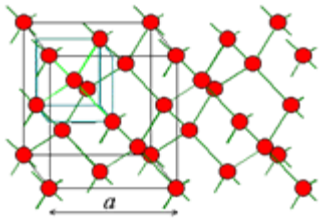
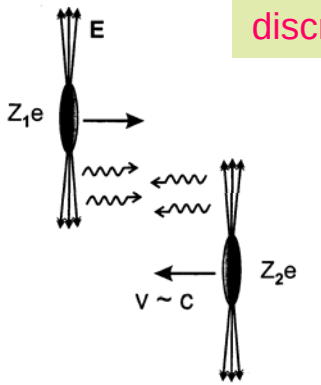
Electromagnetic Interactions of Channeled Ions

No channeling

flat (or bent) Si crystal



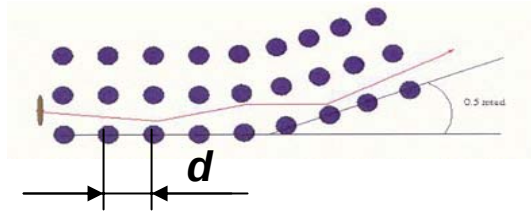
discrete potential



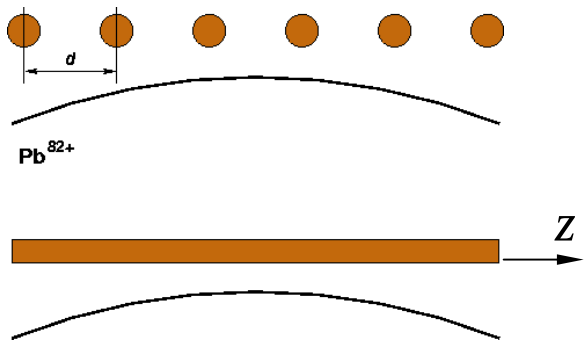
$$\omega^{\max} = \frac{\hbar}{\Delta t} \sim \frac{\gamma \hbar v}{b},$$

channeling

bent (or flat) Si crystal



continuum potential



$$U(\vec{r}_\perp) = \frac{1}{d}\int_{-\infty}^{\infty} dz V(\vec{r}_\perp, z)$$

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interaction between contracted EM fields is approximated by interaction of quasi-real photons

Number of photons in one collision

$$N(\omega, b) = \frac{Z^2\alpha}{\pi^2}\left(\frac{c}{v}\right)^2 \frac{1}{b^2}\phi(x, b)\,,$$

with

$$\phi(x, b) = \left| \int_0^\infty du\, u^2 J_1(u) \frac{f(-(x^2+u^2)/b^2)}{x^2+u^2} \right|^2,$$

channeling

continuum potential

Integral over the transit time

$$U(\vec{r}_\perp) = \frac{1}{d}\int_{-\infty}^{\infty} dz V(\vec{r}_\perp, z)$$

Screened Coulomb potential

$$V(r) = \frac{Z_1 Z_2 e^2}{r}\left\{1 - \frac{r}{(r^2 + C^2a^2)^{1/2}}\right\}$$

Continuum (single string) potential

$$U(r_\perp) = \frac{Z_1 Z_2 e^2}{d} \ln\left(1 + \frac{C^2a^2}{r_\perp^2 + \frac{1}{2}\rho^2}\right)$$

where mean square thermal displacement from the string is accounted for

Pb-Beam Transport in Continuum Potential

Trajectory is defined by the transverse energy of Pb ion:

distance ***b*** of the ion from atomic raw

$$r < b < d/2$$

Distance of closest approach to the atomic raw: $r = 2.5u_1 = a$

$$a = 0.8853a_0(Z_1^{2/3} + Z_2^{2/3})^{-1/2}$$

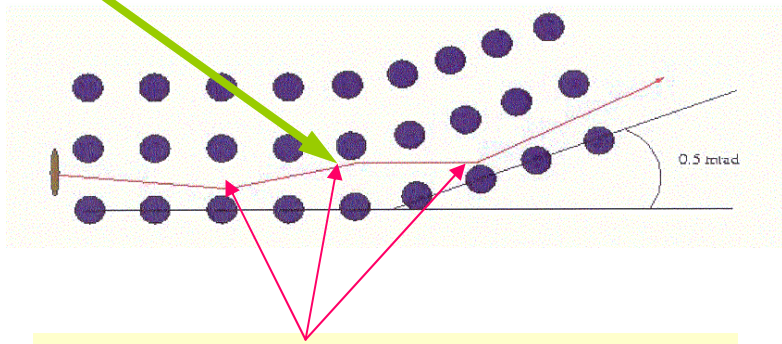
$r = 1\ 10^4$ f

$d/2 = 2.7\ 10^5$ f

u_1 is the amplitude of crystal atoms thermal oscillations

a is the screening length

$a_0 = 0.529\ 10^5$ f — Bohr radius



Largest time to stay in the channel

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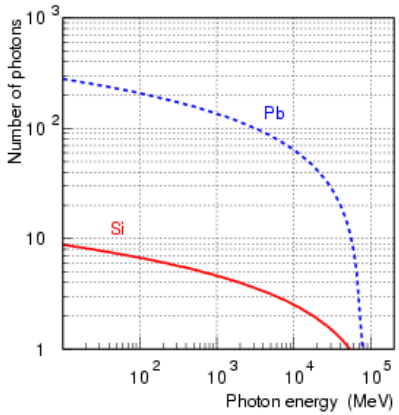
Photon flux from Pb or Si at LHC after integrating over impact parameter ***b***

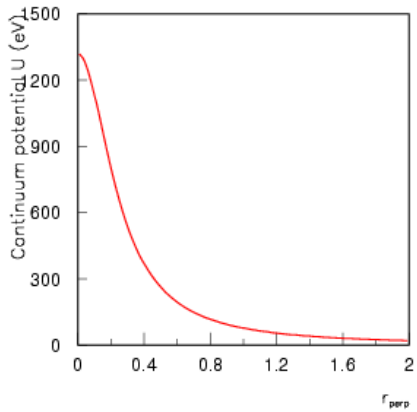
$$n(\omega) = \frac{2Z^2\alpha}{\pi} \ln\left(\frac{\gamma}{\omega R_A}\right)$$



channeling

continuum potential

Potential $U_\perp$ at some arbitrary temperature of the Si crystal



Distance from the atomic raw (Angstrom)

Photon spectrum and photonuclear reactions

discrete potential

b_{min} = 2.9 f

1 MeV < E_{gamma} < 10^5 MeV

continuum potential

b_{min} = 9400 f

E_{gamma} < 1 MeV

$\gamma + {}^{208}\mathbf{Pb}$

Threshold Energies (MeV)								
γ,n	γ,p	γ,t	γ,He-3	γ,α	γ,2n	γ,np	γ,2p	γ,3n
7.37	8.01	12.88	14.39	-0.52	14.11	14.85	15.38	22.19

No reaction on Pb with photon energy < 1 MeV

Post scriptum: Cnanneling radiation

$\theta_c \gamma \ll 1$

Dipole radiation formed by the entire trajectory

$\theta_c \gamma \gg 1$

Synchrotron radiation formed at the part of the trajectory smaller then particle oscillation length

Total intencity

$$I(x) = \frac{2e^2}{3m^2c^3}\gamma^2 |\nabla U(x)|^2 \ .$$

Strongly suppressed radiation from Pb ions