

# Interactions of Multiply Charged Fast Tin Ions with Solid Targets and Neutral Gases

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university of  
 groningen

2014 | 400 years

zernike institute for  
 advanced materials



ADVANCED RESEARCH CENTER FOR NANOLITHOGRAPHY



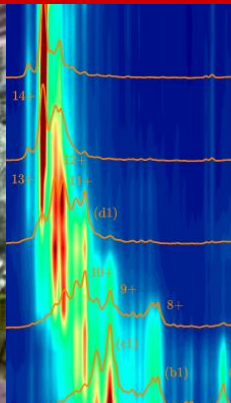
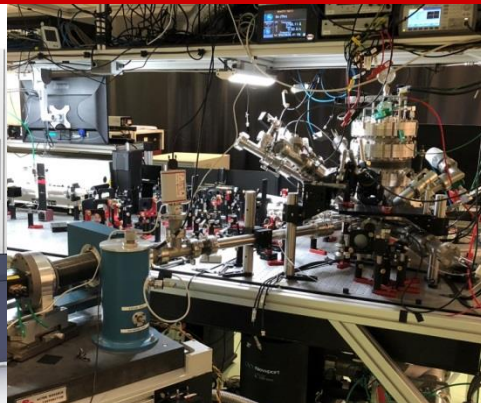
UNIVERSITEIT VAN AMSTERDAM



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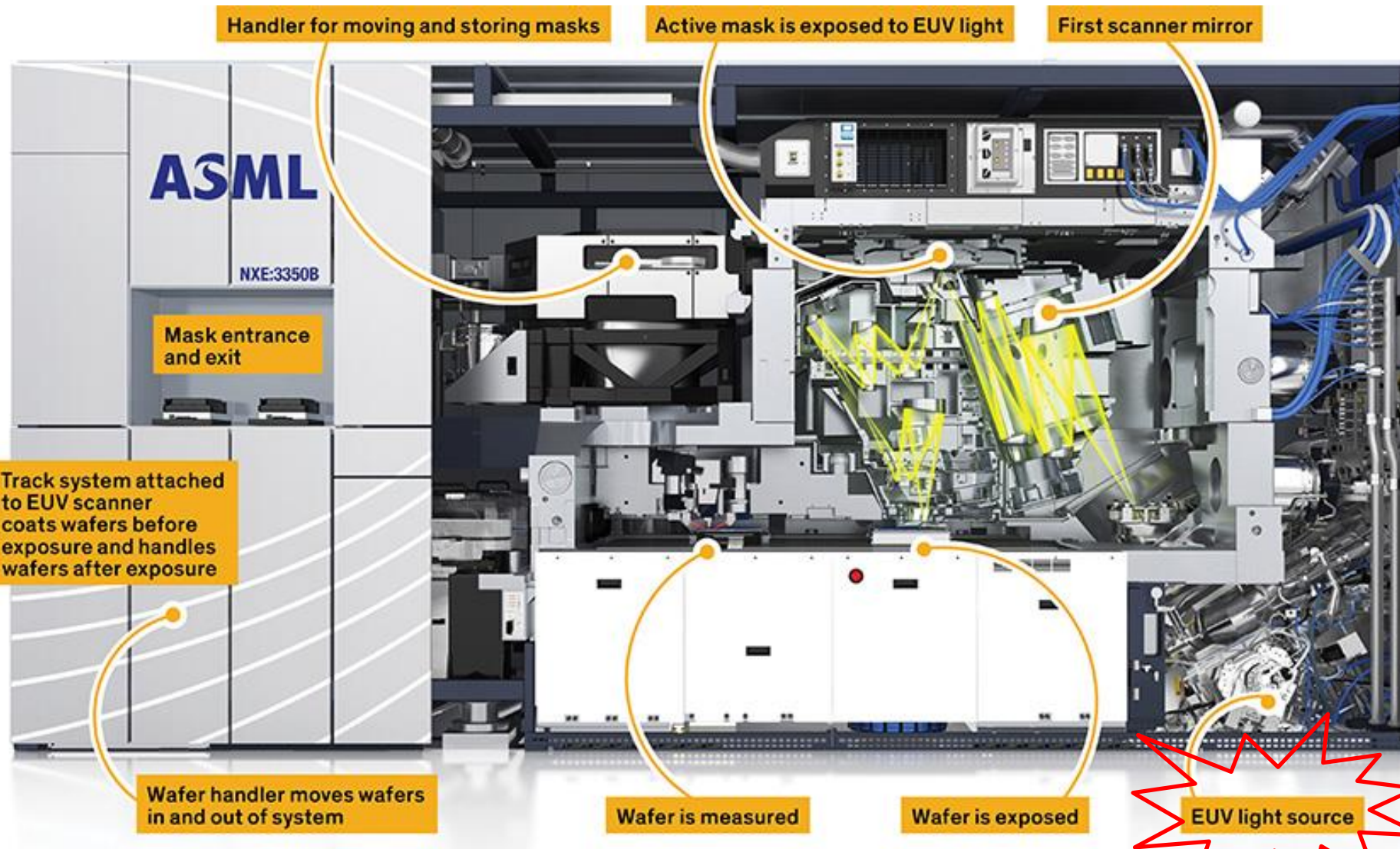
Provincie  
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ASML

