PLANNED EXPERIMENT ON INVESTIGATION OF 'HALF-BARE' ELECTRON TRANSITION RADIATION PROPERTIES ON 45-MeV CLIO FACILITY

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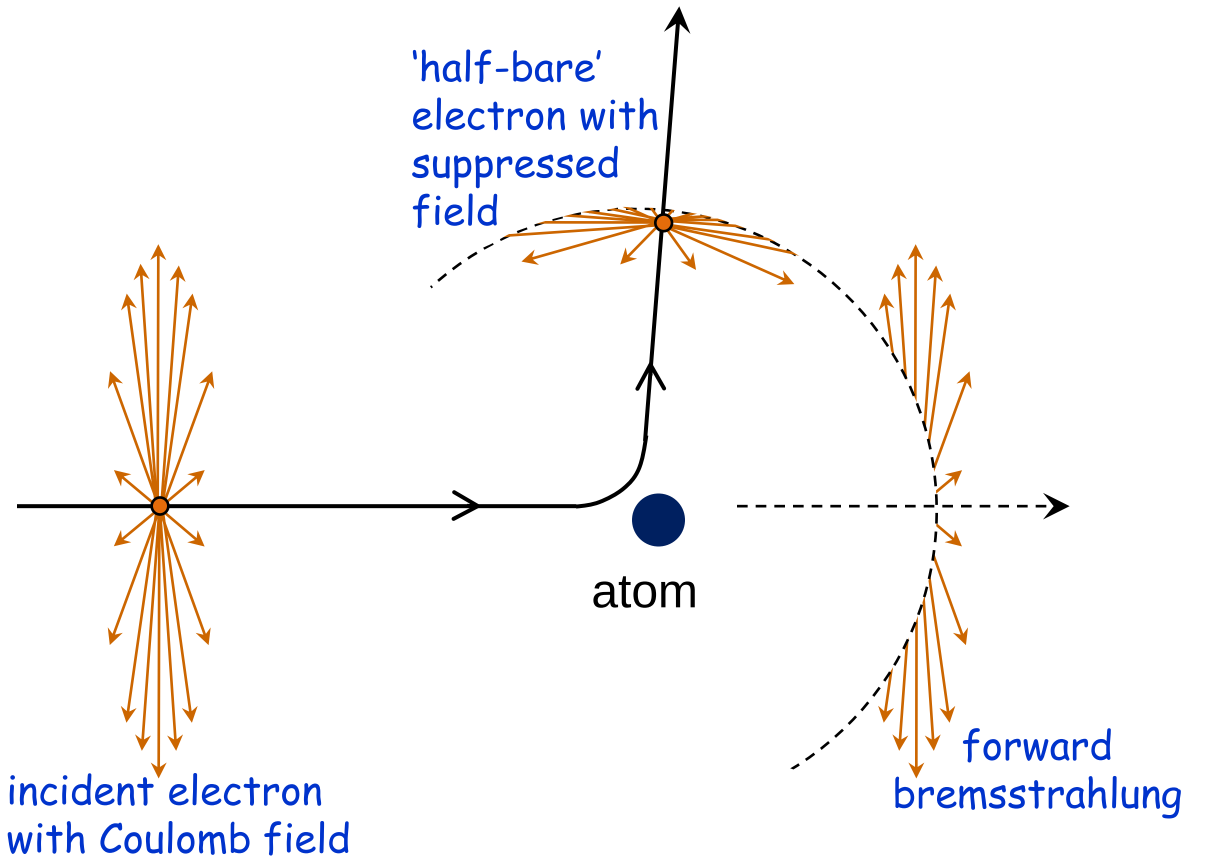
Kharkiv, Ukraine

[3] LAL, Universite Paris-Sud, CNRS/IN2P3, Universite Paris-Saclay,
Orsay, France

S.V. Trofymenko, N.F. Shul'ga, N. Delerue et al. // J.Phys.: Conf. Series, 2017

ELECTRON 'UNDRESSING' AT SCATTERING



Fourier component regeneration distance =
= radiation formation length
$l_F \sim \gamma^2 \lambda$

γ – Lorenz-factor
λ – wavelength

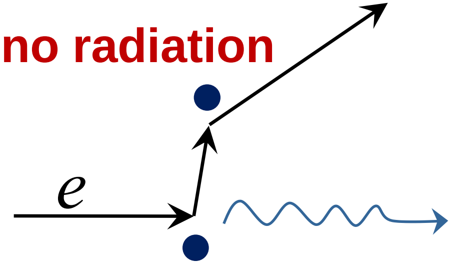
For photon energy ω ~ 1 MeV and electron energy E ~ 10 GeV :
$l_F \sim 100\ \mu\text{m} \gg$ electron mean free path

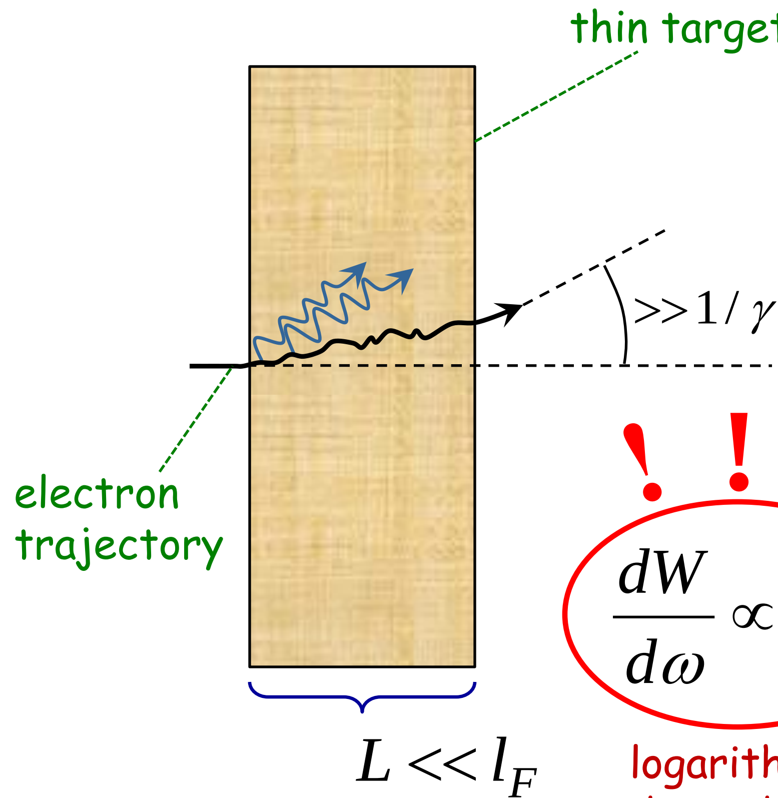
E.L. Feinberg // Sov. Phys. JETP, 1966
E.L. Feinberg // Sov. Phys. Usp, 1980
N.F. Shul'ga, S.P. Fomin // Phys. Lett. A, 1986
A.I Akhiezer, N.F Shul'ga, 'High Energy Electrodynamics in Matter', 1996

