Channeling-2014

Radiation by high energy electrons in ultrathin crystal

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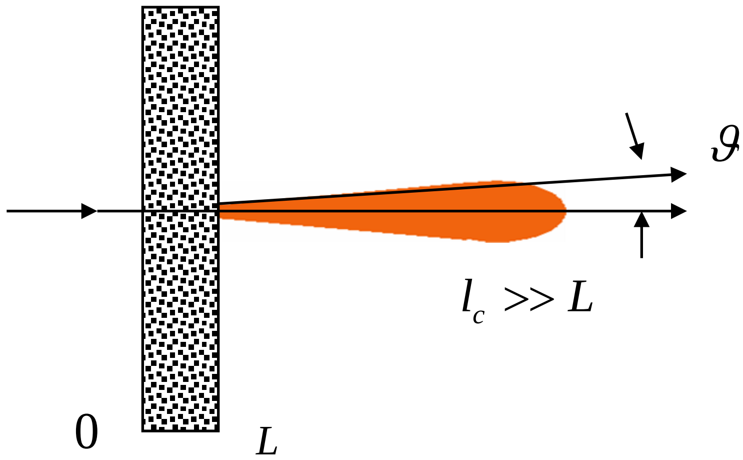
- TSF-effect
- Coherent radiation in ultrathin crystal
- Scattering and radiation (eikonal approximation)

Radiation in thin target (TSF-effect)

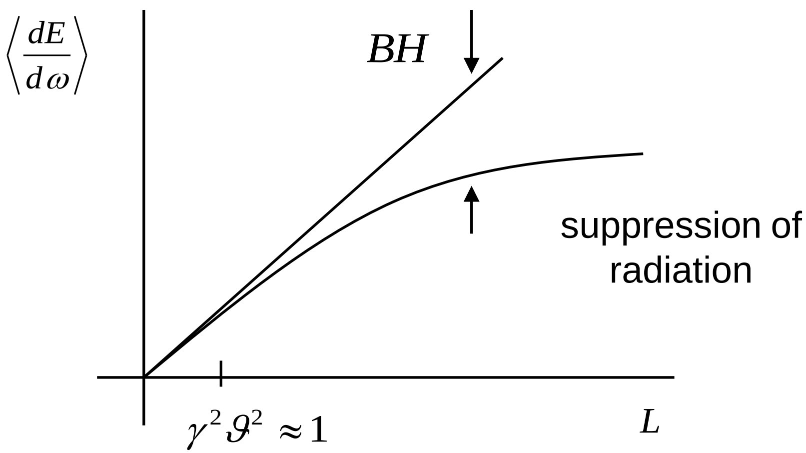
F. **T**ernovskii, JETF 1960, N. **S**hul'ga, S. **F**omin JETP Lett. 1978, 1996



$$l_c = \frac{2\gamma^2}{\omega} \gg L$$

$$\left\langle \frac{dE}{d\omega} \right\rangle = \frac{2e^2}{\pi} \left\langle \left[\frac{2\xi^2+1}{\xi\sqrt{\xi^2+1}} \ln\left(\xi + \sqrt{\xi^2+1}\right) - 1 \right] \right\rangle \approx$$

$$\approx \frac{2e^2}{3\pi} \begin{cases} \gamma^2 \overline{\vartheta^2} \\ 3\ln \gamma^2 \overline{\vartheta^2} \end{cases} \approx \begin{cases} E'_{BH} \\ < E'_{BH} \end{cases}$$



$$\xi = \frac{\gamma\vartheta}{2}$$

Suppression of radiation by relativistic electrons in a thin layer of matter (TSF effect), experiment

