The 13th ICFA Beam Dynamics Mini-Workshop

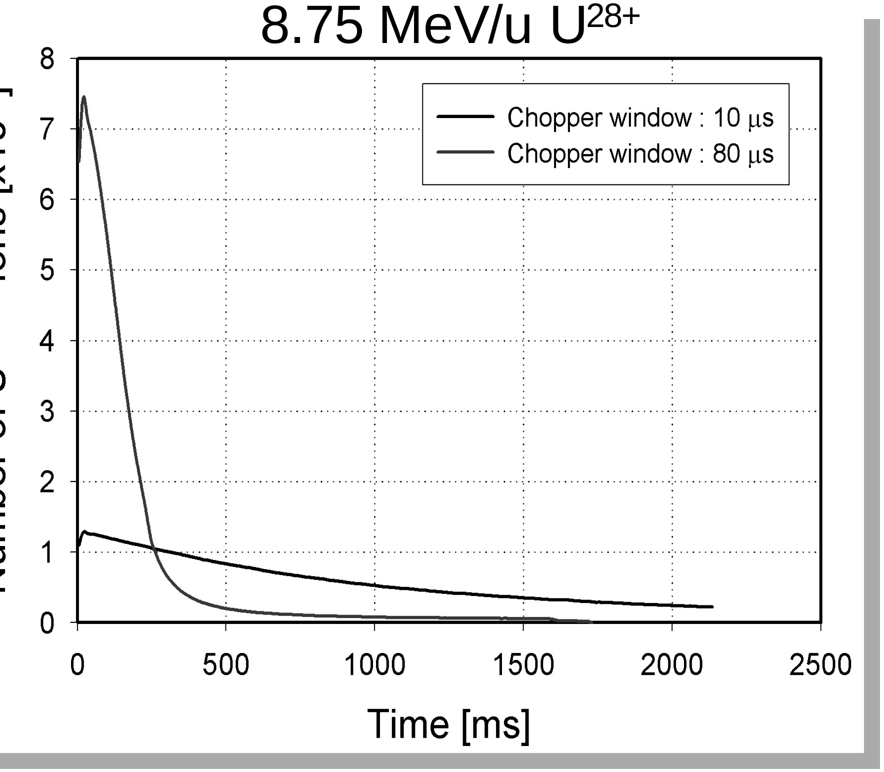
Beam Induced Pressure Rise in Rings

Brookhaven National Laboratory, Upton, NY

December 9 - 12, 2003

Dynamic Vacuum and Beam Lifetime

P. Spiller, December 2001



Desorption processes degenerate the residu gas pressure.

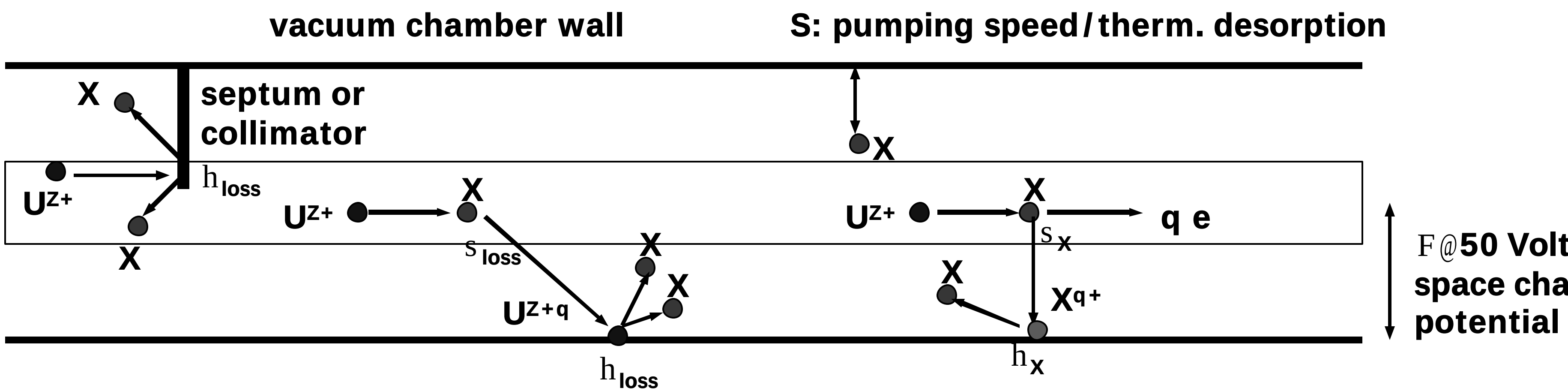
Initiated by:

- Systematic beam losses on acceptance limiting devices (septa)
- Stripped beam ions
- Ionized and accelerated residual gas

Beam losses increase with number of injected ions

(shorter beam life time due to stronger pressure bumps)

Desorption Processes in SIS18



beam loss induced desorption

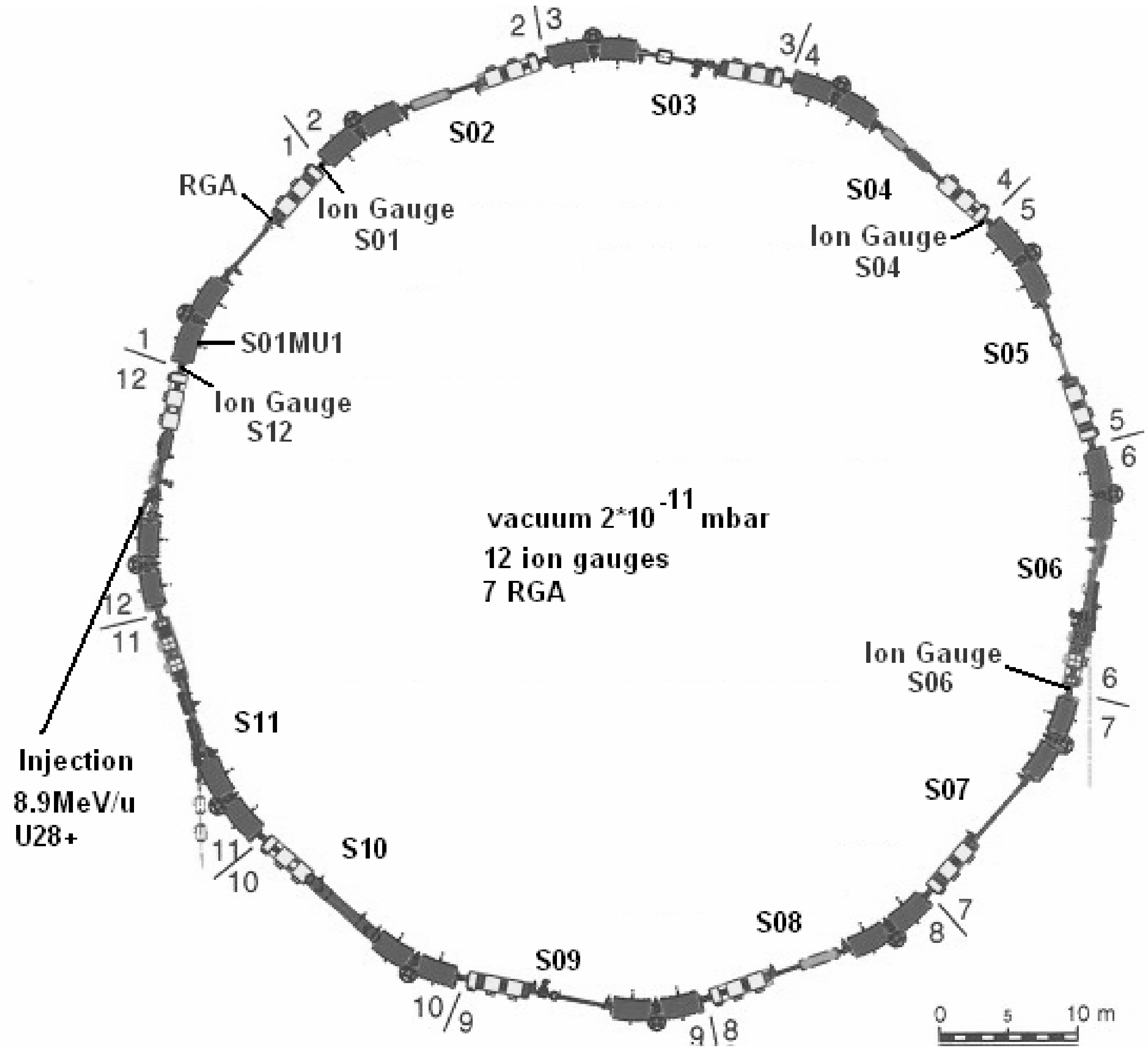
$$h \approx 10^4$$

ion induced desorption

$$h \approx 1-10$$

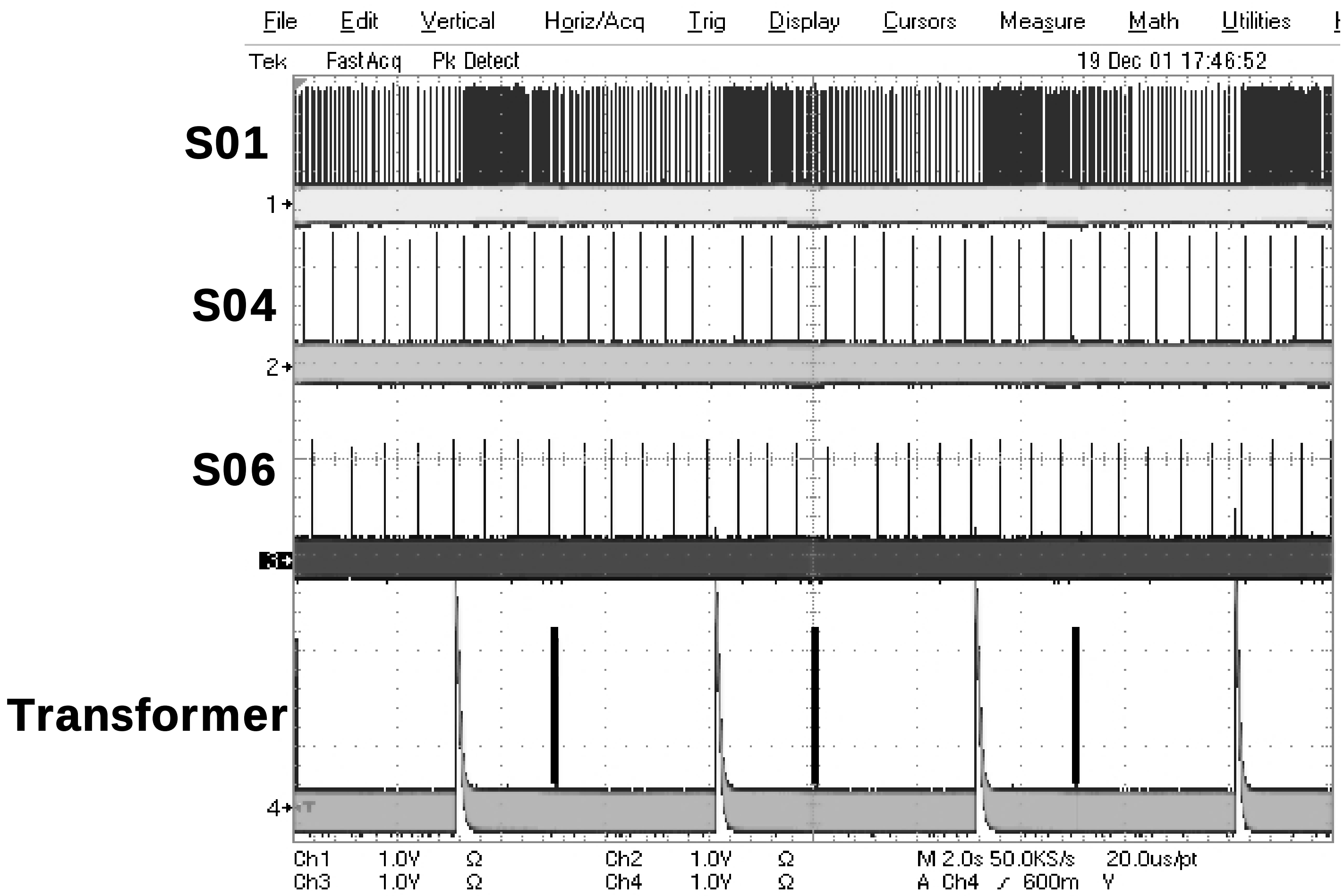
desorption yield η: $$h = \frac{emitted\ \ molecules}{incident\ \ ion}$$