"HALF-BARE" ELECTRON MANIFESTATION IN BREMSSTRAHLUNG
(Ternovsky - Shul'ga - Fomin effect)

F.F. Ternovsky // JETP, 1960

N.F. Shul'ga, S.P. Fomin // JETP Lett., 1978





! ! !

$$\frac{dW}{d\omega} \propto \ln L$$

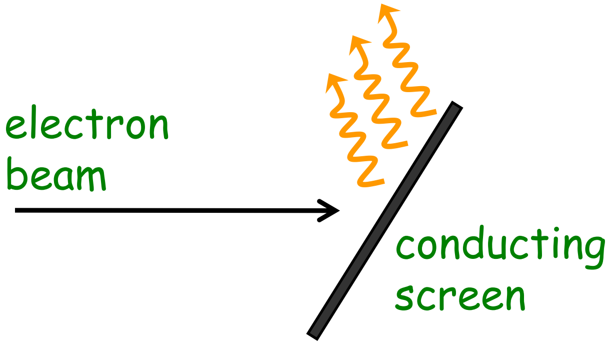
logarithmic dependence, not linear

Observed experimentally by collaboration CERN NA63

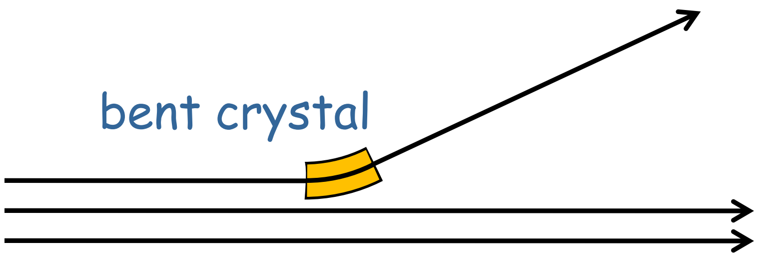
H.D. Thomsen, K.K. Andersen, J. Esberg, H. Knudsen, M. Lund, K.R. Hansen, U.I. Uggerhøj et. al. // Phys.Lett.B, 2009

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

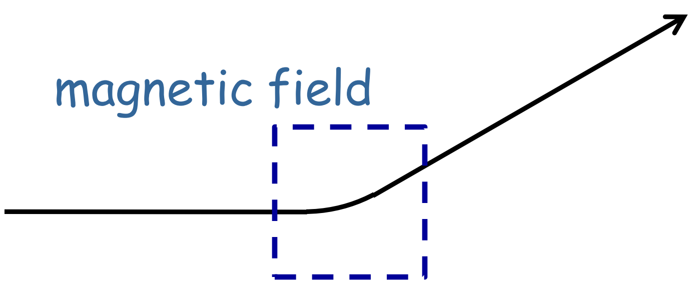
TRANSITION RADIATION. DEFLECTED BEAMS



Extracted and deflected beams may be examples of 'half-bare' particle beams



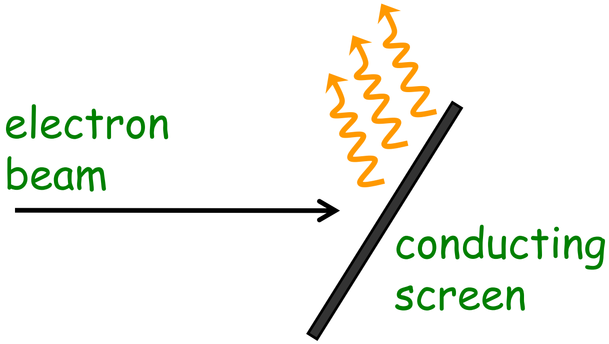
For 45 MeV electrons (CLIO)
in millimeter
wavelength region
$l_F \sim \gamma^2\lambda \sim 8$ m



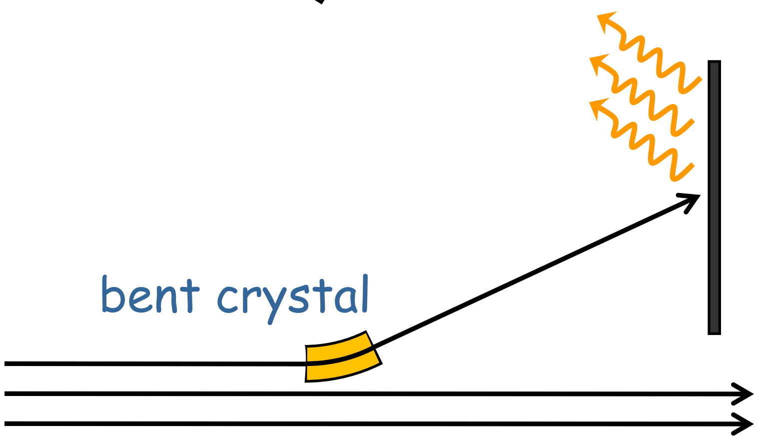
For 10 GeV electrons
even in optical region
$l_F \sim 200$ m

(in millimeter region
$l_F \sim 400$ km !)

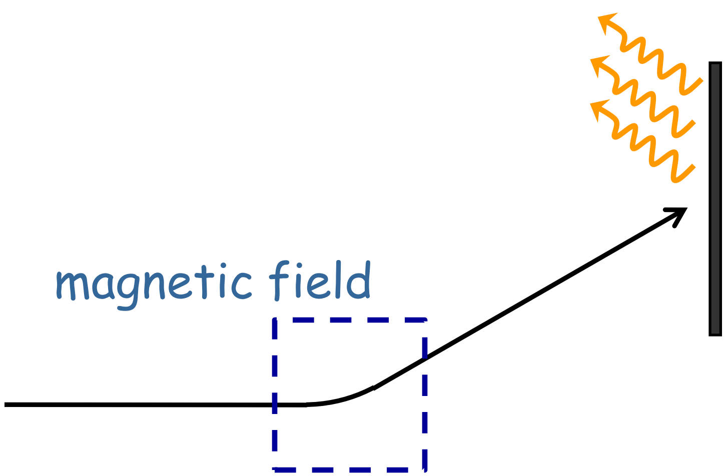
TRANSITION RADIATION. DEFLECTED BEAMS



Extracted and deflected beams may be examples of 'half-bare' particle beams



For 45 MeV electrons (CLIO)
in millimeter wavelength region
$l_F \sim \gamma^2 \lambda \sim 8$ m