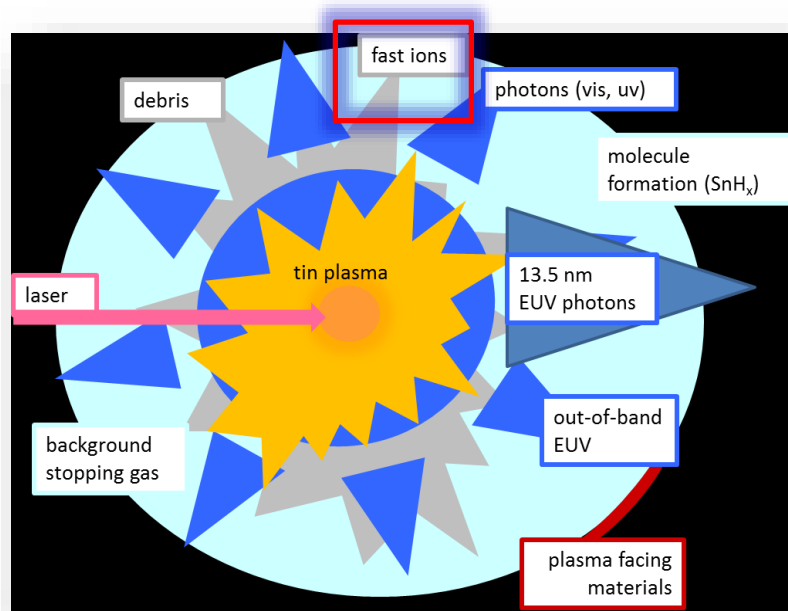
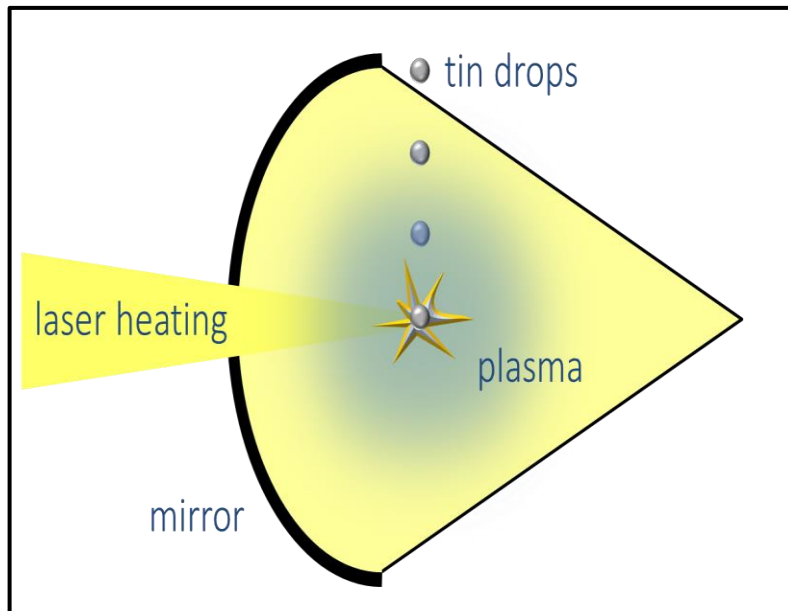


- Ion beam facility ZERNIKELEIF
- Solid Targets
  - Scattering experiments at surface physics setup ( $\text{Si}\phi$ )
  - Investigation of missing Single Collision Peak (SCP)
  - Standard simulation code SRIM and test for heavy Sn/Kr ions
  - Conclusion
- Gas targets
  - Ion-gas crossed beam experiments at CHEOPS setup commissioned

