Ion Induced Desorption Measurements at GSI

- Motivation

  ion-beam loss induced desorption and its consequences for the SIS18 upgrade

- HLI Experiments @ 1.4 MeV/u

  desorption yields for C^{2+}, Cr^{7+}, Zn^{10+} and Pb^{27+} on diff. targets

- SIS Experiments @ 15-1000 MeV/u

  preliminary desorption yields for U^{73+} on diff. targets

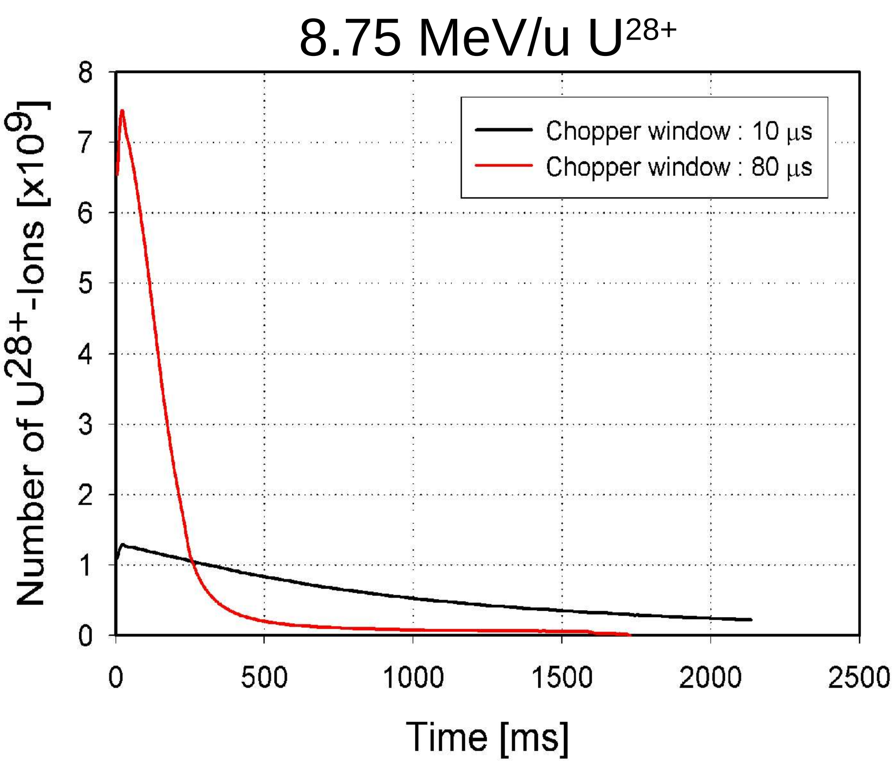
- planned ERDA Experiments

  method of Elastic Recoil ion Detection Analysis
  and its application for ion-induced desorption measurements

M. Bender, A. Kraemer, M.C. Bellachioma and H.K. (GSI)
E. Mahner (CERN)

Dynamic Vacuum and Beam Lifetime

P. Spiller, December 2001



Desorption processes degenerate the residual gas pressure.

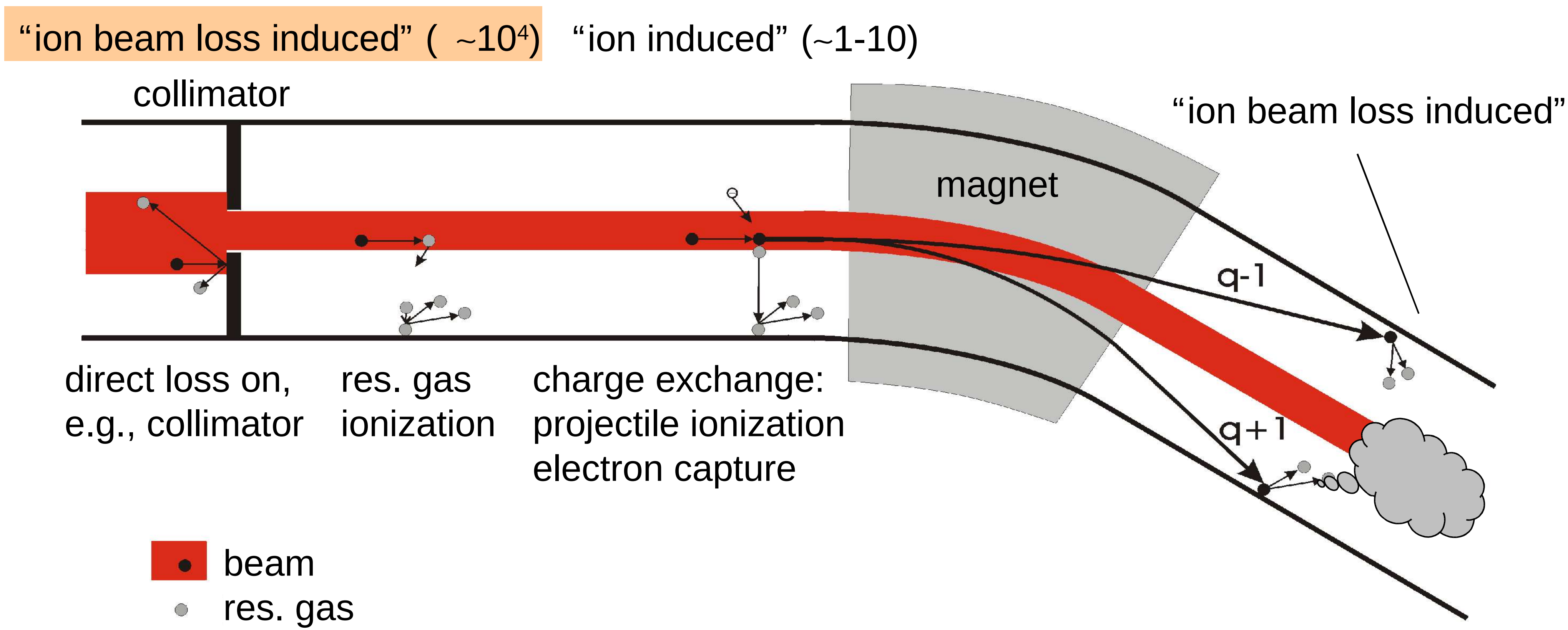
Initiated by:

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

Beam losses increase with number of injected ions

-> “show stopper“ for GSI future facility FAIR (10^{12} ion/s from SIS18)