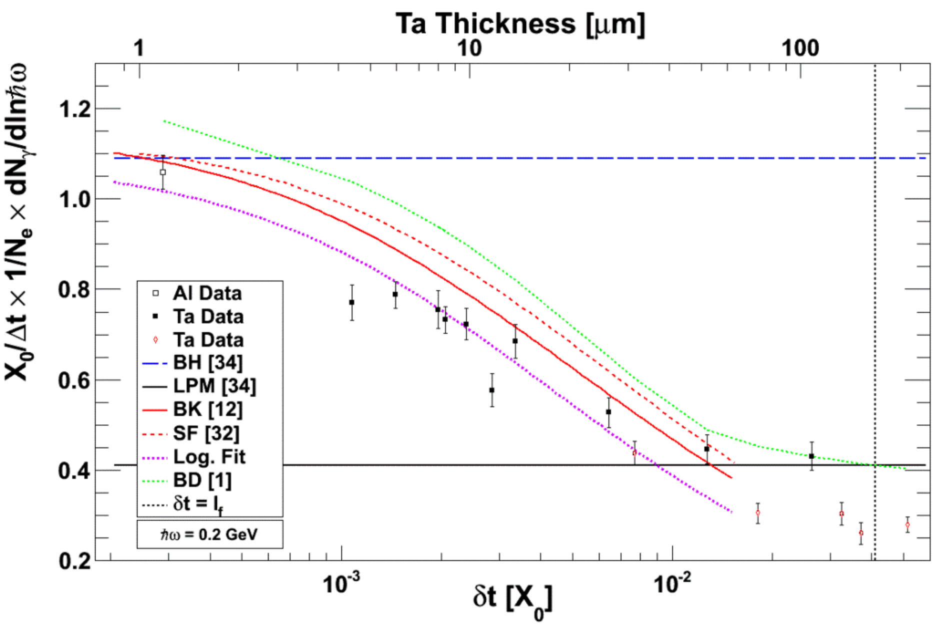
Predicted at KIPT - 1978 - ***N.F.Shul'ga, S.P.Fomin,*** *JETP Letters, **27**(1978)126.*

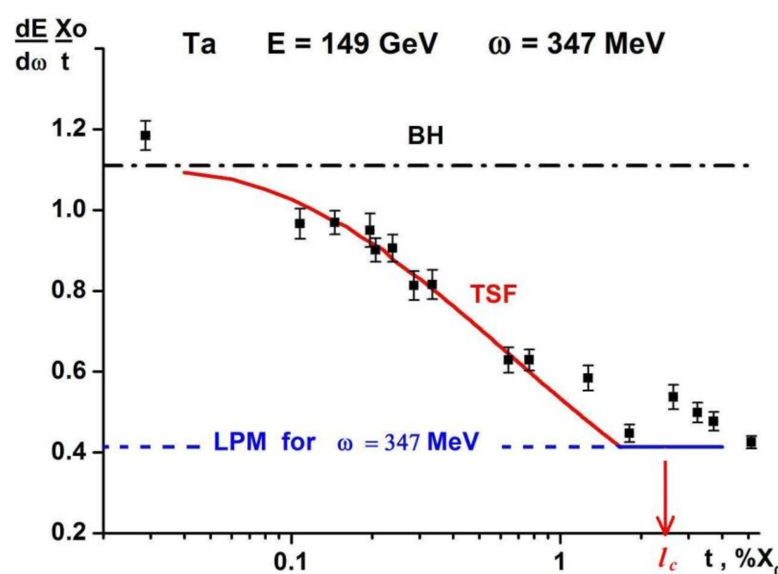
Confirmed at CERN - 2009 - ***H.D.Thomsen et al.,*** *Physics Letters B **672** (2009) 323.*

H.D.Thomsen et al., *Physical Review D **81** (2010) 052003.*

CERN NA63 SPS E = 149 GeV

A.S.Fomin, S.P.Fomin, N.F.Shul'ga
Nuovo Cimento (2011)