Measurements @ SIS18



Fast Pressure Measurements in SIS18

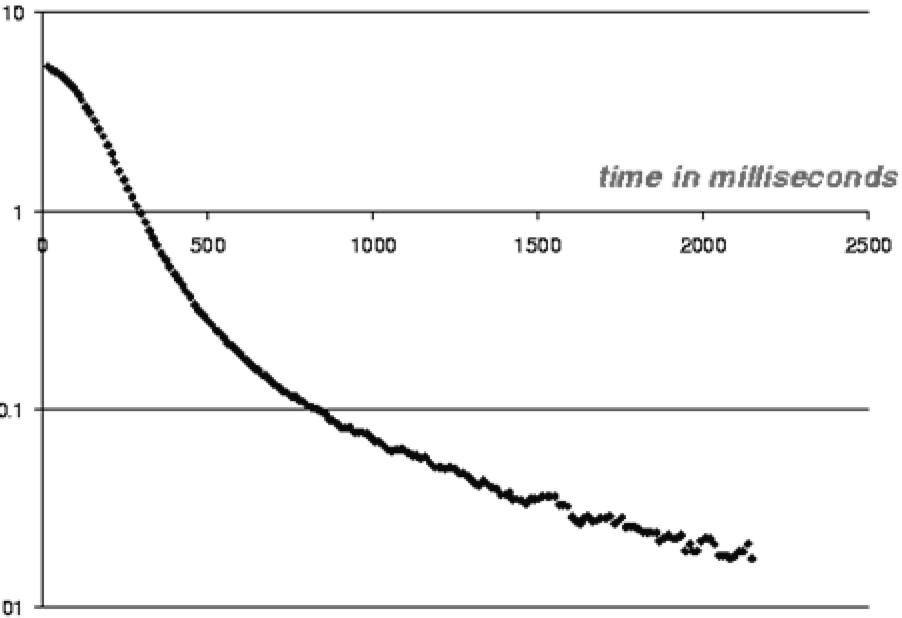
st fast pressure measurements and prove of desorption processes in SIS18 in October 200

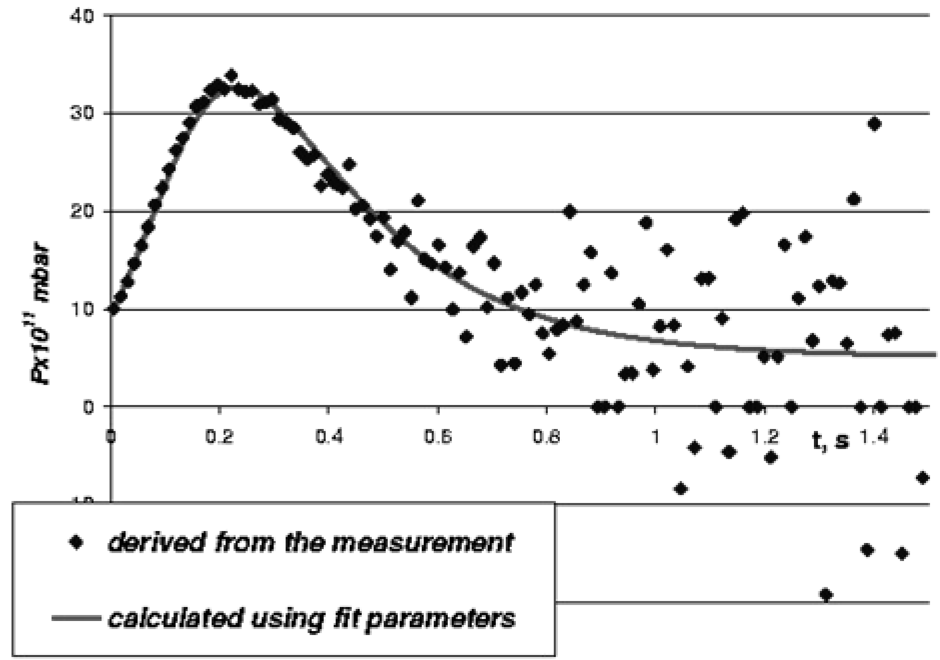


8.9 MeV/u U^{28+}

Vacuum Pressure Instability in SIS18

U^{28+} ion beam lifetime @ 8.9 MeV/u





$$\frac{d}{dt}\ln\left(\frac{I}{I_0}\right) = -\frac{s L n_l}{T} P = \frac{1}{t_{life}}$$

$$\frac{dP}{dt} = -\frac{S}{V}\left(P - P_e\right) + \frac{s h L}{V e Z} I P$$

average pressure, I beam current, S pumping speed, h desorption yield, s charge exchange cross ection.

(E. Mustafin et al., NIM A510, 199 (2003))

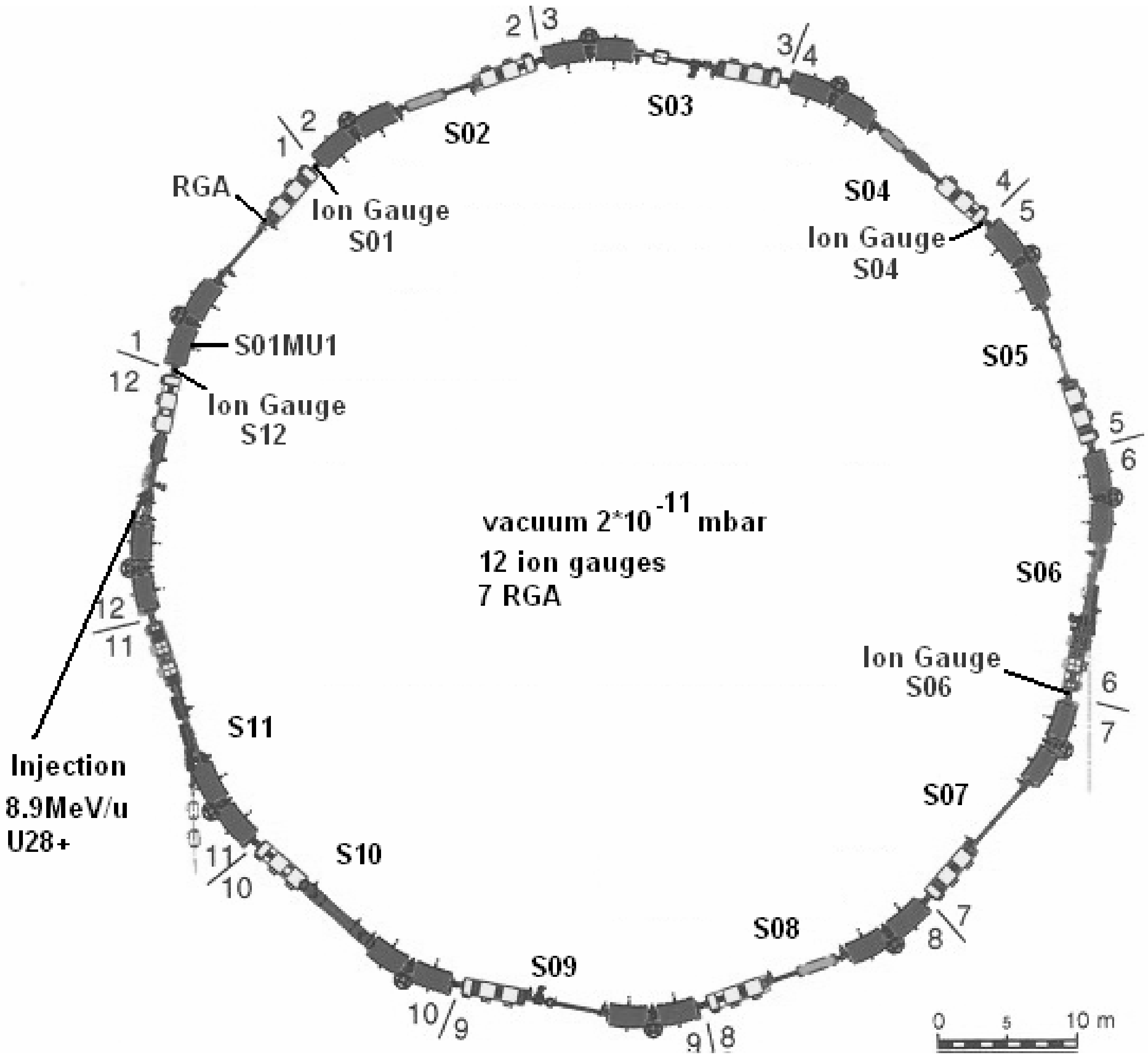
Fit Results for Lifetime Measurements of U^{28+}

E. Mustafin et al., NIM A510, 199 (2003)

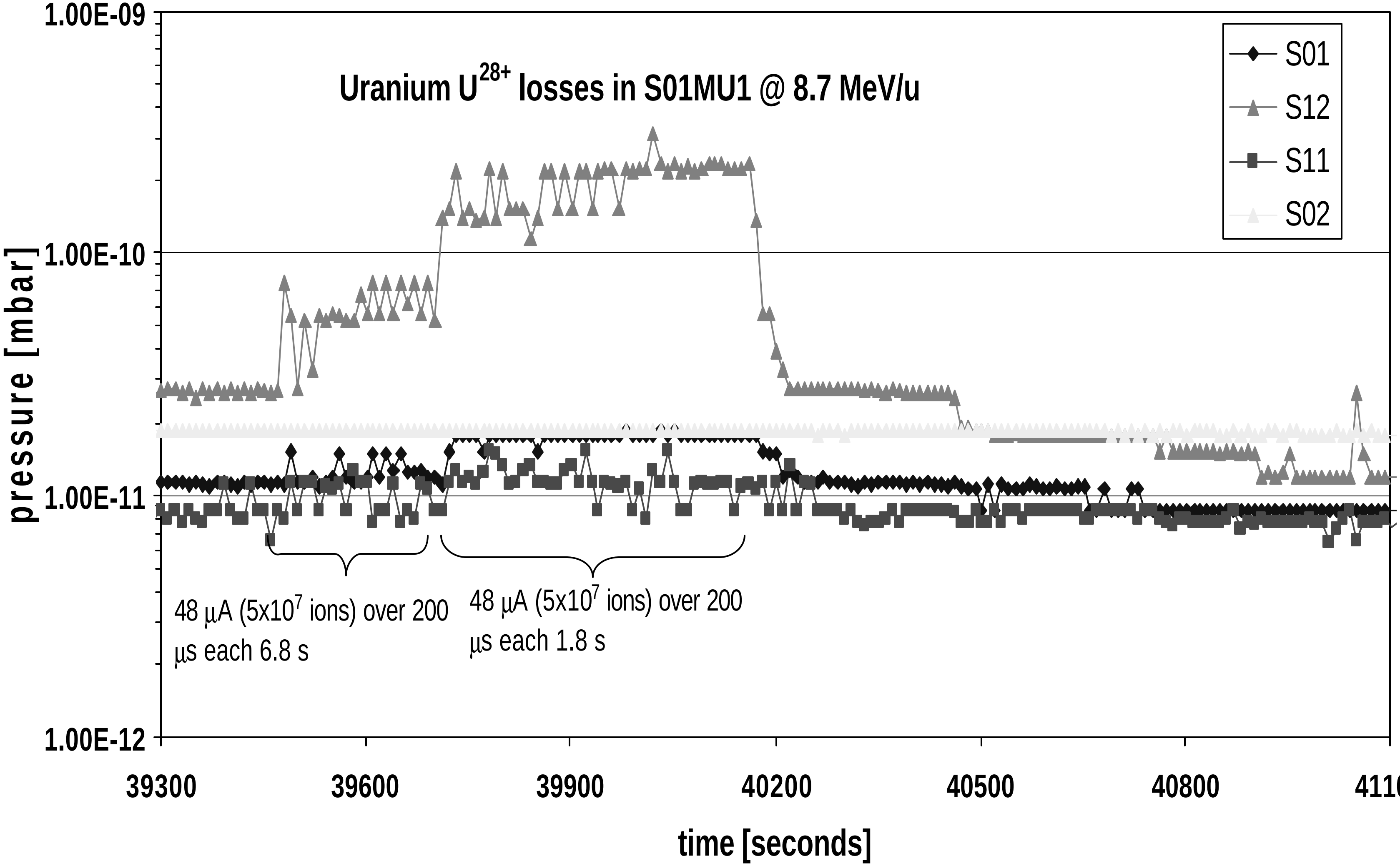
injected ion current [mA]	pumping speed [l/s per pump station]	σ charge exchange cross section [10^{-20} m^2]	desorption yield η	initial pressure [10^{-11} mbar]
1.08	160	1.1	20000	6.0
1.40	120	0.8	27000	14
1.97	160	1.3	16000	6.5
5.36	150	2.1	11000	10

