Transmission of high energy heavy ion beams in the AGOR cyclotron

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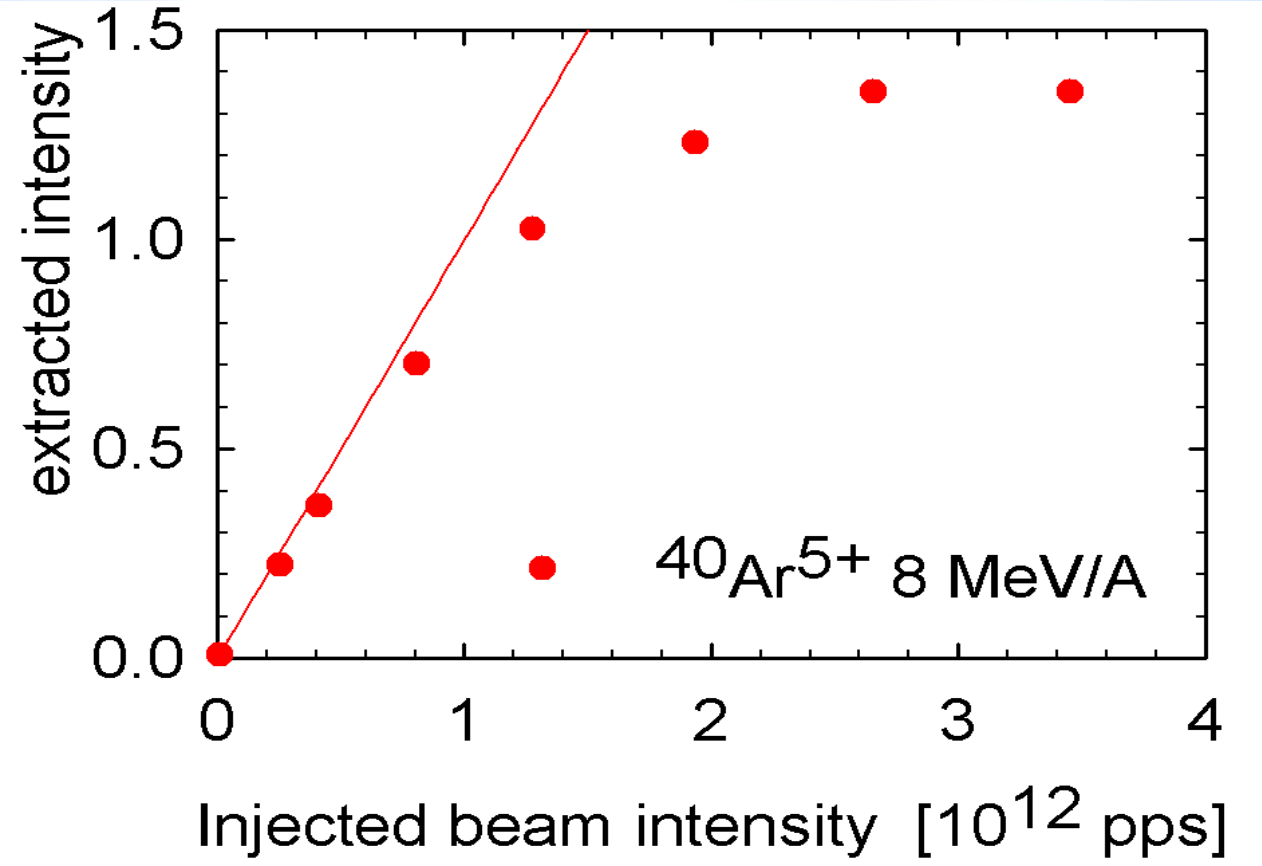
Problem Statement

Need maximum intensity of heavy ion beams

^{206}Pb at 8.5 MeV/u

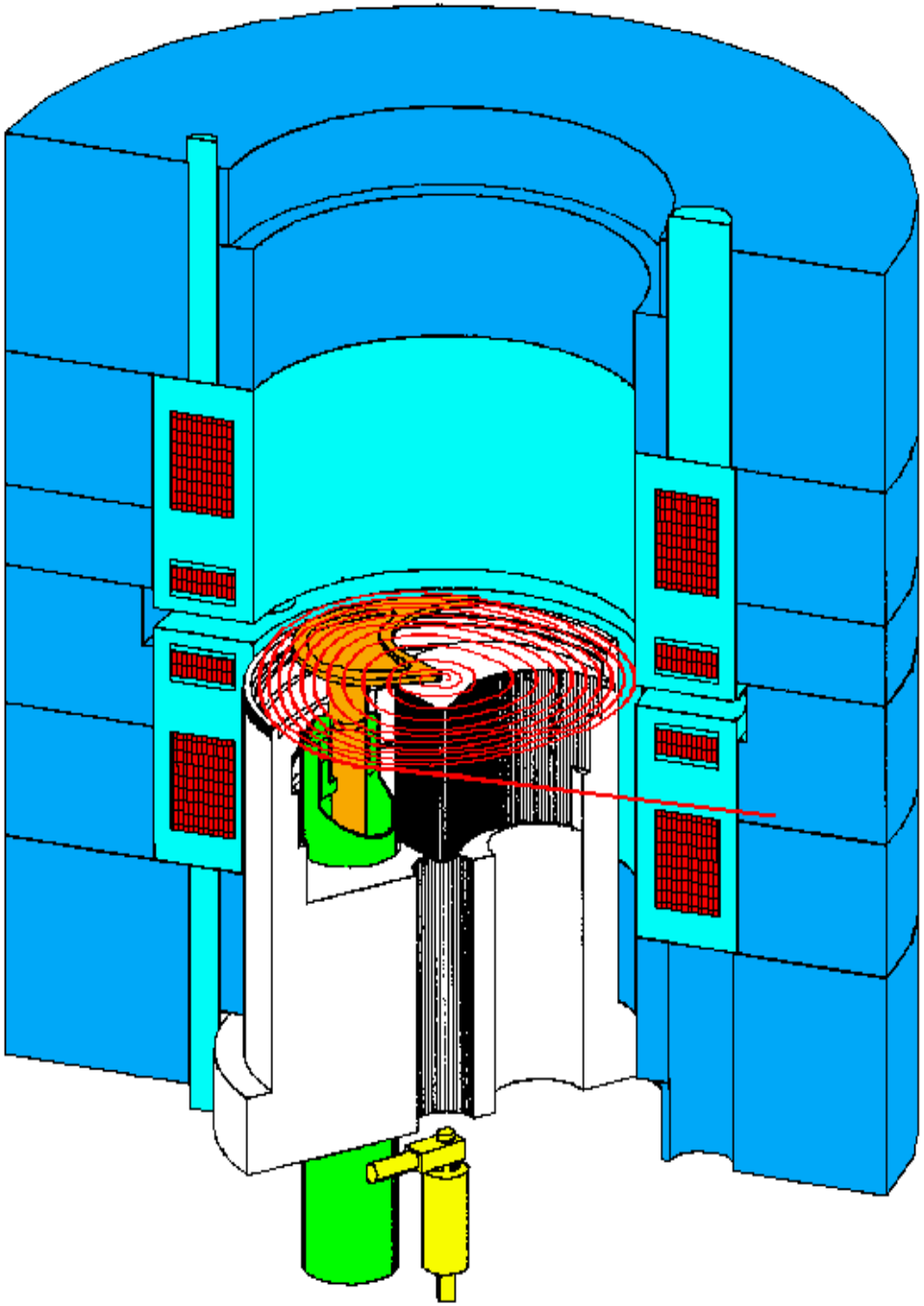
Increased intensity → reduced transmission



- Increase in beam intensity leads to a pressure rise ➡ increased loss of beam particles

Goal : Improve transmission in cyclotron

- Understand beamloss process in a cyclotron
- Mitigation methods



AGOR

Pressure ~ 10^{-7} mbar

No of turns ~ 300

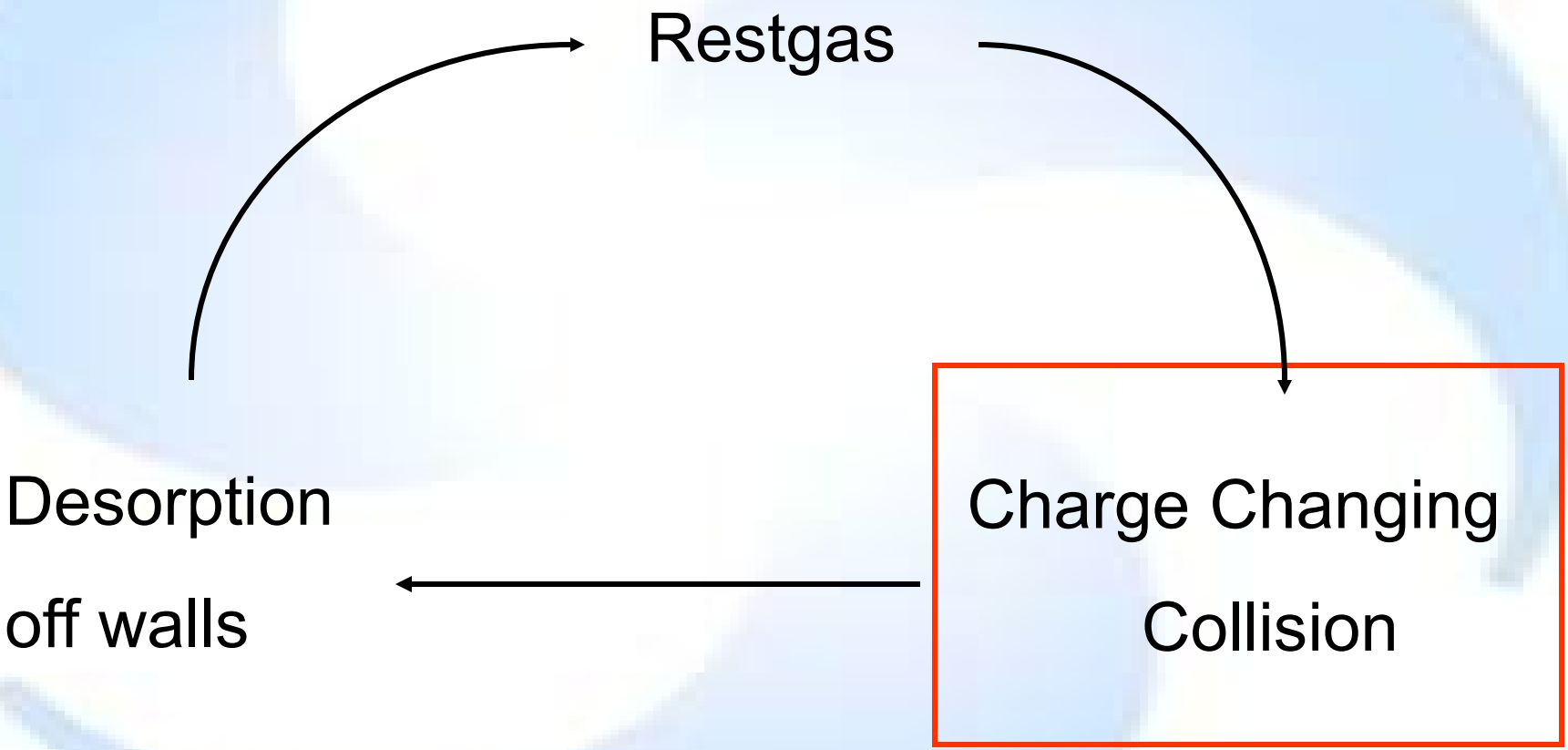
Pathlength ~ 1.5 km

Storage ring
(SIS18, GSI)