For 10 GeV electrons
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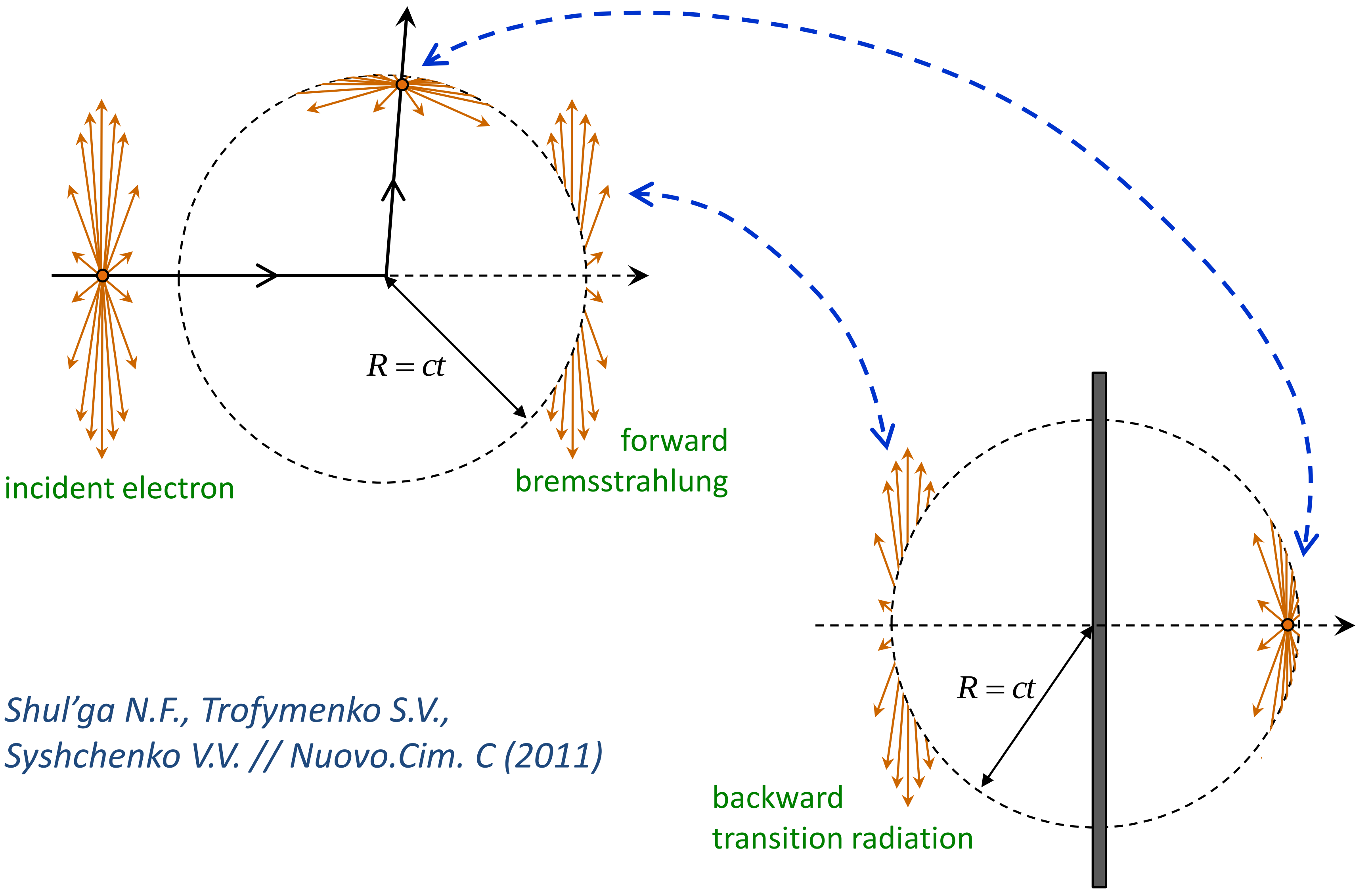
$l_F \sim 200$ m

(in millimeter region
$l_F \sim 400$ km !)