1mA corresponds to 10^9 ions

Measurements @ SIS18



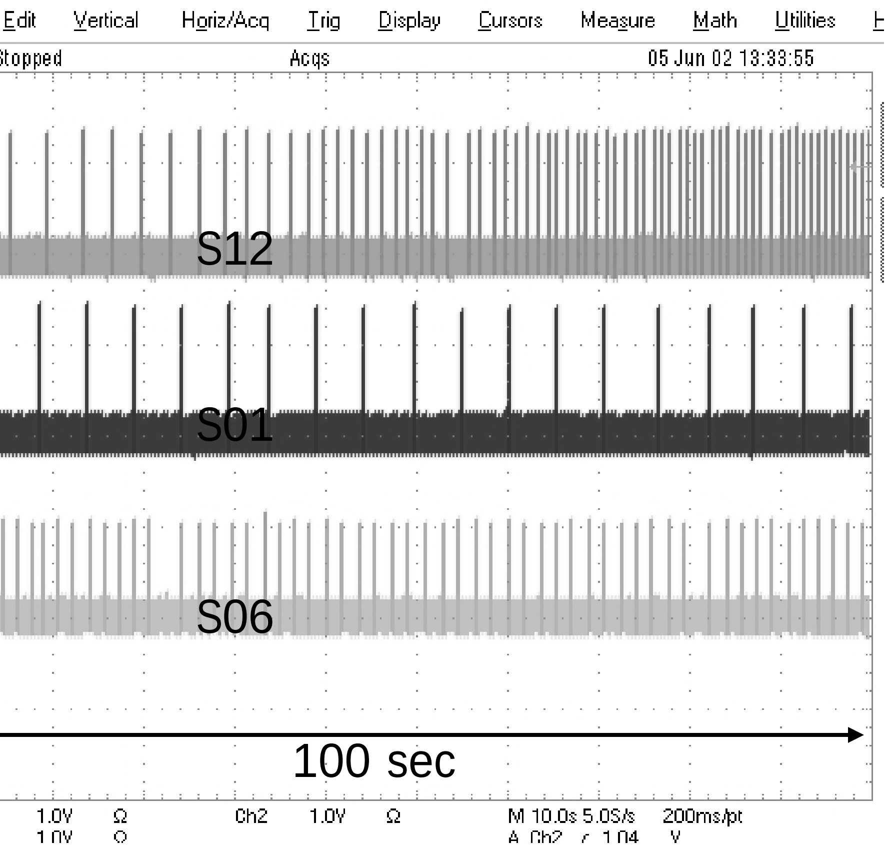
Pressure Rise During Localized Beam Loss

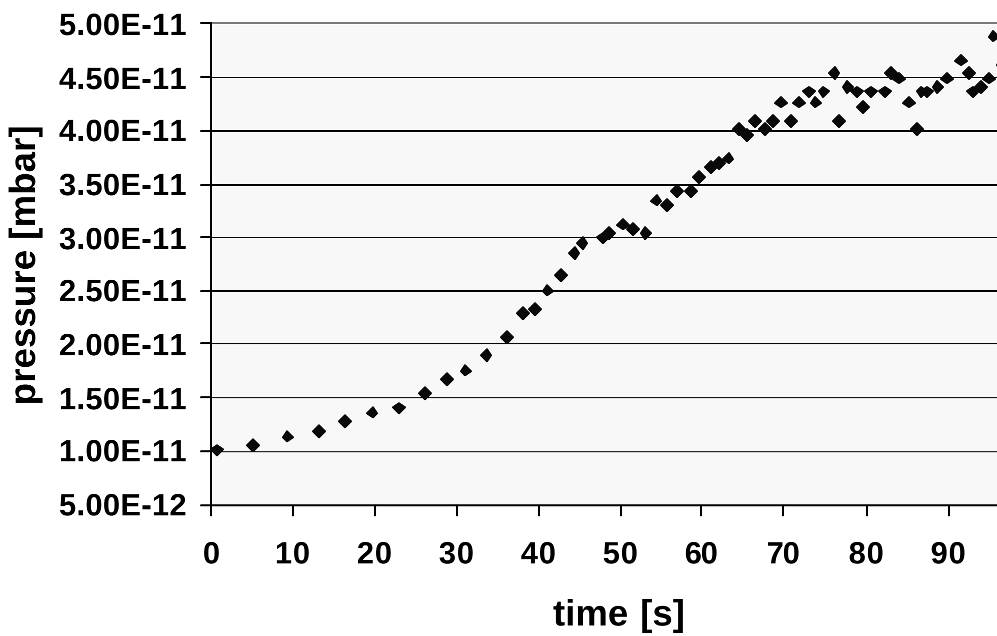


Weinrich et al., GSI Internal Report (2002)

