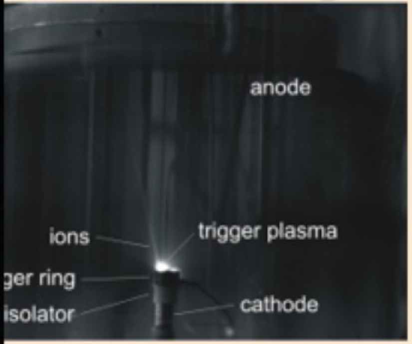
Trigger Pulse: $\tau \sim 20\ \mu s$ U = 12 kV I = 30 A

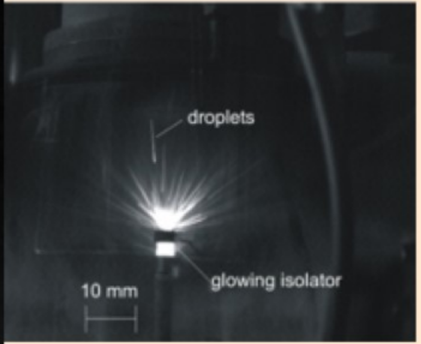
Self Pinching Effect: $I_{Arc} > 700$ A

Vacuum Arc driven Sources

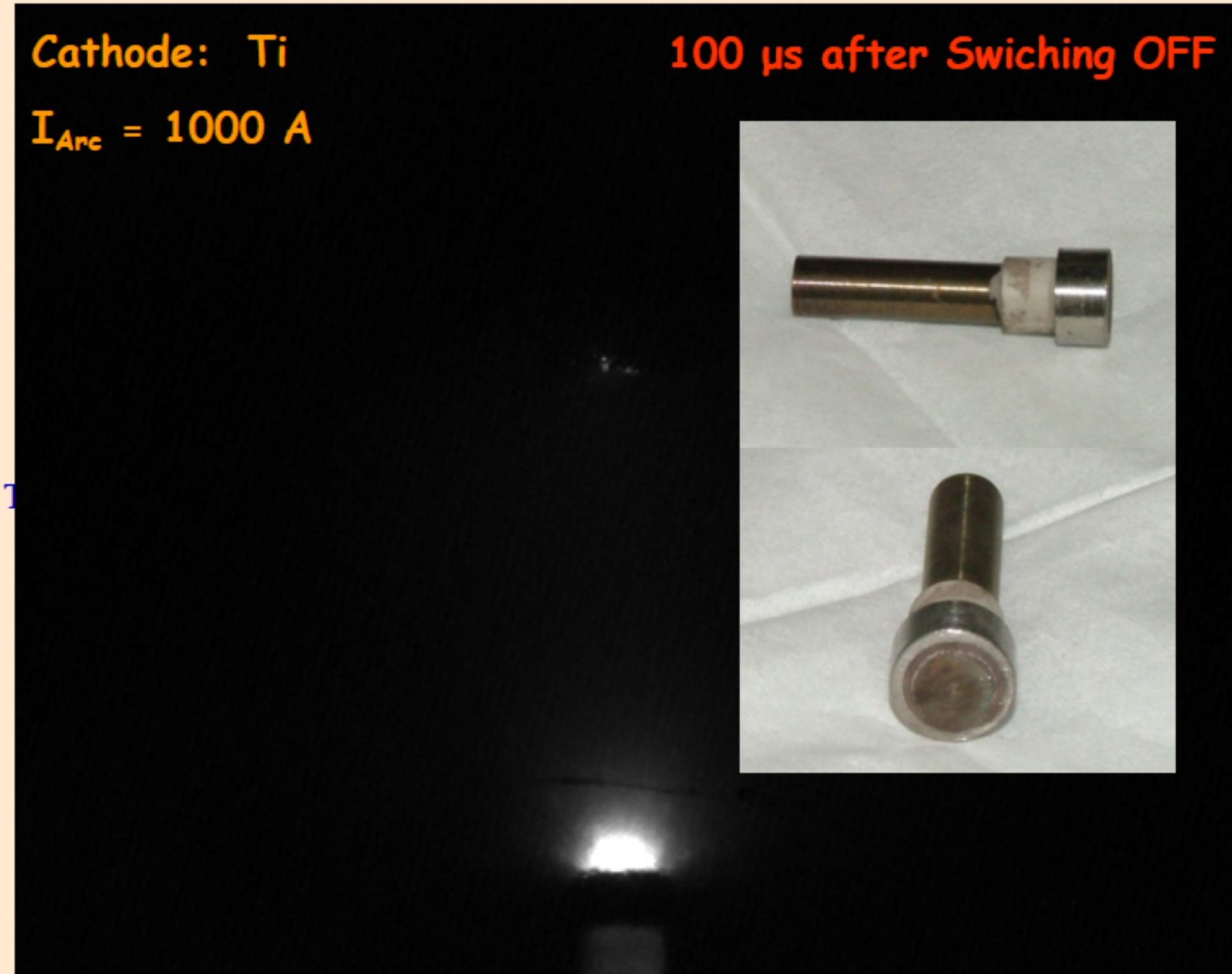


R. Hollinger

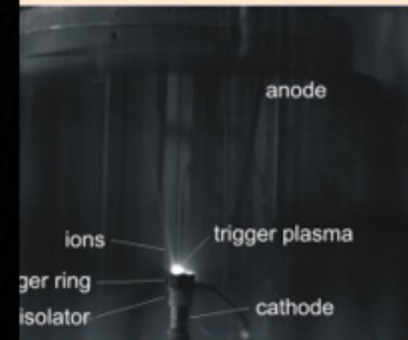


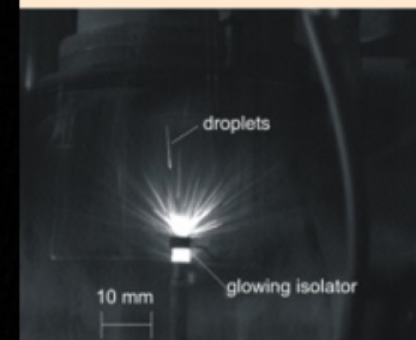


Vacuum Arc driven Sources



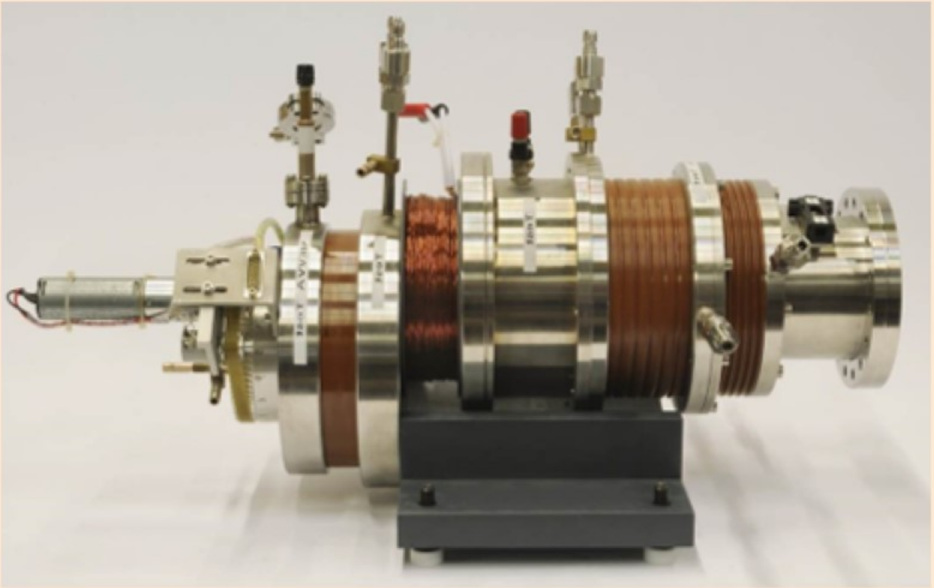
R. Hollinger