Pressure ~ 10^{-11} mbar

Pathlength ~216 m/turn

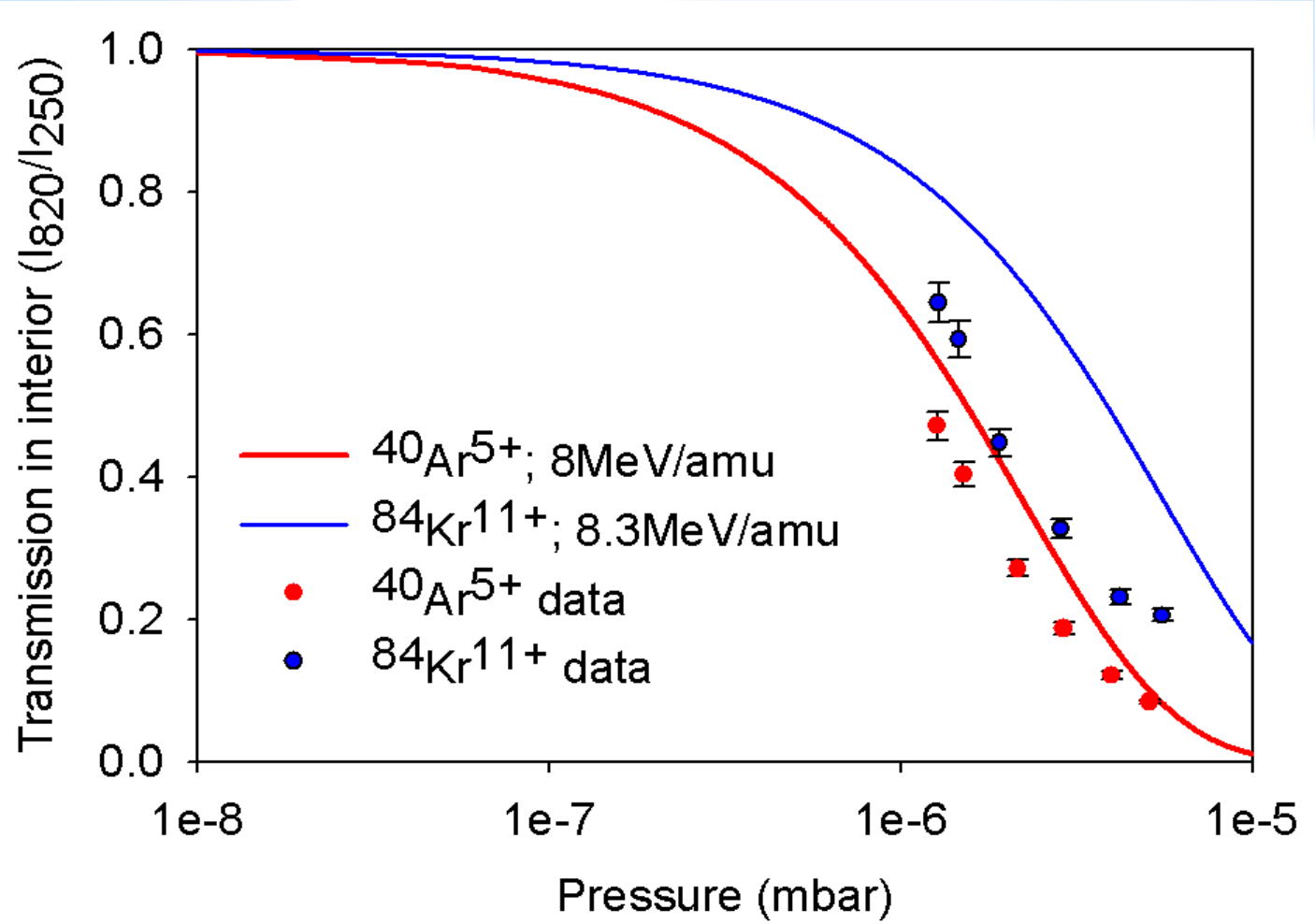
BeamLoss in Cyclotron



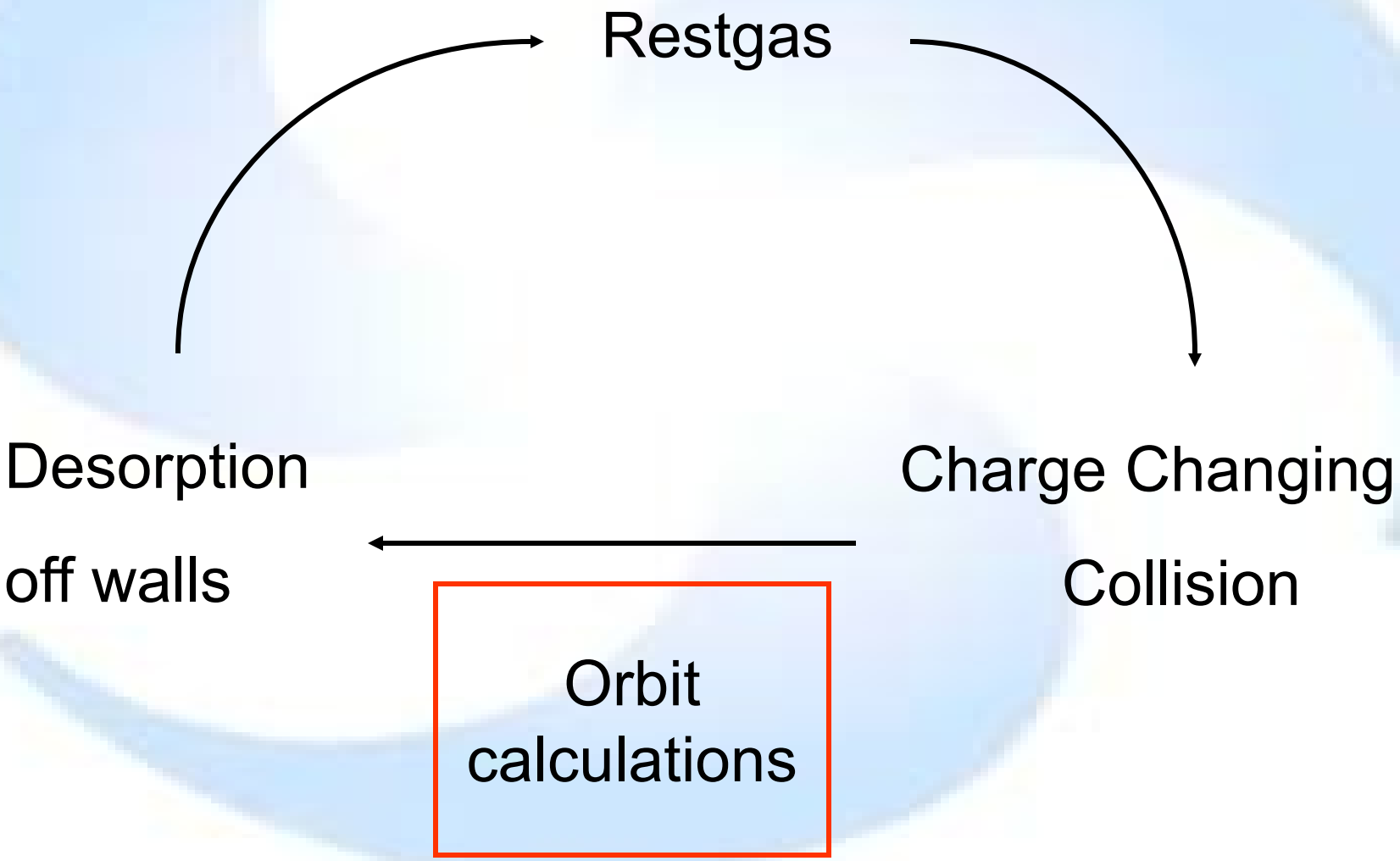
Charge Changing Collision

Loss per turn $\delta N = N_0(r)\{1 - \exp(-\sigma * 2\pi r * \eta * P)\}$

η = Loschmidt number



BeamLoss in Cyclotron



Orbit Calculations.

Track the beam particles after charge changing collisions

- unit change in charge
- negligible change in $\vec{p}$ for beam particle

negligible effect on axial motion

Consider radial motion:

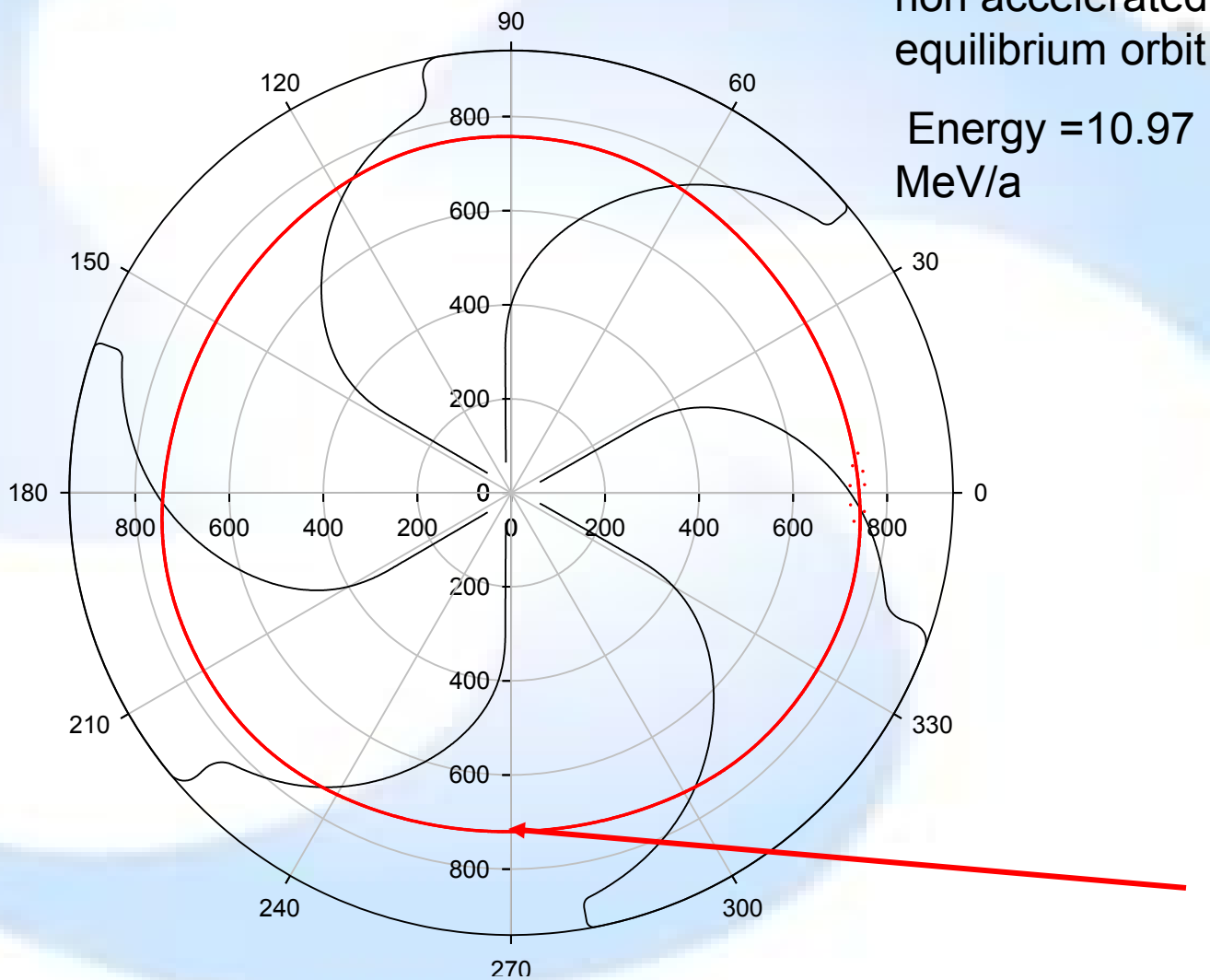
- Energy on impact
- Angles of incidence
- Point of impact