# ASML EUV NANOLITHOGRAPHY MACHINE



# TIN LPP AND FAST IONS



**Fast  $\text{Sn}^{q+}$  ions** (tens of keV) also generated

Special EUV collecting multilayered mirrors may get damaged

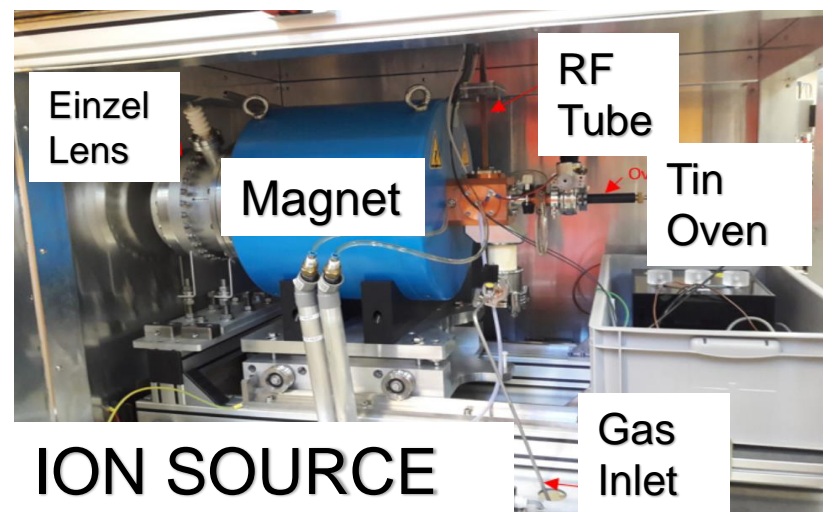
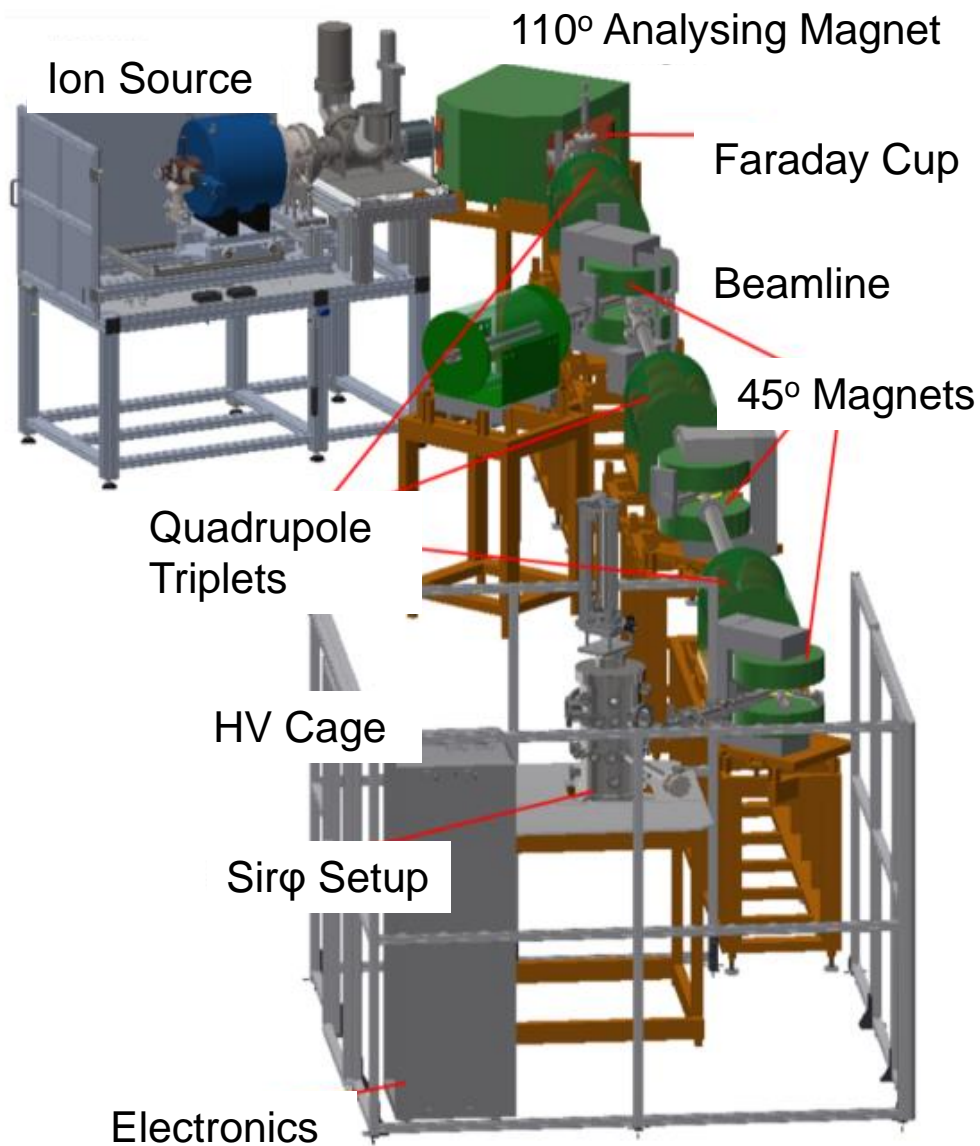
Reduce energy by stopping gas