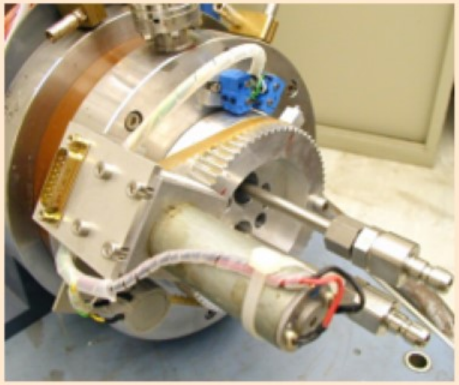


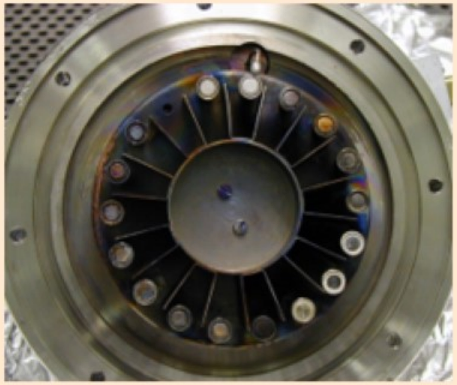
Vacuum Arc driven Sources

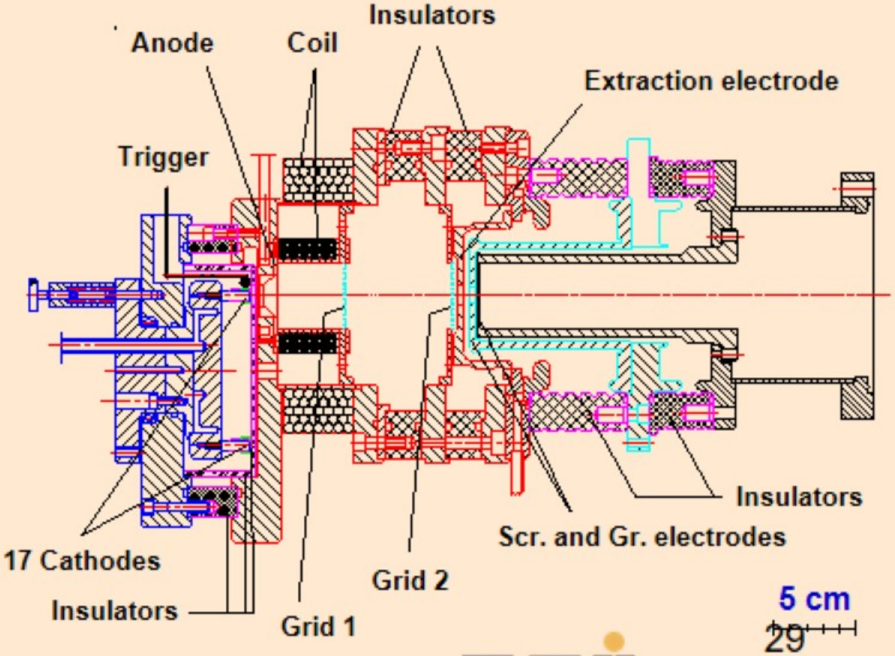
MEVVA (Metal Vapor Vacuum Arc Ion Source)



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)



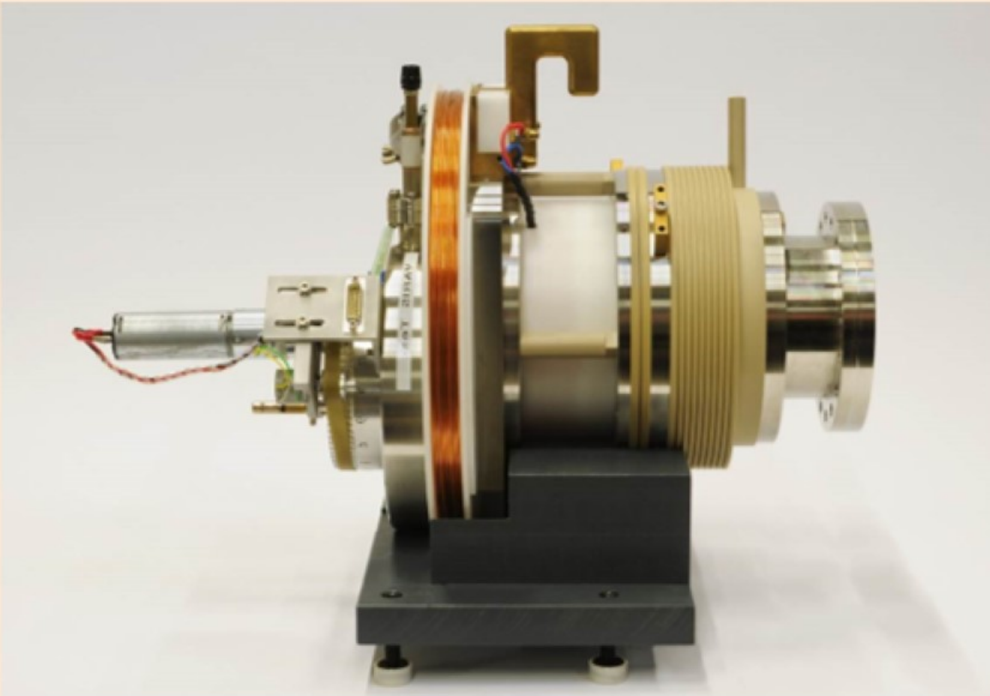




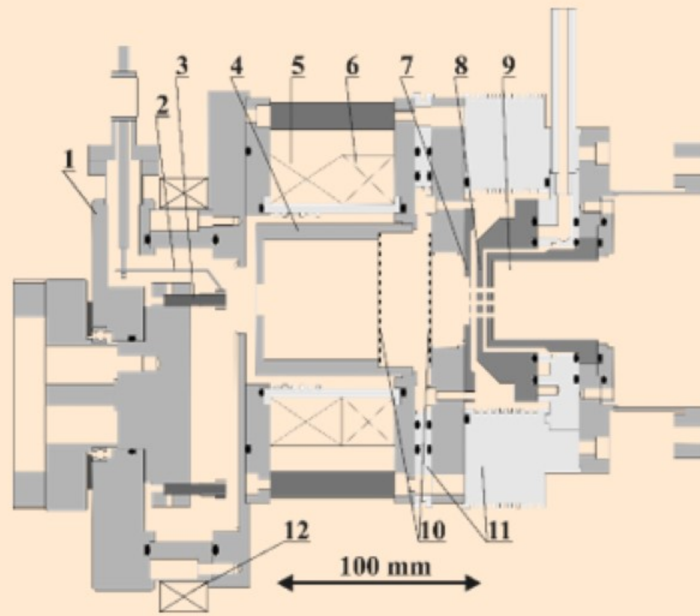
I. Brown

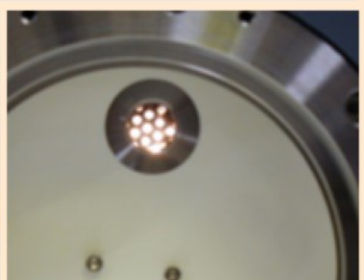
Vacuum Arc driven Sources

VARIS (Vacuum Arc Ion Source)