Fast Pressure Measurements

Continuous injection of 8.7 MeV/u $5 \cdot 10^7$ U^{28+} ions every 1.8 sec

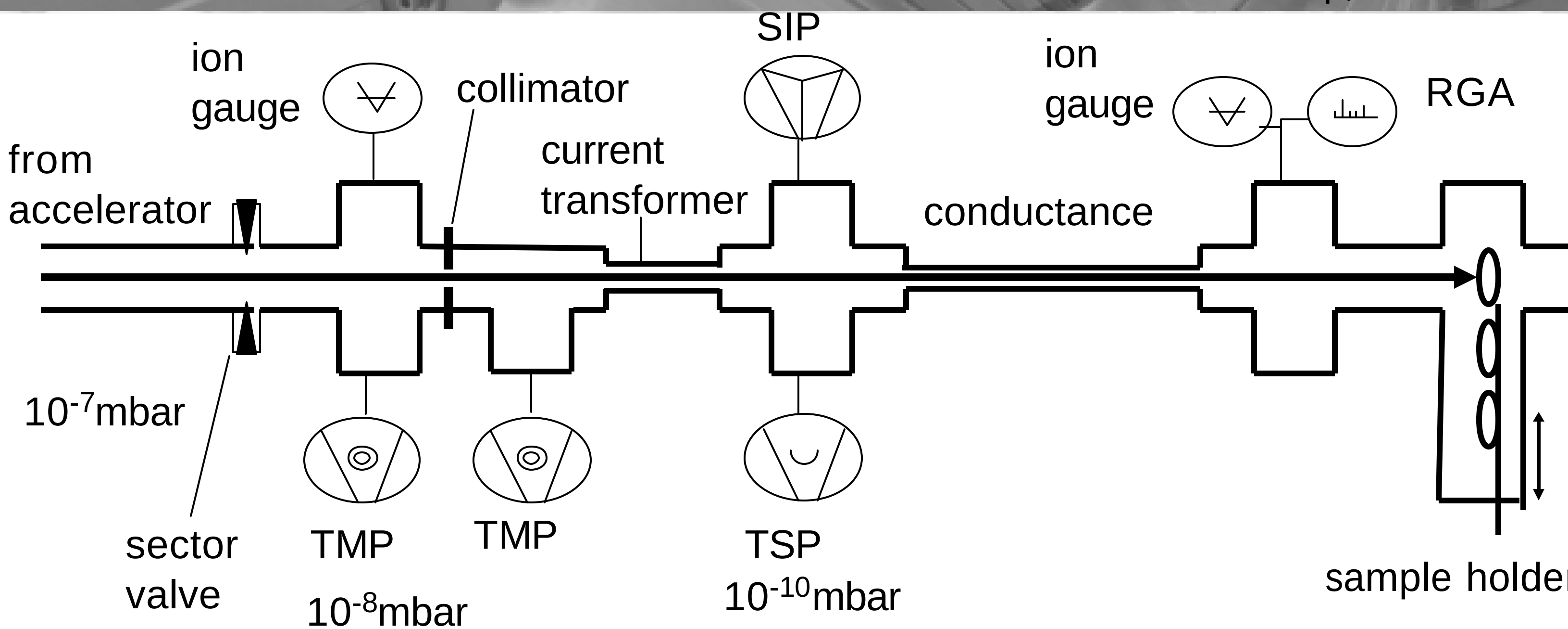


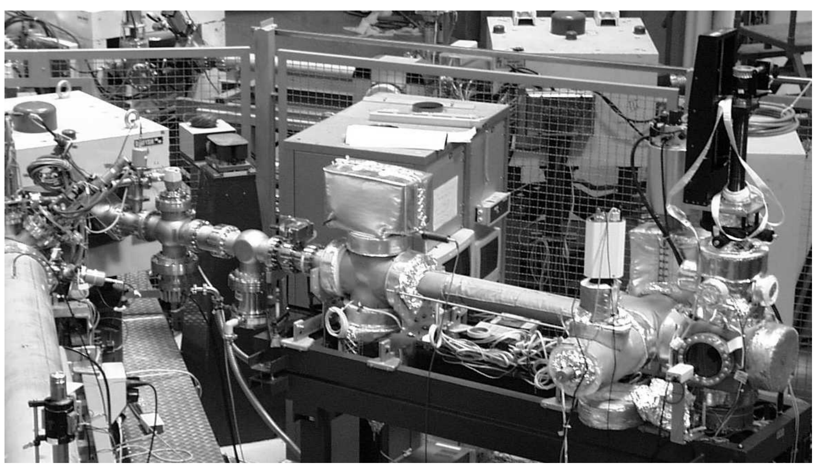


$\eta \approx 5200$

U. Weinrich et al., GSI Internal Report (2002)

Experimental Setup for Ion Beam Induced Desorption Yield Measurements

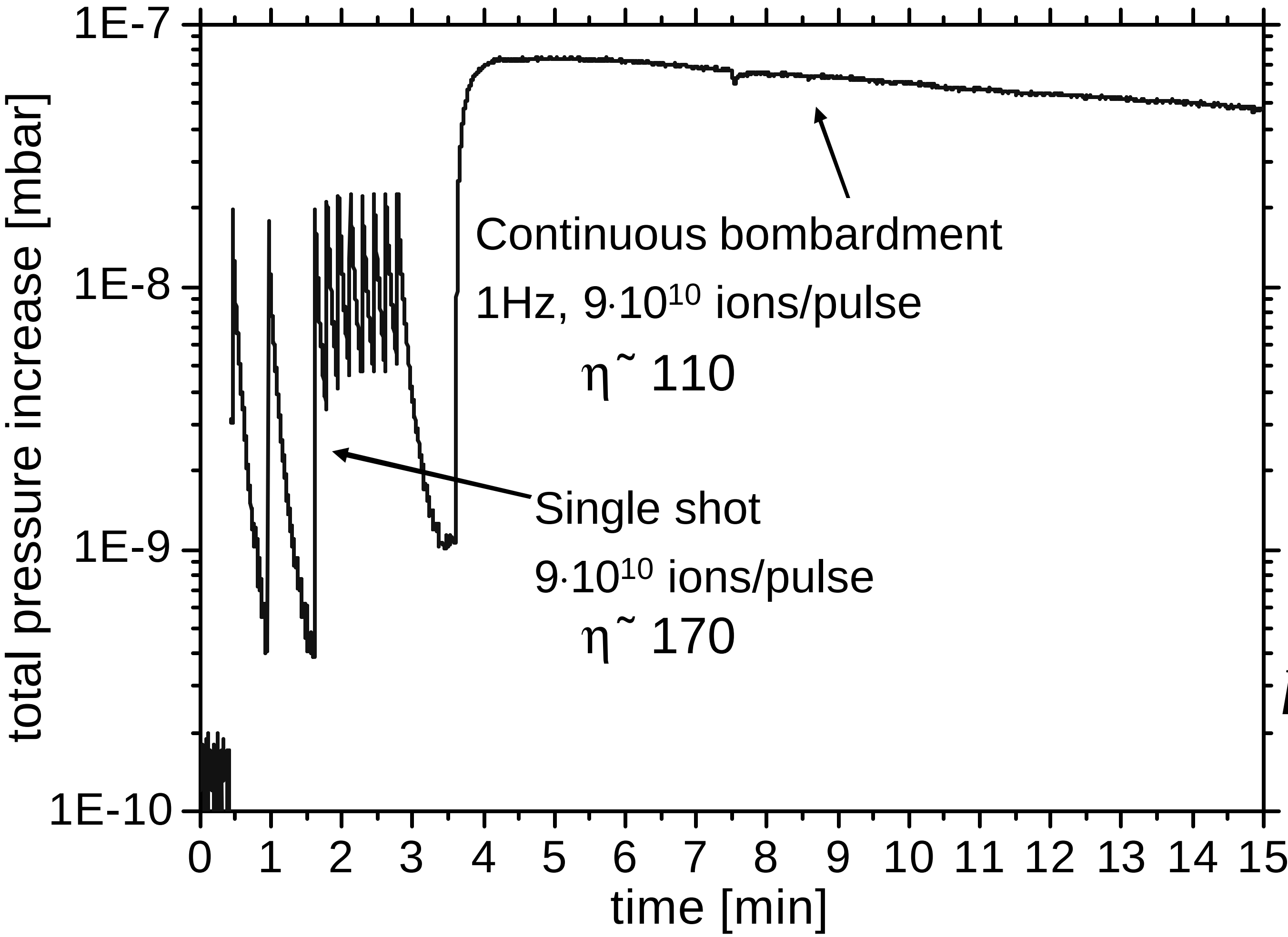




Experiments by:
M. Bender (GSI)
H. Kollmus (GSI)
A. Krämer (GSI)

Total Pressure Increase due to Desorption

1.4 MeV/u $C^{2+} \Rightarrow$ Al, perpendicular incidence



Single shot

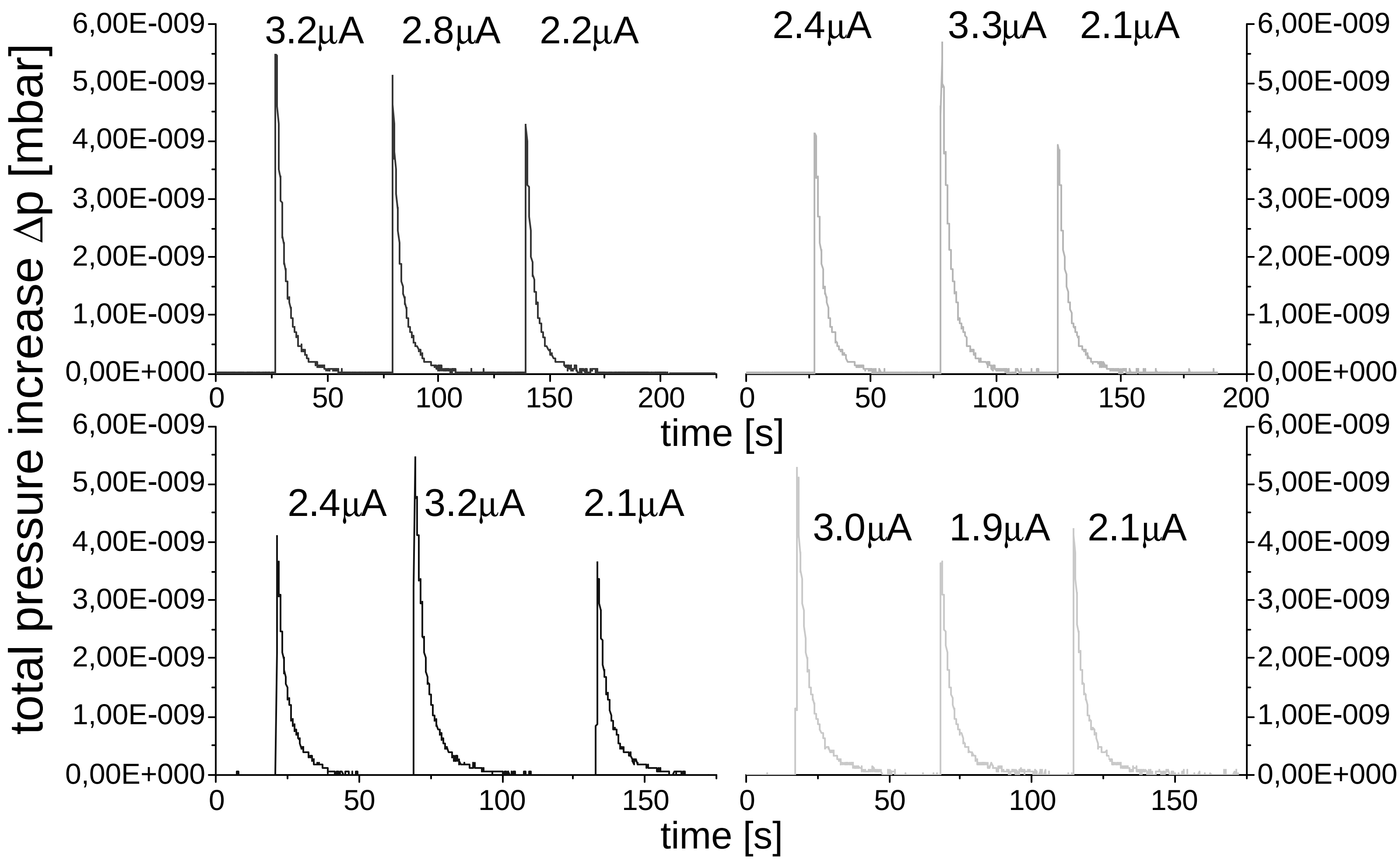
$$h_{eff} = \frac{\Delta p \times V}{N_{ion} \times k_B \times T}$$

Continuous bombardment

$$h_{eff} = \frac{\Delta p \times S}{\dot{N}_{ion} \times k_B \times T}$$

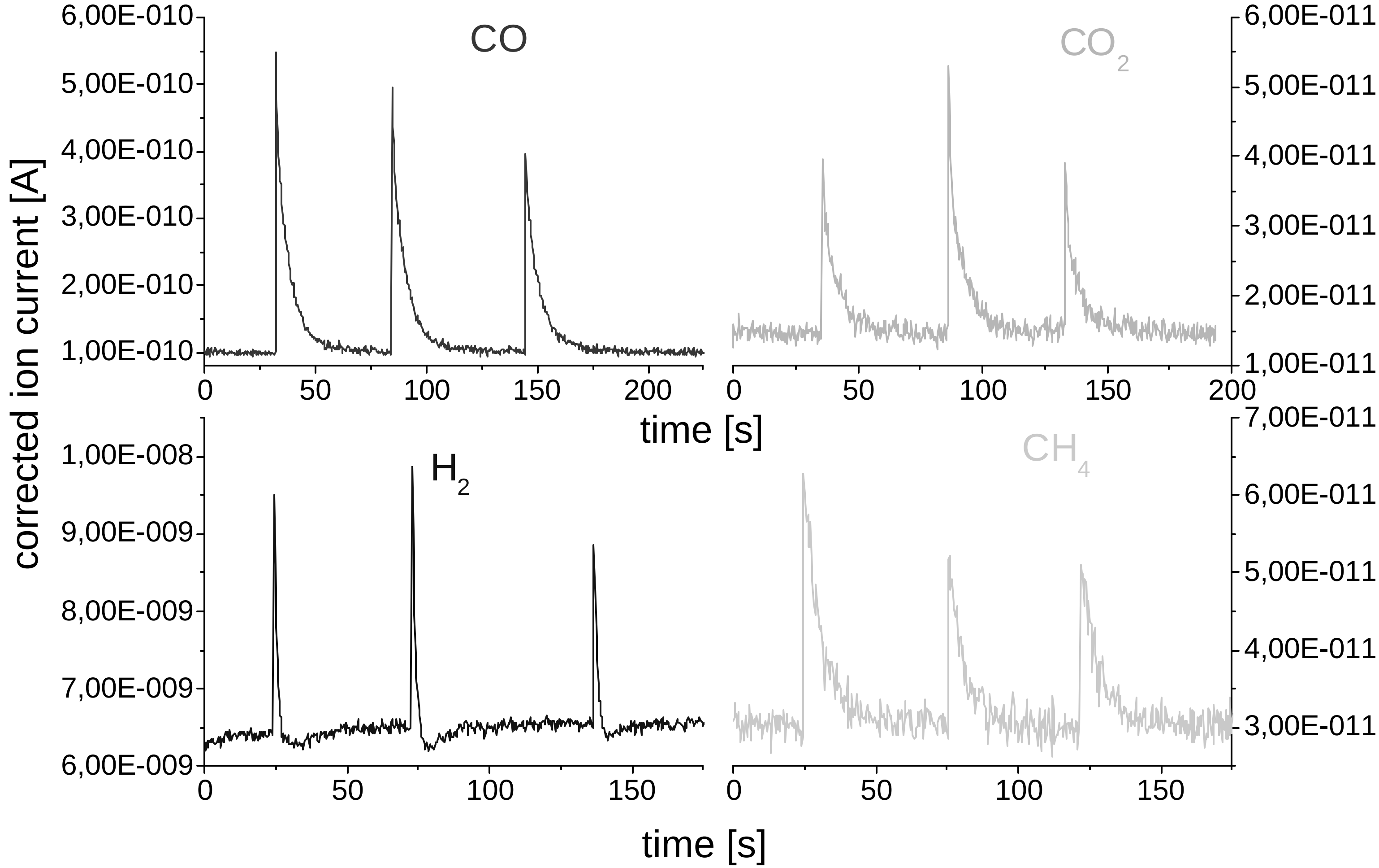
Total Pressure Increase due to Ion Beam Induced Desorption