Damage thresholds

Experiments to evaluate simulation codes as SRIM



# ION BEAM FACILITY: ZERNIKELEIF



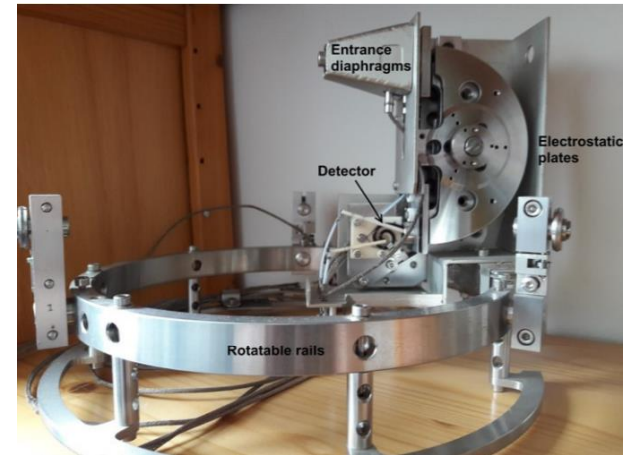
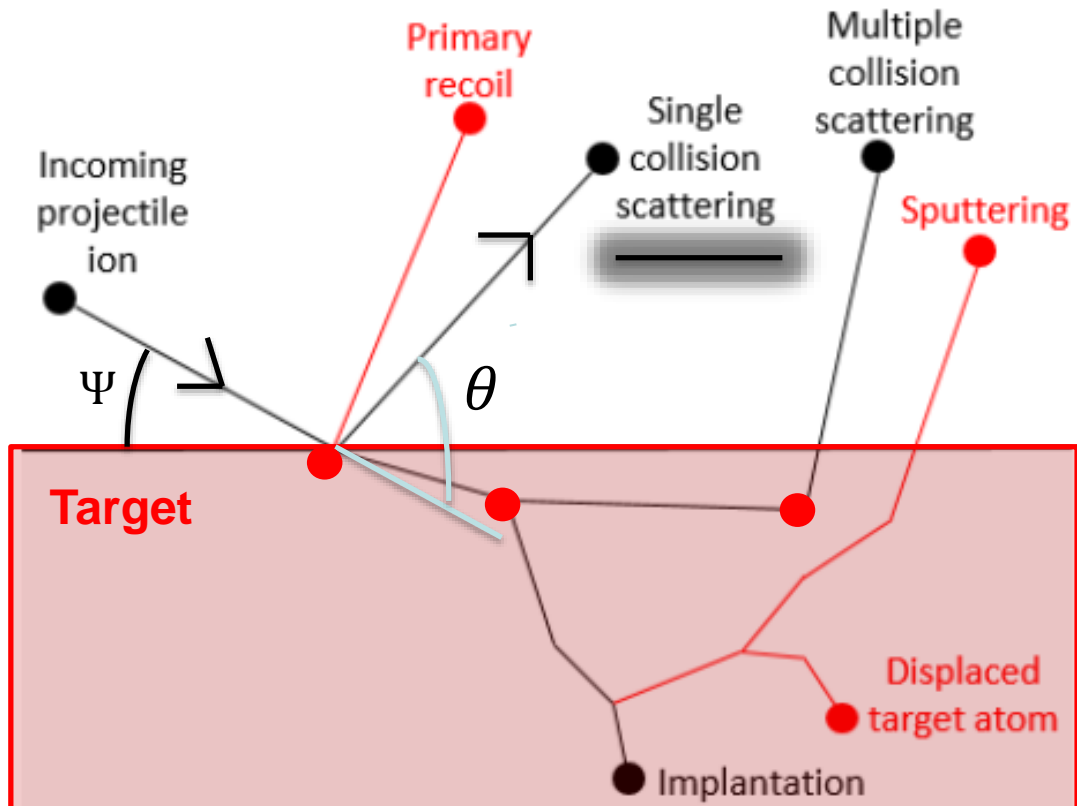
ION SOURCE

energy, mass and charge state selected  $\text{Sn}^{q+}$  ion beam facility with a full suite of auxiliary analysis equipment

# ION SCATTERING EXPERIMENTS @ SIRΦ

● Ions : mass  $m_p$

● Target : mass  $m_t$



E/q selection by Electro Static Analyzer (

Measure energy of scattered and sputtered ions as a function of

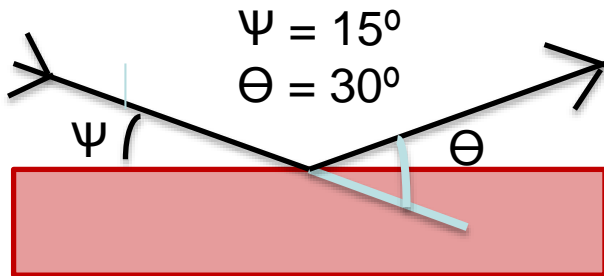
- Projectile energy,  $E_0$
- Incident angle,  $\Psi$
- Scattering angle,  $\theta$

For single collision scattering,

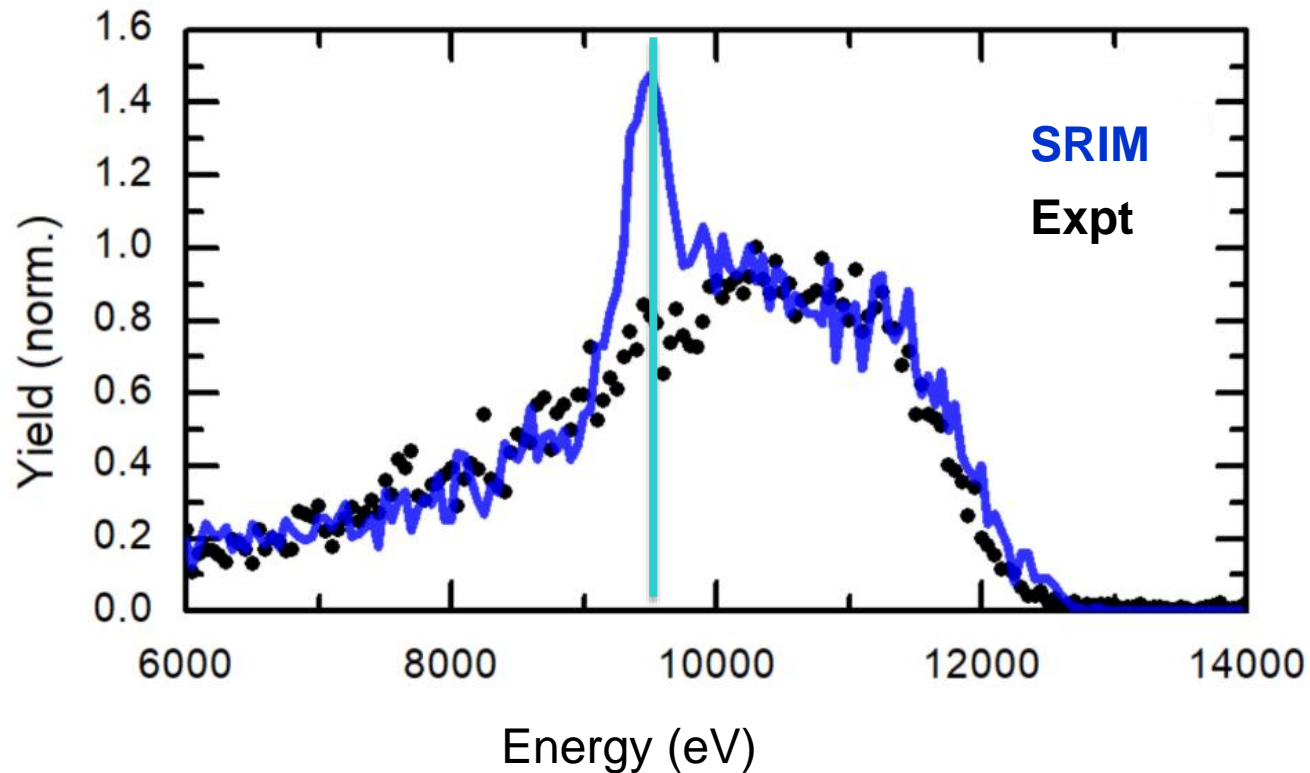
$$E_f/E_0 = \left( \frac{\cos(\theta) + \sqrt{(m_t/m_p)^2 - \sin^2(\theta)}}{1 + m_t/m_p} \right)^2$$