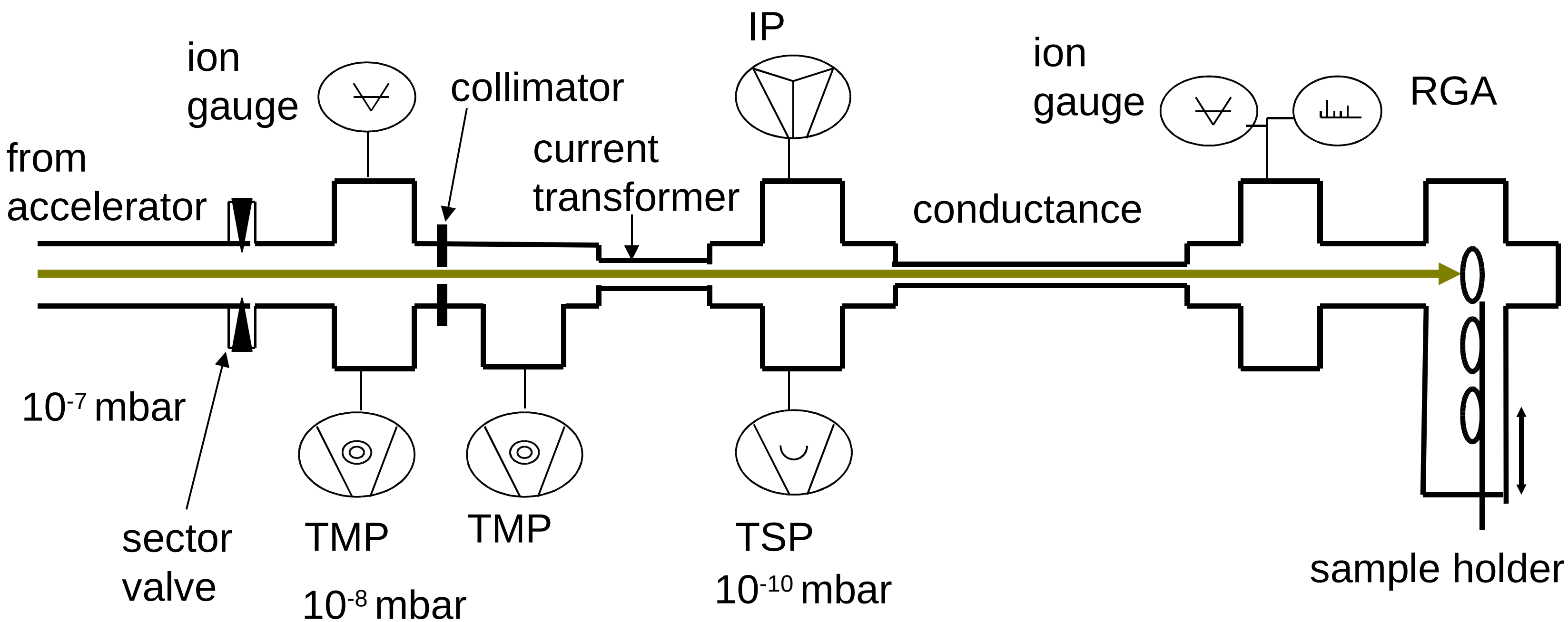
Beam Loss Processes



desorption coefficient $\eta = \frac{\text{molecules (atoms)}}{\text{ion}}$

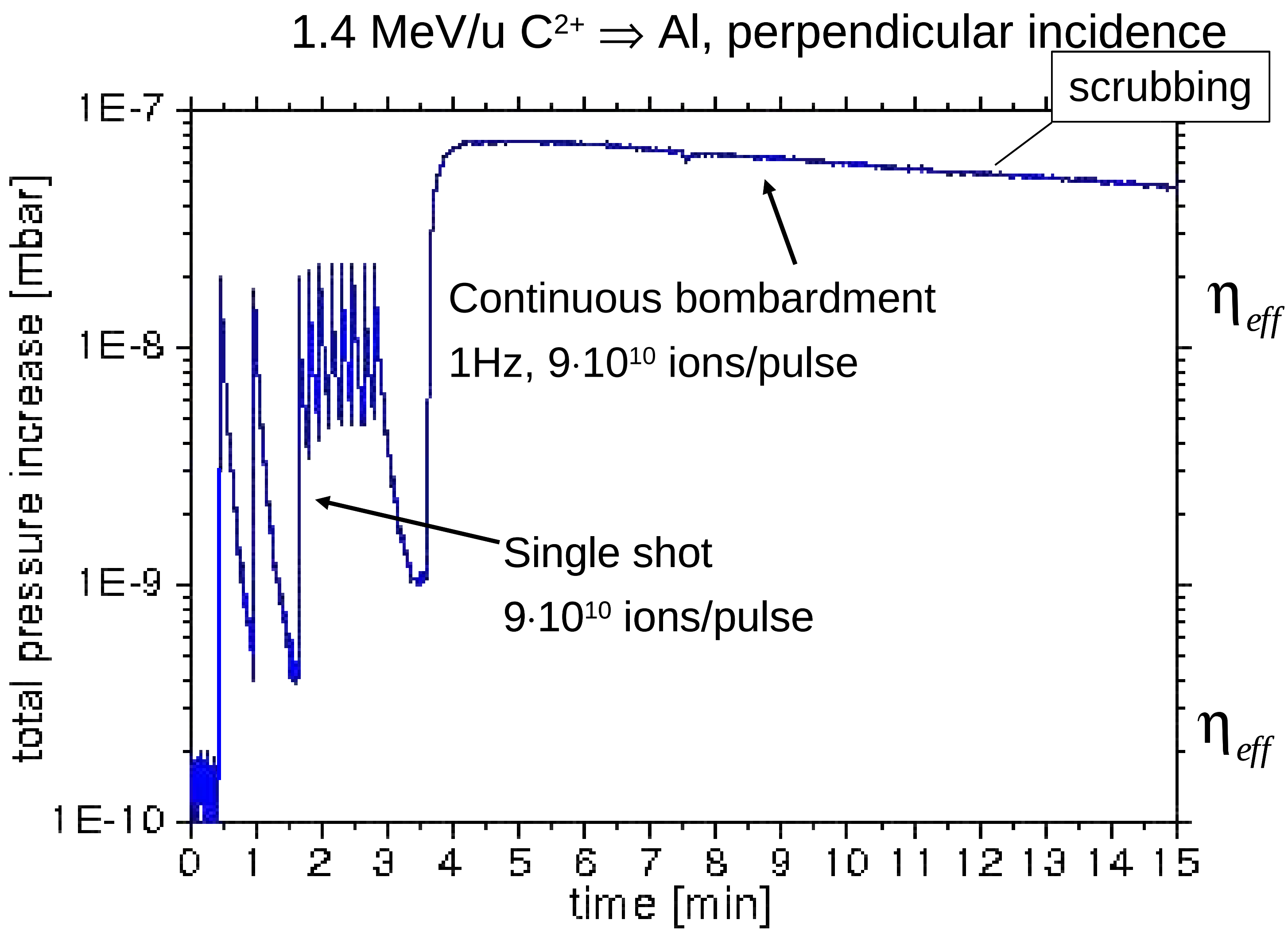
$$\eta \overset{?}{=} \eta(M, E, Z, T, \varphi, \ldots)$$

Experimental Setup for Ion Beam Induced Desorption Yield Measurements



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

Total Pressure Increase due to Desorption



Single shot

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

(conductance)