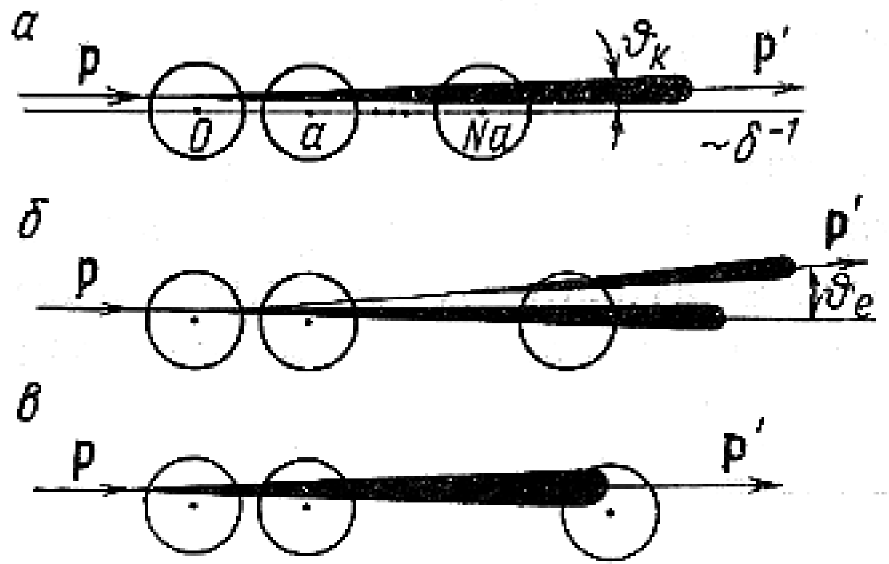




U. Uggerhøj : … we have seen the half - bare electron !

Coherent Bremsstrahlung (CB) at interaction with atomic string

A.I. Akhiezer, N.F. Shul'ga, 1975

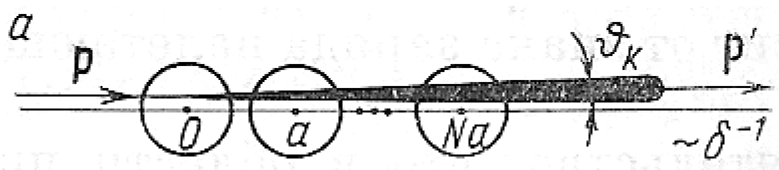


$$Z|e| \longrightarrow NZ|e|$$

$$\frac{NZe^2}{\hbar c} > 1$$

CB on N atoms of string

A.I. Akhiezer, N.F. Shul'ga, 1975



$$\frac{NZe^2}{\hbar c} \square\ 1 \qquad\qquad \frac{NZe^2}{mR} \square\ \frac{q}{m} << 1$$

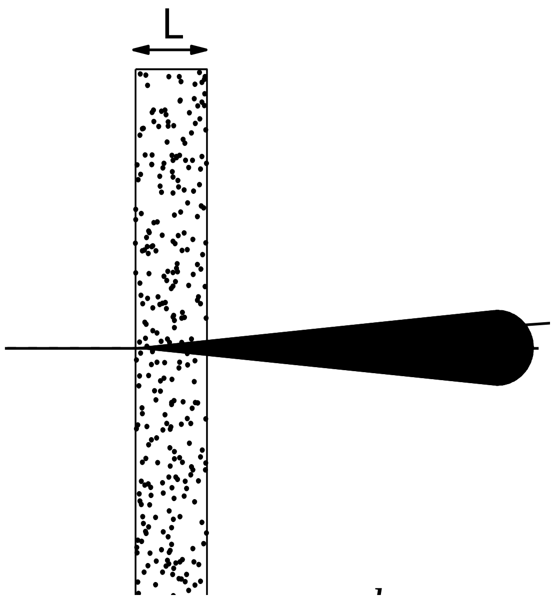
$$\hbar\omega \frac{d\sigma^{(N)}}{d\omega} \approx \frac{16e^2(NZe^2)^2}{3m^2} \frac{\varepsilon'}{\varepsilon} \left(1 + \frac{3}{4} \frac{\hbar^2\omega^2}{\varepsilon\varepsilon'}\right) \ln \frac{mR}{NZe^2}.$$