Orbit Calculations

$^{129}Xe^{26+}$, 18 MeV/amu

non accelerated equilibrium orbit

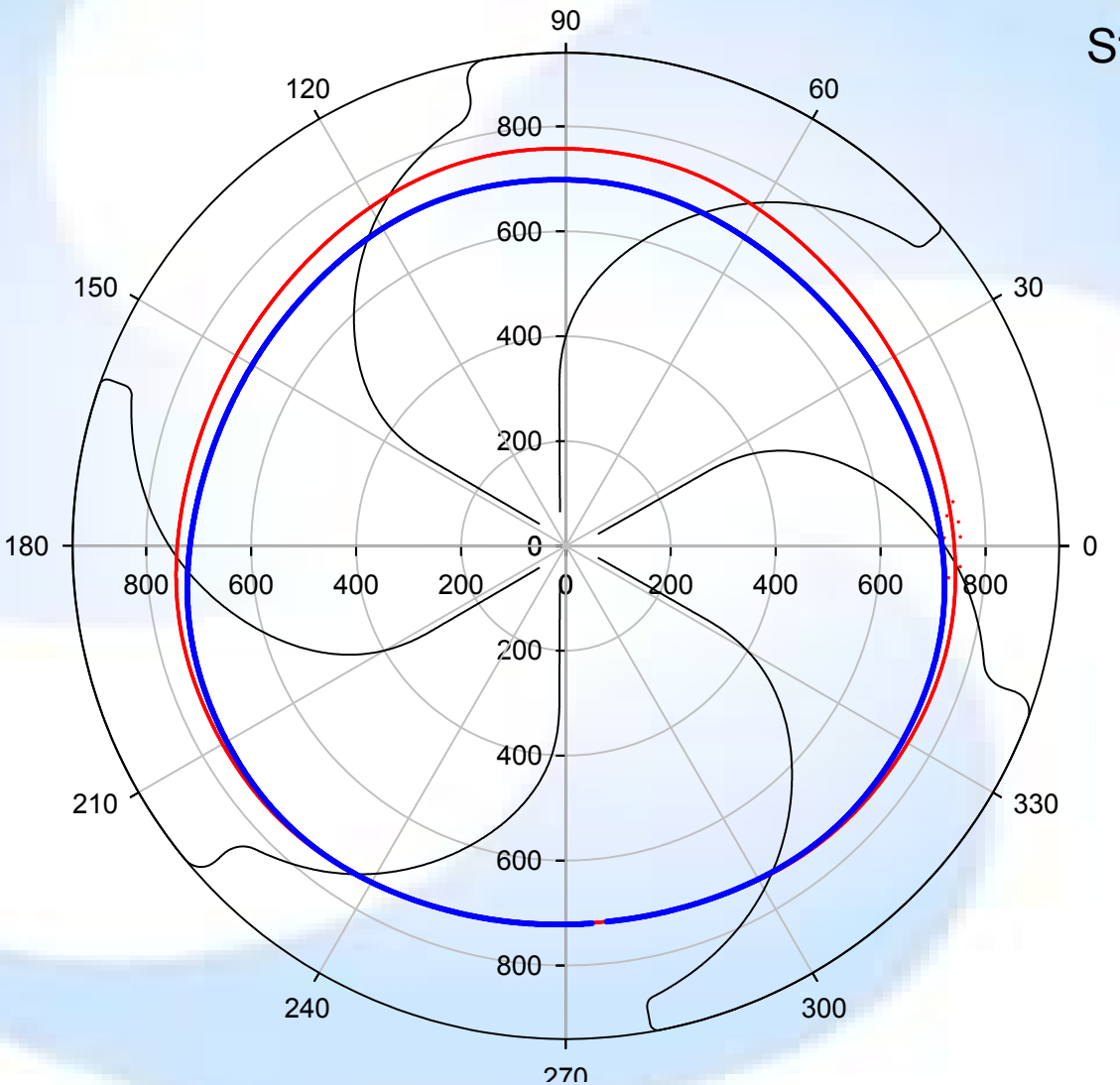
Energy =10.97 MeV/a



Orbit Calculations

$^{129}Xe^{26+}$, 18 MeV/amu

Stripping



Orbit Calculations

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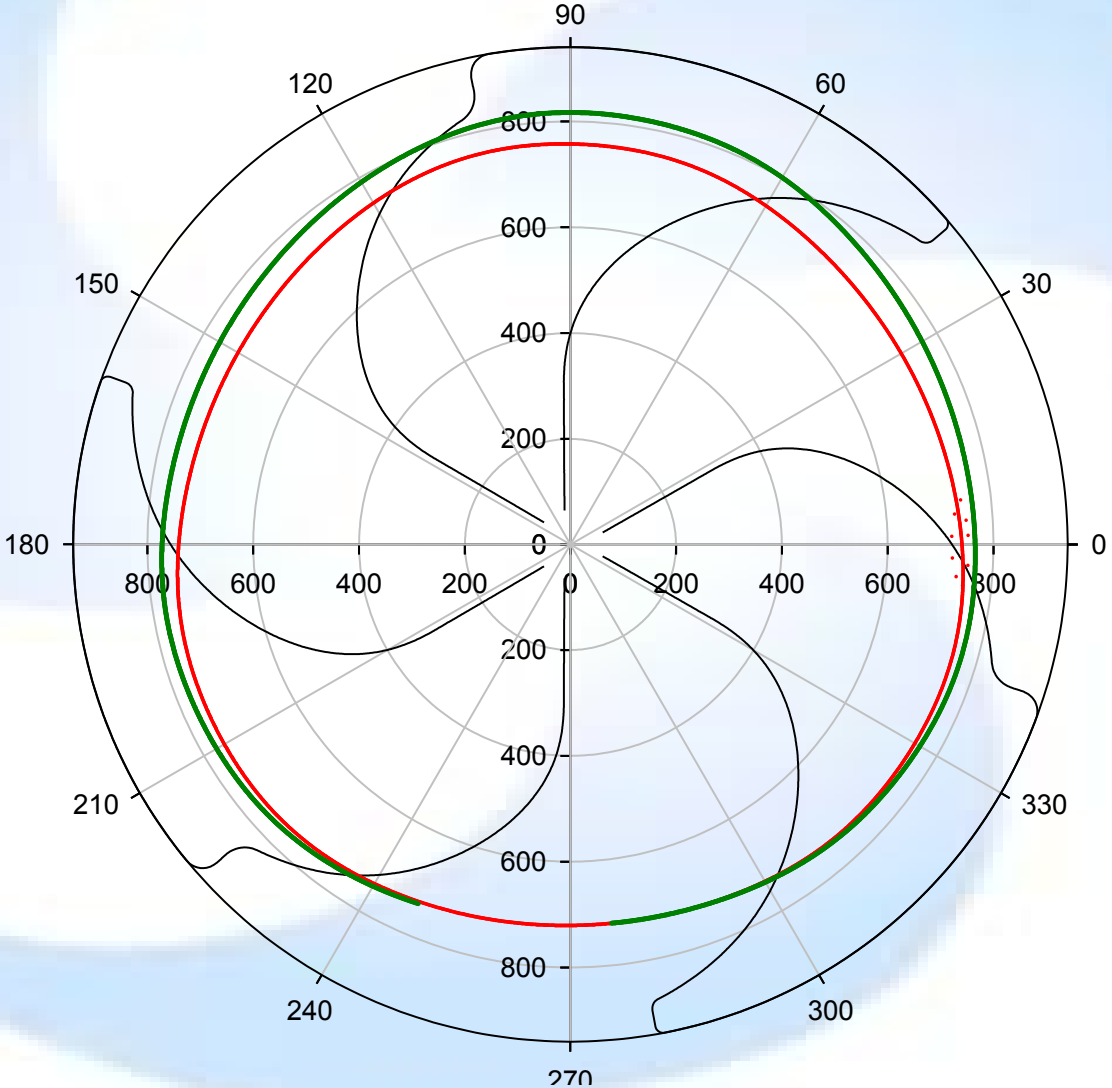
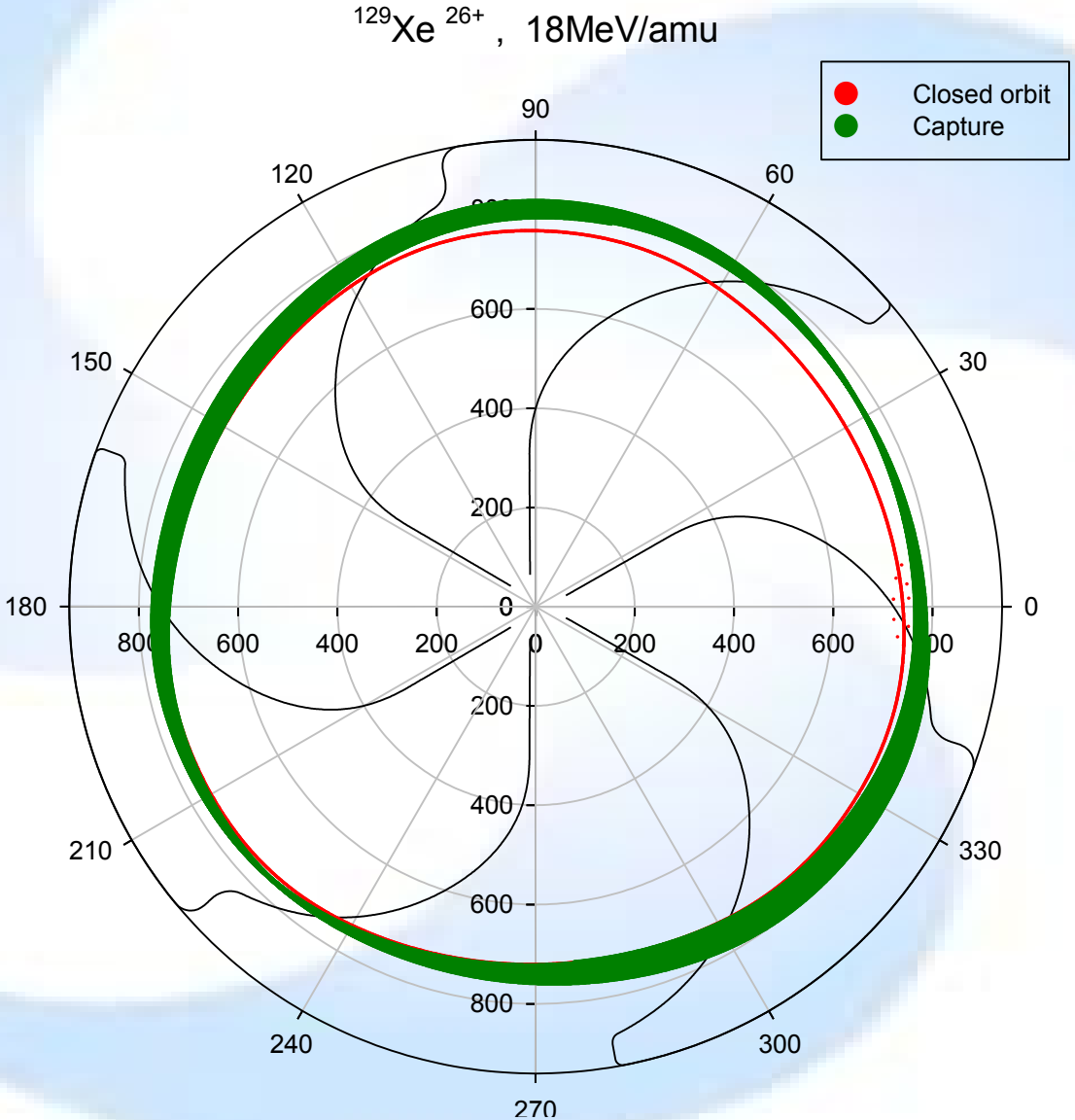
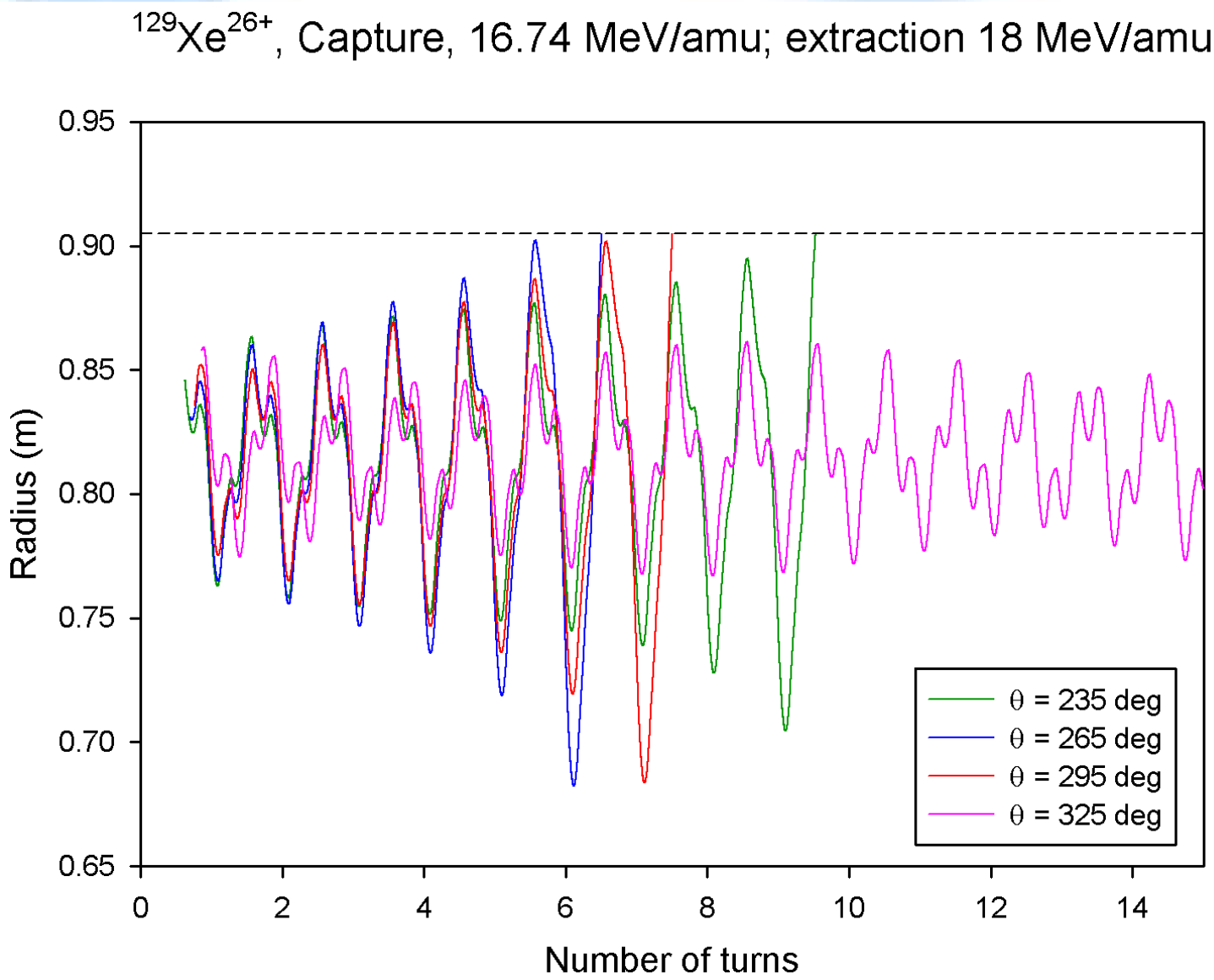