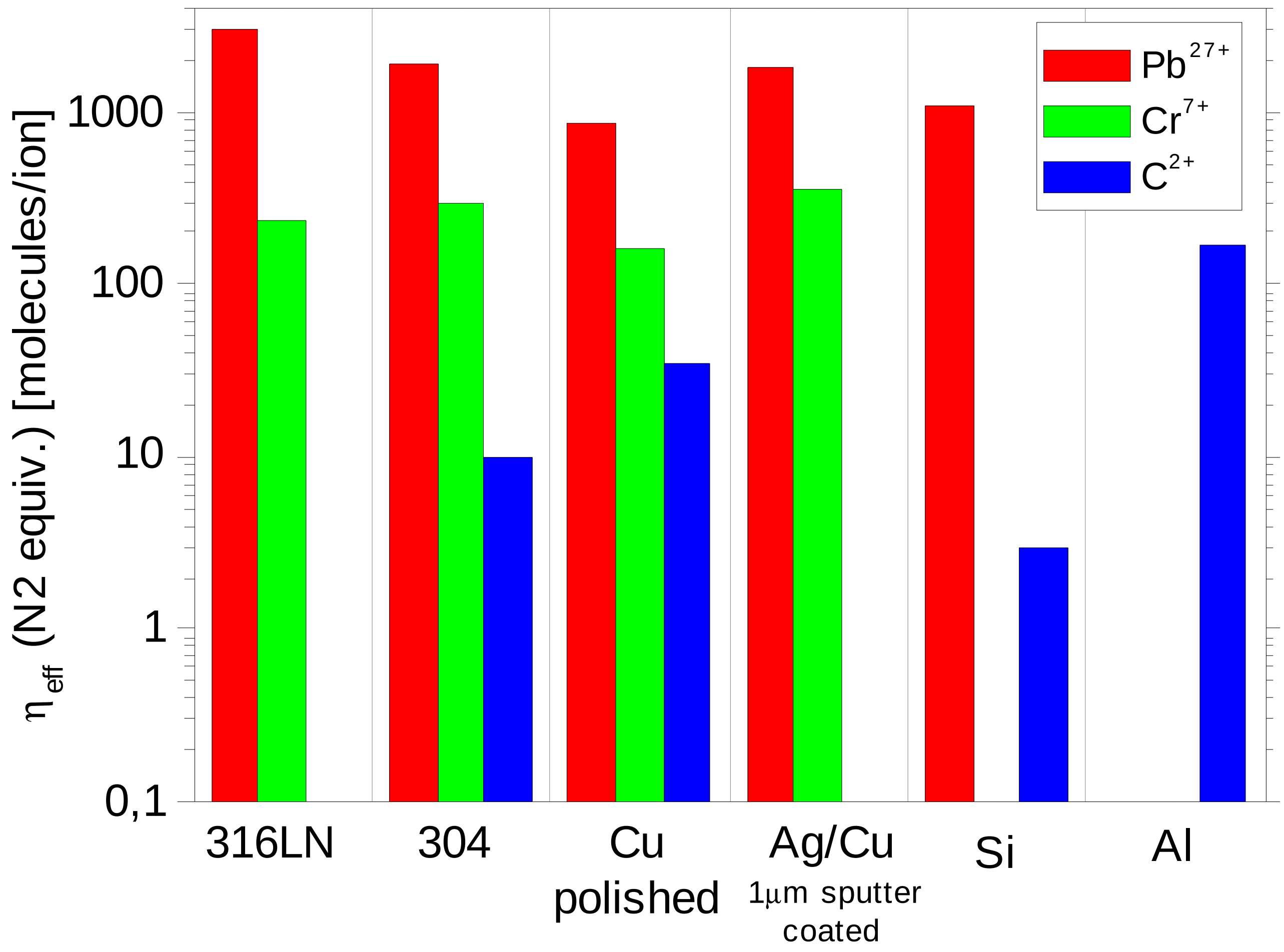
Continuous bombardment

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

Single Shot Results of Desorption Yield Measurements at GSI

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

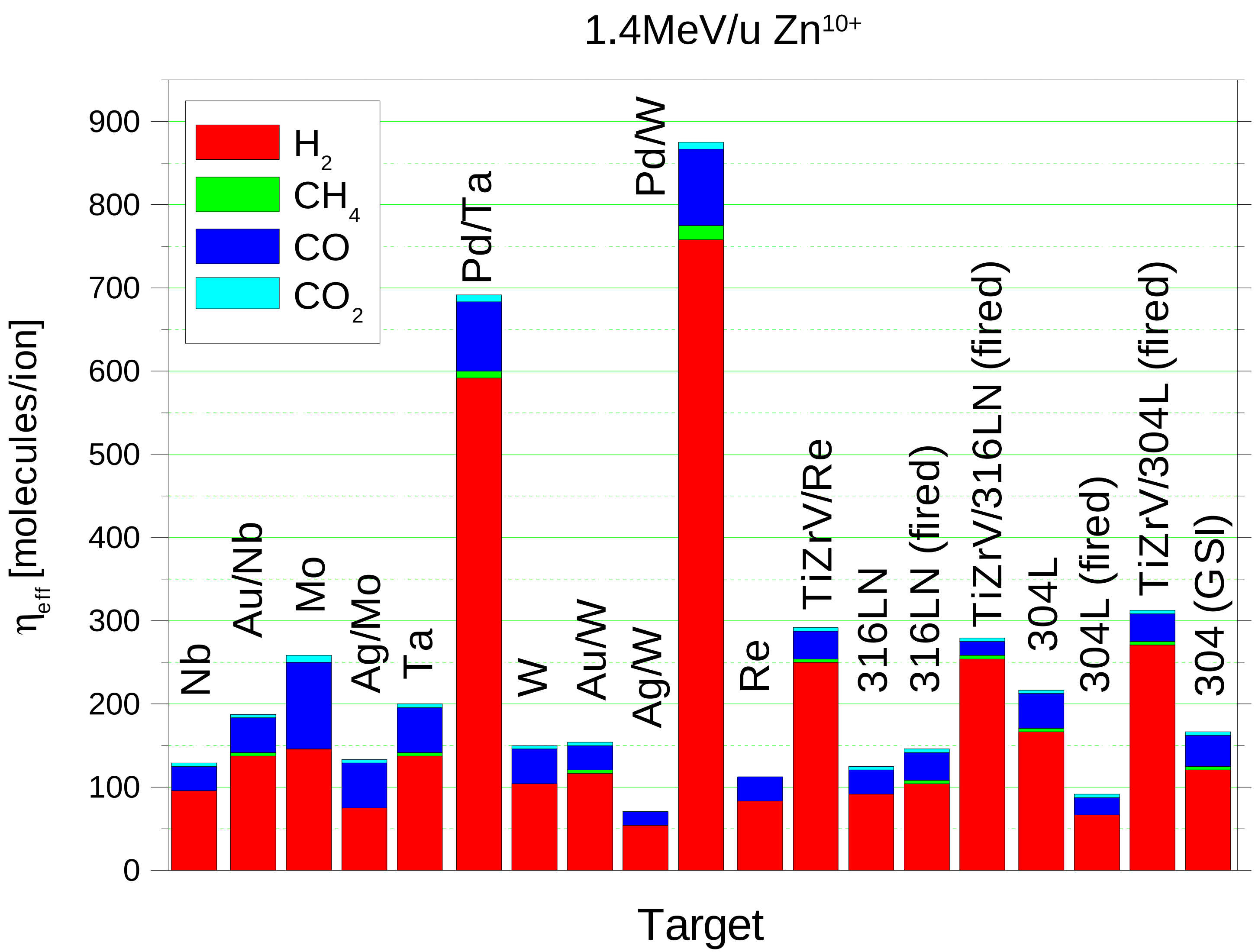
desorption yield η between 3 and 3000



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

η scales with mass and charge state

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



Mainly desorbed gases are H_2 and CO.

targets provided by

SIS18 Desorption Teststand

September 2004:
First test-experiment to measure ion beam induced desorption yields of U^{73+} at energies from 15 to 1000 MeV/u bombarding stainless steel 316LN, stainless steel P506, Al, Cu and Inconel625