ANALOGOUS FIELD STRUCTURE IN TRANSITION RADIATION AND BREMSSTRAHLUNG PROCESSES

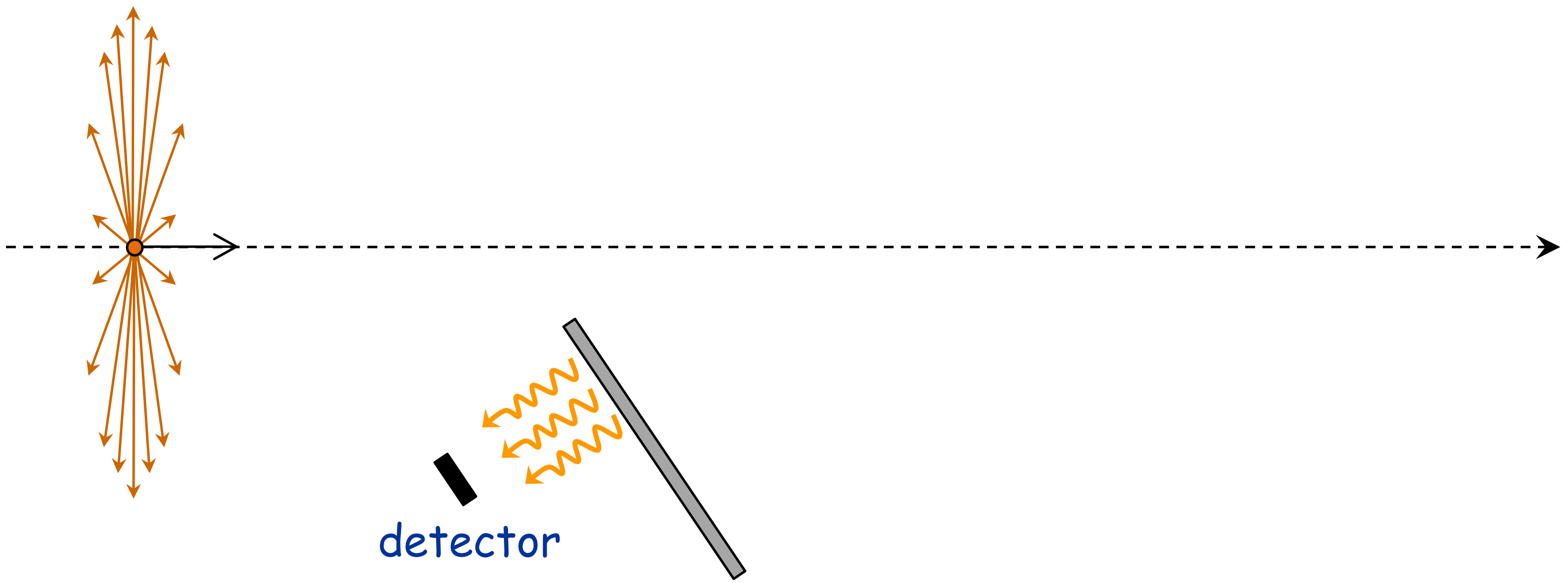


Shul'ga N.F., Trofymenko S.V., Syshchenko V.V. // Nuovo.Cim. C (2011)

“Half-bareness” in diffraction radiation:

G. Naumenko, X. Artru, A. Potylitsyn et al. // J.Phys., 2010

G. Naumenko, Y. Popov, M. Shevelev // J. Phys., 2012



“Half-bareness” in optical fibers and Smith-Purcell radiation:

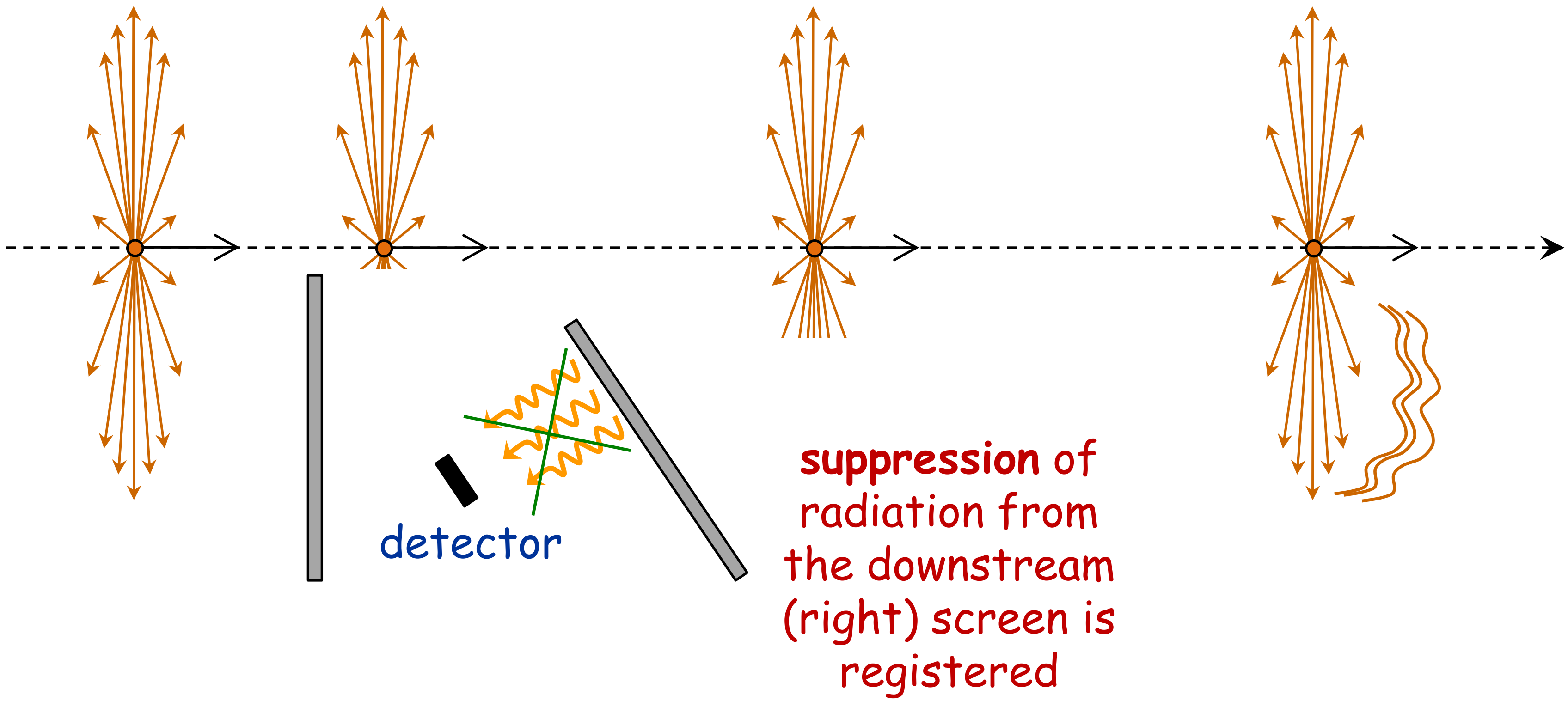
X. Artru, C. Ray // NIM B, 2008

X. Artru // Il Nouovo Cim. C, 2011

“Half-bareness” in diffraction radiation:

G. Naumenko, X. Artru, A. Potylitsyn et al. // J.Phys., 2010

G. Naumenko, Y. Popov, M. Shevelev // J. Phys., 2012



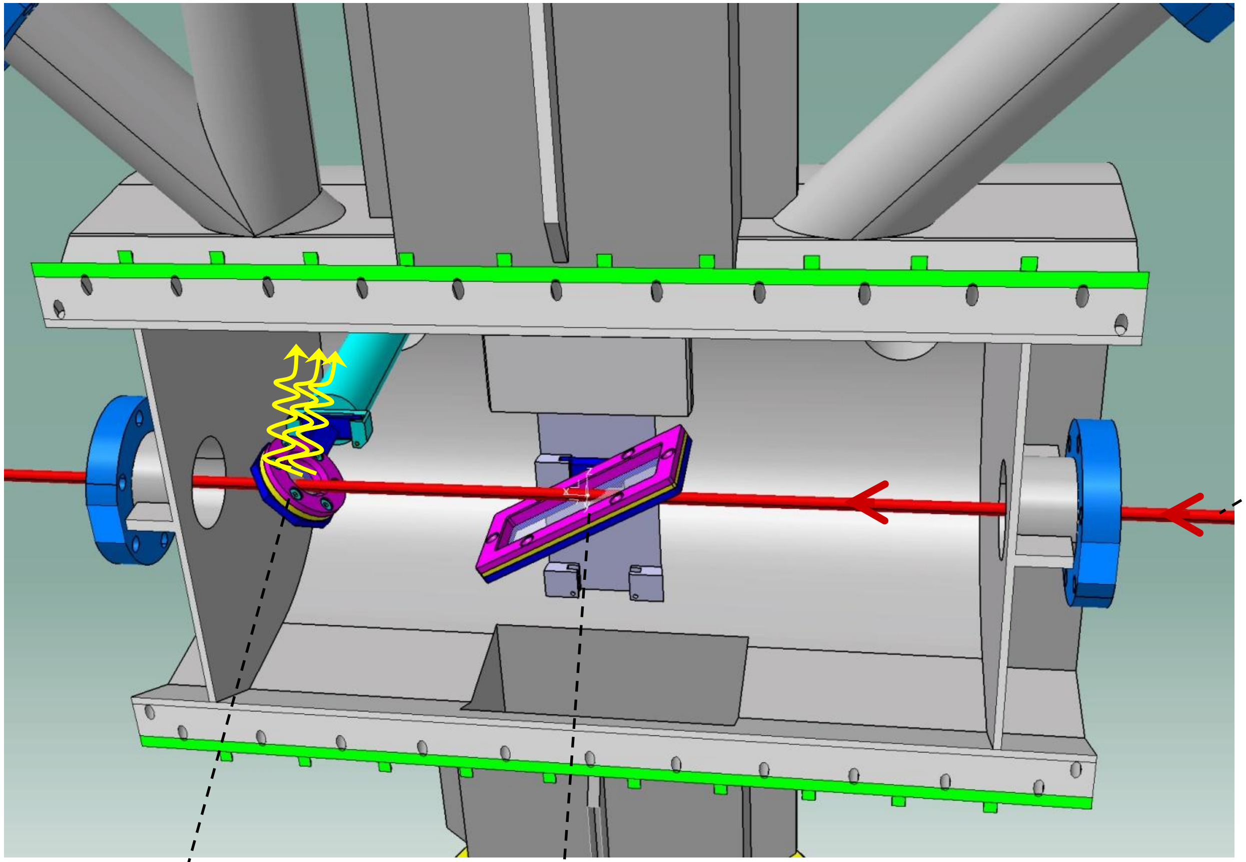
“Half-bareness” in optical fibers and Smith-Purcell radiation:

X. Artru, C. Ray // NIM B, 2008

X. Artru // Il Nouovo Cim. C, 2011

EXPERIMENT ON HALF-BARE ELECTRON TR INVESTIGATION BEING PREPARED AT CLIO

S. Trofymenko, N. Shul'ga, N. Delerue, S. Jenzer, V. Khodnevych, A. Migayron // J. Phys. (2017)



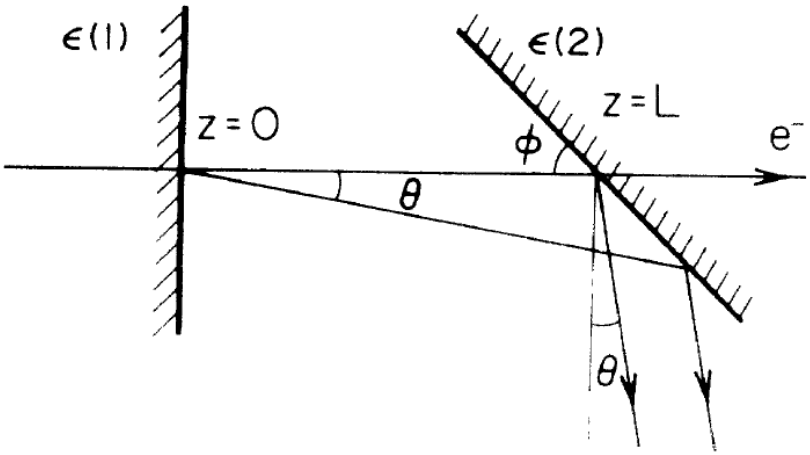
15 - 45 MeV electron beam

radiating screen (downstream)

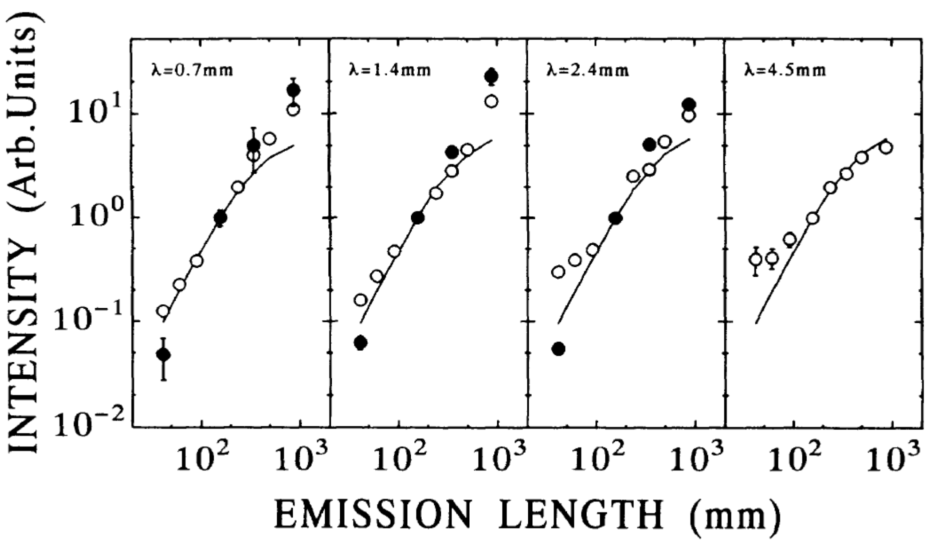
"undressing" screen (upstream)

EARLIER EXPERIMENT IN THE ANALOGOUS CONFIGURATION (150 MeV electrons)

