Interaction of highly charged ions with solid state targets studied by means of crystal channeling

- Why channeling?
- Experimental details
- Results and Discussion

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Ion -solid interaction processes

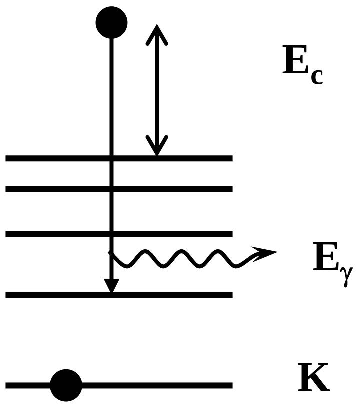
ESR beams $\eta << 1$; $\eta = [(m_e/M_i) x (E_i/E_e)]^{1/2}$

Close collisions processes :

Mechanical Electron Capture (MEC) : non radiative capture, dominant in ion-solid collisions

- 3-body capture (target recoil)

Nuclear Impact Ionization



Interaction with a quasi free electron gas :

Radiative Electron Capture (REC) :

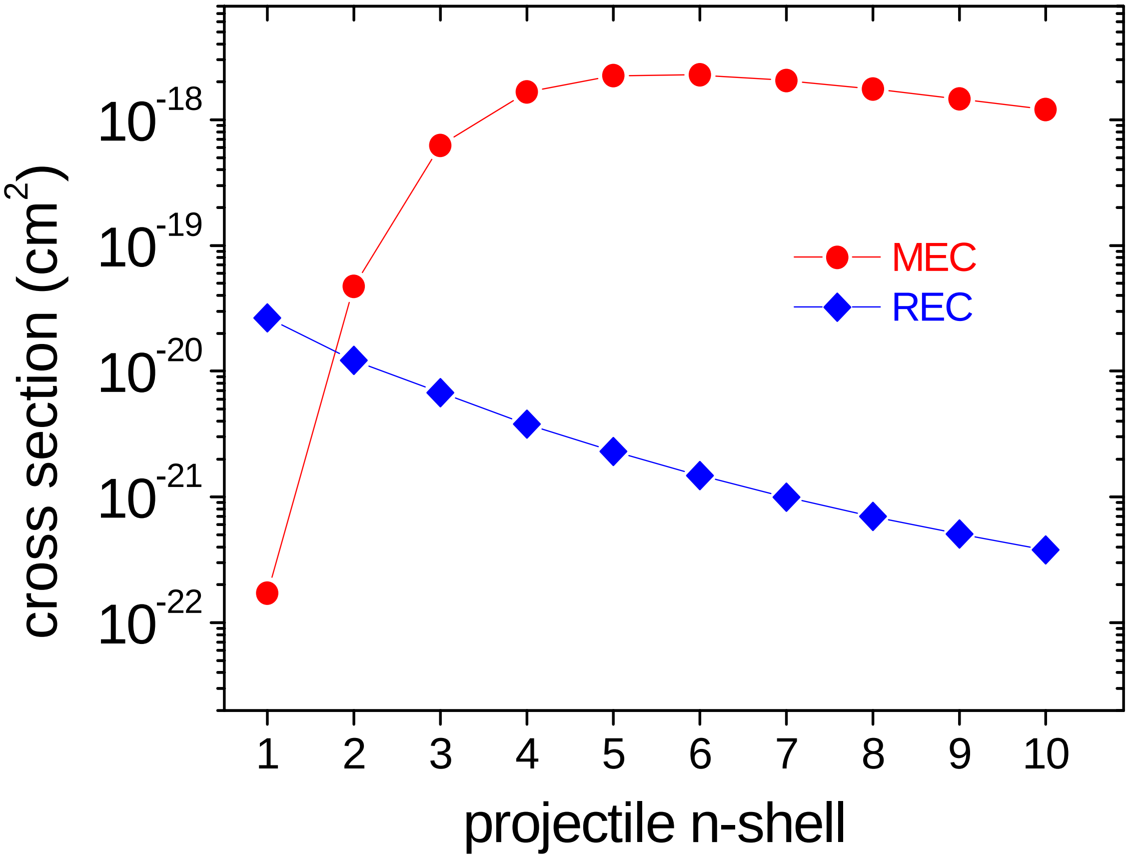
- Energy and momentum balance: photon emission