# Missing Single Collision Peak

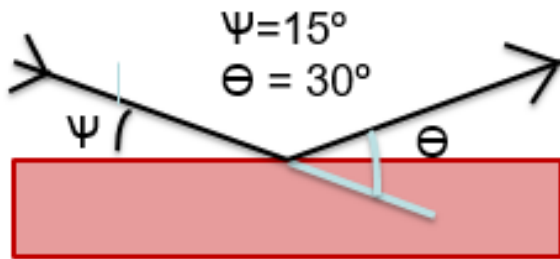
Projectile : 14 keV  $\text{Sn}^{2+}$   
Target : Polycrystalline Mo



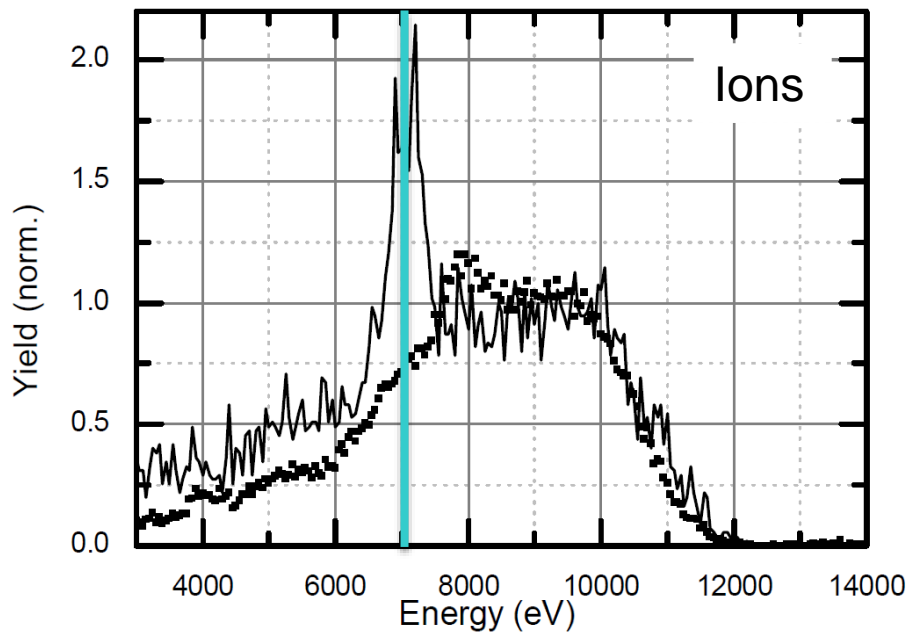
Single Collision peak (**SCP**) at  
**9.6 keV**