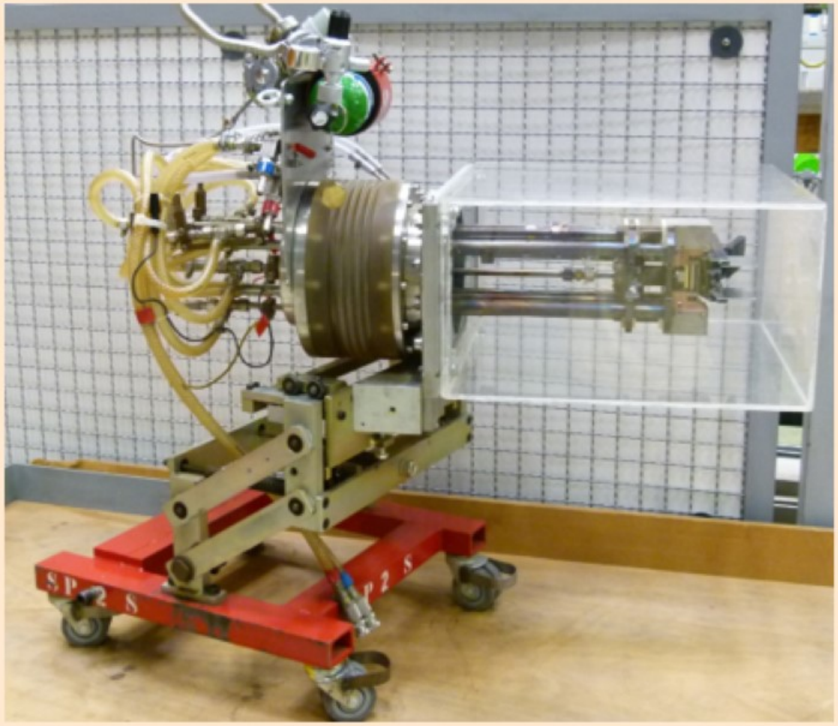
- Optimized for Uranium (67% of $^{238}U^{4+}$)
- NO water cooling necessary
- Emission current density: 170 mA/cm²
  - 156 mA @ 32 kV
  - 55 mA @ 131 kV
- Beam in front of the RFQ: 16 mA