Electron Impact Ionization

Perturbation of the electron gas by slow HCI

MEC / REC competition

20 MeV/u U^{91+} on Si



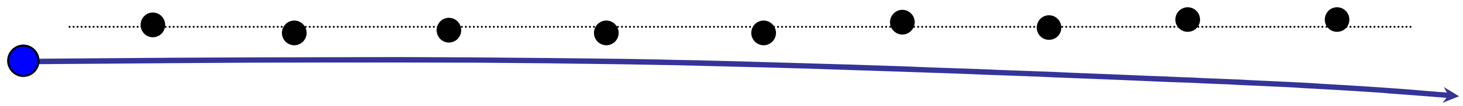
σ_{MEC}: CDW calculation

σ_{REC}: dipole approximation

- MEC dominates REC
- Capture into highly excited states competes with ionization in a solid target

Why channeling?

E_{ion}, b



Channeling allows the reduction of close collisions with the target atoms and confines the projectiles in a space far from the rows and planes of the target: suppression of close impact parameters

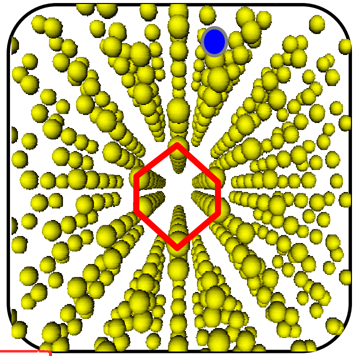
Transverse energy:

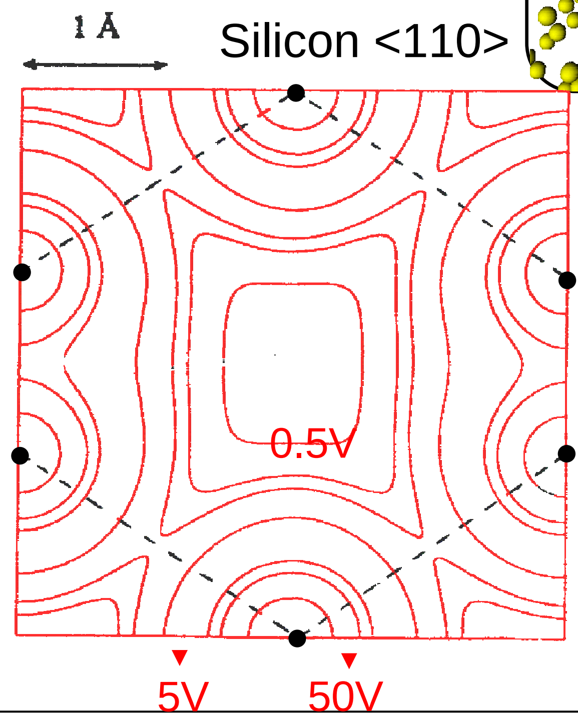
$E\perp = QV(r_{init}) + E\Psi_{init}^2$