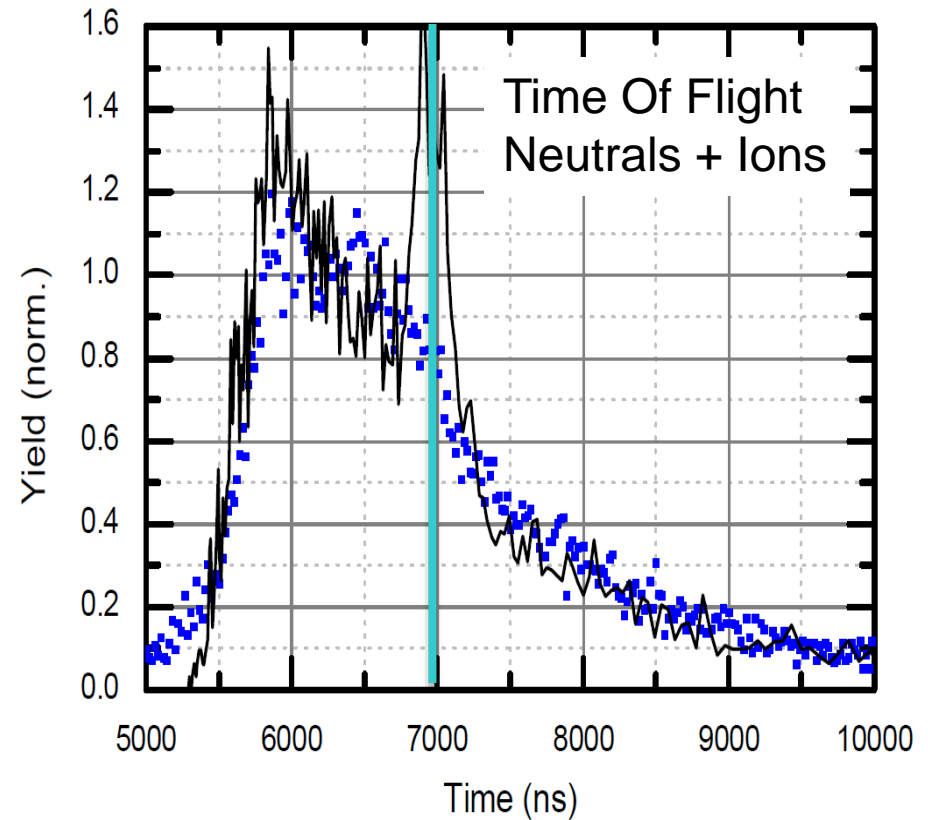
# 14 keV Sn<sup>2+</sup> on Ru



**SCP @ 7.1 keV**



**SCP @ 7 μs**



## SRIM related causes

- Potentials
- Prescattering
- ...???



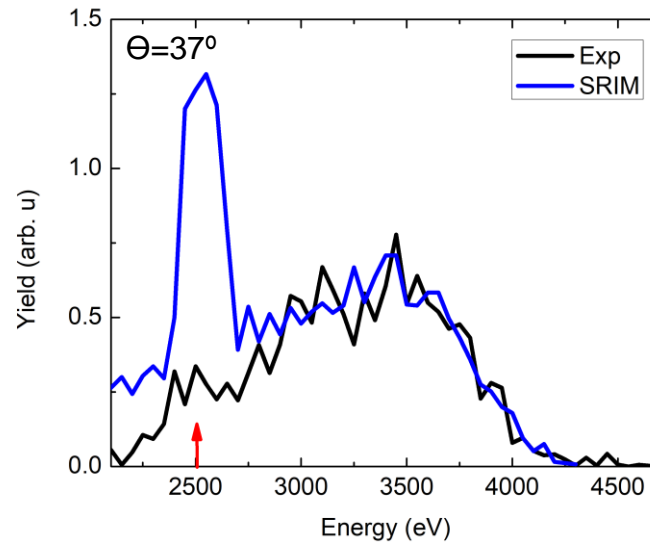
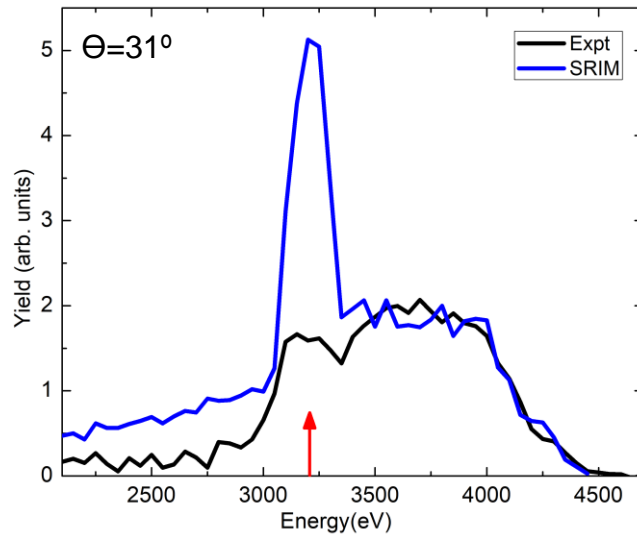
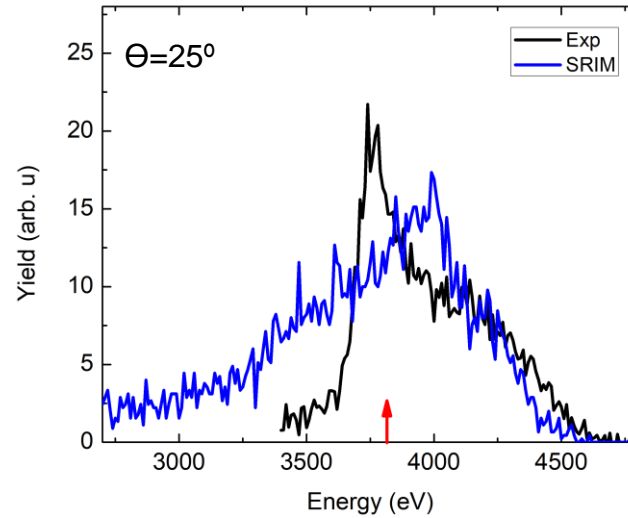
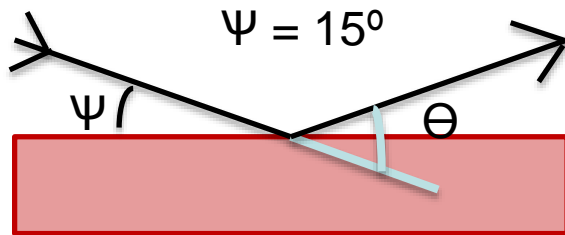
# INVESTIGATORY TESTS CONDUCTED