Schematic Drawing of Experimental Setup

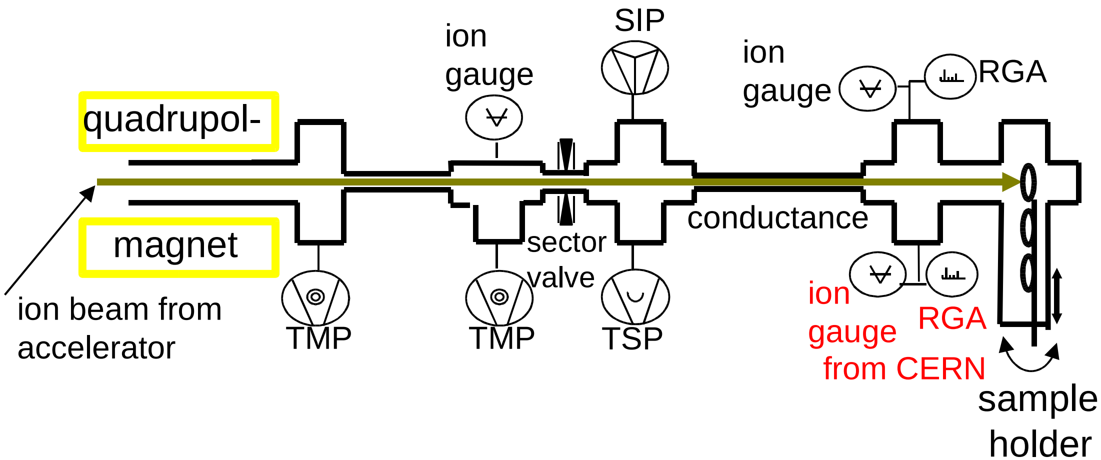
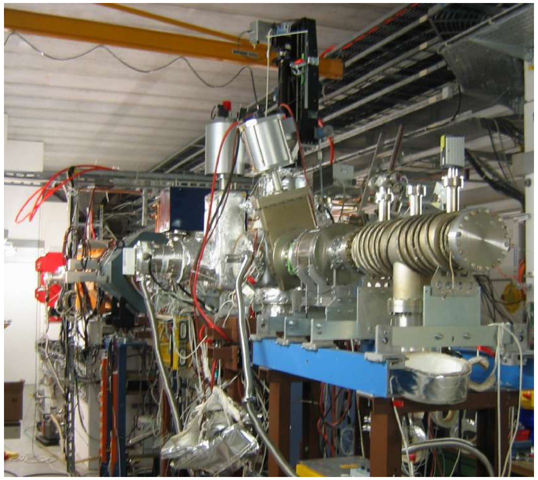


Photo of Experiment at Cave HHT



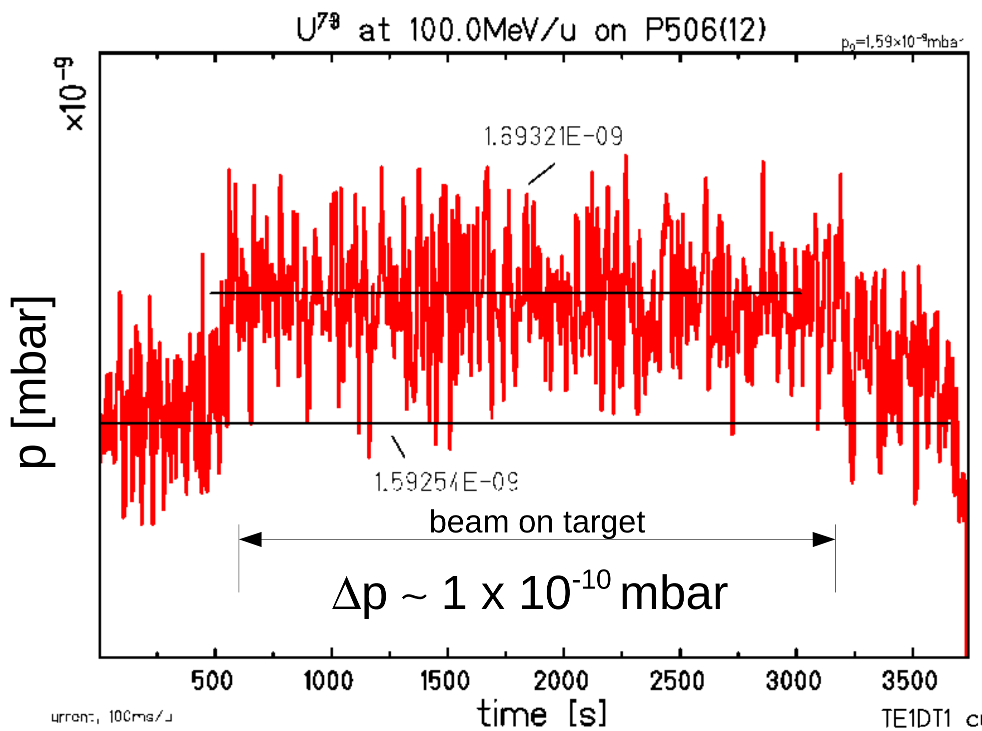
Target Holder

Experiment by: M.C. Bellachioma, M. Bender, H. Kollmus, A. Krämer (GSI), E. Mahner (CERN), O. Malyshev (ASTeC; UK), L. Westerberg, E. Hedlund (TSL; Sweden)

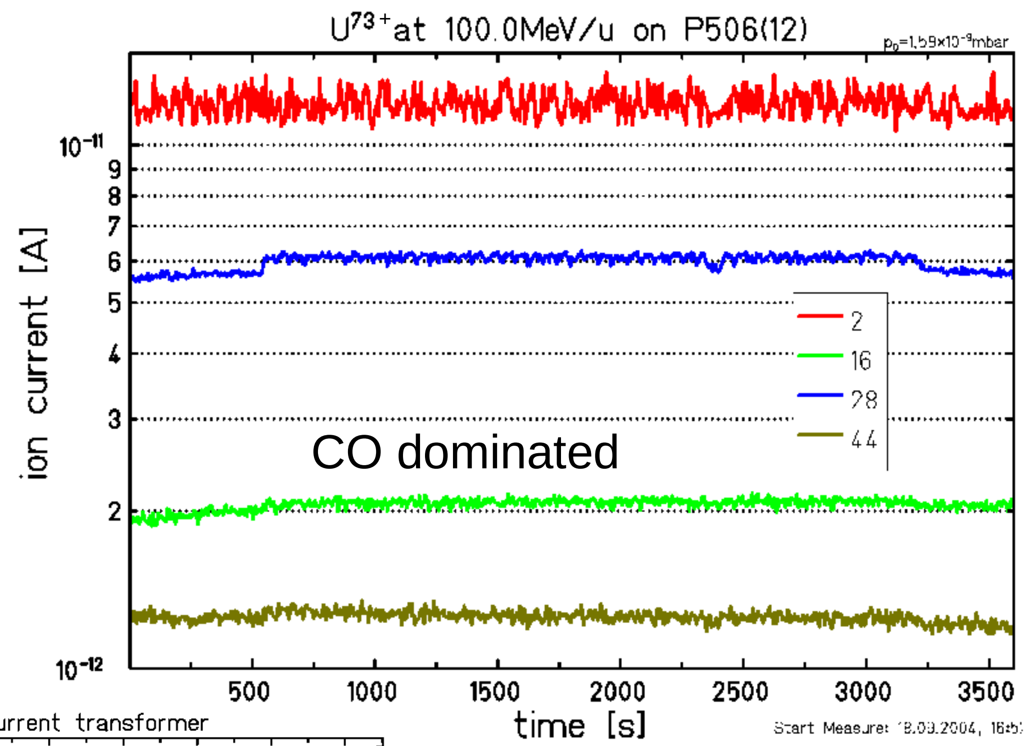
SIS Experiment

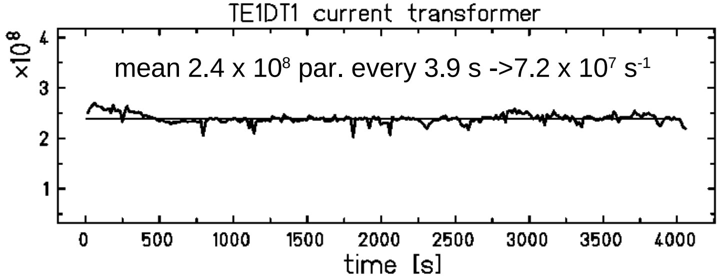
15, 40, 100, 408, 1000 MeV/u U^{73+} -> 316LN, Al, Cu, Inconel625, P506 (Boehler stainless steel)
number of ions ~ 5 x 10^7 s^{-1}

total pressure (N_2 equivalent)