$A(E\perp)$ = accessible transverse space

flux redistribution

Silicon <110>

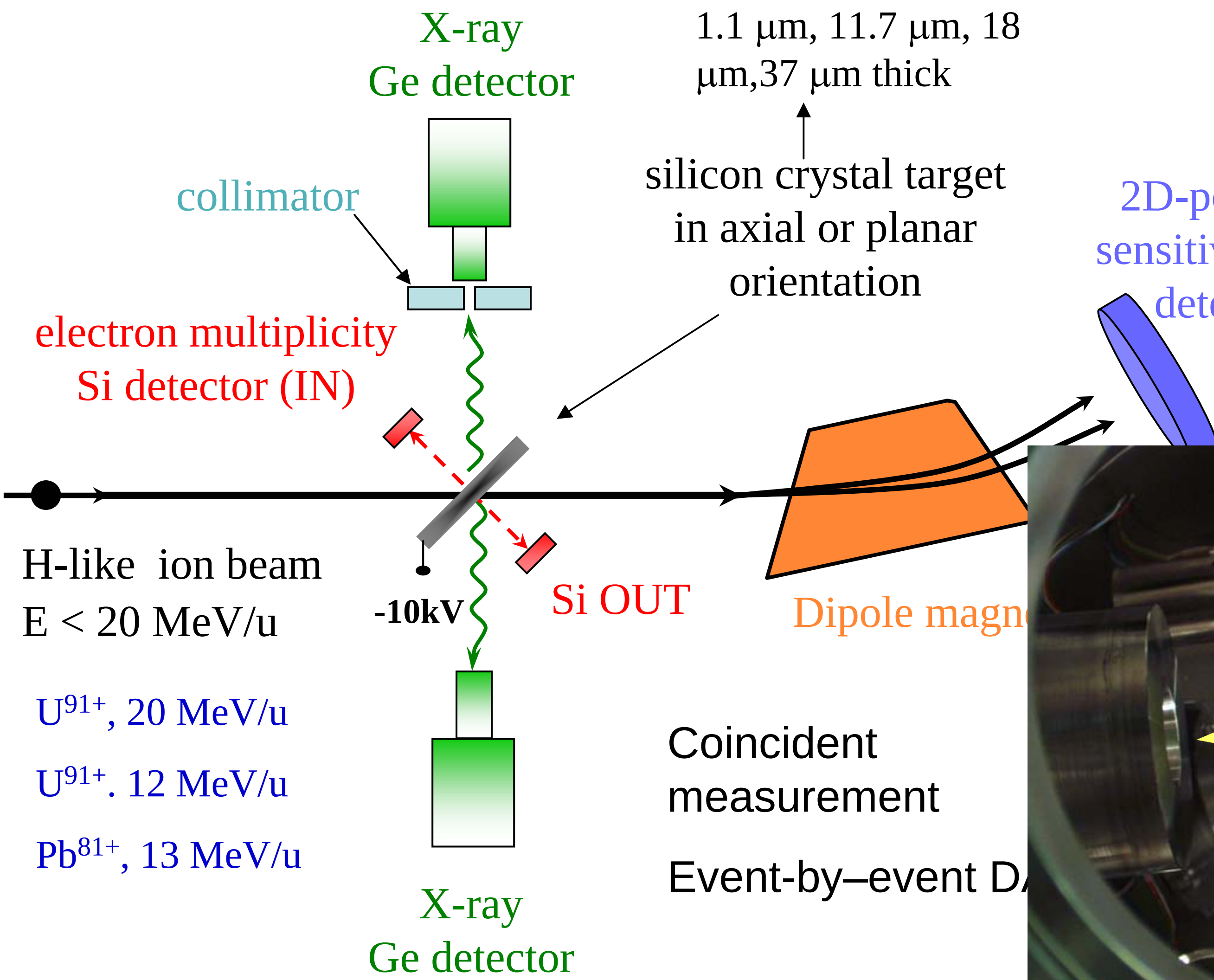




Fast, few-electron heavy ions are excellent tools to study ion-matter interaction depending on charge state and impact parameter (far from equilibrium charge state)