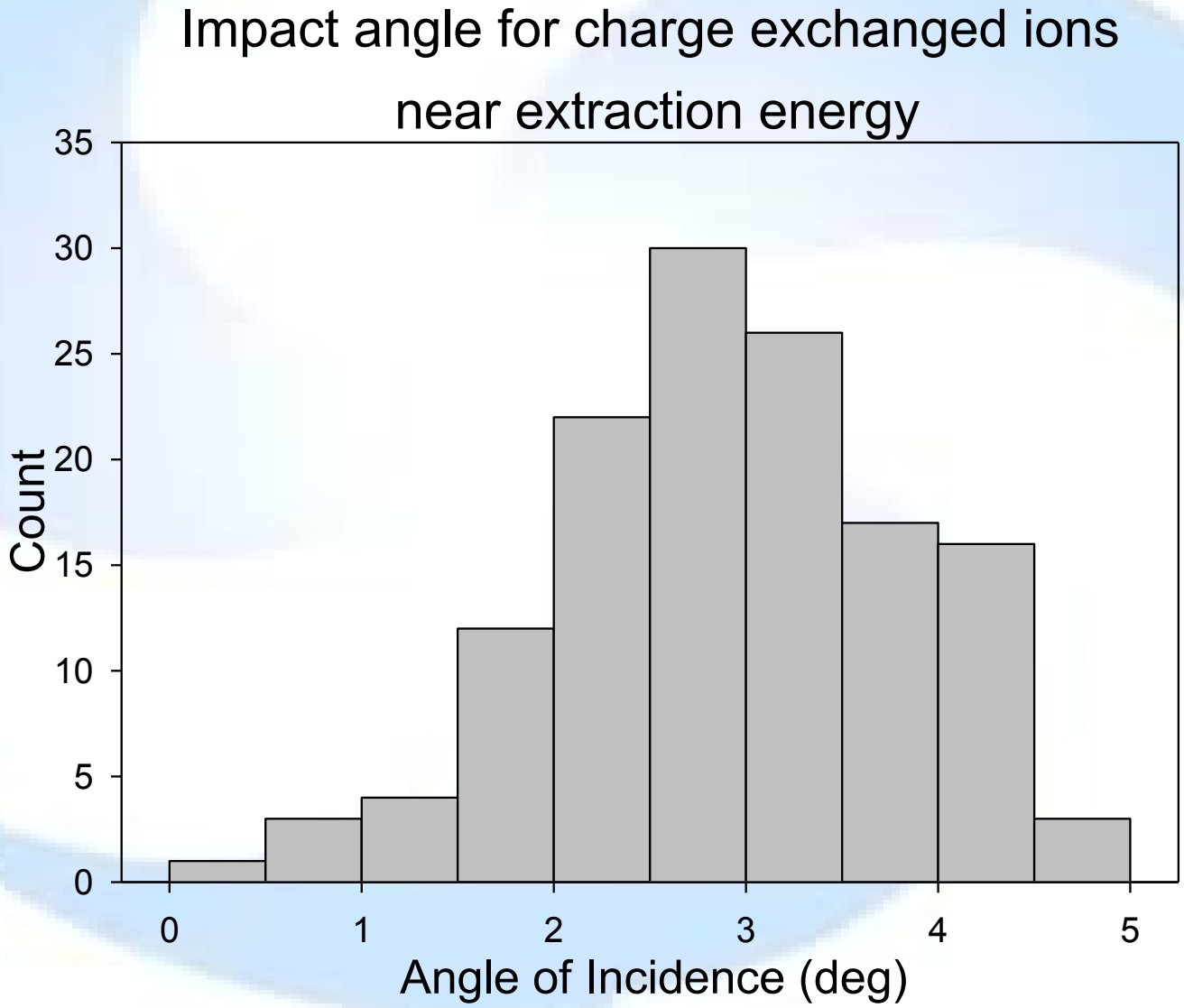
Orbit Calculations



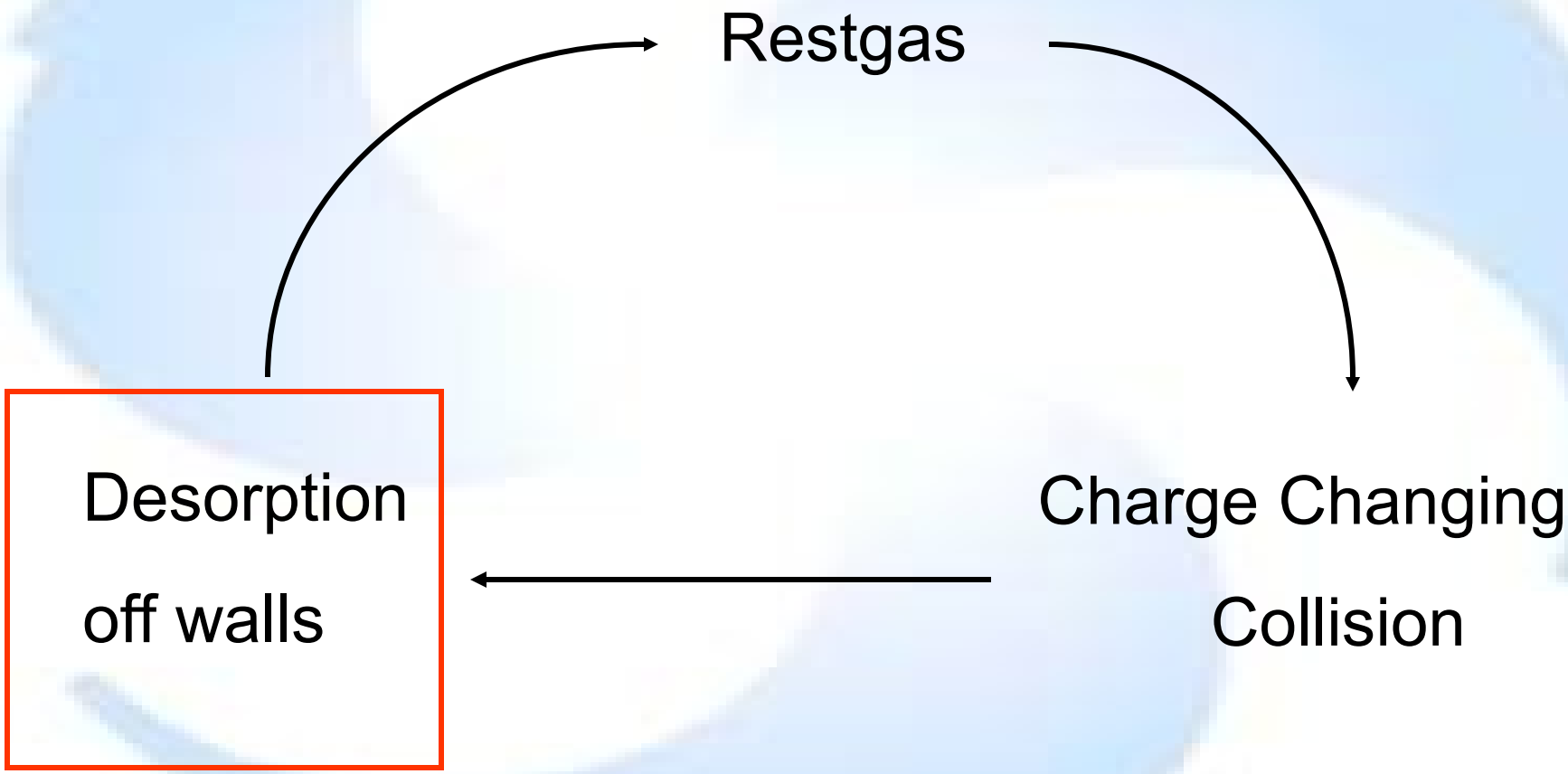
Orbit Calculations



Orbit calculation



BeamLoss in Cyclotron



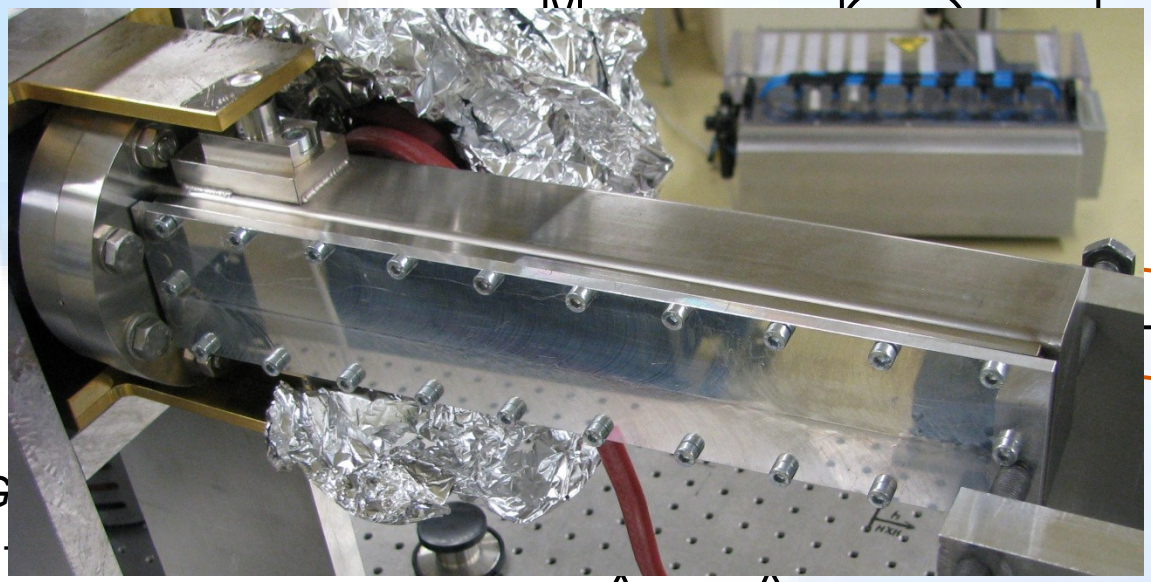
Desorption

beam particles hit walls → release material

Depends on

- Energy
- Angle of incidence
- Z (beam)
- Surface material

Experiment to Measure Desorption



RGA

Orifice

Target Chamber

IG

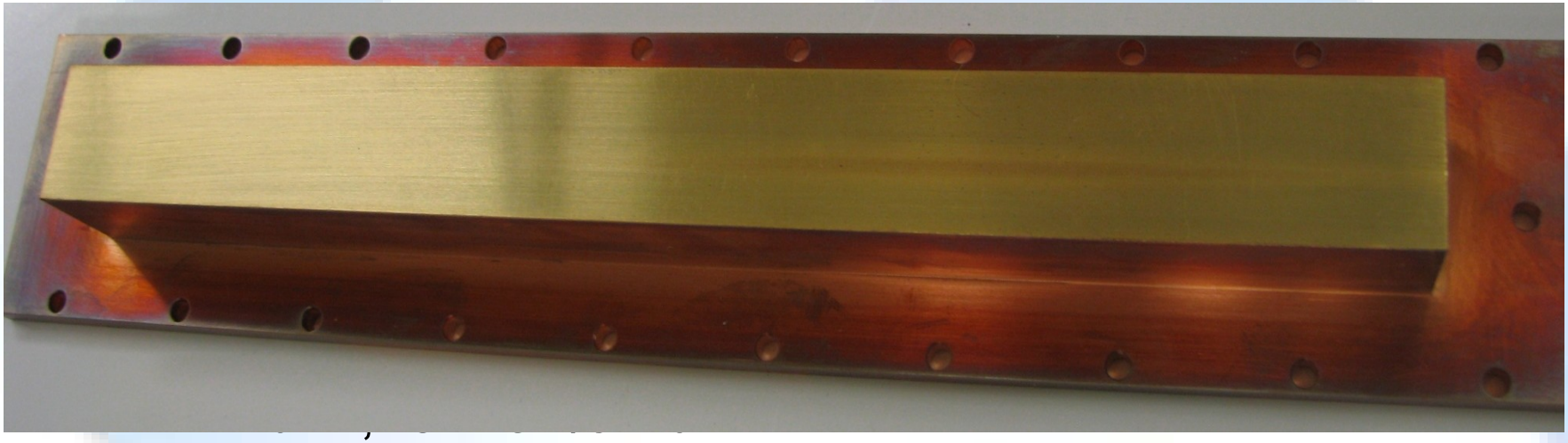
RG

IG

- Higher pressure
- Angle dependence
- Different energy

**E. Mahner et al., "Ion-Stimulated gas desorption yields and their dependence on the surface preparation of stainless steel", EPAC 2002,*