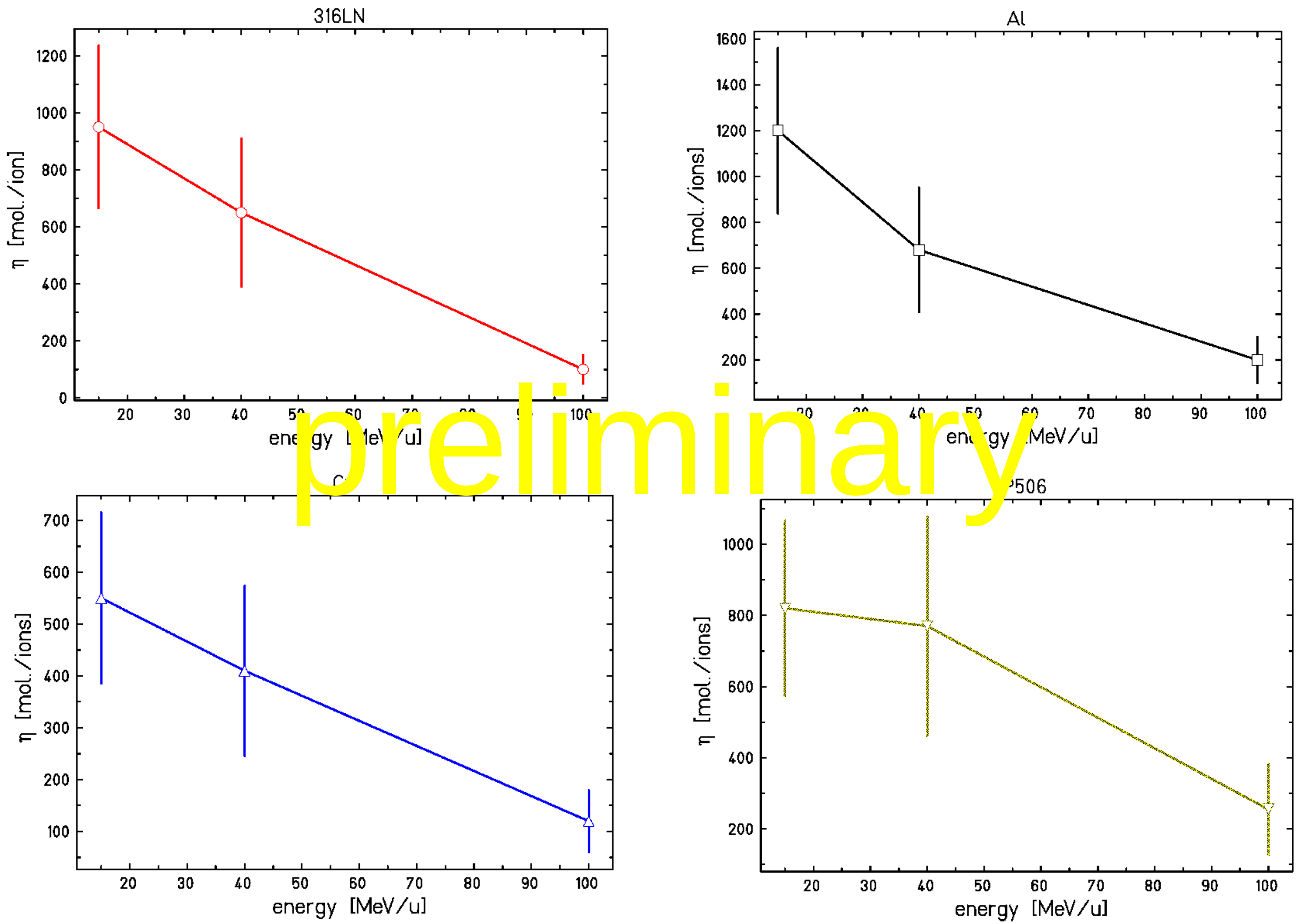


res. gas distribution (ion current)





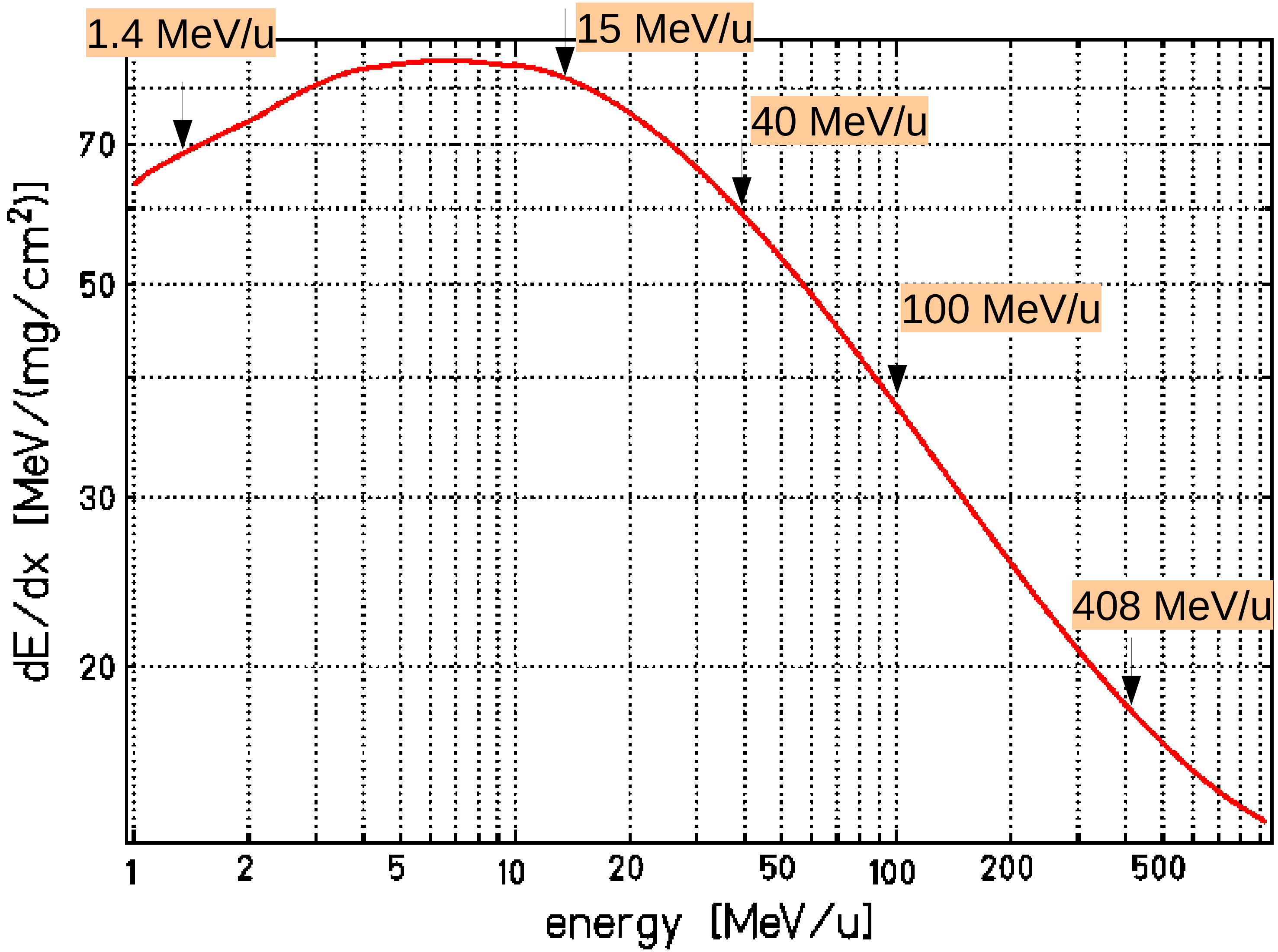
Yield vs. Energy – SIS Measurements



no gaugeable pressure rise for 408 and 1000 MeV/u U^{73+} on 316LN (η less then 100)