Y. Shibata, K. Ishi, T. Tokahashi et al. // Phys. Rev. E, 1994

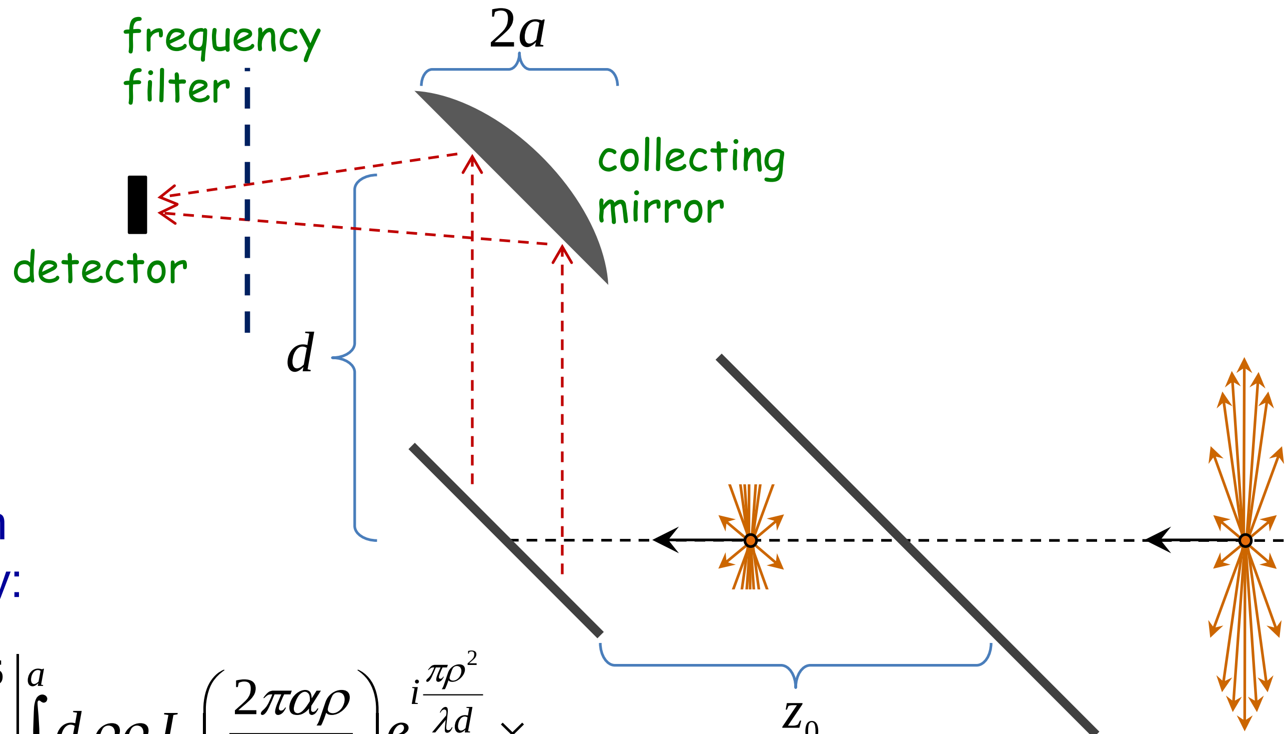


Signal increase with the increase of the distance between the screens was observed



No comparison with the signal in the case of the upstream screen absence was made

EXPECTED SIGNAL AT CLIO



single electron radiation spectral-angular density:

$$\frac{d^2W}{d\lambda do} = \frac{2e^2}{\lambda^2 d^2 \pi}\left(\frac{2\pi}{\lambda}\right)^6 \left| \int_0^a d\rho \rho J_1\left(\frac{2\pi\alpha\rho}{\lambda}\right) e^{i\frac{\pi\rho^2}{\lambda d}} \times \right.$$

$$\left. \times \int_0^\infty dx \frac{x^2}{x^2+\gamma^{-2}}\left\{1-e^{-i\pi z_0(x^2+\gamma^{-2})/\lambda}\right\}\int_0^{R_2} drrJ_1\left(\frac{2\pi xr}{\lambda}\right) J_1\left(\frac{2\pi\rho r}{\lambda d}\right) e^{i\pi r^2/\lambda d}\right|^2$$

total yield from the bunch:

$$\delta W = \int d\lambda do \frac{d^2W}{d\lambda do} f(\lambda)[n + n(n-1)F(\lambda)]$$