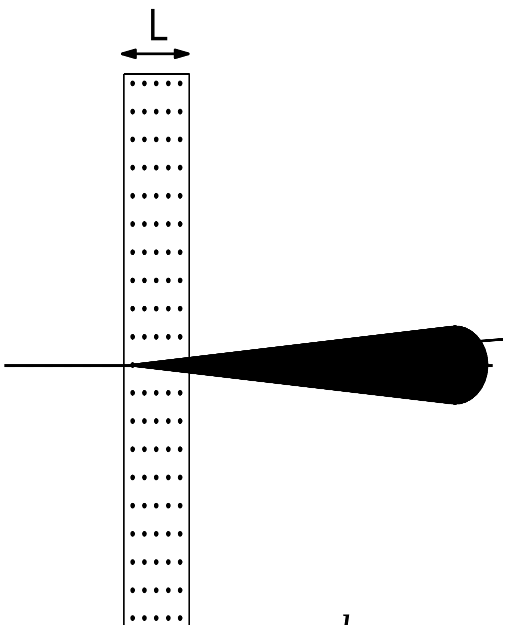
CB suppression

$$\frac{NZe^2}{\hbar c} \square\ 1 \qquad\qquad \frac{NZe^2}{mR} \square\ \frac{q}{m} \square\ 1$$

$$\hbar\omega \frac{d\sigma^{(N)}}{d\omega} = \frac{4e^2R^2}{3} \frac{\varepsilon'}{\varepsilon} \left(1 + \frac{\hbar^2\omega^2}{2\varepsilon\varepsilon'}\right) \left(\ln \frac{NZe^2}{mR}\right)^3.$$

CB in ultrathin crystal



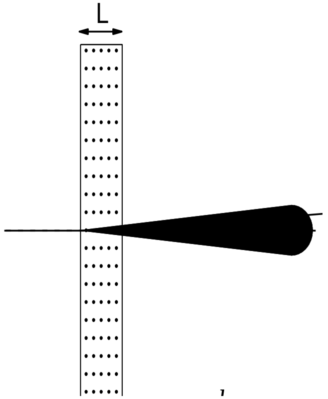


H. Thomsen et al.
Phys. Rev. D81 (2010)
Ta, *L*~5μm

P.R.L. 108 (2012)
Ferrara, Italy
Construction of Si crystals
with *L*□50nm

CB in ultrathin crystal (eikonal approximation)

N.Shul'ga, S.Shul'ga, Phys. Lett. A378 (2014) 3074



$$d\sigma(q_\perp) = dW(q_\perp)\, d\sigma_s(q_\perp)$$

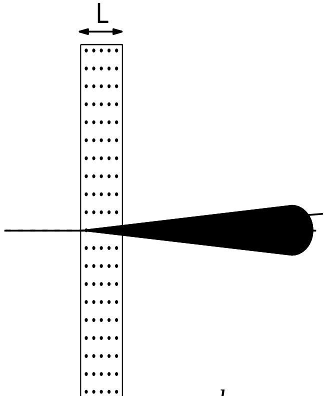
$$\frac{dW}{d\omega} = \frac{2e^2}{\pi\omega}\frac{\varepsilon'}{\varepsilon}\left[\frac{2\xi^2\left(1+\hbar^2\omega^2/2\varepsilon\varepsilon'\right)+1}{\xi\sqrt{\xi^2+1}}\ln\left(\xi+\sqrt{\xi^2+1}\right)-1\right], \qquad \xi = q_\perp/2m$$

$$\frac{d^2\sigma_s^{eik}}{d^2q_\perp} = \frac{1}{4\pi^2}\left|\int d^2\rho\, e^{i\vec{q}\vec{\rho}}\left(e^{i\sum_{n=1}^{N_c}\chi(\vec{\rho}-\vec{\rho}_n)}\right)\right|^2$$

$$\chi(\vec{\rho}-\vec{\rho}_n) = -\frac{1}{v}\int_{-\infty}^{\infty} dz\, u(\vec{\rho}-\vec{\rho}_n, z).$$