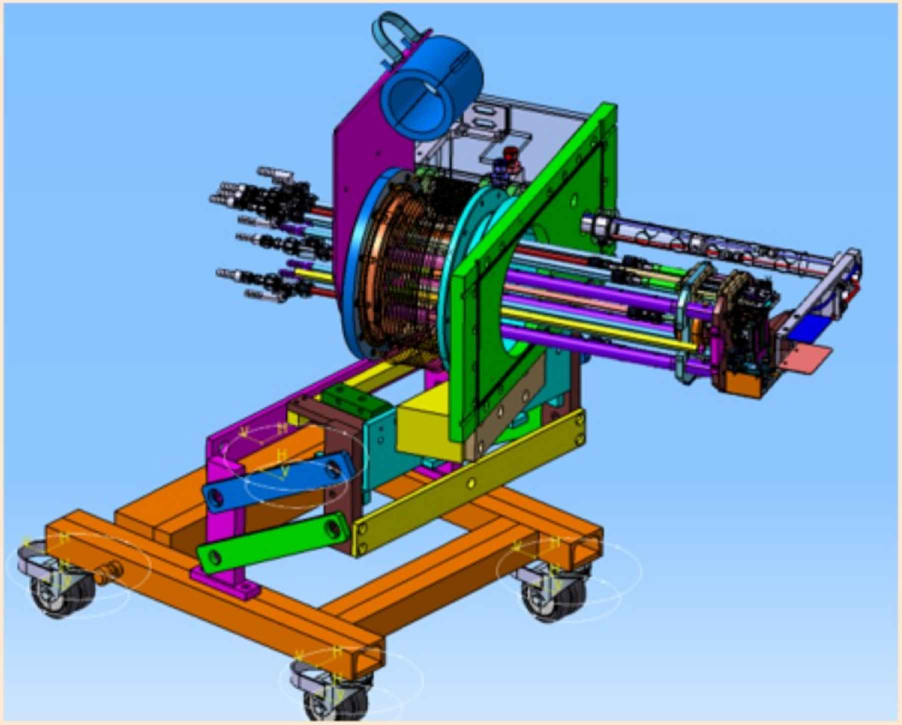


R. Hollinger

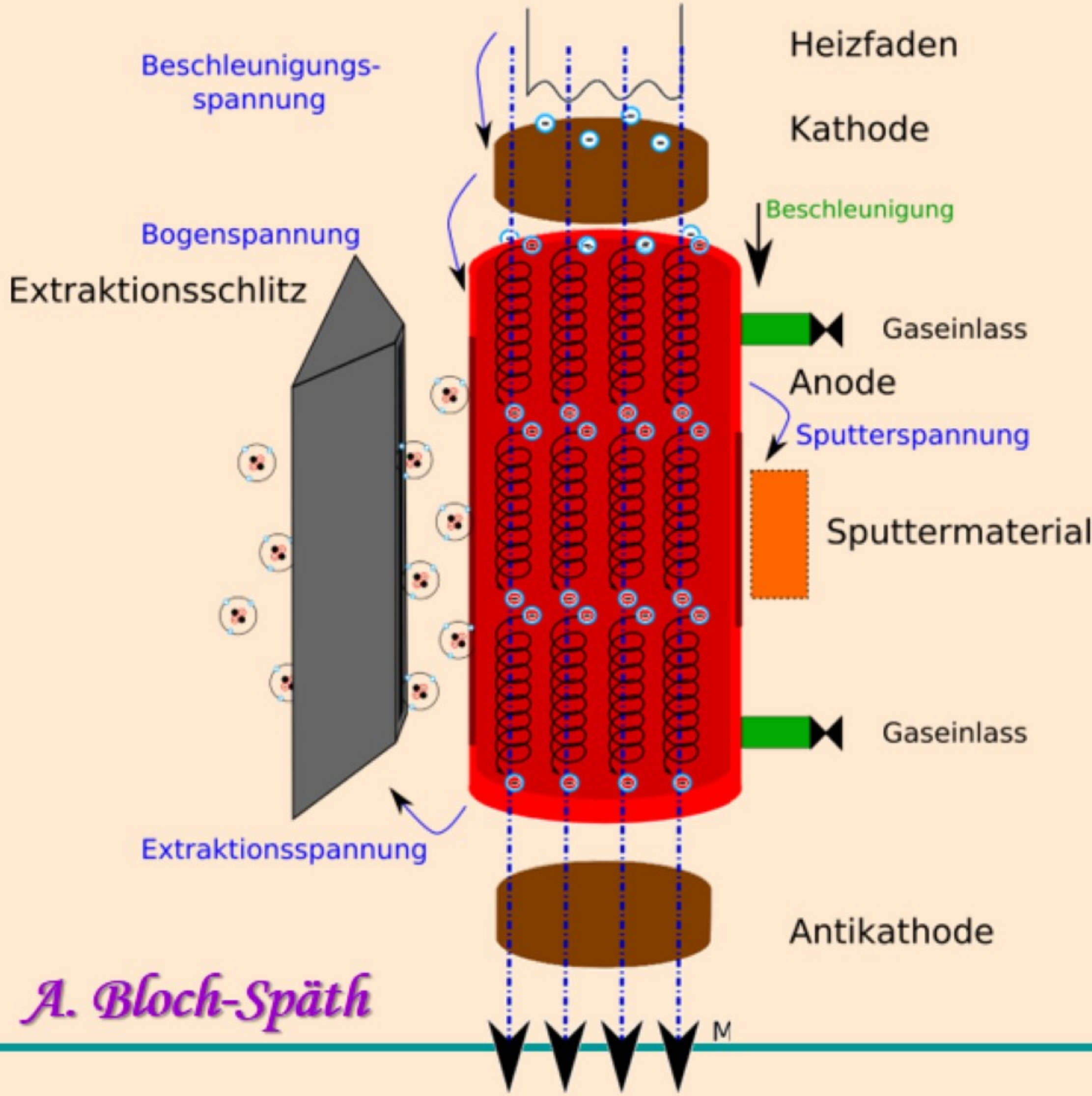
High Duty Factor Ion Source

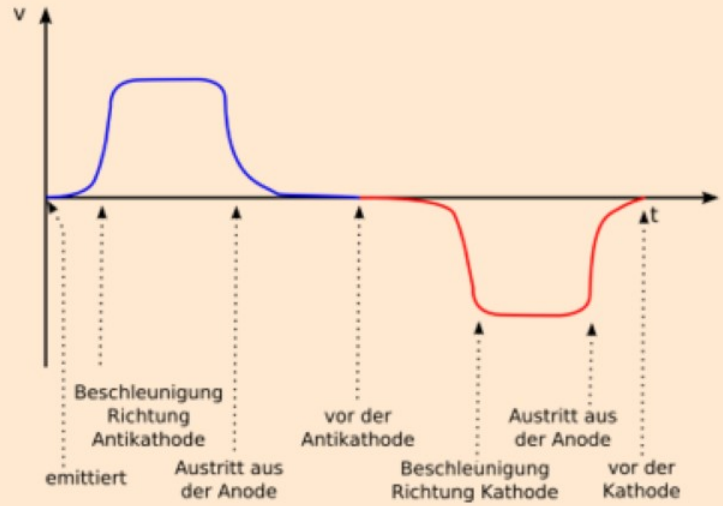


PIG



Operation principle



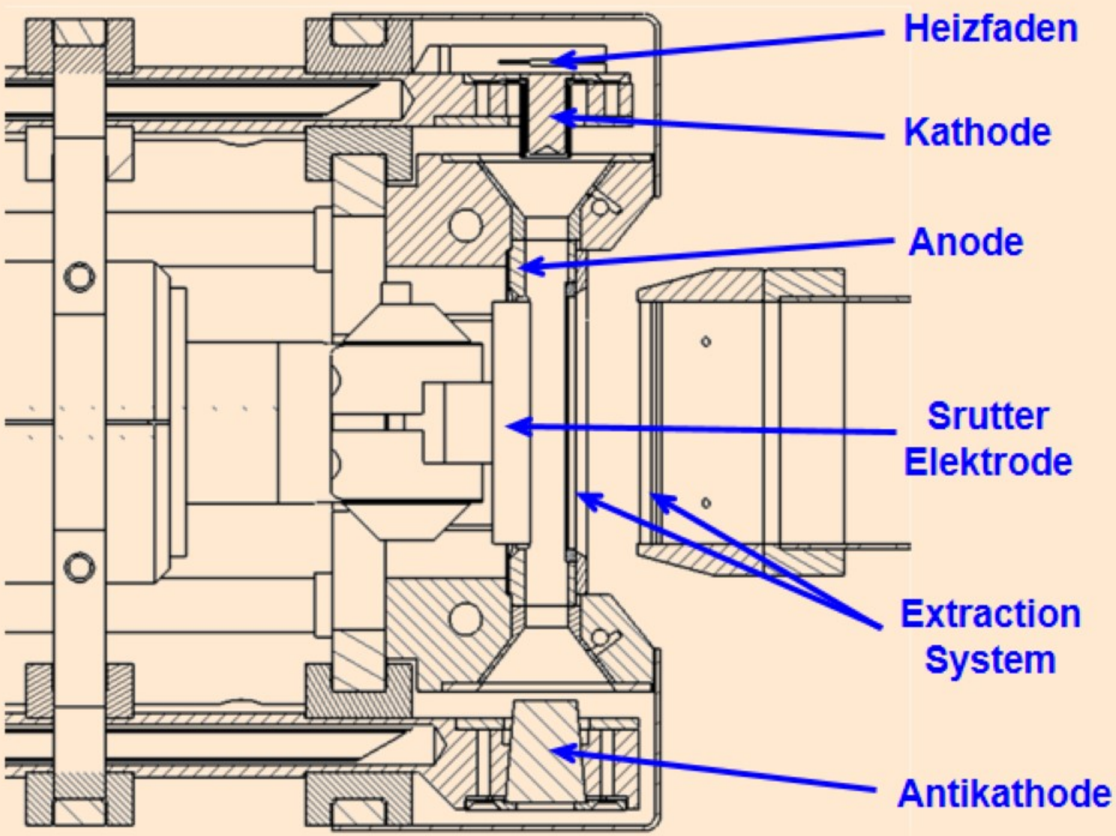


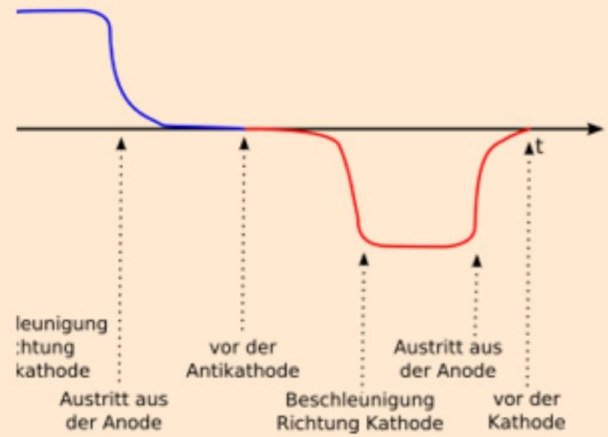
- $I_{Heizfaden}$ = 65 ÷ 75 A
- $U_{Besch.}$ = 500 ÷ 800 V
- U_{Pulser} = 1200 ÷ 2500 V
- $U_{Sputter}$ = 400 ÷ 1800 V
- $U_{Exr.}$ up to 23 kV