Electronic Energy Loss

U -> stainless steel, calculated using the TRIM code



Outlook

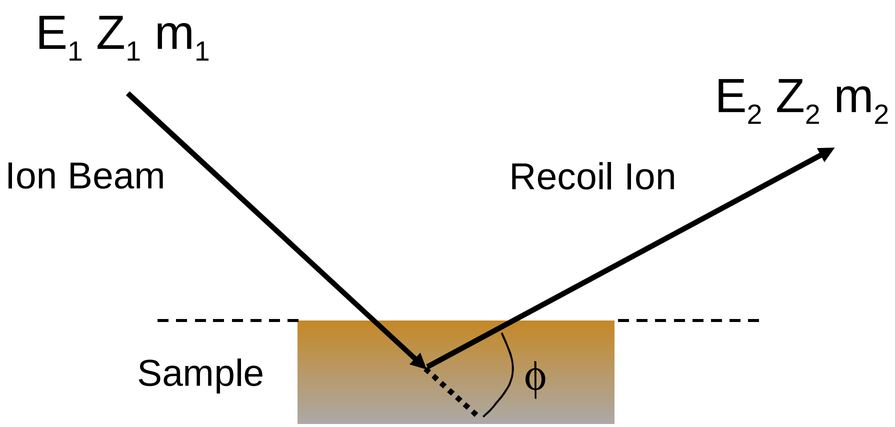
- Desorption measurements were performed for a multiplicity of projectile charge states and energies, scaling with mass was observed
- preliminary energy dependence for U^{73+} measured – dE/dx scaling

todo:

- repetition of energy dependence measurements
- charge state dependency? (not expected - equilibrium *q*)
- angle dependency of desorption yield – depth of energy loss test of dE/dx
- desorption yields of cold surfaces (with condensed gases)

- ERDA-Measurements – understanding of the physics behind the ion-induced desorption

Elastic Recoil Ion Detection Analysis (ERDA)



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

Rutherford-Scattering:

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

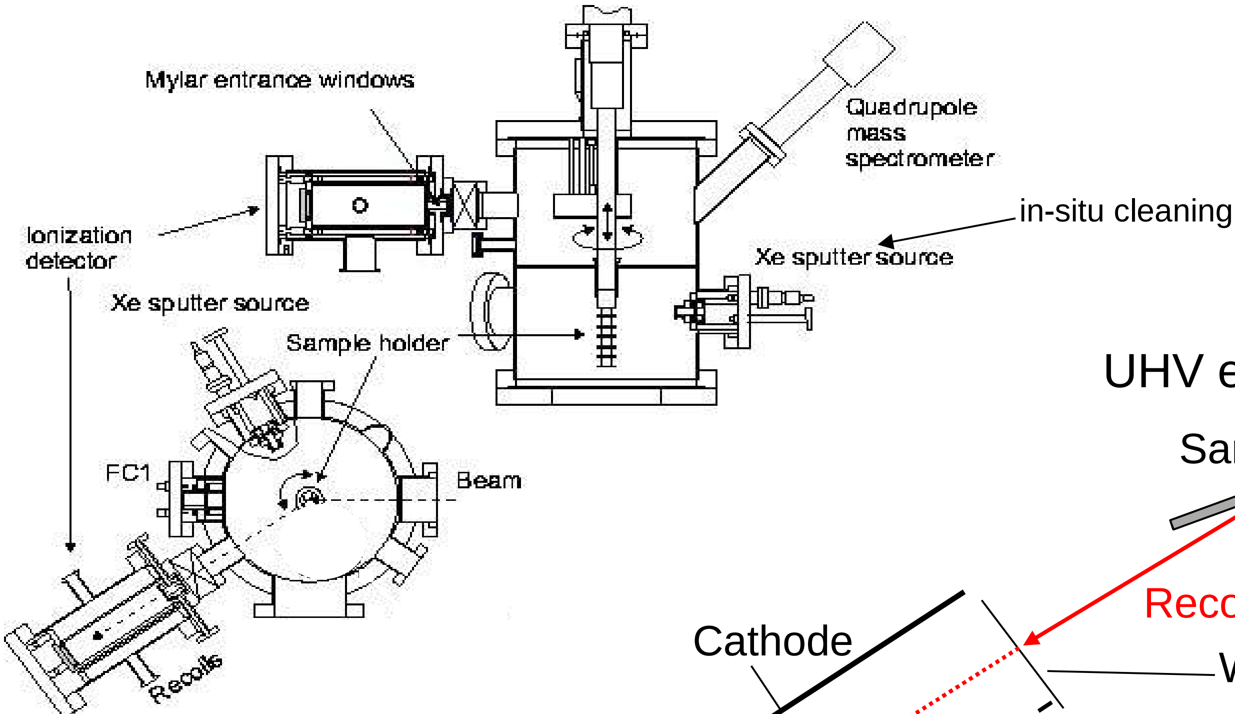
ERDA-Cross Section:

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

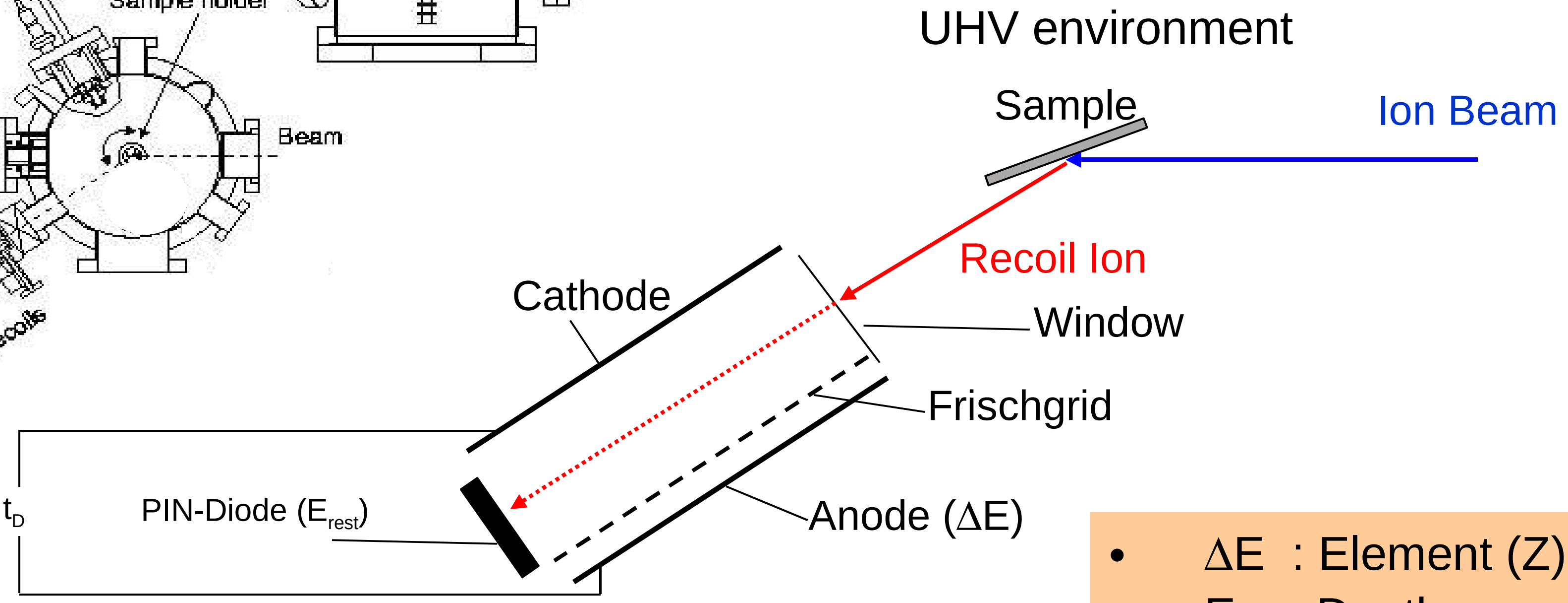
for heavy ions: $m_2/m_1 \ll 1$

$\rightarrow$ all recoil ions have approx the same velocity *v* ($\rightarrow$ similar energy loss)

Experimental Setup for ERDA Measurement



set-up installed at
HLI of GSI
ready for commissioning
PhD Markus Bender

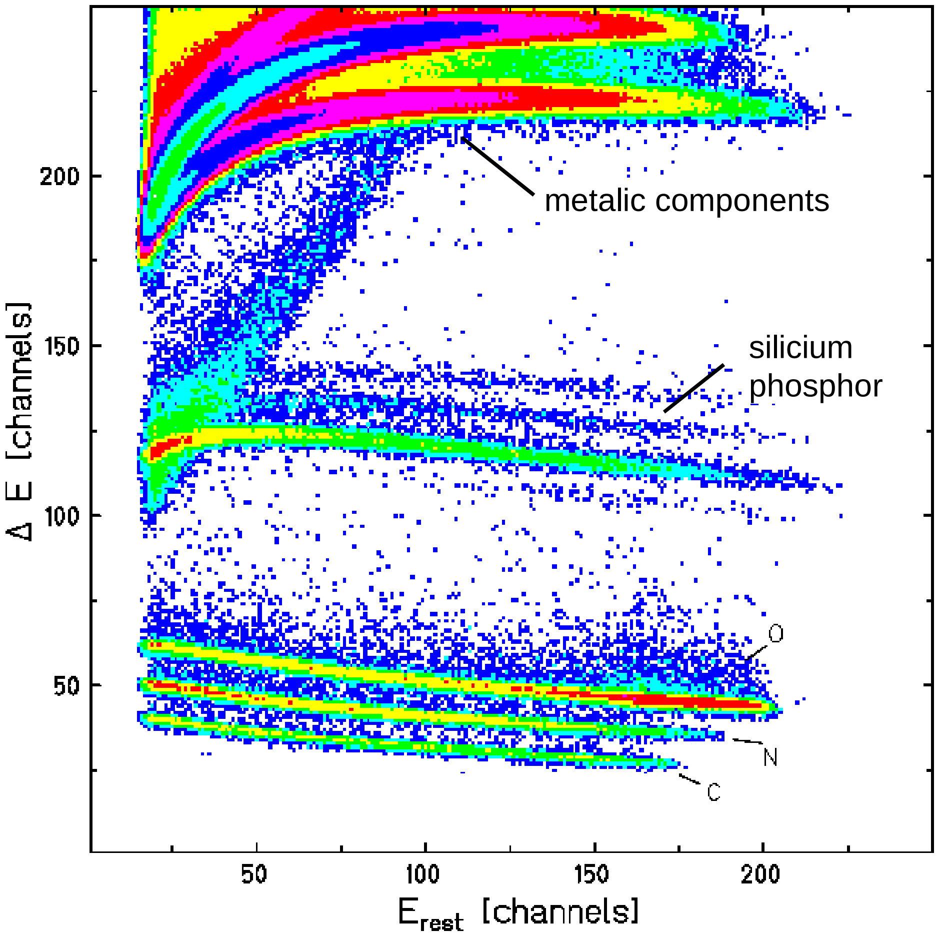


- ΔE : Element (Z)
- E_{rest} : Depth
- t_D : Emission Angle (ϕ)

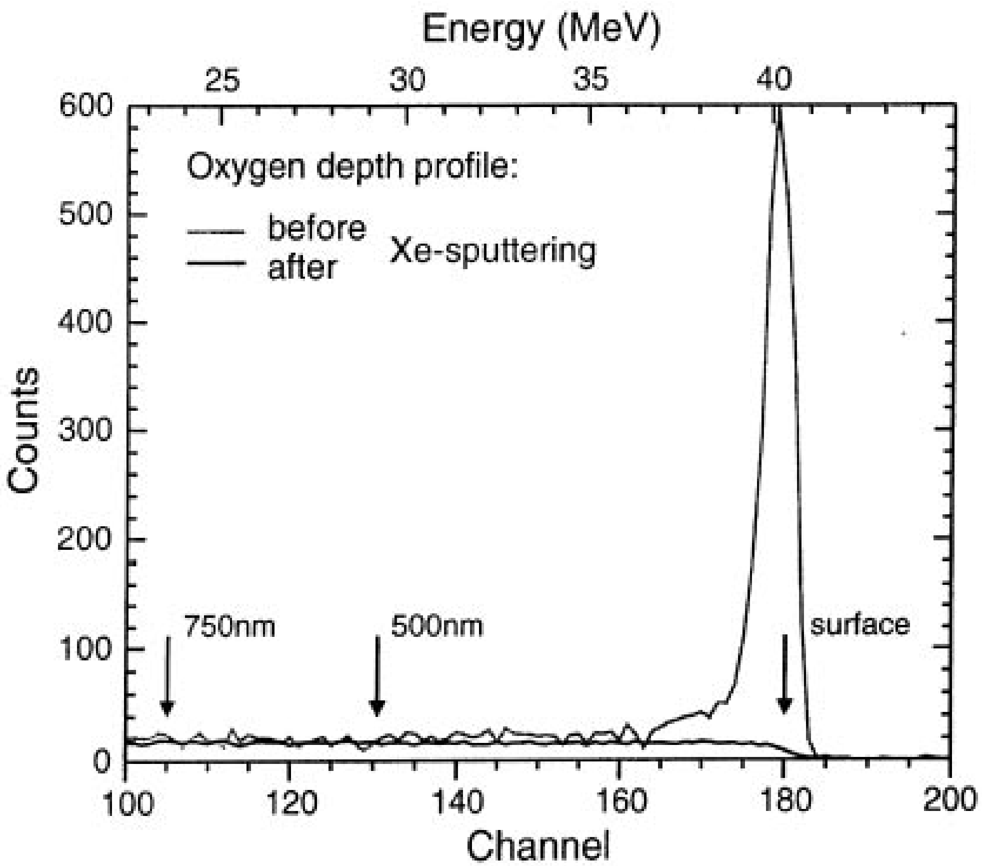
H. D. Mieskes et al., Measuring sputtering yields of high energy heavy ions on metals, NIM B 146 (1998)