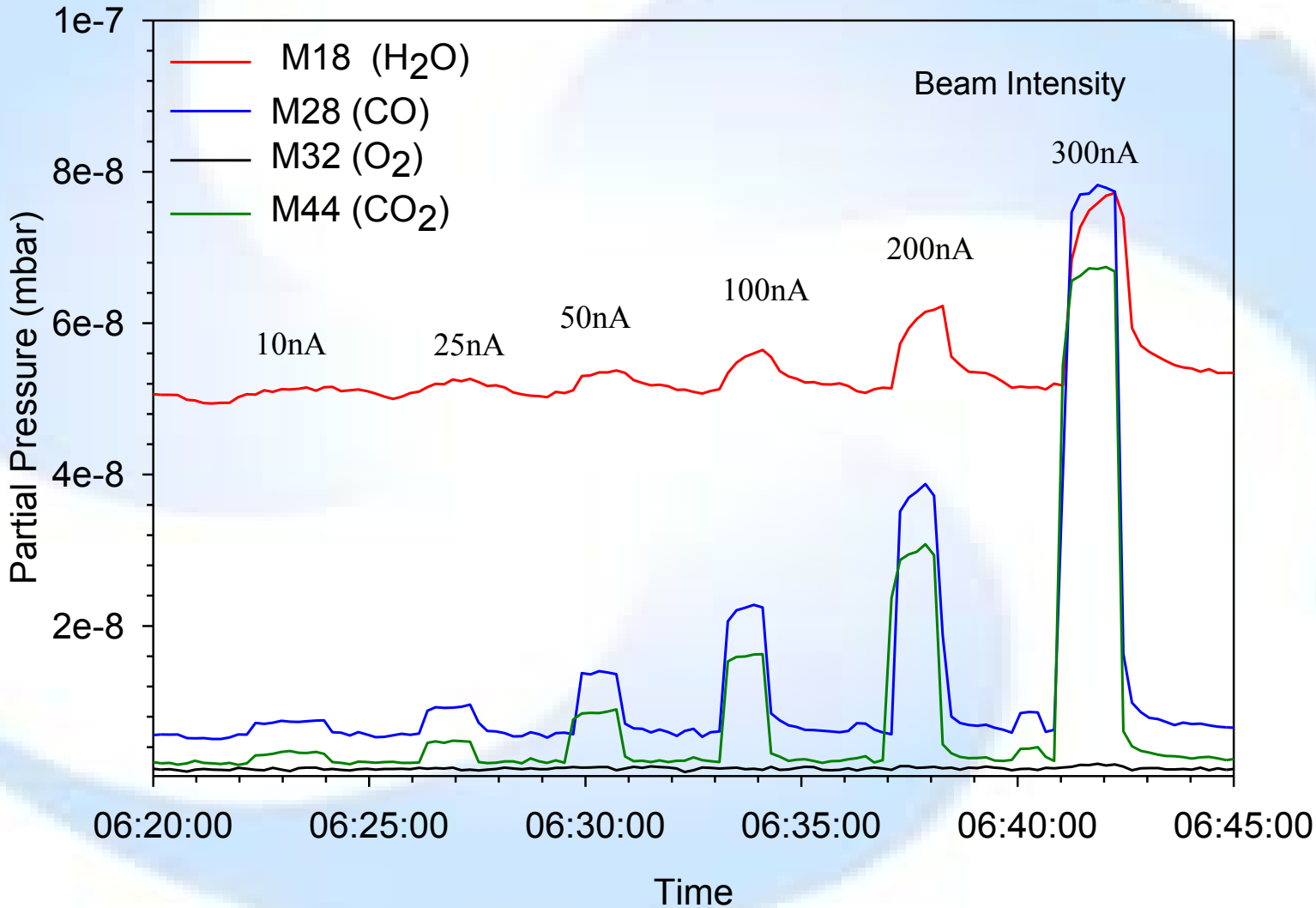
Beams and Targets



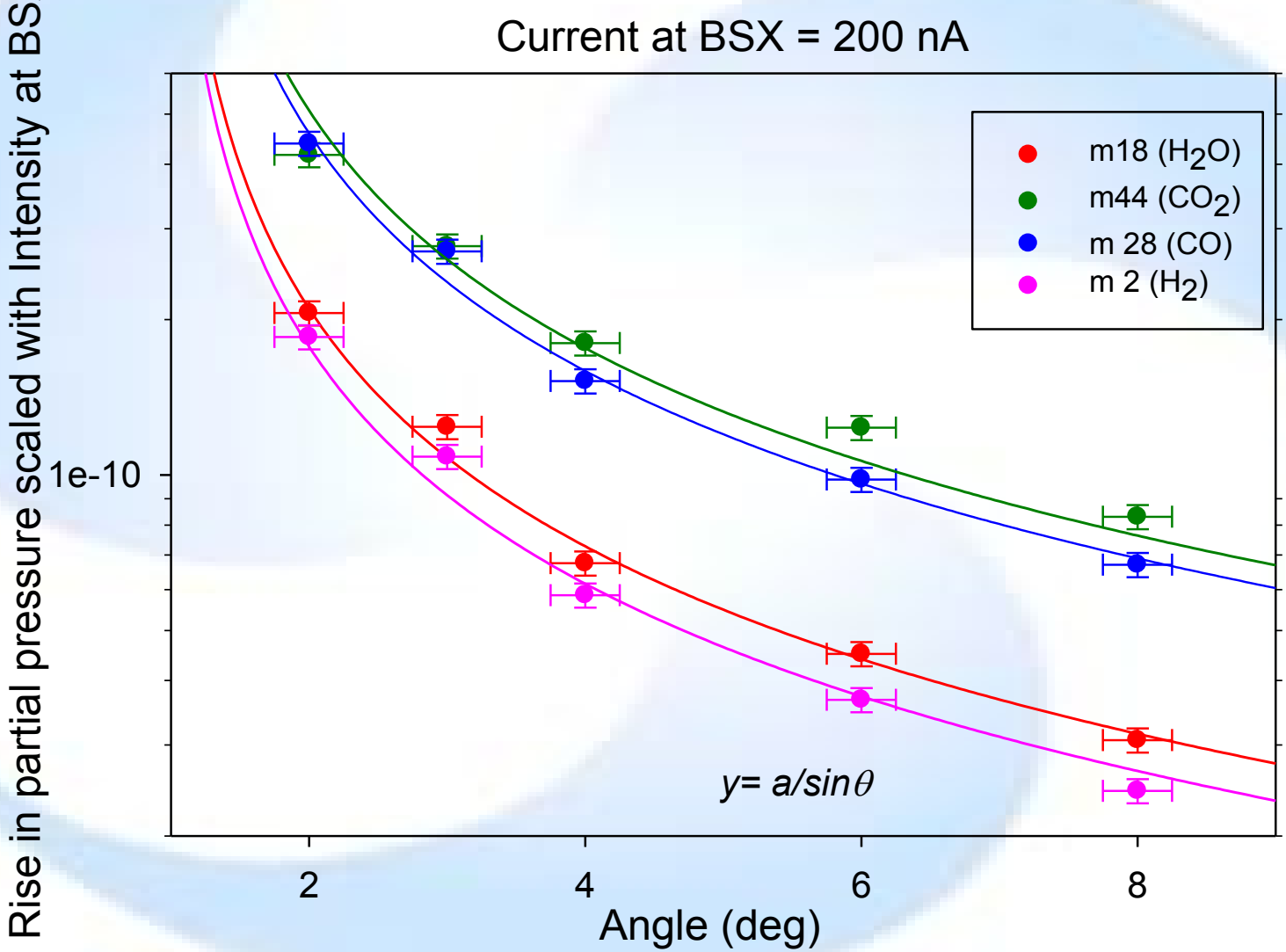
- Aluminum
- Copper
- Stainless Steel
- Gold plated Copper [1]

[1]C. Omet, H. Kollmus, H. Reich-Sprenger, P.Spiller, Proc. EPAC08(2008)]