J_1 – Bessel function

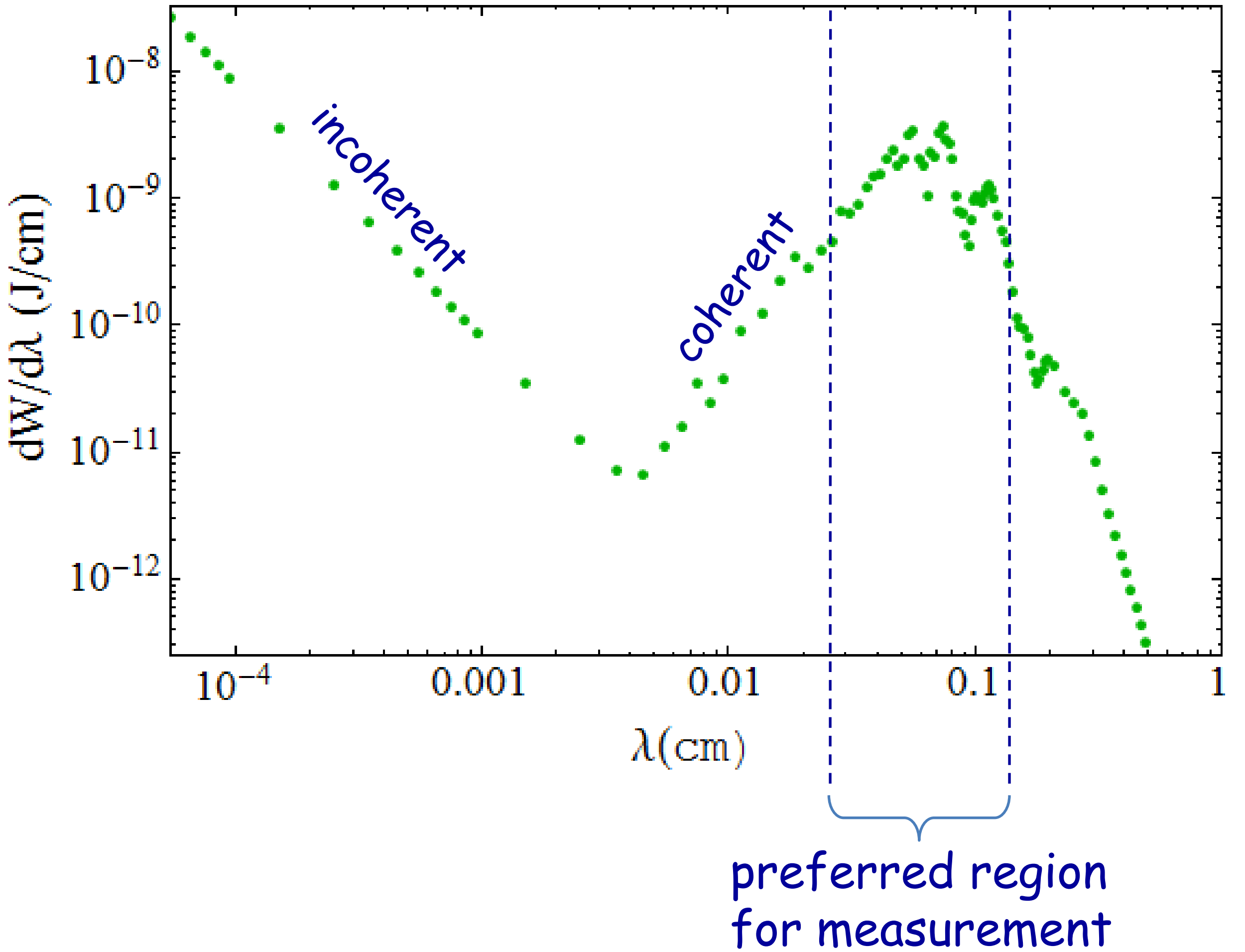
n – number of particles per bunch

$F(\lambda)$ – bunch form-factor

$f(\lambda)$ – filter transmission function

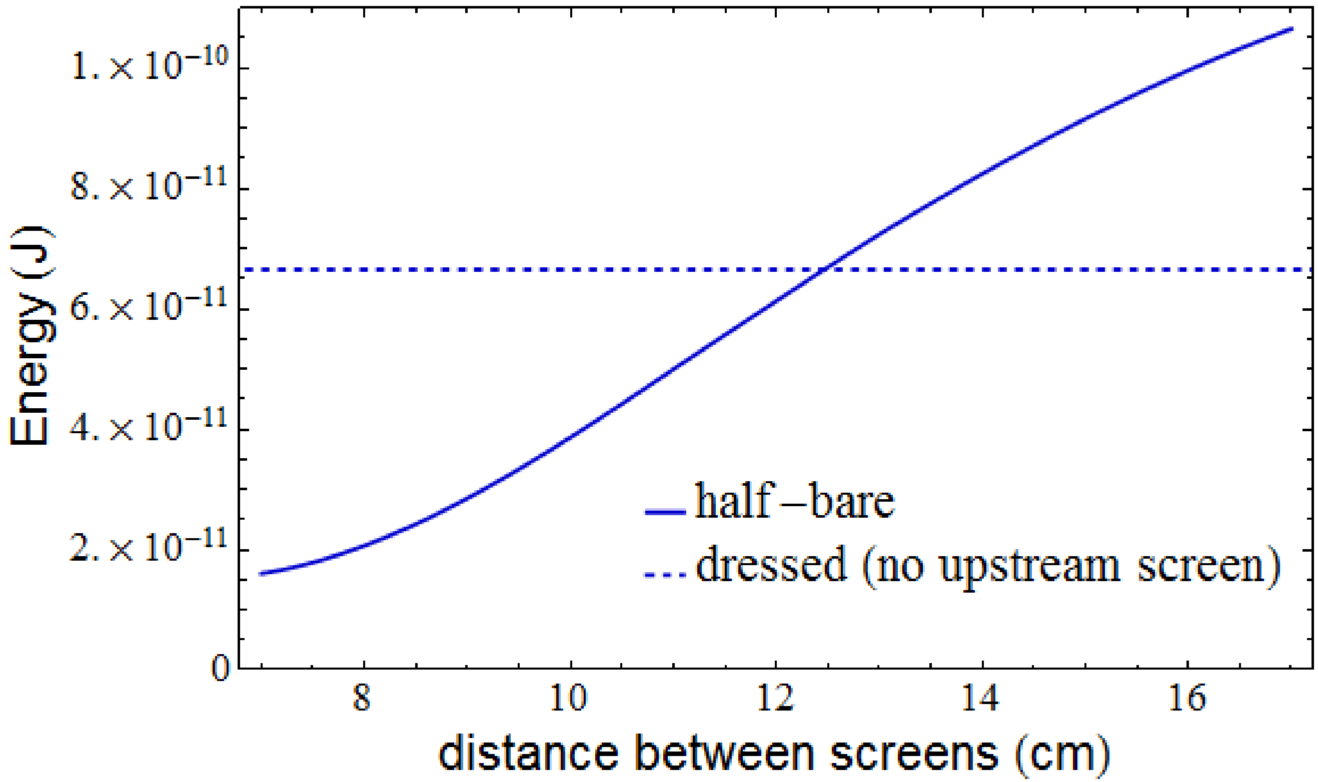
EXPECTED SIGNAL AT CLIO
(single bunch of 1 nC)

Radiation spectrum (no upstream screen)



EXPECTED SIGNAL AT CLIO
(single bunch of 1 nC)