ERDA-Spectra

1 MeV/u Au<30+> → 304 L stainless steel

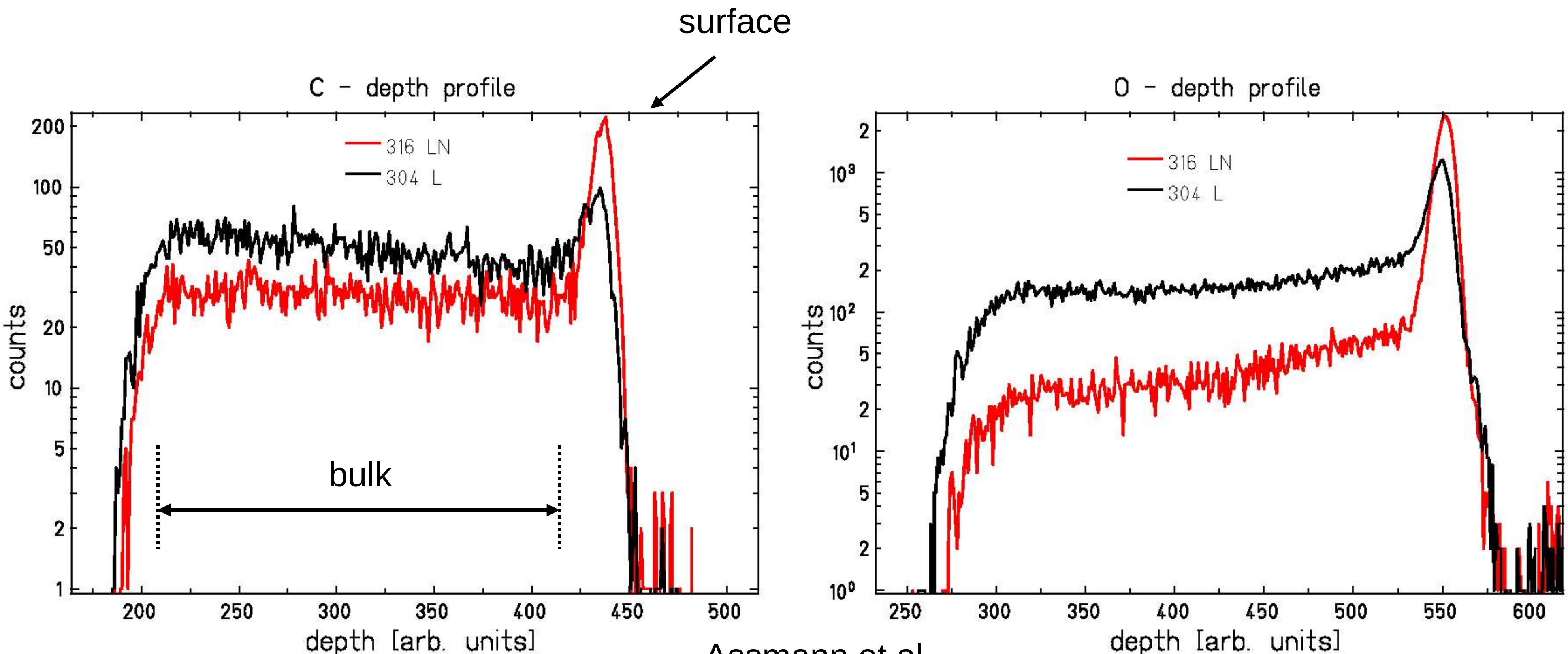


in-situ ERD energy profile of O-contamination in a *Ti* - sample



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

ERDA of Stainless Steel Samples

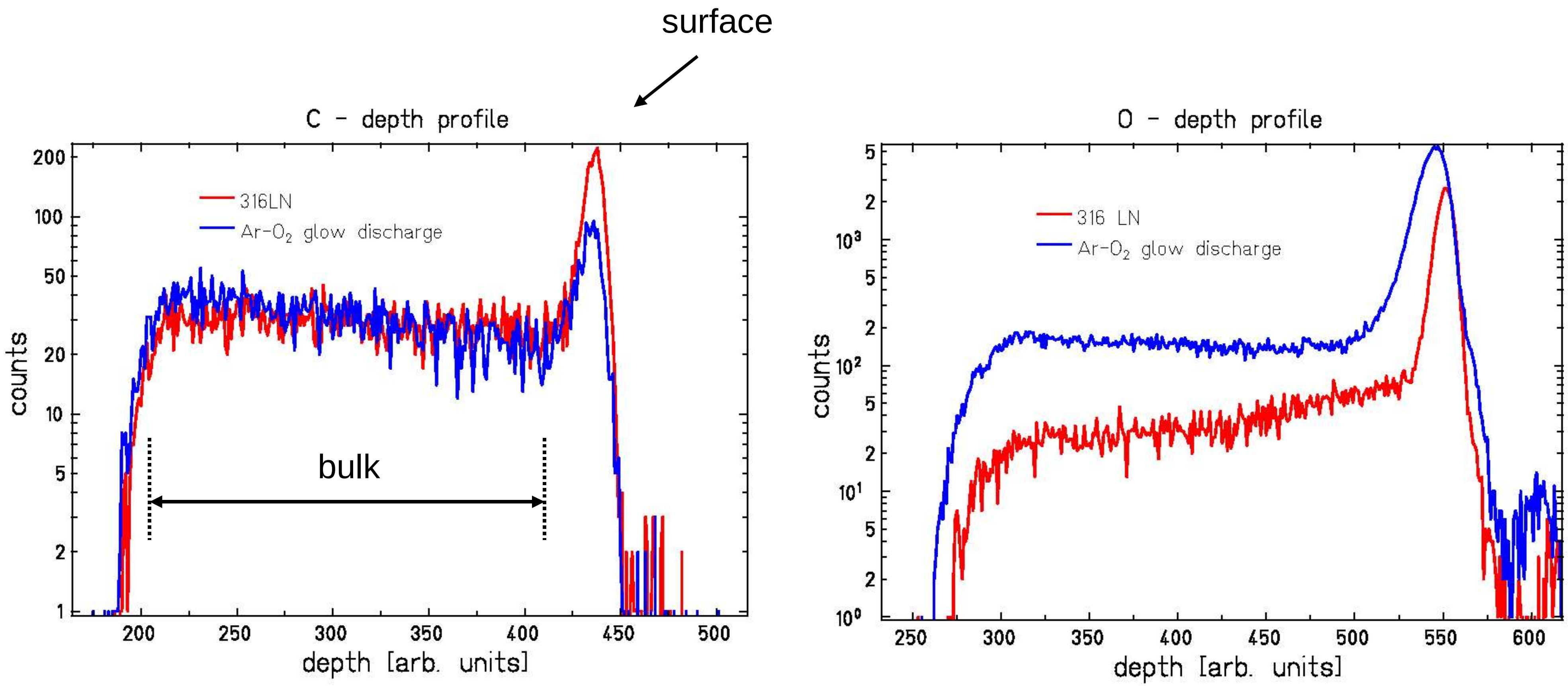


Assmann et al.

- the desorption yield of 316 LN was measured to be higher than the one of 304 L (Mahner et al.)
- all samples were exposed to atmosphere
- the ERDA measurements were performed in 1 x 10^{-7} mbar region

samples provided by E. Mahner (CERN)

ERDA of Stainless Steel Samples (2)



- the desorption yield of 316 LN – Ar-O_2 glow discharge was measured to be higher compared to the untreated 316 LN (Mahner et al., Phys. Rev. ST-AB6, 013201 (2003))

Outlook ERDA

- *in-situ* cleaning of targets with a sputter gun
- modifications of the target characteristics under ion bombardment
- correlations between target properties and desorption yields
- clear distinction between surface and bulk effects

planned experiments:

- influence of the oxide layer on the desorption yield
- desorption yield of single crystals monitored with ERDA
- desorption of “fancy“ target, like multiple layered targets with diffusion barriers
- measurement of electronic desorption yields