A. Bloch-Späth

Penning Ion Source

Operation principle

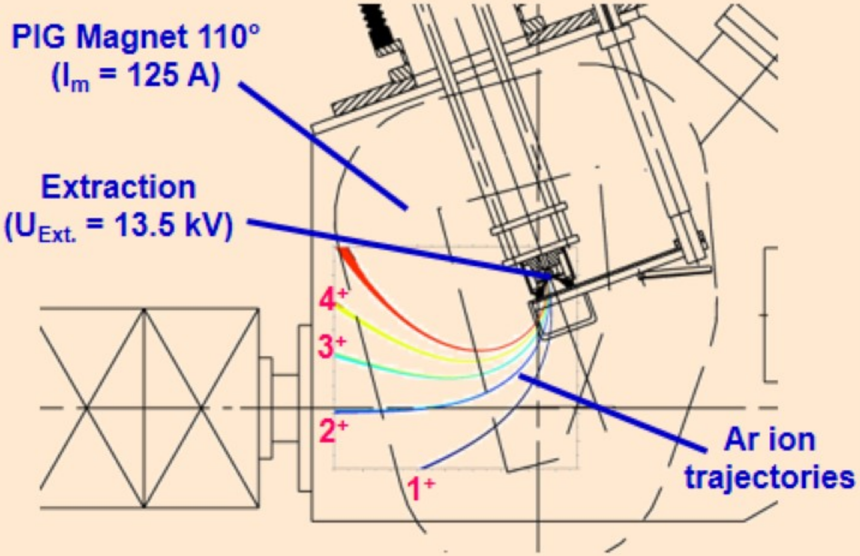


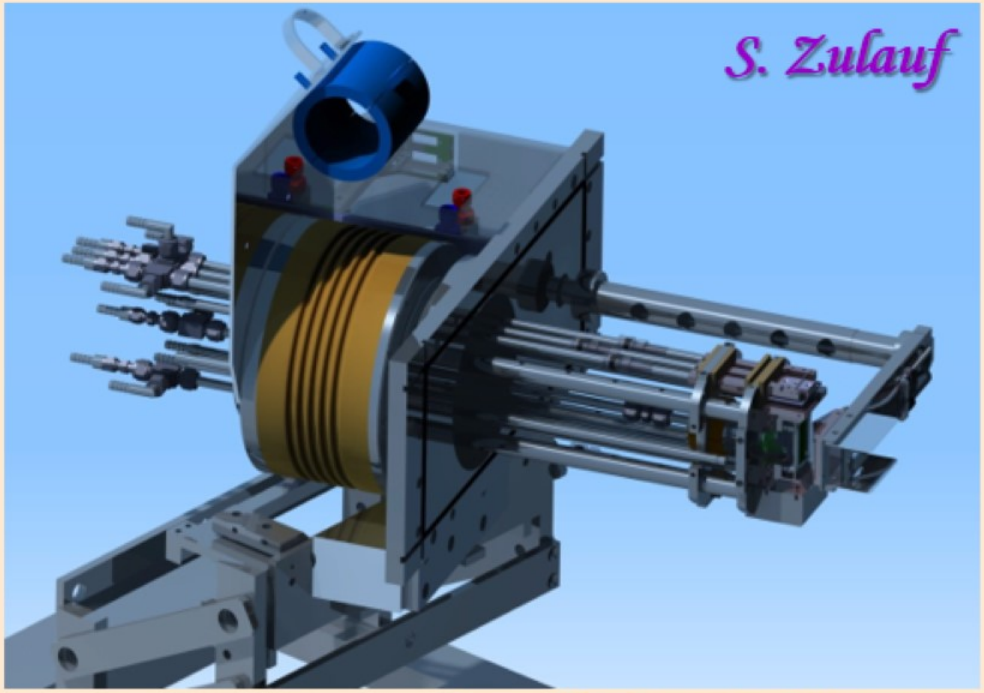


- $I_{Heizfaden} = 65 \div 75$ A
- $U_{Besch.} = 500 \div 800$ V
- $U_{Pulser} = 1200 \div 2500$ V
- $U_{Sputter} = 400 \div 1800$ V
- $U_{Exr.}$ up to 23 kV

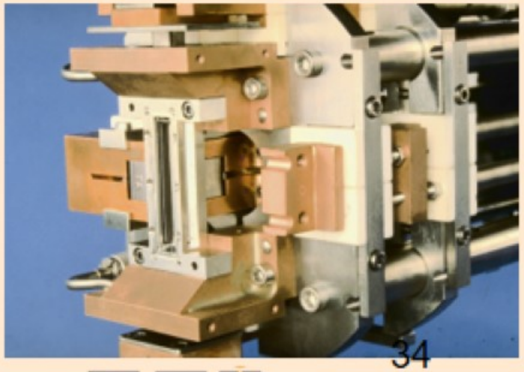
Penning Ion Source

PIG (Penning Ionization Gauge)

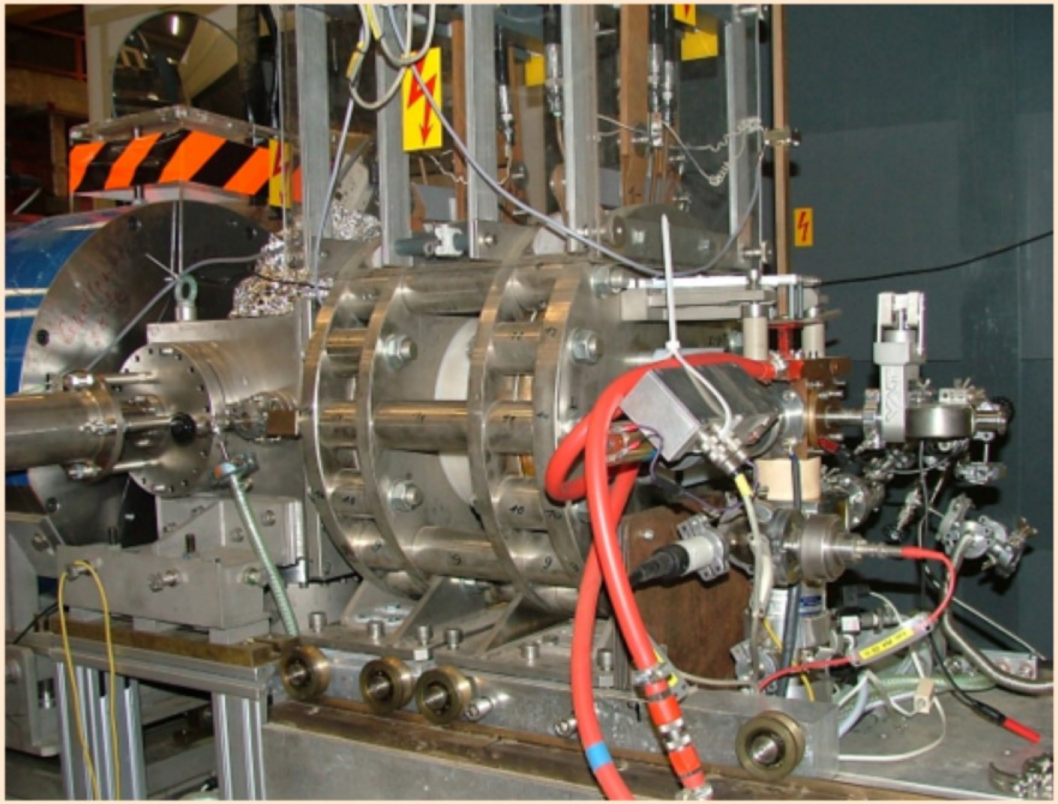




- Slit Extraction System
- Working Material:
  Gases and conductive Metals
- Duty Cycle: up to 50Hz / 5ms
- Emission Current Density:
  up to 100 mA/cm²
- Charge State: 1+...10+