## original experiment: 14 keV Sn<sup>2+</sup> - Mo

Parameter		Outcome
incoming charge state	Sn <sup>1+ - 4+</sup>	as 14 keV Sn <sup>2+</sup>
energy	5 – 30 keV	as 14 keV Sn <sup>2+</sup>
ion species	He <sup>1+</sup> , Ne <sup>1+</sup>	no difference between exp. and SRIM
	Xe <sup>1+ - 2+</sup>	as 14 keV Sn <sup>2+</sup>
	Kr <sup>2+</sup>	larger difference than 14 keV Sn <sup>2+</sup>
outgoing charge state	neutrals	similar effect
target	Ru	larger difference than 14 keV Sn <sup>2+</sup>

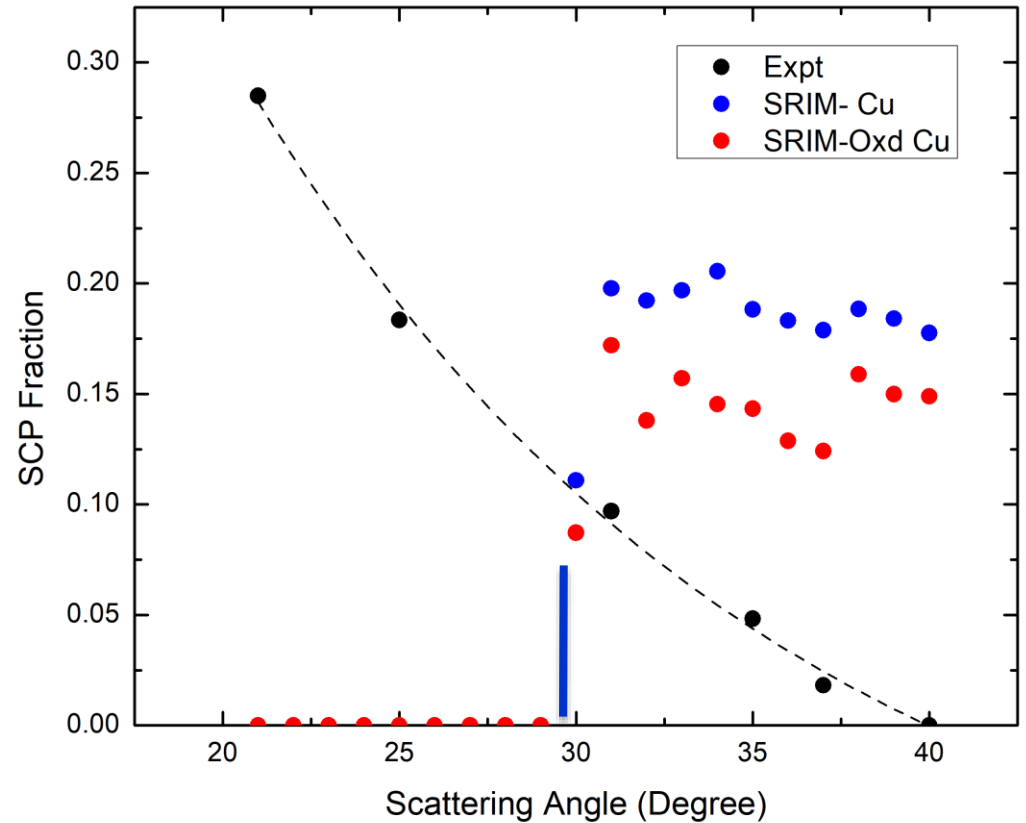
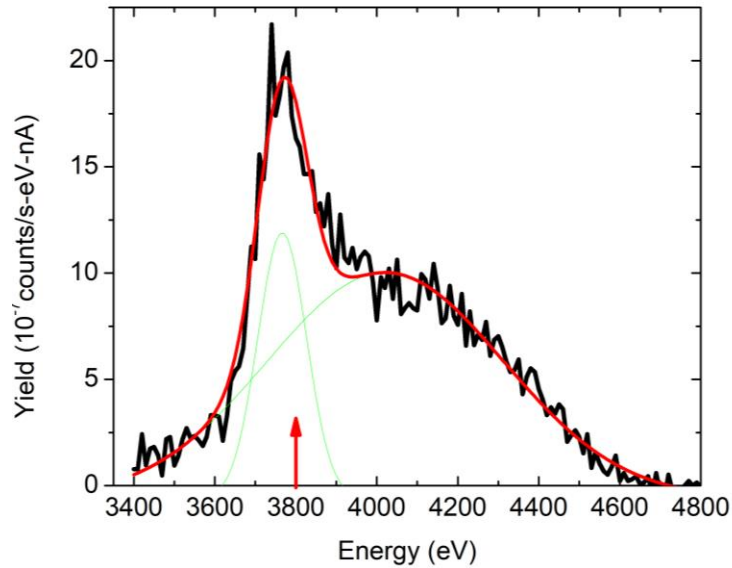
# 7 keV Kr<sup>1+</sup> on Cu