Continuum potential $V(r_{\perp})$

Experimental setup



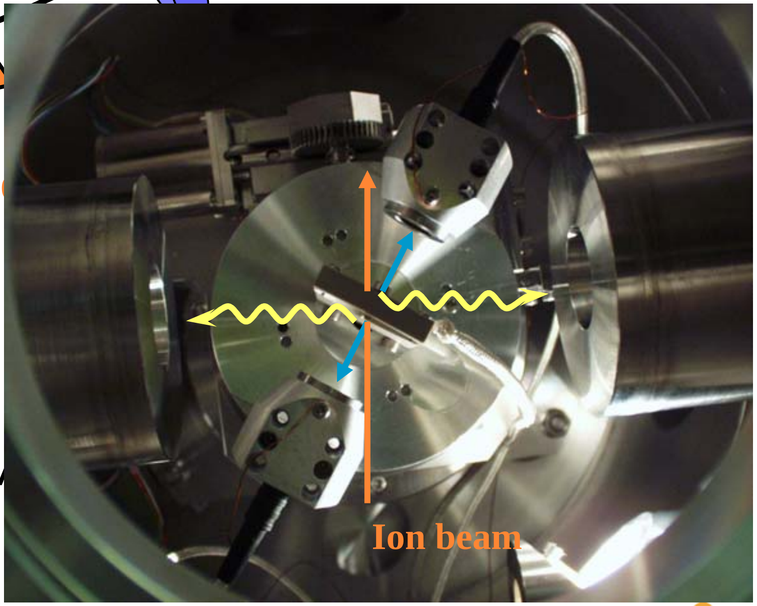
U^{91+}, 20 MeV/u

U^{91+}. 12 MeV/u

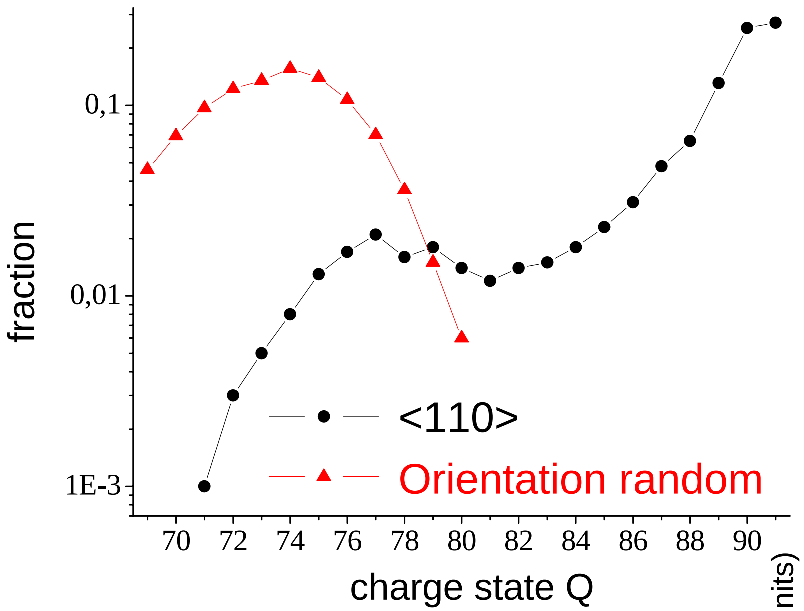
Pb^{81+}, 13 MeV/u

Coincident measurement

Event-by–event DA

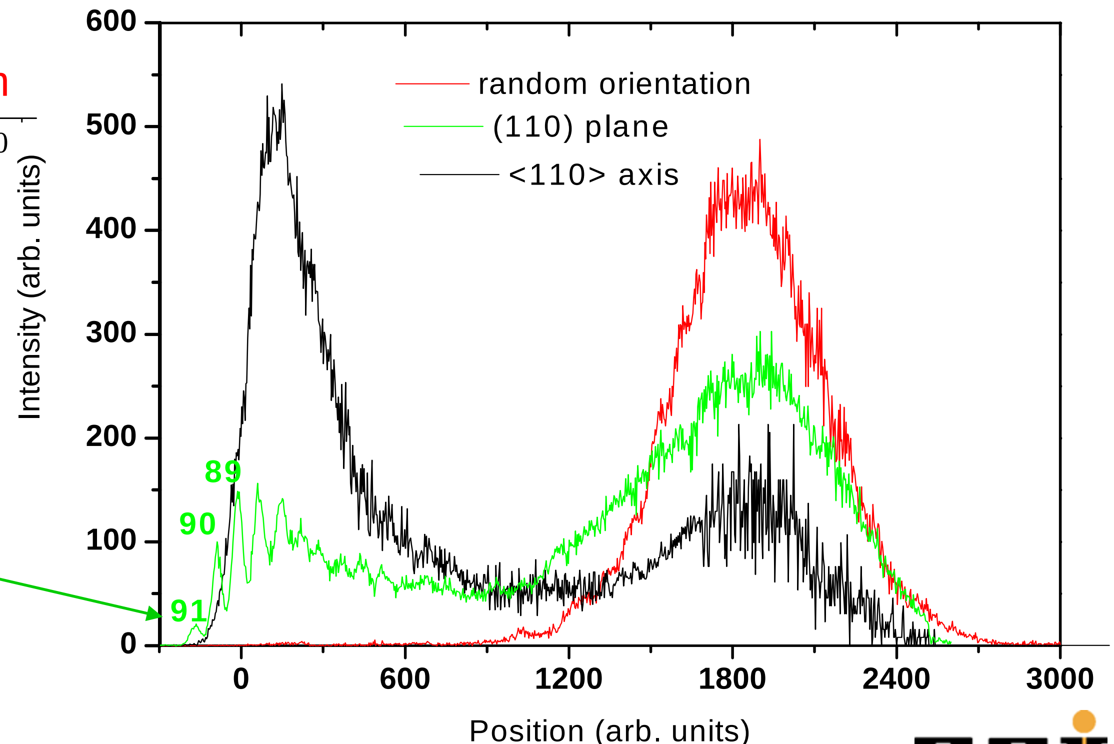