1.4MeV/u 1.8-3.1·10^9 (1.9-3.3μA, 4ms) Pb^{27+} → stainless steel 304



Partial Pressure Increase due to Ion Beam Induced Desorption

1.4MeV/u 1.8-3.1·10^9 Pb^{27+} Þ stainless steel 304



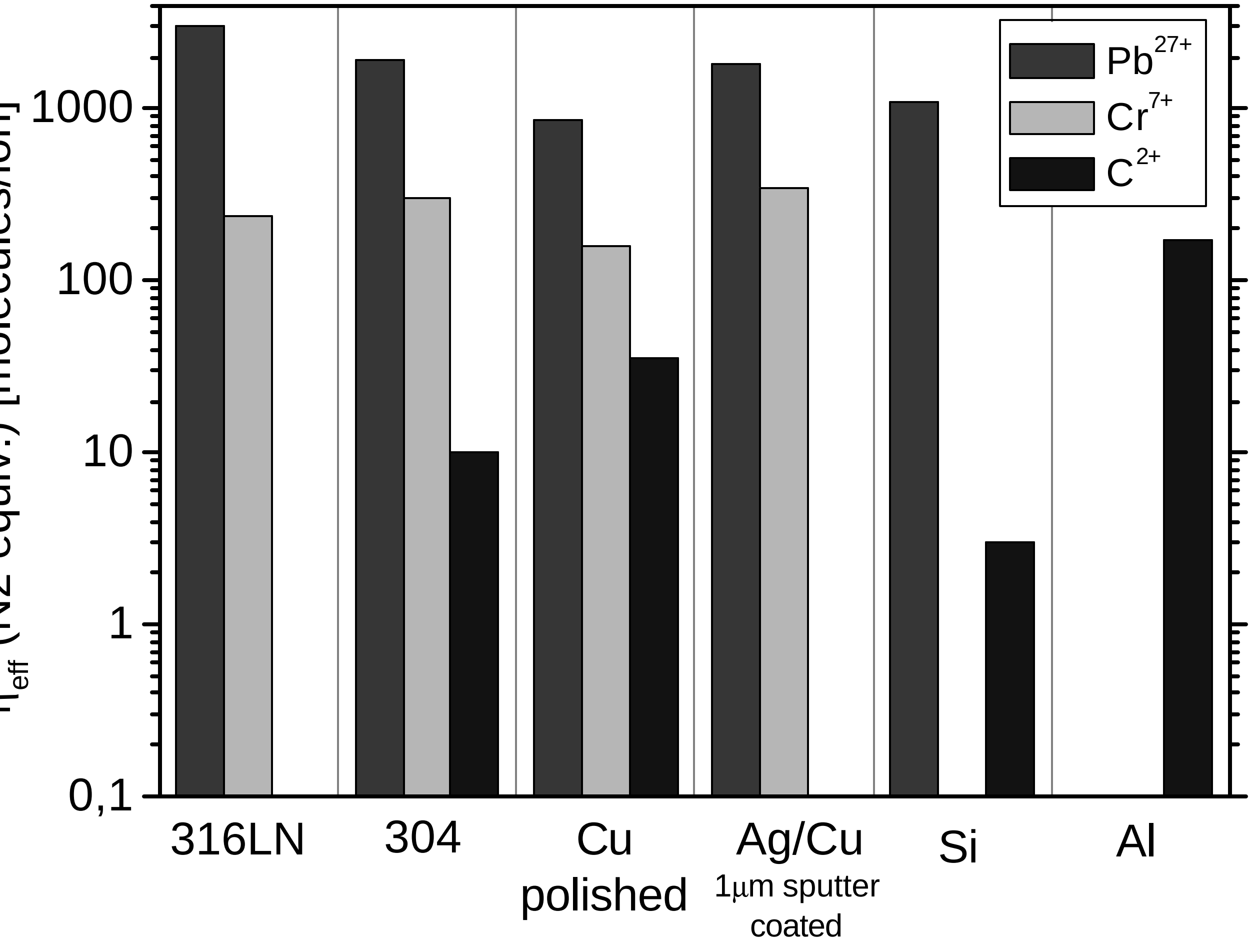
The measured ion current was correc for the ionization probabilities of the different gases:
H_2: x2.3
CO: x0.95
CO_2: x0.71
CH_4: x0.625

Þ Desorption dominated by H_2 (87%) and CO (11%)

Single Shot Results of Desorption Yield Measurements at GSI

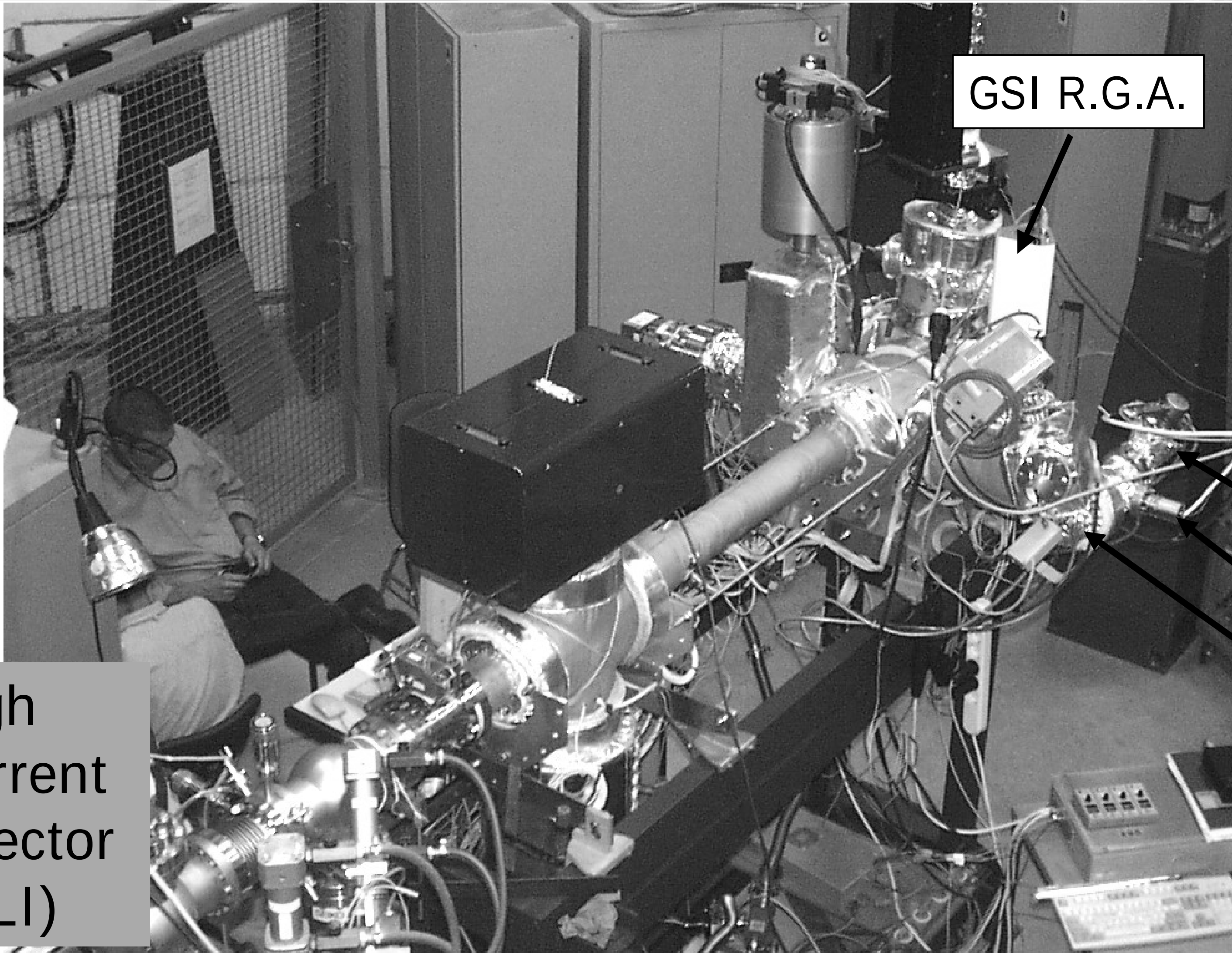
[M. Bender, H. Kollmus, A. Krämer (GSI UHV group)]

Energy: 1.4 MeV/u, Intensities: 10^9 – 10^{11} ions per pulse, perpendicular incidenc



The calculated desorption yields are not corrected for the "real" gas composition, which is H_2 dominated. Therefore the desorption yields are underestimated b a factor of about 2.

Experimental Set-Up with additional CERN hardware



gh
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ILI)

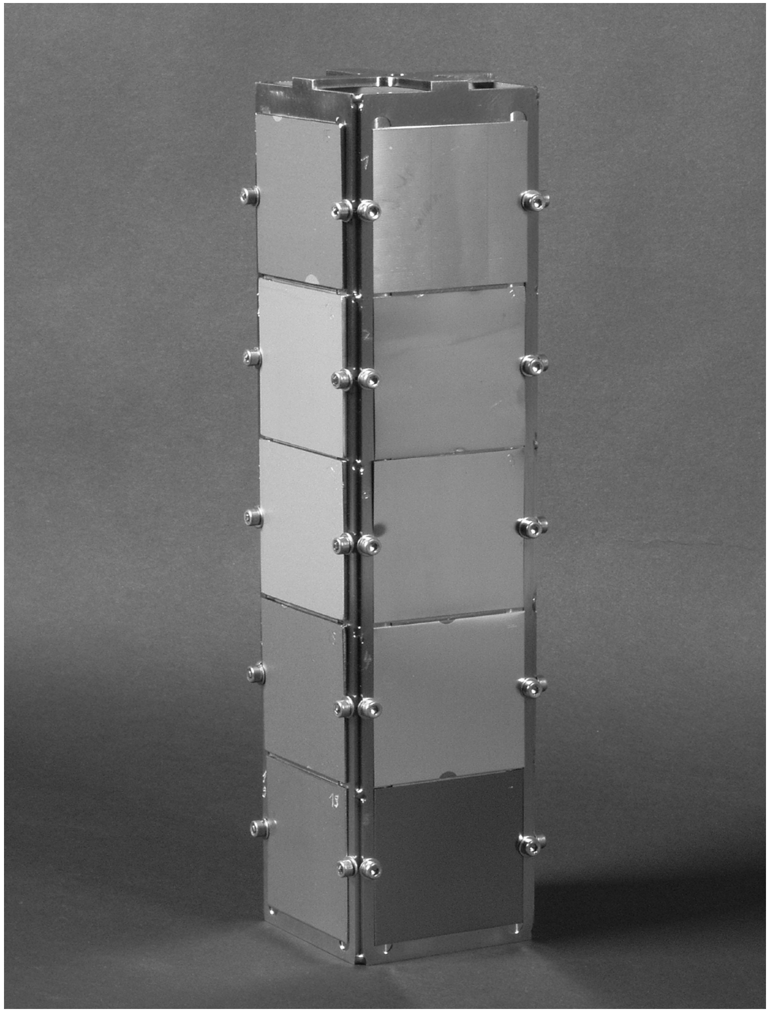
1.4MeV/u Zn^{10+}

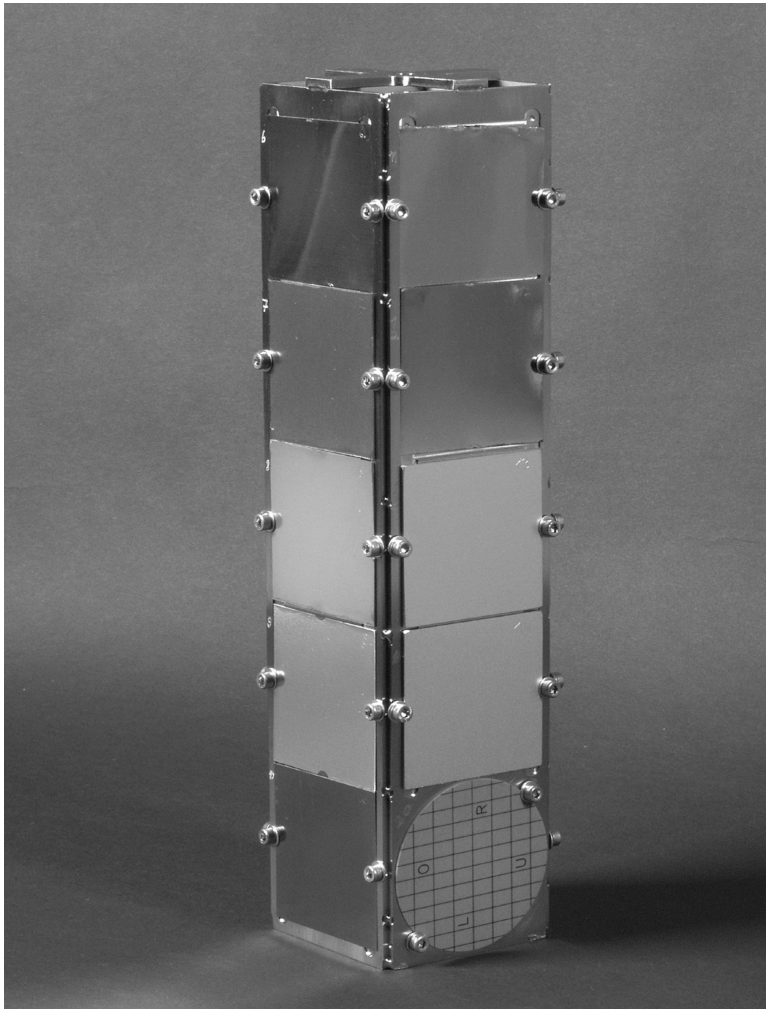
Experiment by:
E. Mahner (CER
M. Bender (GSI)
H. Kollmus (GSI
A. Krämer (GSI)