High Charge State Ion Source



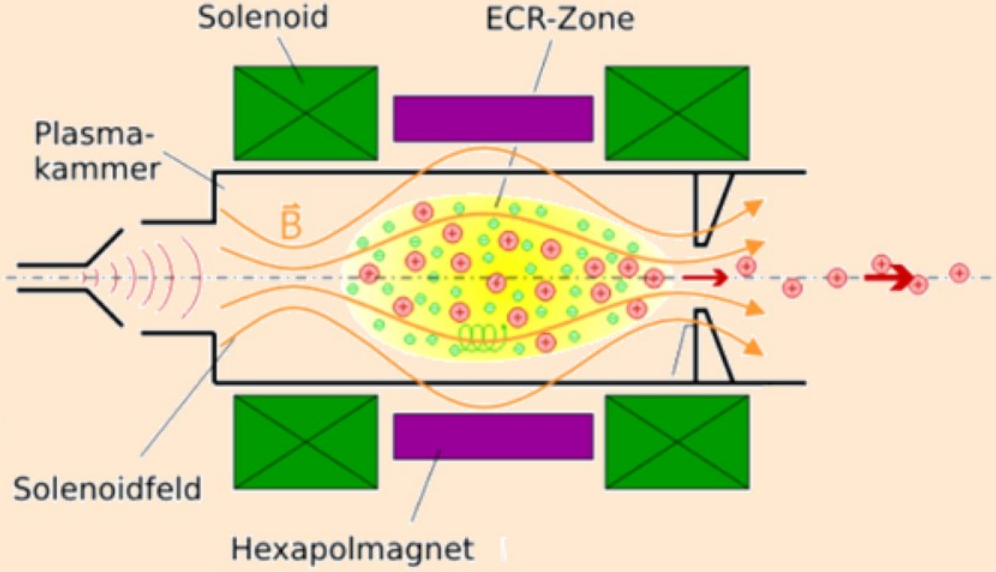
ECR

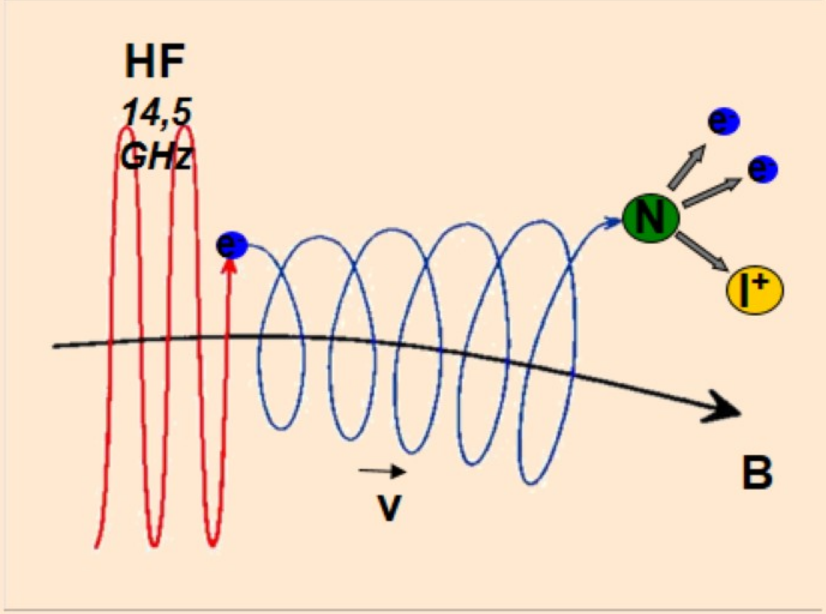
R. Geller

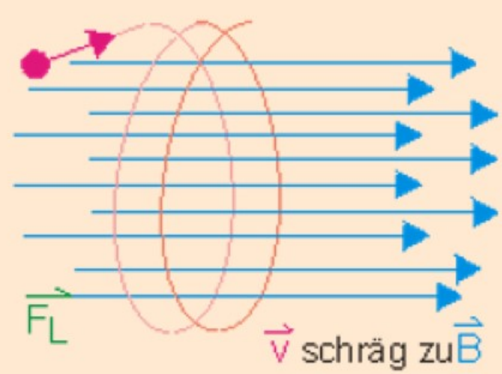
Operation principle

ECR: $$\omega_{HF} = \omega_{Cyc} = B \cdot \frac{e}{m}$$

For ω_{HF} = 14.5 GHz there is a Resonance Field of B = 0.52 T



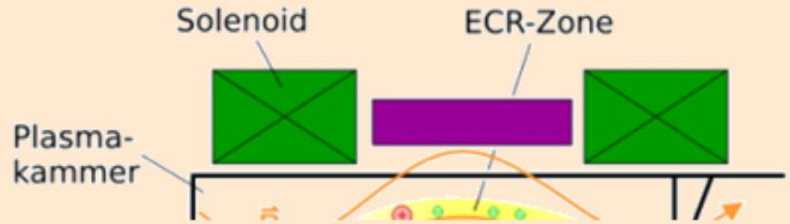




R. Geller

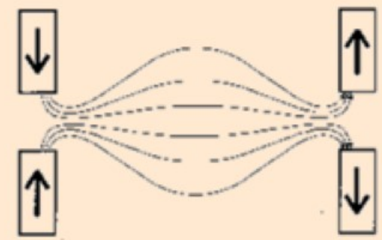
Operation principle

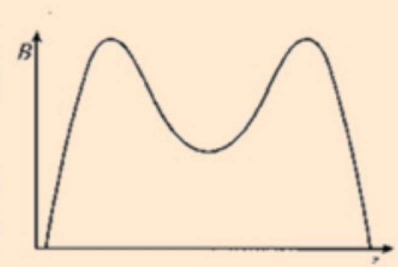
ECR: $\omega_{HF} = \omega_{Cyc} = B \cdot \frac{e}{m}$