Charge state distribution



U^{91+} 20 MeV/u → 11,7 µm Si (GSI)

U^{91+} 12 MeV/u → 18,3 µm Si



0.3% U^{91+} % in axial channeling

U^{91+} frozen ions

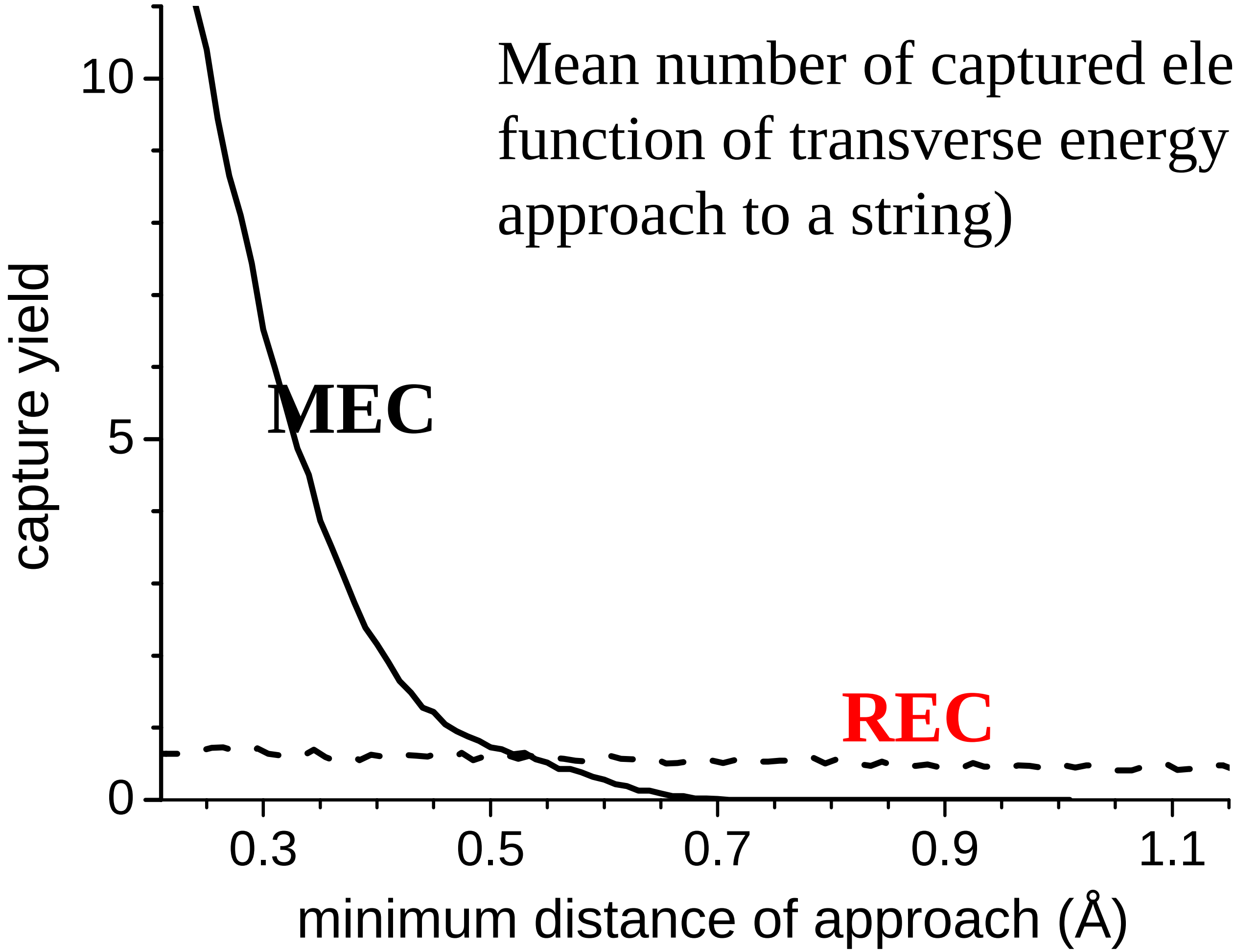
E_{loss}= 3. 5 MeV/u

higher then in random orientation!