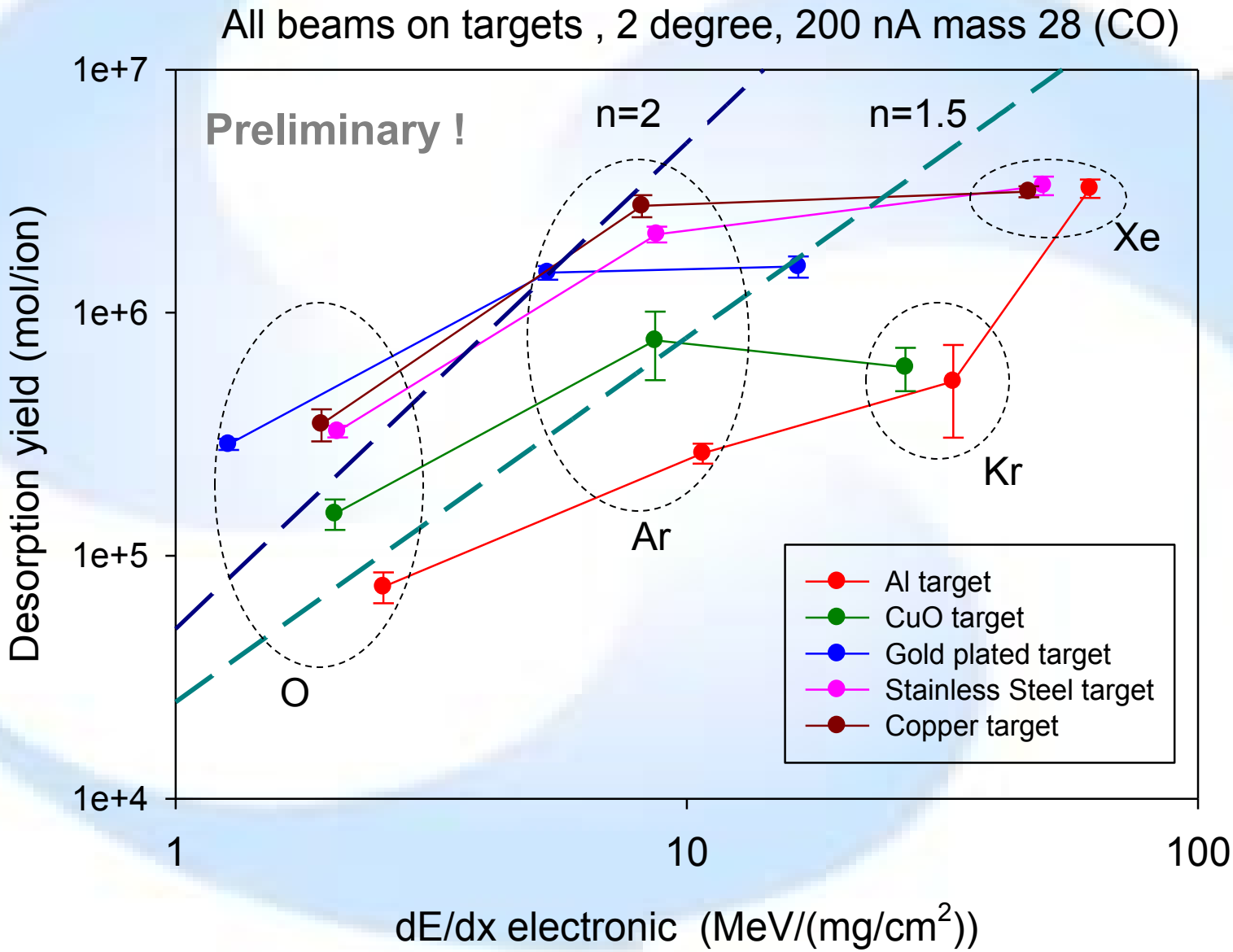
$^{40}Ar^{5+}$ beam on Cu



$^{40}Ar^{5+}$ beam on Cu



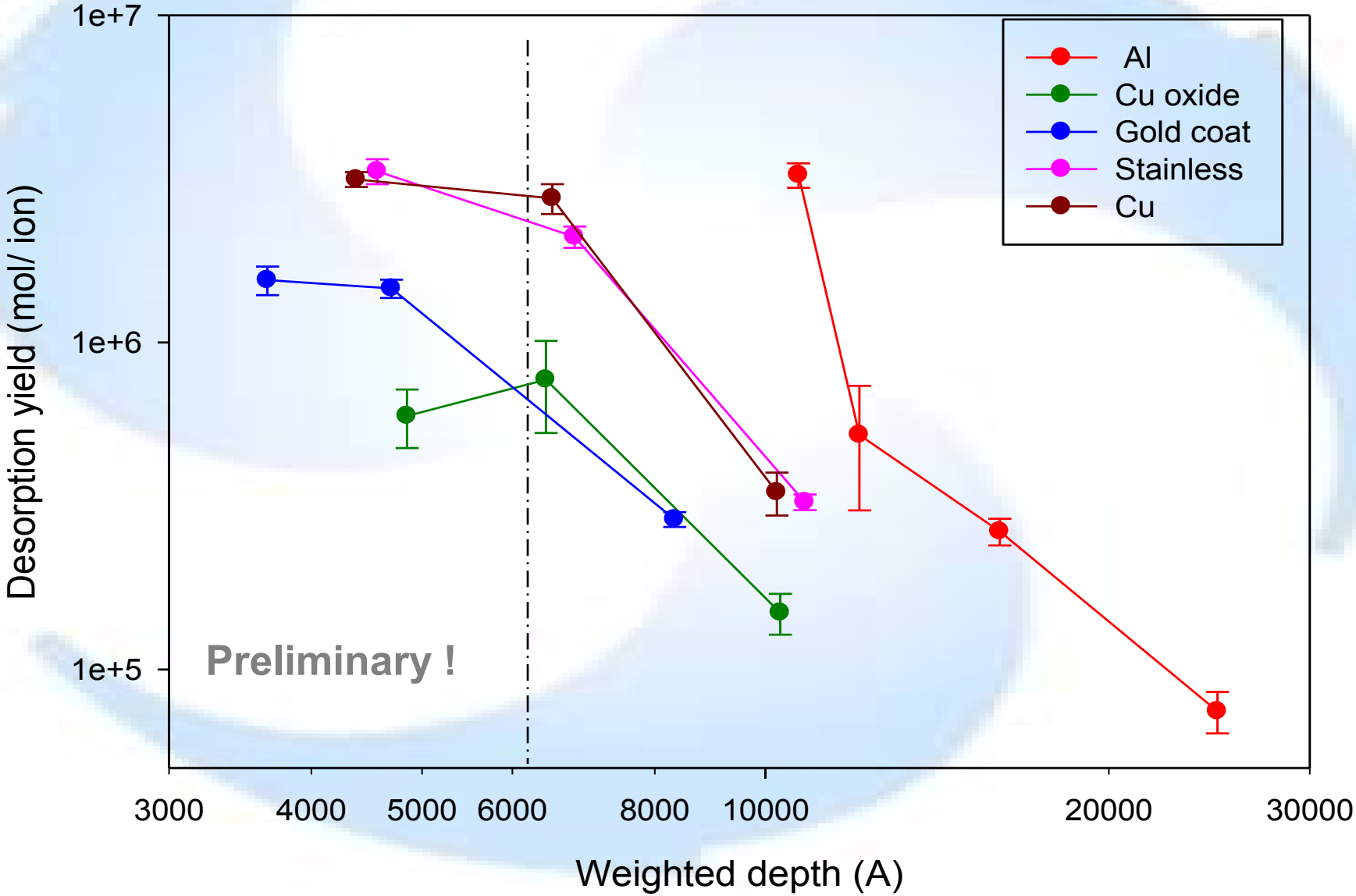
Dependence on $(dE/dx)^n$



Dependence on weighted depth

(weighted with the stopping power)

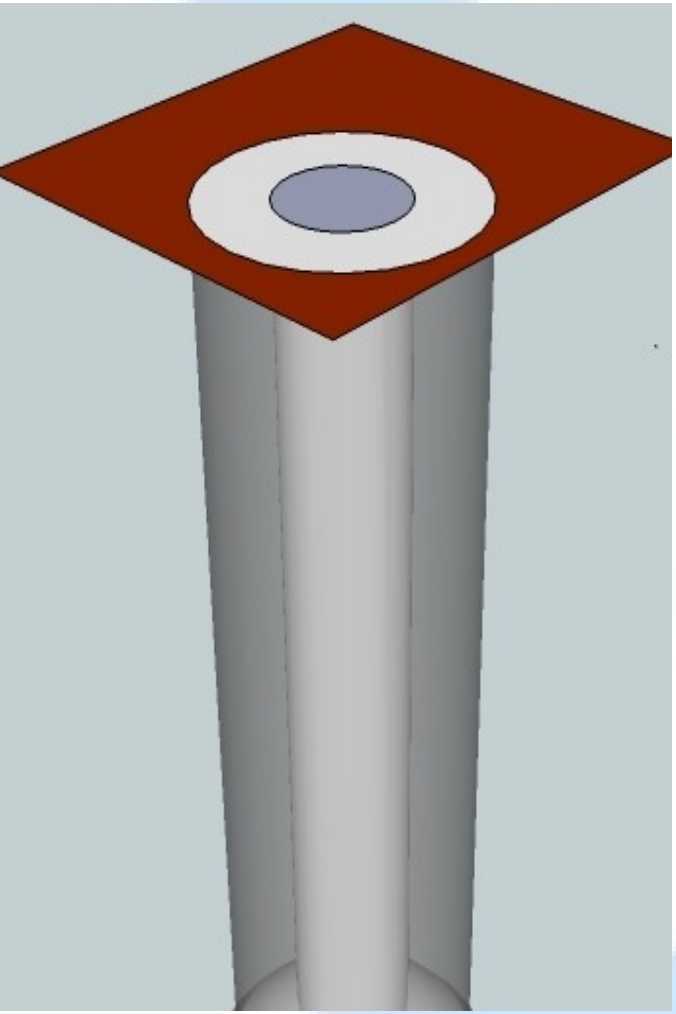
All beams on target , 2 degree 200 nA mass 28 (CO)



Observation

- Desorption different for different rest gas species
- Pressure rise inversely proportional to angle