Scattering and CB in ultrathin crystal

N.Shul'ga, S.Shul'ga, Phys. Lett. A378 (2014) 3074



$$4\pi^2\left\langle \frac{d^2\sigma_s}{d^2 q_\perp}\right\rangle = \int d^2\rho\, d^2\rho' e^{i\vec{q}\left(\vec{\rho}-\vec{\rho}'\right)} F_{N_c}\left(\vec{\rho},\vec{\rho}'\right)$$

$$\vec{\rho} \approx \vec{\rho}'$$

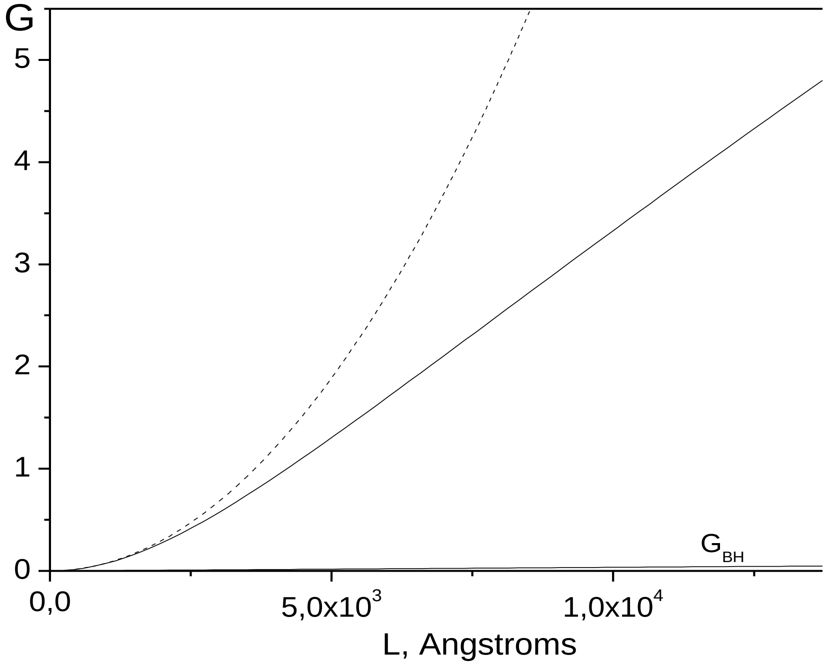
$$F_{N_c}\left(\vec{\rho},\vec{\rho}'\right) = \prod_{n=1}^{N_c}\int d^2\rho_n f\left(\vec{\rho}_n\right) e^{i\left(\chi\left(\vec{\rho}-\vec{\rho}_n\right)-\chi\left(\vec{\rho}'-\vec{\rho}_n\right)\right)} = \exp\left[iN\left(\vec{\rho}-\vec{\rho}'\right)\frac{\partial}{\partial\vec{\rho}'}\overline{\chi_c}\left(\vec{\rho}'\right)\right]$$

$$\left\langle \frac{d^2\sigma_s}{d^2 q_\perp}\right\rangle = \int d^2\rho' \delta\left(\vec{q}_\perp + N\frac{\partial}{\partial\vec{\rho}'}\chi_c\left(\vec{\rho}'\right)\right) \qquad N = L/a$$