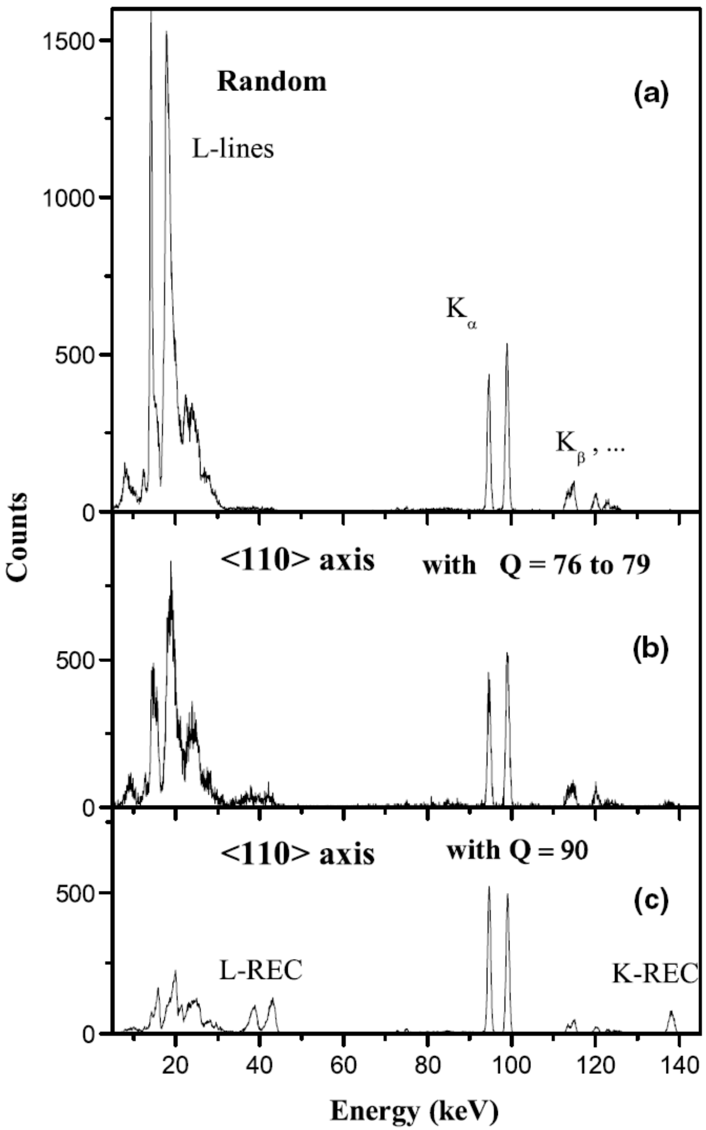
Electron capture

U^{91+} 20 MeV/u on 11.7 µm Si crystal

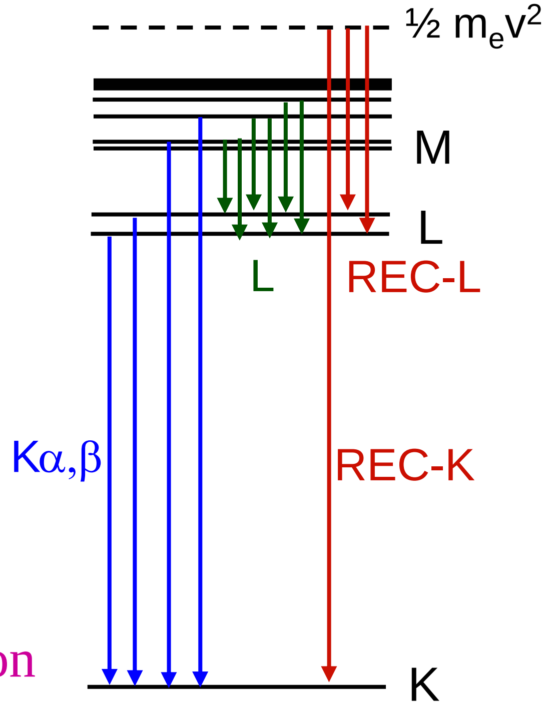
Mean number of captured electrons as function of transverse energy (distance of approach to a string)