Latest Experiment with Zn^{10+} at 1.4MeV/u
CERN Samples by Edgar Mahner

Substrate	Dimensions [mm^3]	Temper, cleaning, vacuum firing	Sample #	Sputter coatings CERN	Final thickness
^{41}Nb (Niob)	50×50×0.25	annealed, degreasing	1 2	- Au (1.5 μm)	- **(2.4 mm)**
^{42}Mo (Molybdän)	50×50×0.25	annealed, degreasing	3 4	- Ag (1.5 μm)	- **(1.5 mm)**
^{73}Ta (Tantal)	50×50×0.25	annealed, degreasing	5 6	- Pd (1.5 μm)	- **(0.3 mm)**
^{74}W (Wolfram)	50×50×0.20	as rolled, degreasing	7 8 9 10	- Au (1.5 μm) Ag (1.5 μm) Pd (1.5 μm)	- **(2.4 mm)** **(1.5 mm)** **(0.3 mm)**
^{75}Re (Rhenium)	50×50×0.125	annealed, degreasing	11 12	- TiZrV (1.5 μm)	- **(1.5 mm)**
316 LN 316 LN 316 LN	50×50×1.5 50×50×1.5 50×50×1.5	as received, degreasing as received, degreasing, 950°C vacuum firing as received, degreasing, 950°C vacuum firing	13 14 15	- - TiZrV (1.5 μm)	- - **(1.5 mm)**
304 L 304 L 304 L	50×50×1.5 50×50×1.5 50×50×1.5	as received, degreasing as received, degreasing, 950°C vacuum firing as received, degreasing, 950°C vacuum firing	16 17 18	- - TiZrV (1.5 μm)	- - **(1.5 mm)**
1.4301 GSI	50×50×2	standard UHV cleaning	19	-	-

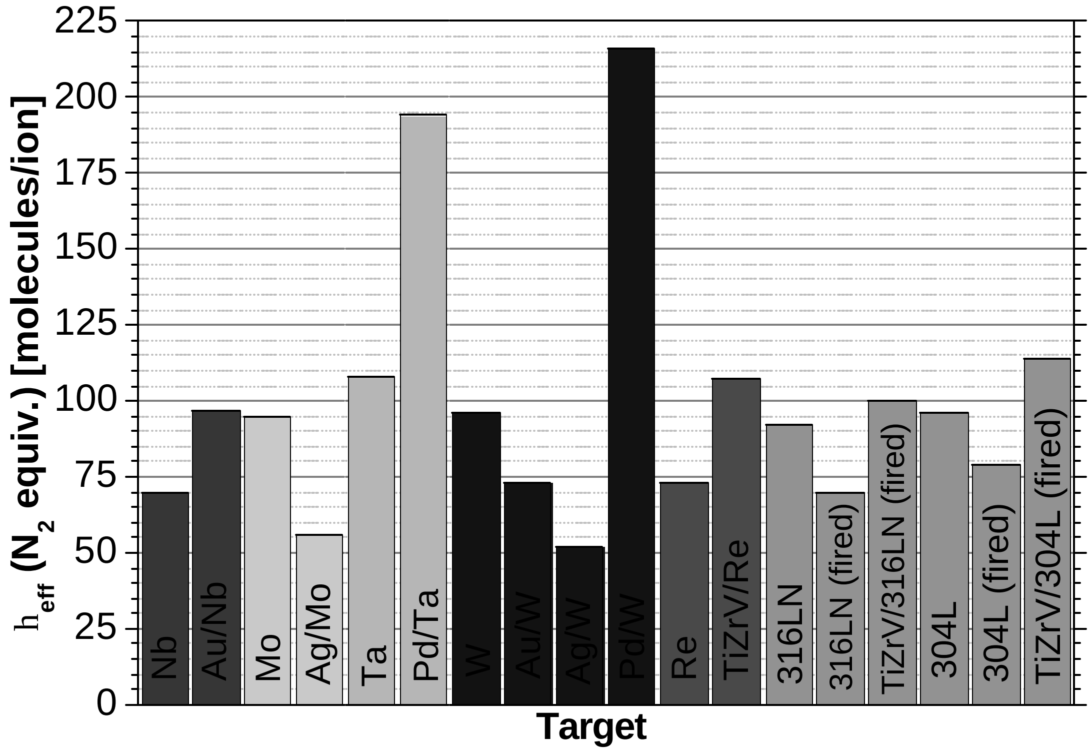
Target Holder with CERN Samples





[pictures by G. Otto (GSI)]

Desorption Yields calculated out of Single Shot Experiments



1.4MeV/u Zn^{10+}

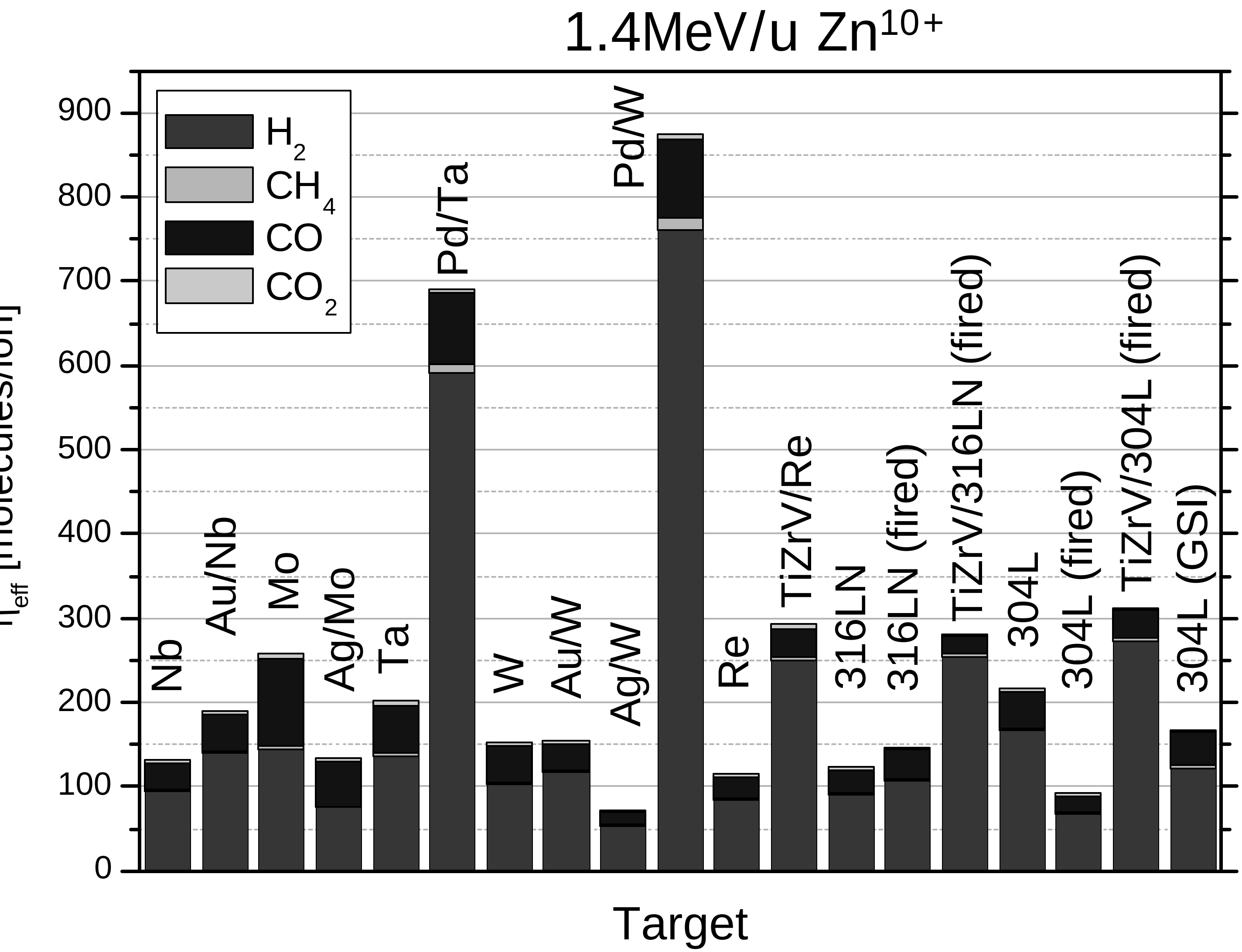
Desorption yields are calculated with:

$$h = \frac{\Delta p \times S}{\dot{N} \times k_B \times T}$$

assuming S=5.52l/s (N_2 equivalent)
Δp was measured with ar extractor ion gauge.

- No influence of the high melting temperatures of Nb, Mo, Ta, W, Re in comparison to 316LN and 304L
- η of coatings independent of thickness and bulk material

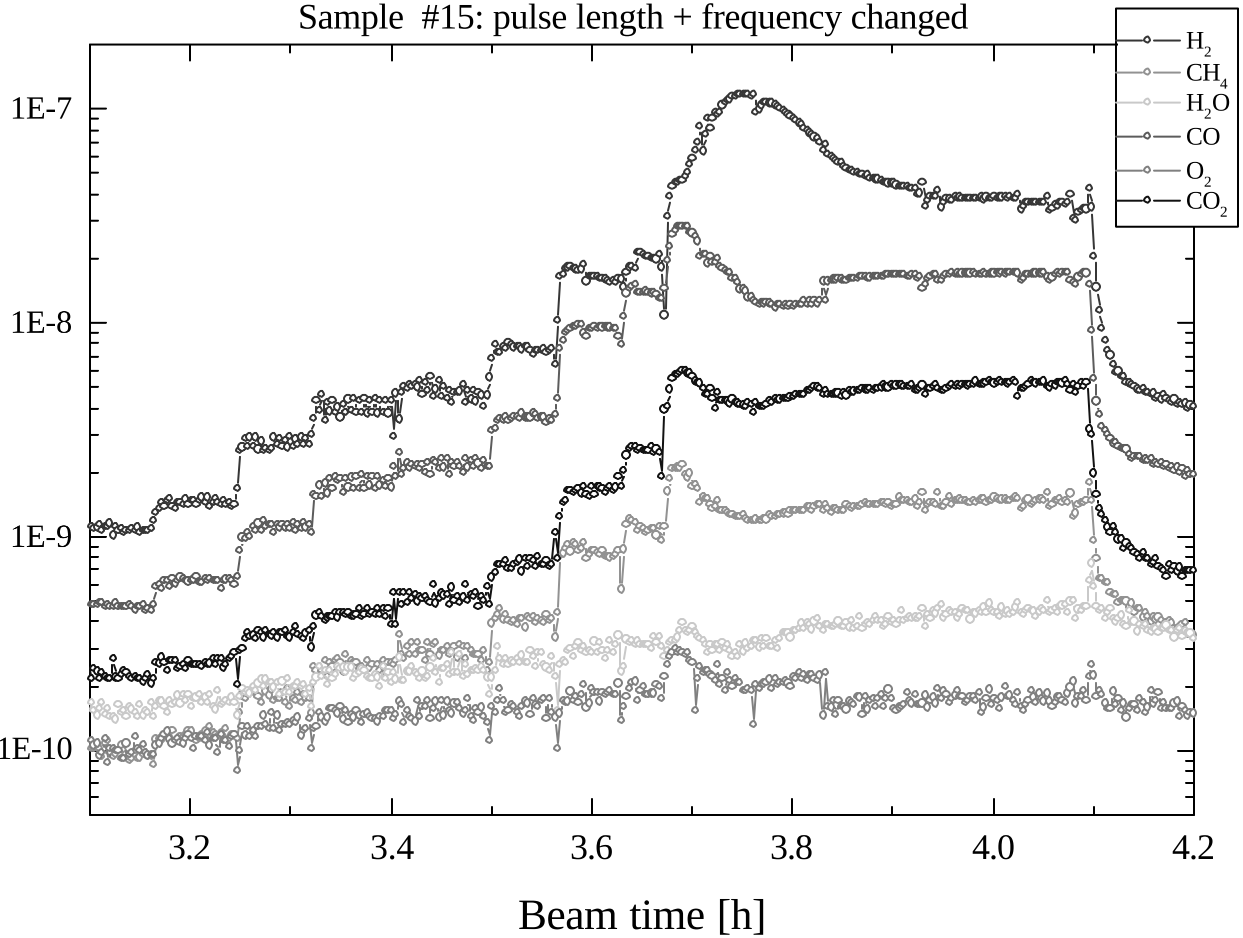
Desorption Yields Calculated from Scrubbing Plots by E. Mahner (CERN)



Mainly desorbe gases are H_2 ar CO.