- Data not described by current models (Thermal Spike, Shockwave.)

Desorption Model



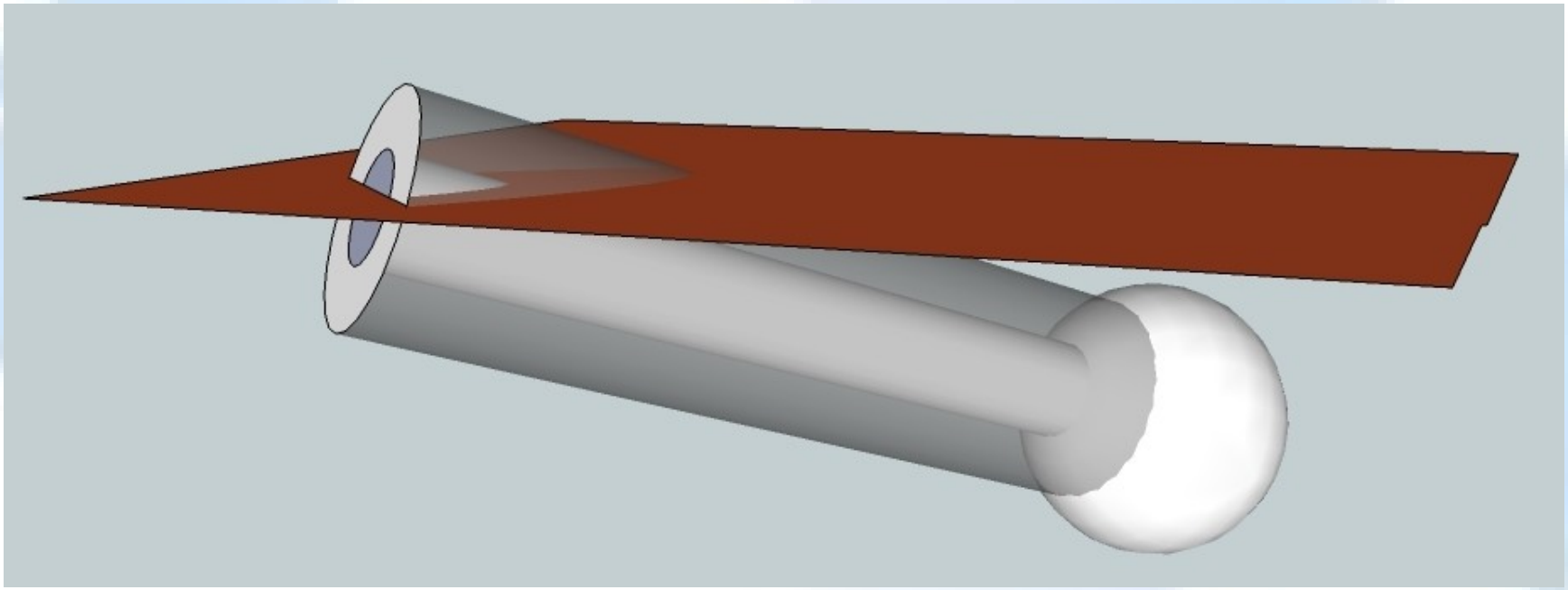
Thermal spike model

- Yield depends on the temperature distribution on surface *T(r,t)*
- *T(r,t)* is a gaussian in the central cylindrical core
- Contribution from the bragg peak is not considered

$$Y \propto \left(\frac{dE}{dx} \right)^2$$ [2]

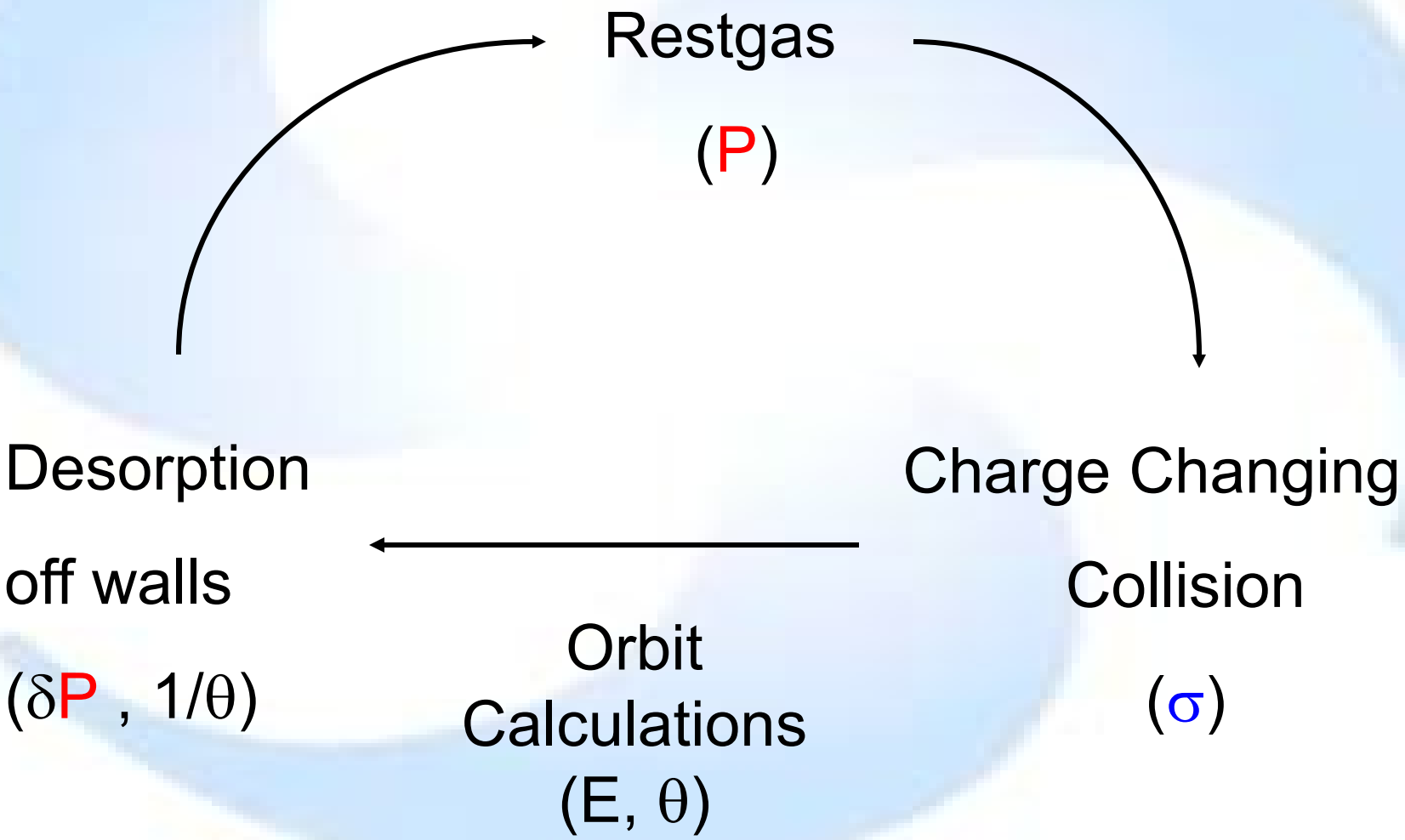
[2] R. Johnson, Int. Jour. of Mass Spectrometry and Ion Processes, 78(1987), 357 – 392.