Longitudinal confinement

magnetic mirror field



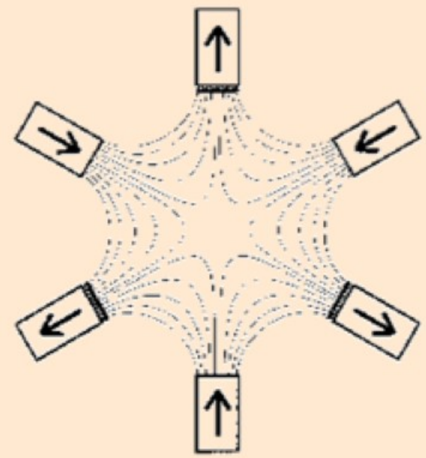


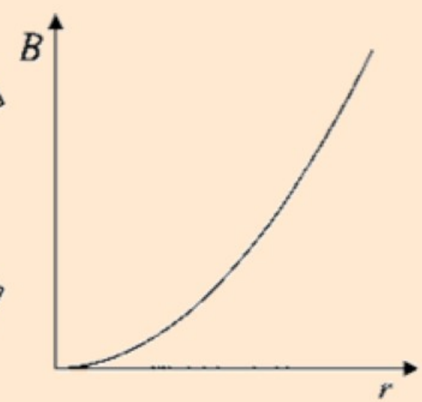
Radial confinement

magnetic multipole field:

quadrupole, hexapole,

octupole, decapole ...





Complex resulting field:

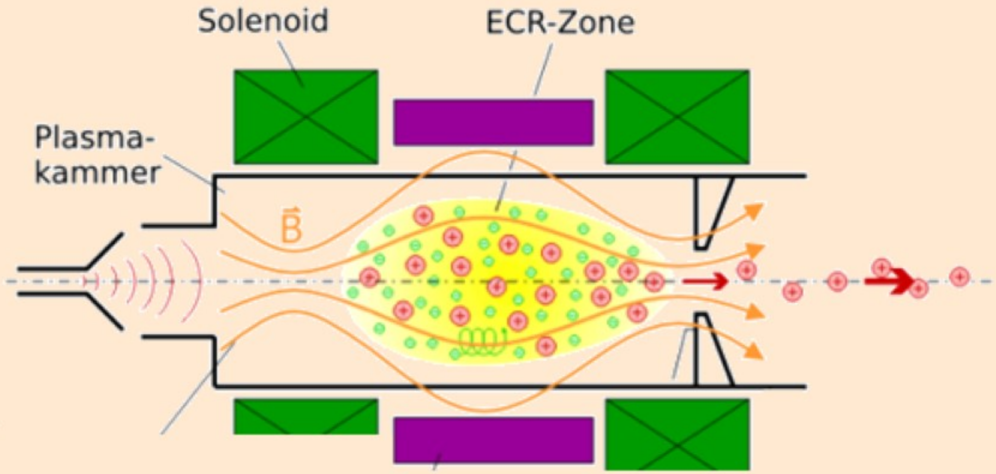
superposition of mirror + multipole

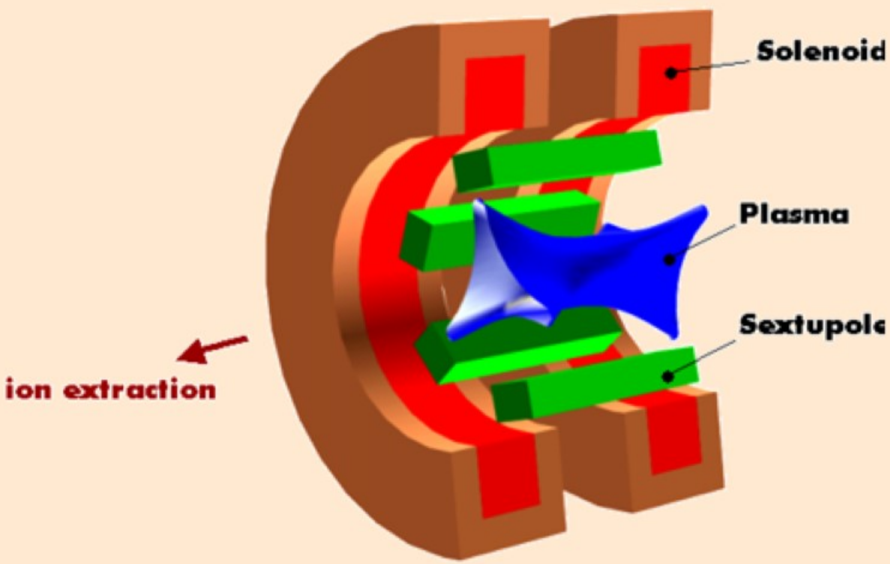
R. Geller

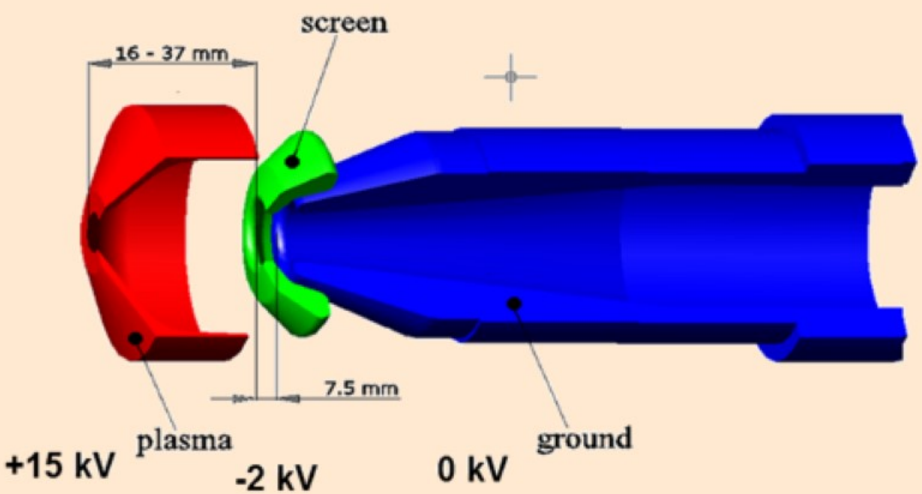
Operation principle

ECR: $\omega_{HF} = \omega_{Cyc} = B \cdot \frac{e}{m}$

For ω_{HF} = 14.5 GHz there is a Resonance Field of B = 0.52 T

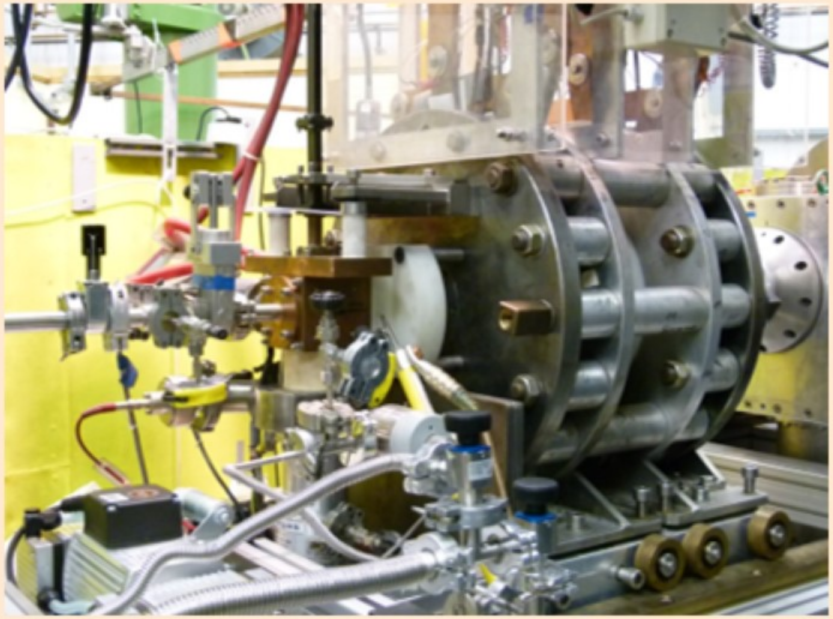




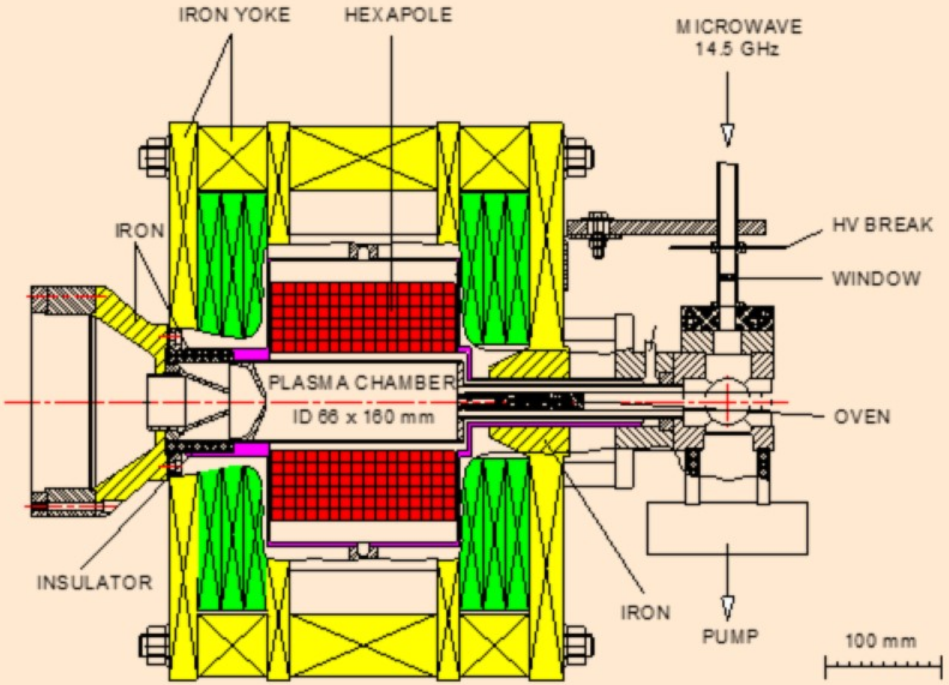


ECR Ion Source

ECRIS (Electron Cyclotron Resonance Ion Source)



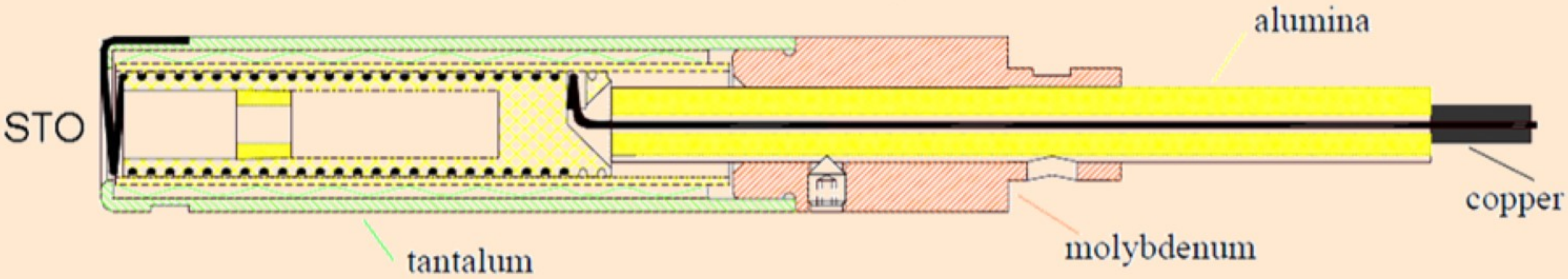
- Gas consumption: 1 scm^3/h
- Current density: 1 mA/cm^2
- Electron energies: several 100 keV

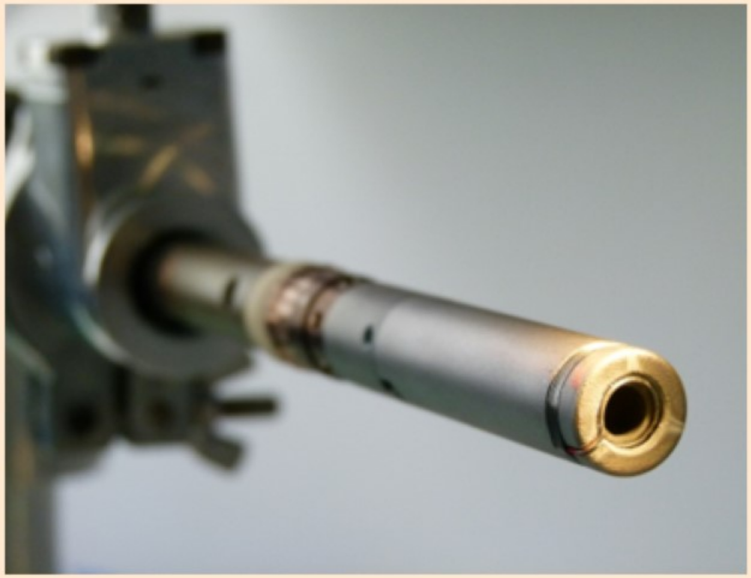


- Hexapole field: 1 ÷ 1.2 T
- Solenoid field: 0.8 ÷ 1.4 T
- μW-Power: 50 ÷ 700 W (CW)
- μW-Frequency: 14.5 GHz
- Gas pressure: $10^{-6} \div 10^{-4}$ mbar

K. Tinschert

Oven (for Me operation)





Setup:

- Central connection for current lead
- Heating helix on ceramic body
- Water cooled translation rod

Operation:

- Electric power: 20 ÷ 120 W
- Temperature: 400 ÷ 1550 °C
- Material consumption: 0.2 ÷ 5 mg/h

R. Lang

Features of ECRIS:

- no filaments → reduced maintenance
- effective thermal evaporation of Me-elements → long lifetime
- low material consumption → high efficiency
- long ion confinement times → high charge states accessible
- high charge states → injection into LINAC without PA
- CW operation → no limitation of duty cycle

As a conclusion...


MUCIS

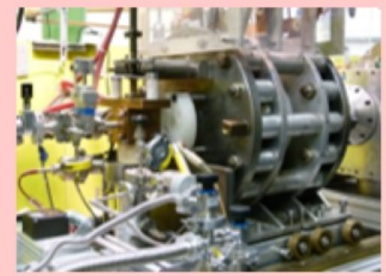

MUCIS New


CHORDIS


MEVVA


VARIS


PIG


ECR