Pulse Length and Frequency Dependence of Partial Pressures

1.4 MeV/u Zn^{10+} ⇒ TiZrV/316LN (fired)



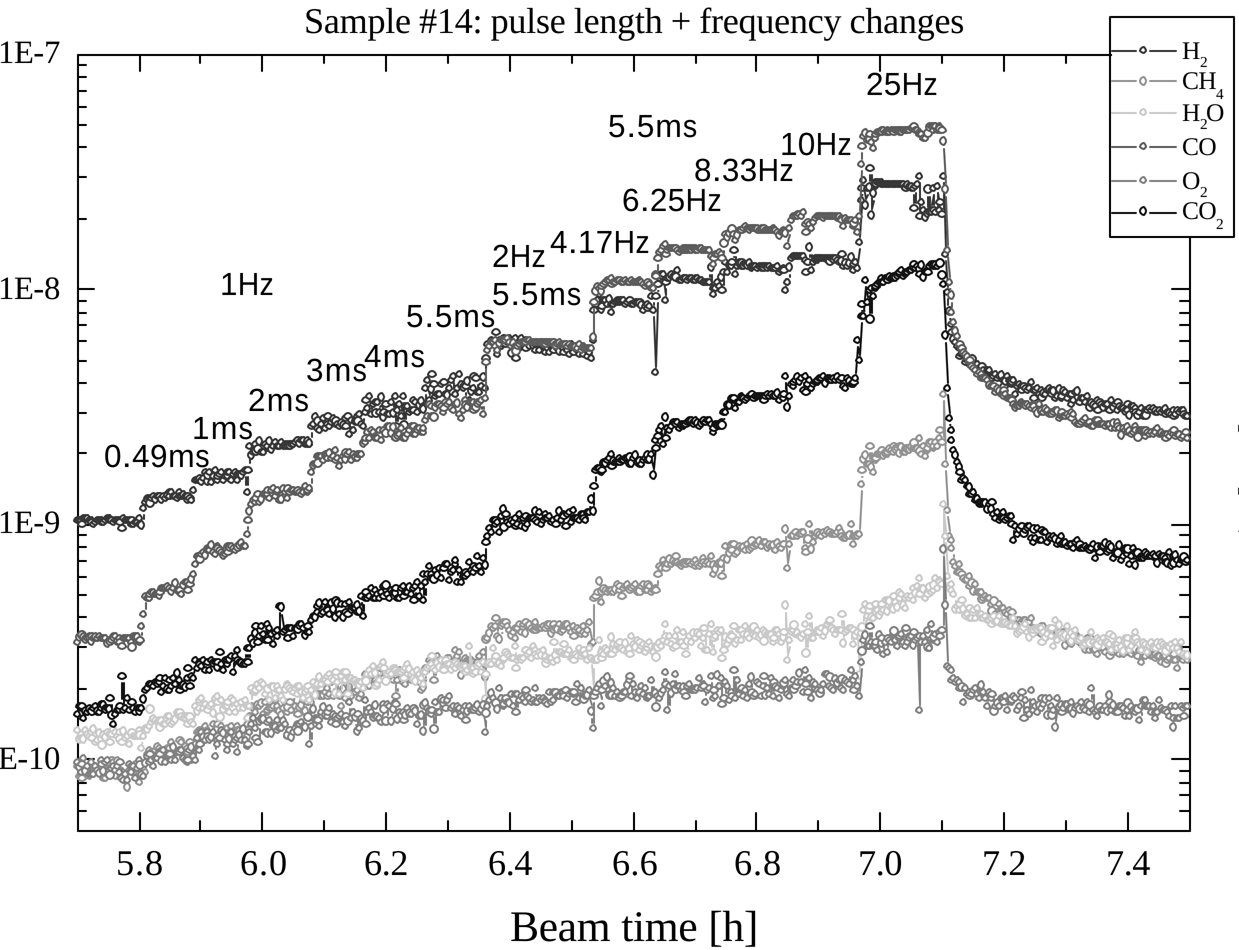
Rate [Hz]	Pulse length [ms]
1	0.49
1	2
1	4
1	5.5
2	5.5
6.25	5.5
10	5.5
25	5.5

Intensity dependence of η:
- linear?
- new effects at high intensities?

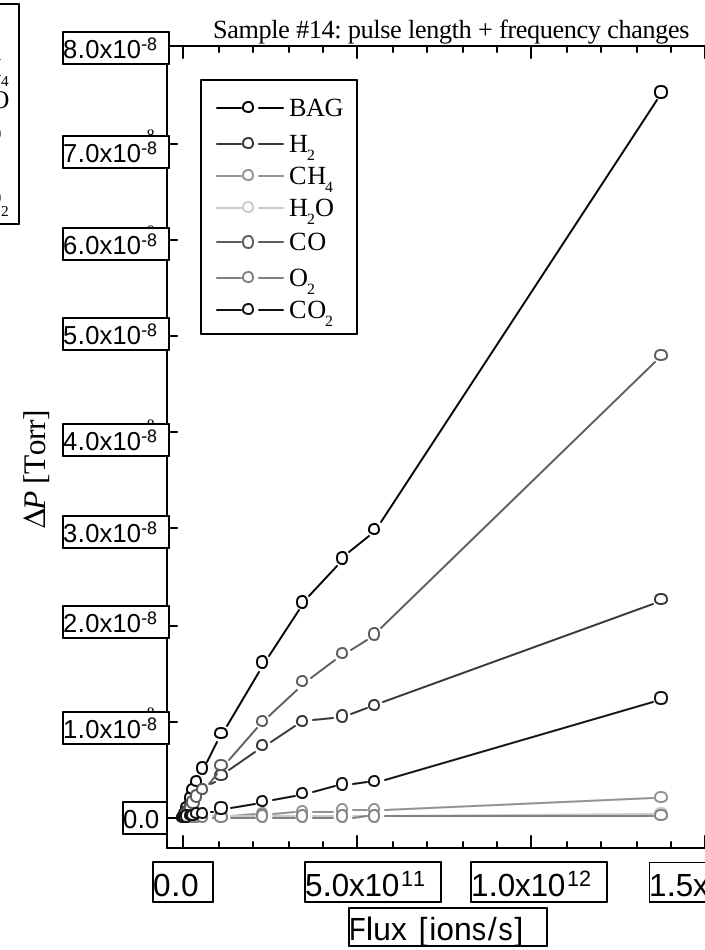
t by E. Mahner (CERN)

Pulse Length and Frequency Dependence of Partial Pressures

1.4 MeV/u Zn^{10+} ⇒ 316LN (fired)



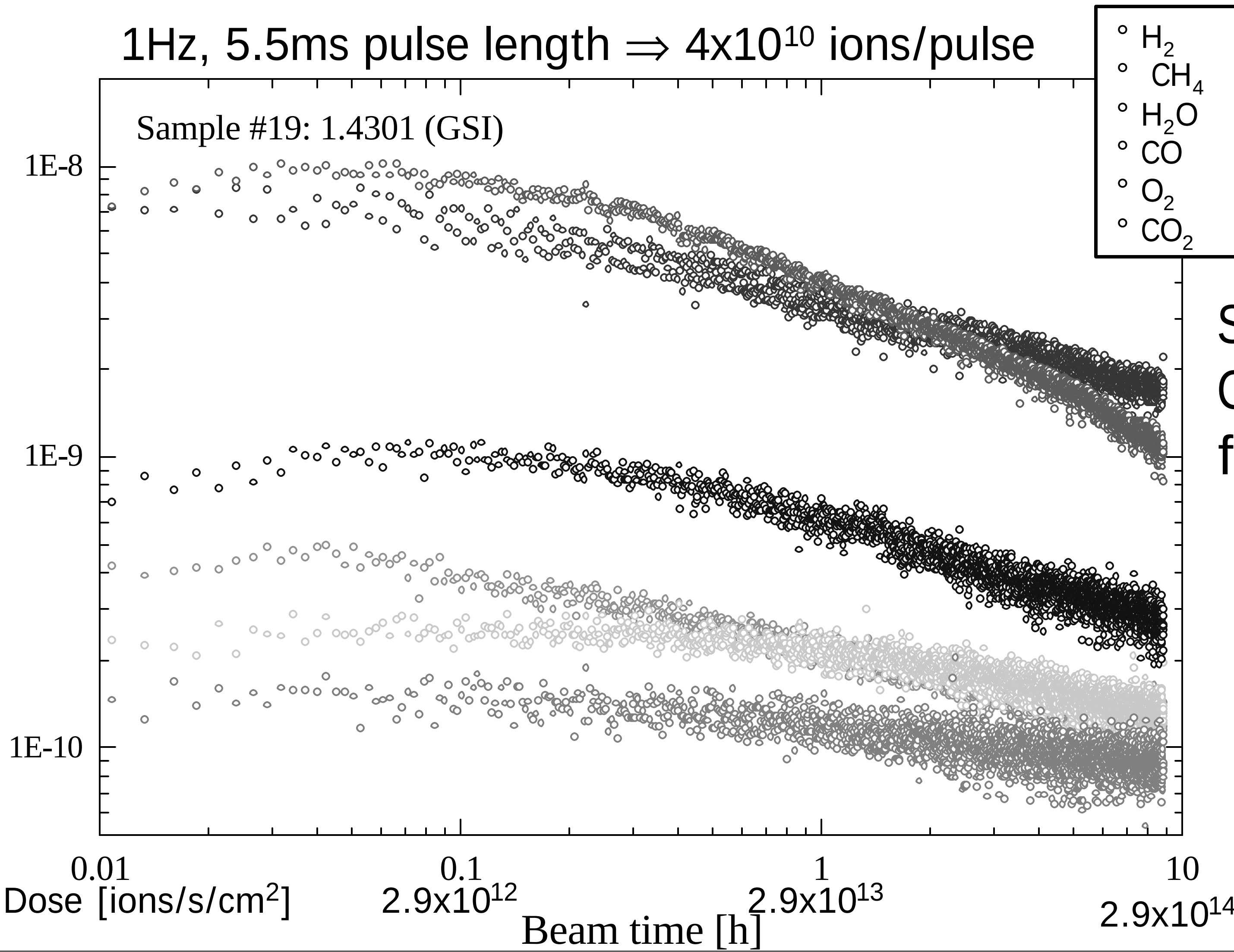
Flux vs Δp



ots by E. Mahner (CERN)