X-ray spectra

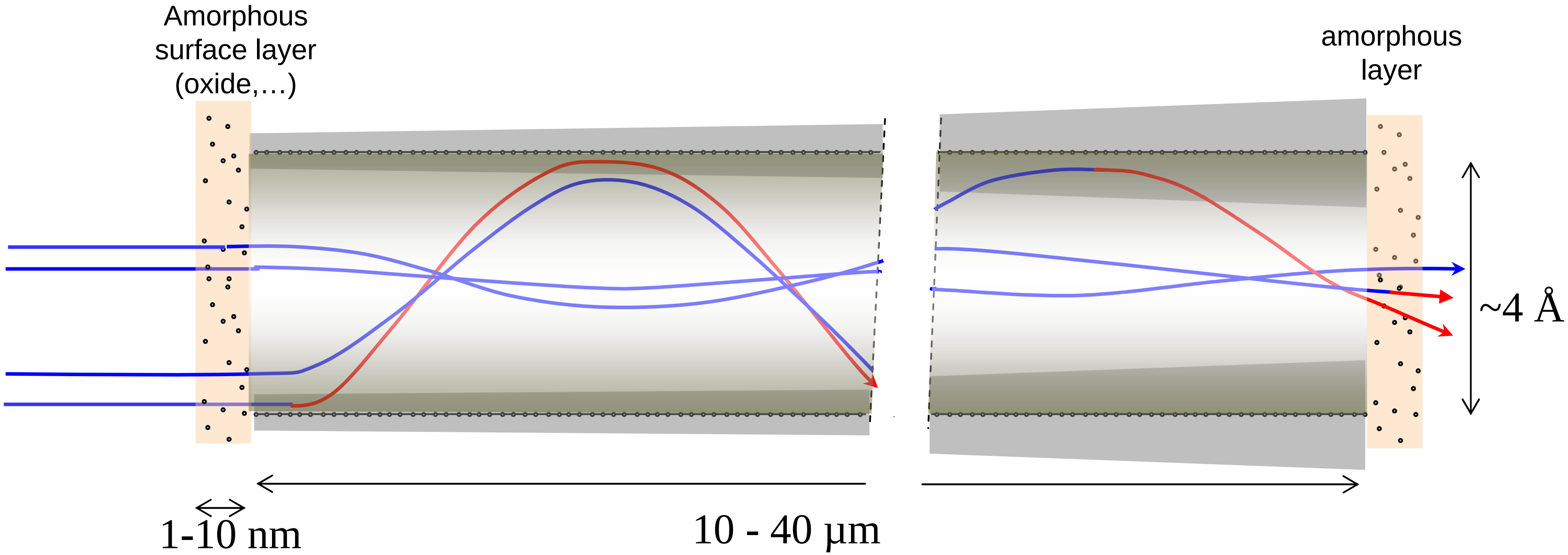


U^{91+}, 20 MeV/u in 11.7 µm Si,
Θ_{lab} = 90 deg.



MEC / REC competition at a minimum distance of the order of core orbital radius

H-like U ion deceleration in a crystal



Frozen 91+ survive to:

- MEC close to the strings (r_{min} < ~ 0,5 Å at 20 MeV/u)
- REC (maximum close to the strings)

- MEC in the entrance/exit amorphous layers :

$$P_{out}(MEC)=P_{in}(MEC) \times (E_{initial}/E_{finale})^{-5.5}$$

Conclusions

- **Channeling of highly charged, slow heavy ions**

  Detailed study of charge exchange as a function of impact parameter

  MEC: capture into high n-shells far from atomic strings

  REC: probe for the dynamic electron gas polarization

- **High energy loss rate: deceleration**

Deceleration of Ion ⇒ help for ion trapping ?

E. Testa, Ph.D. Thesis, Universite Claude Bernard, Lyon, 2005