Similar  $\frac{\text{Target mass}}{\text{Projectile mass}}$



# SCP FRACTION

## SRIM with pure and oxidized copper



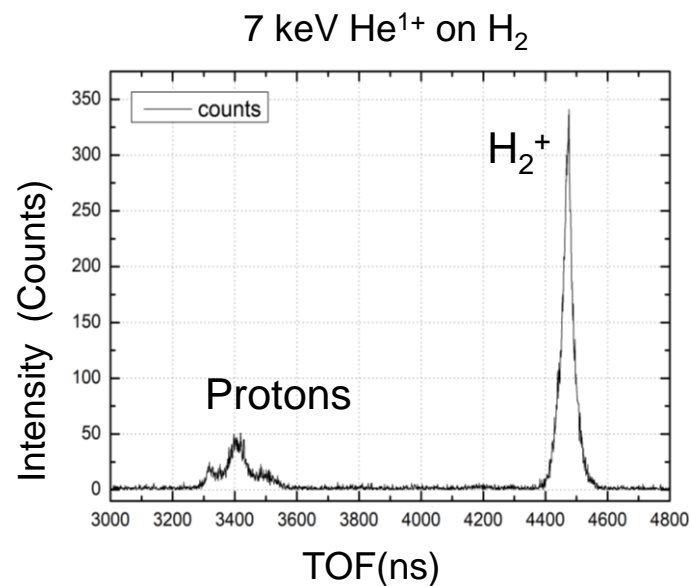
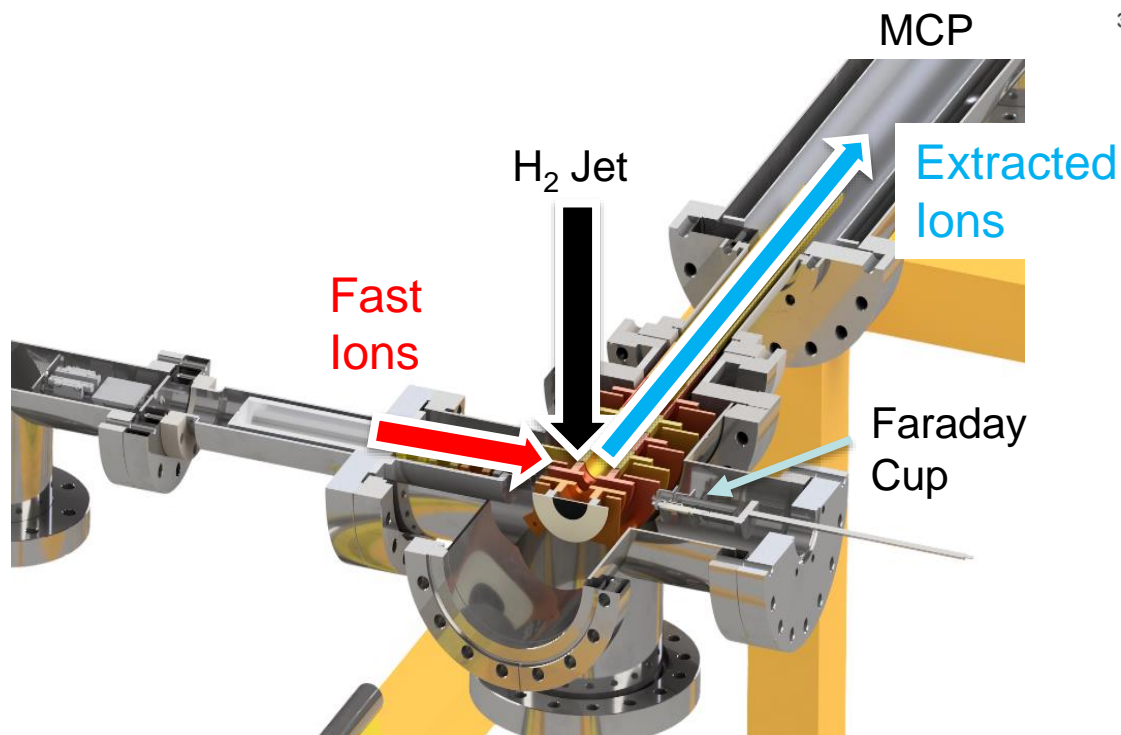
SRIM predictions not in agreement with experiments

## Ion scattering experiments in $\text{Si}r\phi$

- Single collision peaks absent in  $\text{Sn}^{q+}$  experiments
- Numerous investigatory experiments (energy, targets, charge state, species)
- Consistent discrepancies in all heavy ion - heavy target systems limitation of SRIM
- Peaks in Kr/Cu experiment: different but possibility for tuning potentials to get good correspondence
- More advanced package (SDTrimSP) recently developed at the Max Plank Institute for Plasma Physics.

# ION-GAS CROSSED BEAM EXPERIMENTS @ CHEOPS

Preliminary tests experiments underway



Ions generated due to collision extracted

TOF mass spectrometry

Charge exchange cross-section determination





- QISD group, Zernike Institute for Advanced Materials
  - Ronnie Hoekstra
  - Harry Jonkman
  - Sybren, Walewein, Roeland
  - Eva, Joël, Otte, Erik, Lukas
  - Jan Mulder
- EUV Plasma Processes group
  - Oscar Versolato
  - Ronnie Hoekstra
  - Wim Ubachs
  - Entire EUVPP team