Beam Scrubbing 1.4 MeV/u Zn^{10+} ⇒ 304

1Hz, 5.5ms pulse length ⇒ 4×10^{10} ions/pulse



Scrubbing effect f
CO stronger than
for H_2

Plot by E. Mahner (CEF

Summary & Outlook

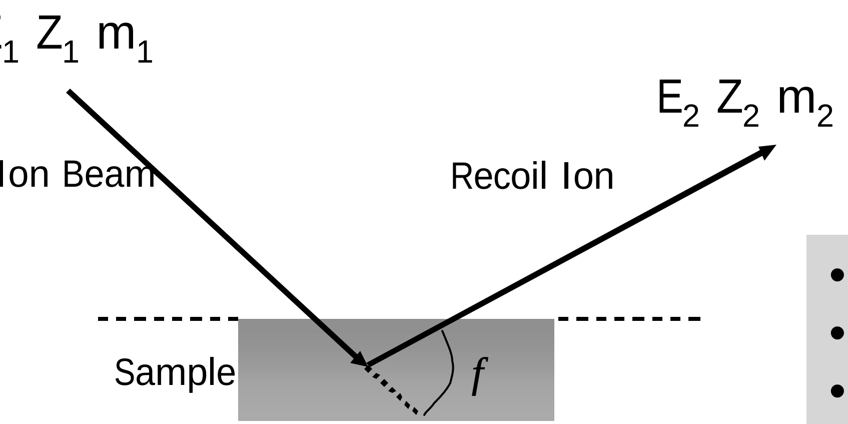
- First experiments under perpendicular incidence with different projectile ions and target materials/coatings at 1.4MeV/u at GSI

- Next Step: Modified(?) experimental setup at UNILAC with energies up to 11MeV/u [implementation of an electron detector]
- Together with material science: ERDA measurements for surface and bulk analysis up to 1μm depth (Ph.D. thesis)

Further to be studied:

- Desorption at higher energies up to 1GeV/u
- Desorption of cold vacuum chamber walls for SIS100 and SIS300

Elastic Recoil Ion Detection Analysis (ERDA)



- same sensitivity for all elements
- Z_1^4 dependence (*m=2Z*)
- depth profile easy accessible

Rutherford-Scattering:

$$\frac{E_2}{m_2} = \frac{4\cos^2 f}{(1 + m_2 / m_1)^2} \frac{E_1}{m_1}$$

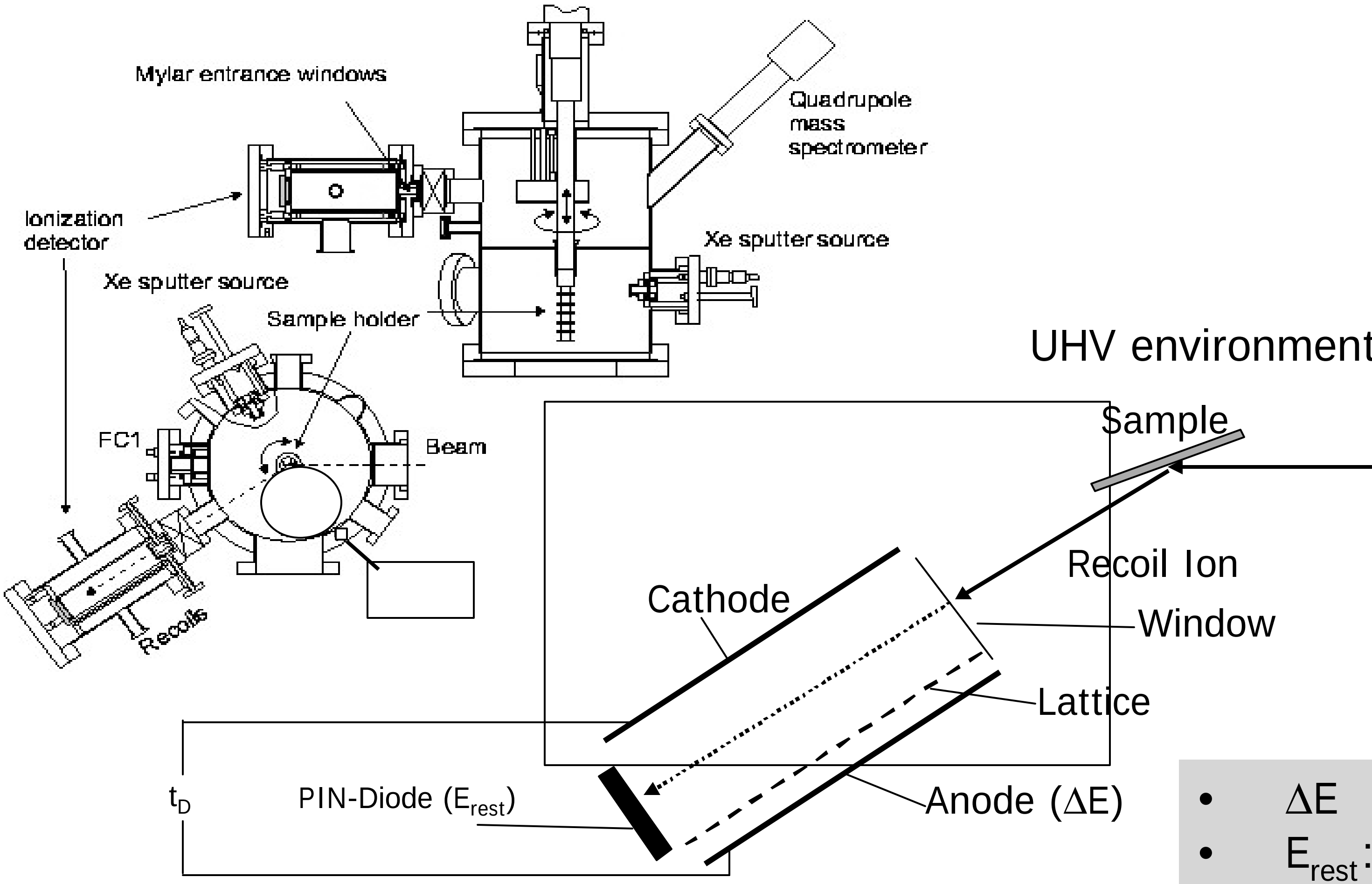
ERDA-Cross Section:

$$s_{ERD} = \left(\frac{Z_1 Z_2 e^2}{2E_1}\right)^2 \left(\frac{m_1 + m_2}{m_2}\right)^2 \cos^{-3} f$$

for heavy ions: $m_2/m_1 << 1$

→ all recoil ions have approx the same velocity *v* (→ similar energy loss)

Experimental Setup for ERDA Measurement

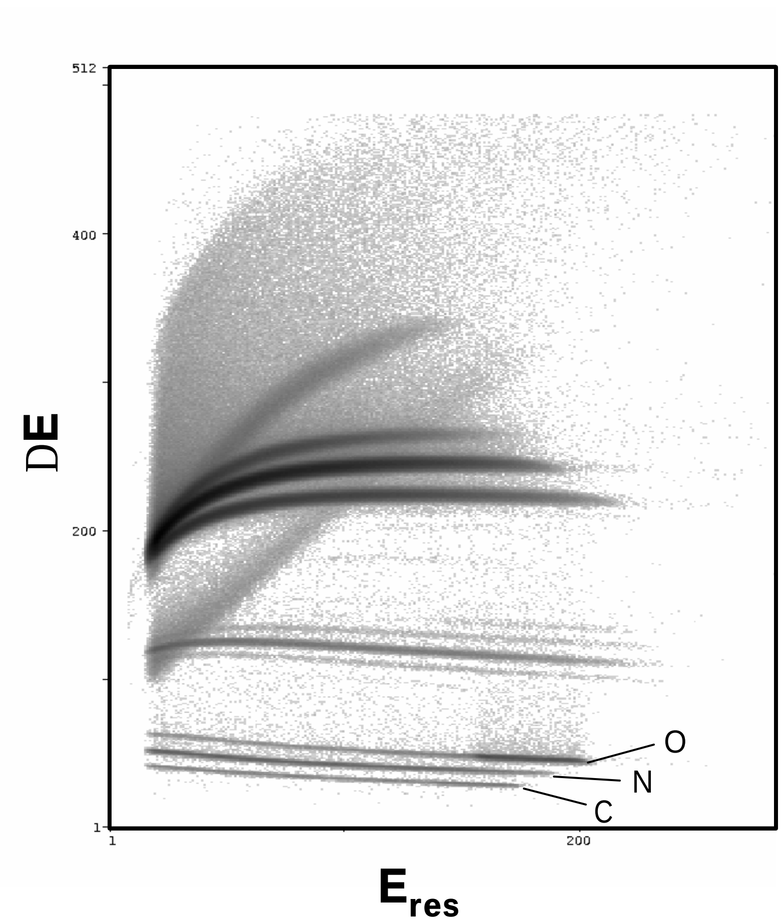


- ΔE : Element (Z)
- E_{rest}: Depth
- t_D : Emission Angle (f)

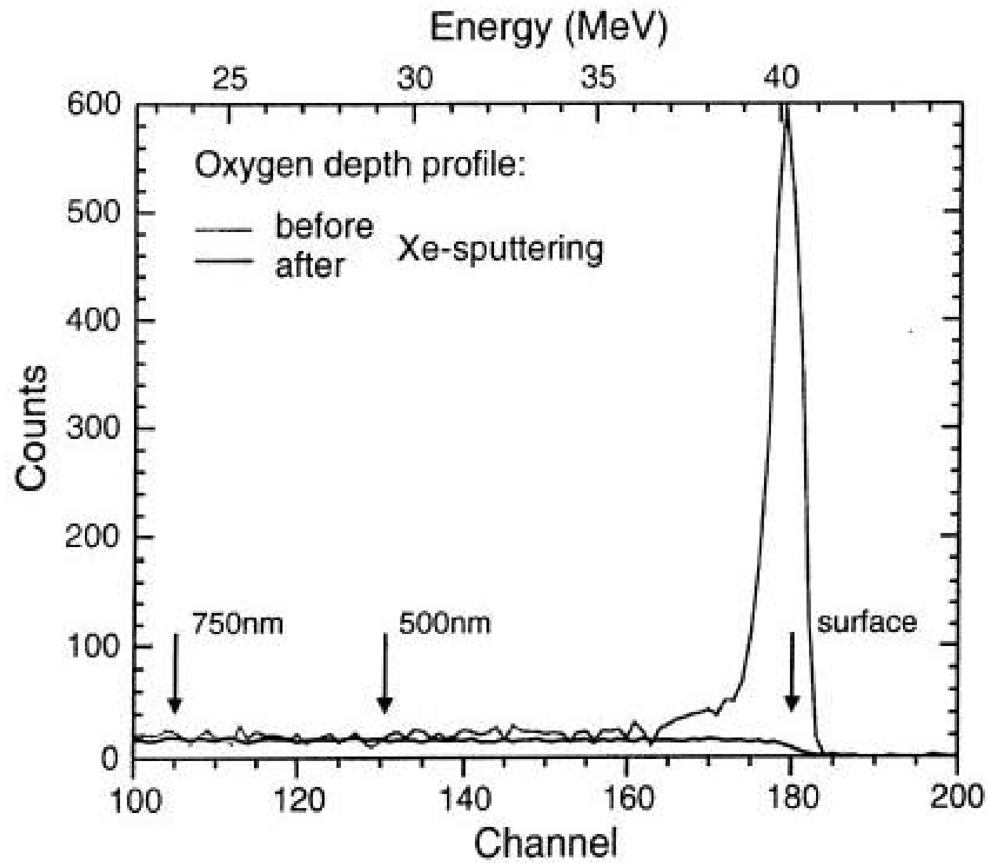
D. Mieskes et al., Measuring sputtering yields of high energy heavy
s on metals, NIM B 146 (1998)

ERDA-Spektra

200 MeV $Au^{<30+>} \rightarrow$ 304 L stainless steel



in-situ ERD energy profile of O-contamination in a *Ti* - sample



H. D. Mieskes et al., NIM B 146 (1998)

Advantages of ERDA

- element specific depth profile,
  typical depth up to 1 μm with 20 nm resolution
- clear distinction between surface and bulk
- in-situ measurement of material changes under radiation

- combinable with total and partial pressure measurements
- combinable with measurement of electronic desorption yields

Acknowledgement

- M. Bender, O. Boine-Frankenheim, B. Franczak, W. Kaufmann, H. Kollmus, E. Mustafin, H. Reeg, H. Reich-Sprenger, P. Schütt, P. Spiller, U. Weinrich (GSI; Accelerator Division)
- E. Mahner (CERN; AT-Division, Vacuum Group)
- C. Trautmann (GSI; Material Science)
- W. Assmann (LMU Munich)