Desorption at grazing angle



- Extension of thermal spike model
- Contribution from Bragg peak

BeamLoss in Cyclotron



Outlook

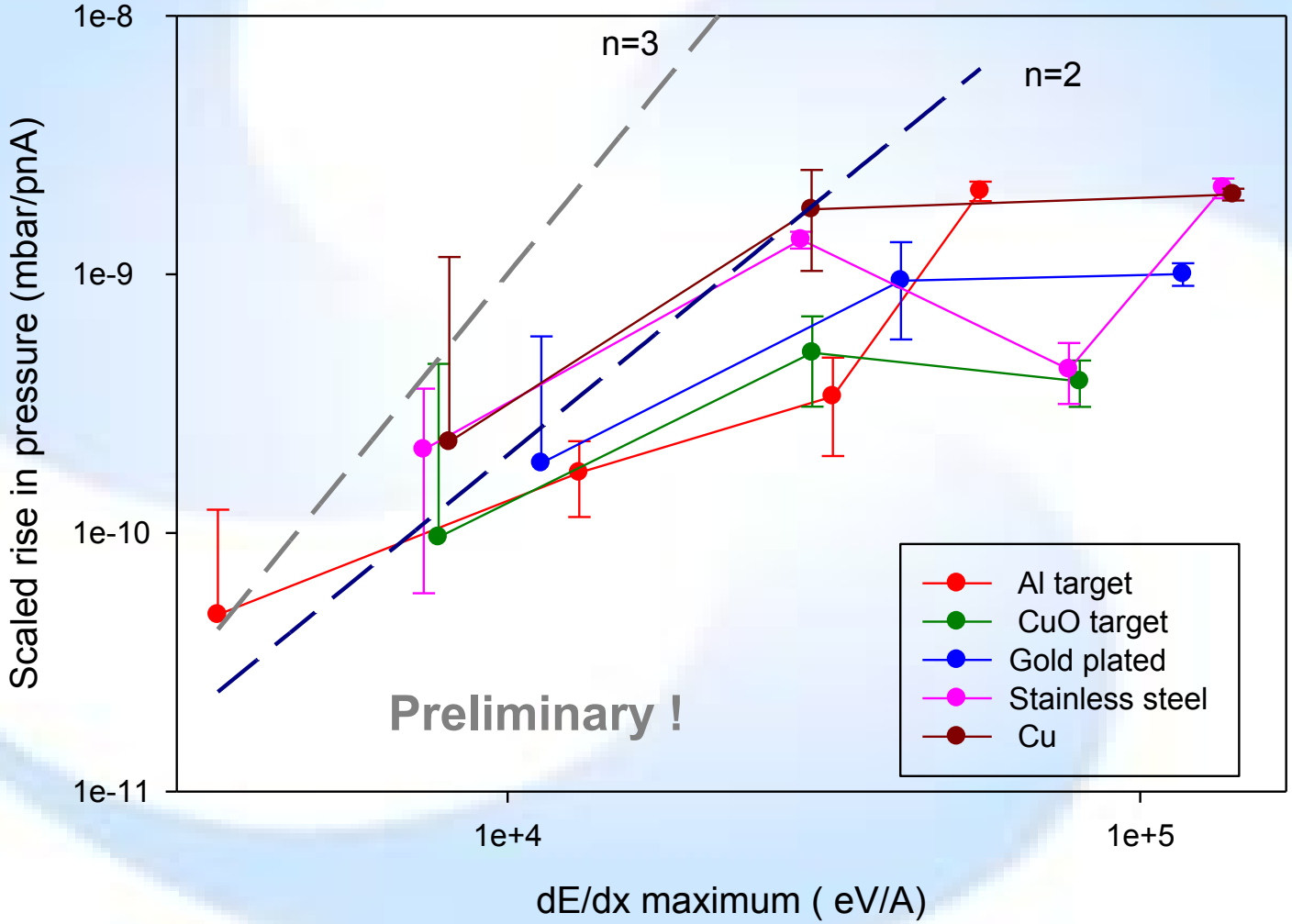
Extension of thermal spike model for grazing incidence

Mitigation methods

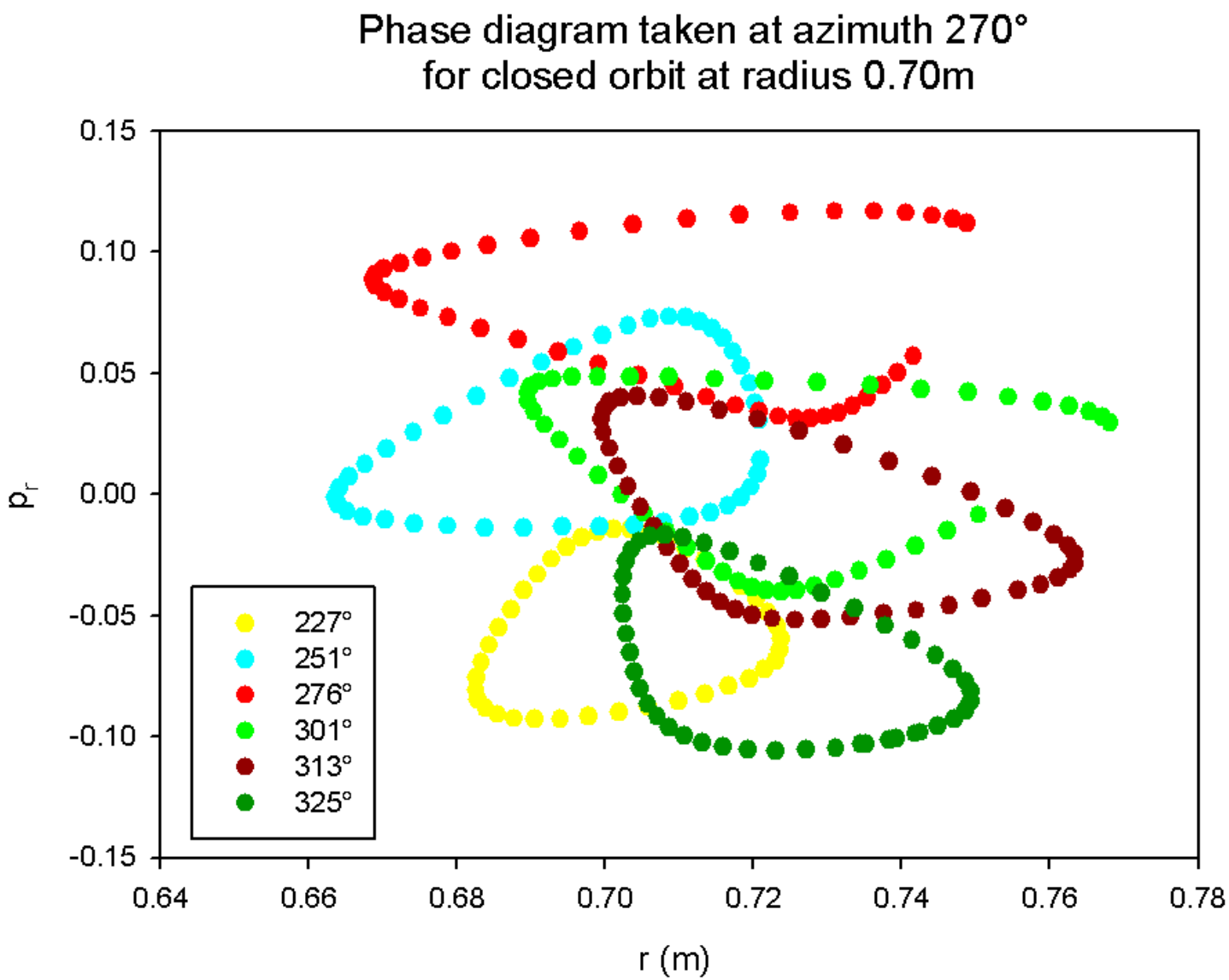
- Scrapers (not practical)
- Surface treatment {with beam}
- Coating to seal bulk effects (already done)

Dependence on $(dE/dx)^n$

All beams on targets , 2 degree, 200 nA mass 28 (CO)

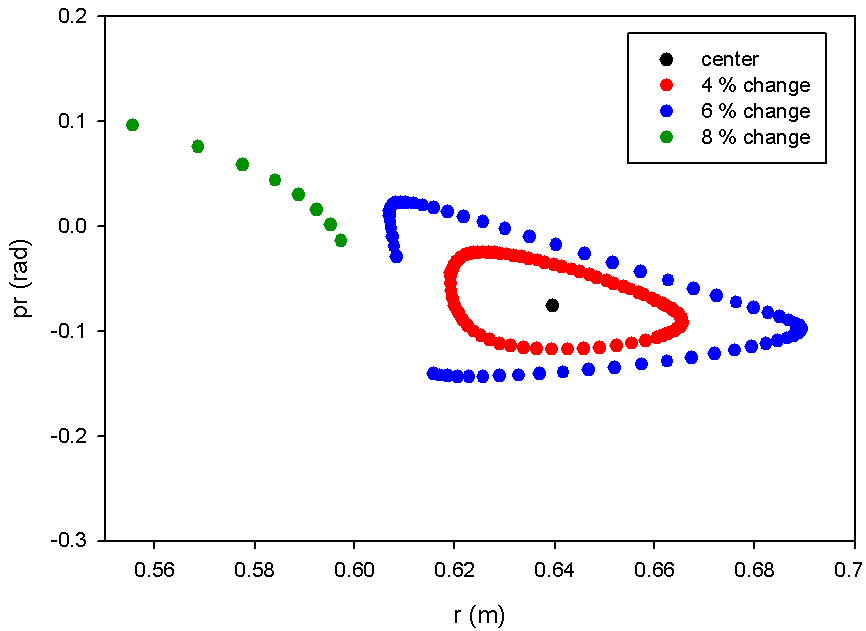


Stability of off-centered orbits



Stability of off-centered orbits

Turn 50



Turn 70