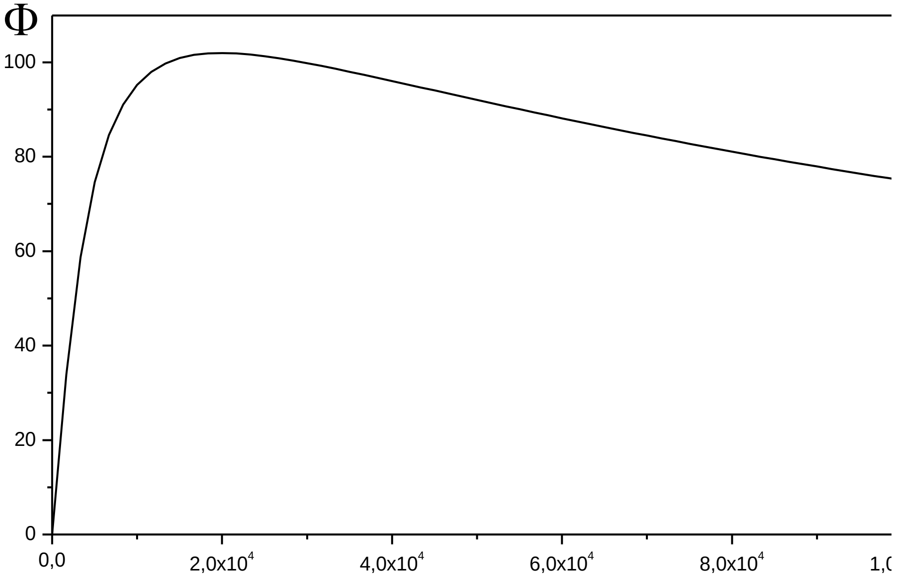
$$\boxed{\frac{d\sigma_c}{d\omega} = \int d^2\rho' \frac{dW\left(-N\,\partial\chi_c(\vec{\rho}')/\partial\vec{\rho}'\right)}{d\omega}}$$

CB and suppression of CB in ultrathin crystal

$$G = \frac{1}{A}\frac{d\sigma_c}{d\omega}$$

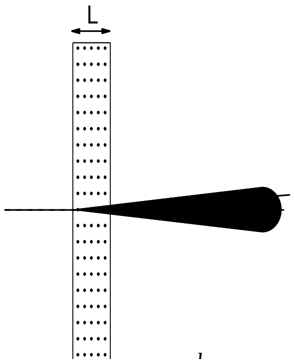


$$\Phi = \frac{d\sigma_c / d\omega}{d\sigma_{BH} / d\omega}$$



Conclusions

1. Validity conditions



$$l_c = 2\gamma^2 / \omega >> L$$

$$|\chi_0| >> \chi_1, \qquad \kappa = \frac{Ze^2}{12\rho R}\frac{L}{Rd} << 1$$

for $E = 150\,\mathrm{GeV}$, $\omega = 1\,\mathrm{GeV}$, $L = 1\,\mu\mathrm{m}$, Si

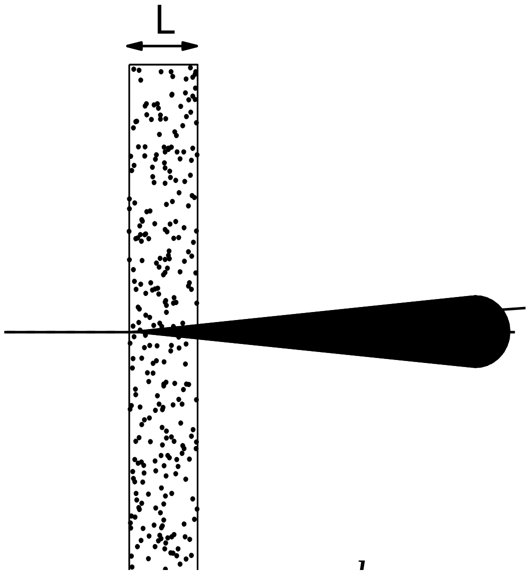
$$l_c \sim 60\,\mu\mathrm{m} >> L, \qquad \kappa < 10^{-1}.$$

2. The proposed method can be also used for study of:
   a) TSF-effect
   b) beam-beam coherent radiation

Thank you for your attention!

Radiation in thin layer of amorphous medium (TSF-effect)

N. Shul'ga, S. Fomin, 1978



$$l_{coh} = \frac{2\gamma^2}{\omega} \cdot \frac{1}{1 + \gamma^2 \overline{\vartheta^2} + \left(\gamma\omega_p / \omega\right)^2 + \left(\gamma\vartheta_{rad}\right)^2}$$

$$l_{coh} > L$$