Dependence of the signal on distance between the screens **at 30 MeV**

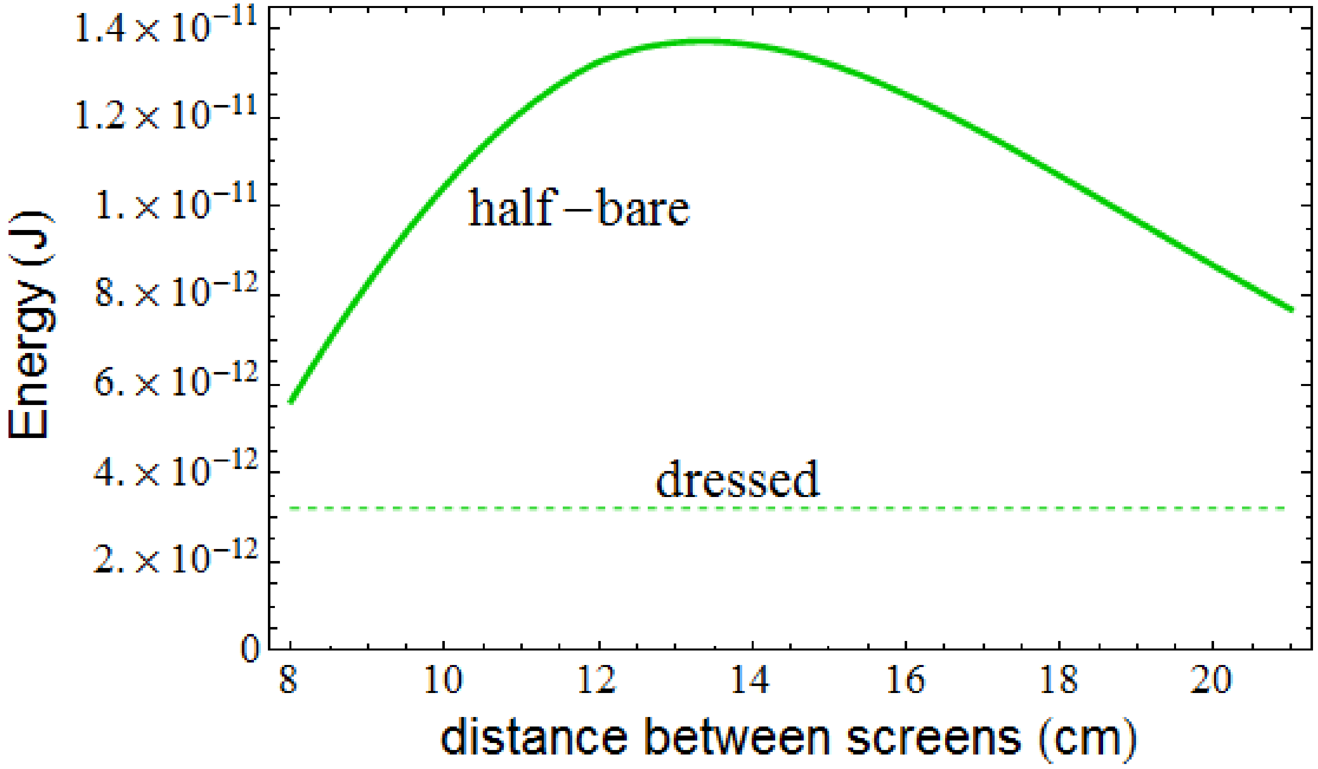


Both the effects of signal **suppression and enhancement** comparing to the case of the upstream screen absence are expected to be observed

EXPECTED SIGNAL AT CLIO
(single bunch of 1 nC)

Dependence of the signal on distance between the screens **at 12.5 MeV**

integration over wavelength range 0.048 cm < λ < 0.054 cm



The effect of **signal decrease** with the increase of distance between the screens is expected to be observed

THEORETICALLY INVESTIGATED MANIFESTATIONS OF "HALF-BARE" STATE IN OTHER PROCESSES

1) Ionization energy loss in thin targets

2) Parametric X-ray emission in thin crystal

3)

4) } more examples in the report of S.P. Fomin

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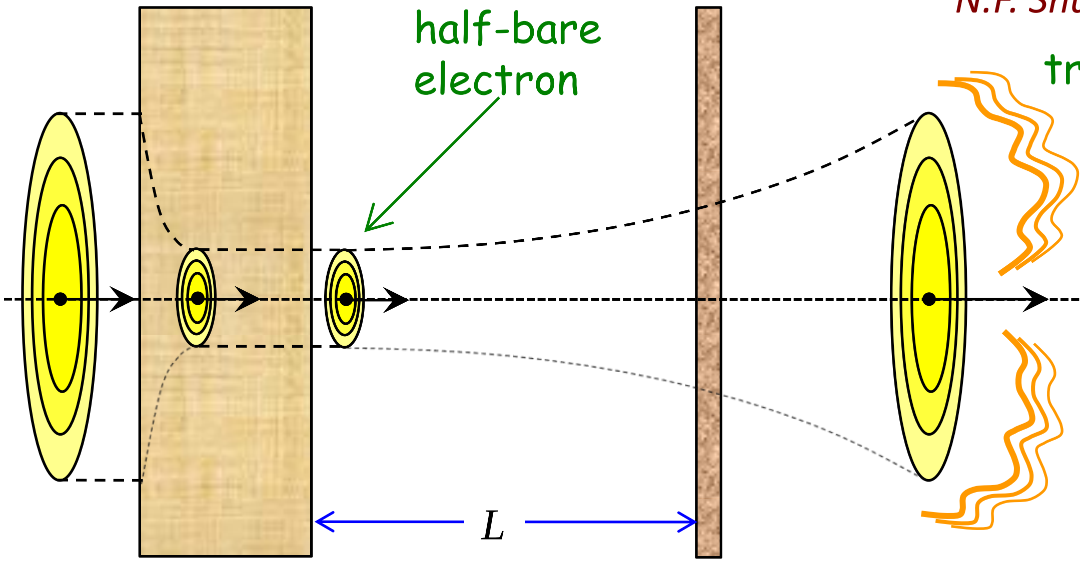
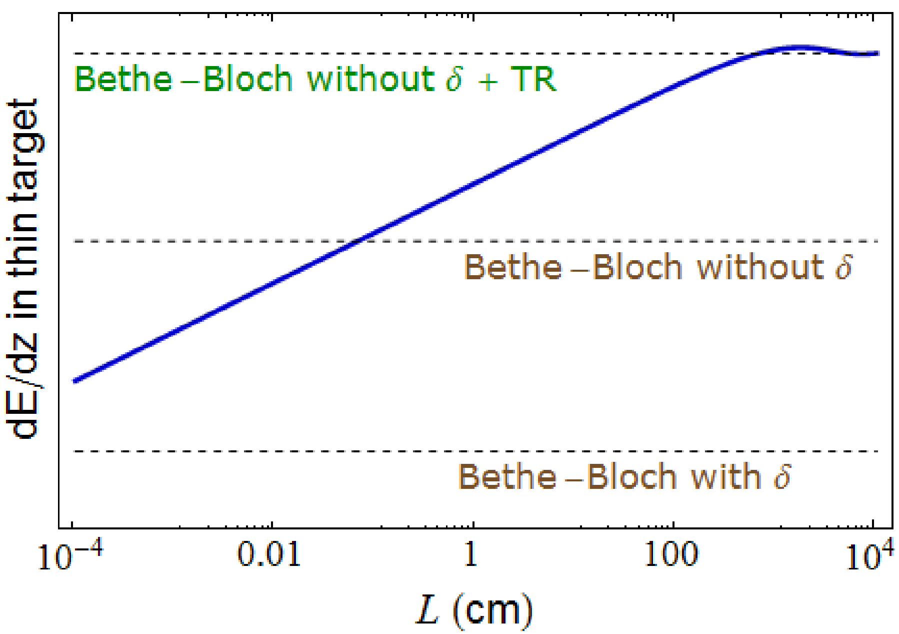
HALF-BARE ELECTRON IONIZATION LOSS

N.F. Shul'ga, S.V. Trofymenko // Phys. Lett. A, 2012



Ionization loss in thin target is not defined by Bethe-Bloch formula within macroscopically large range of L

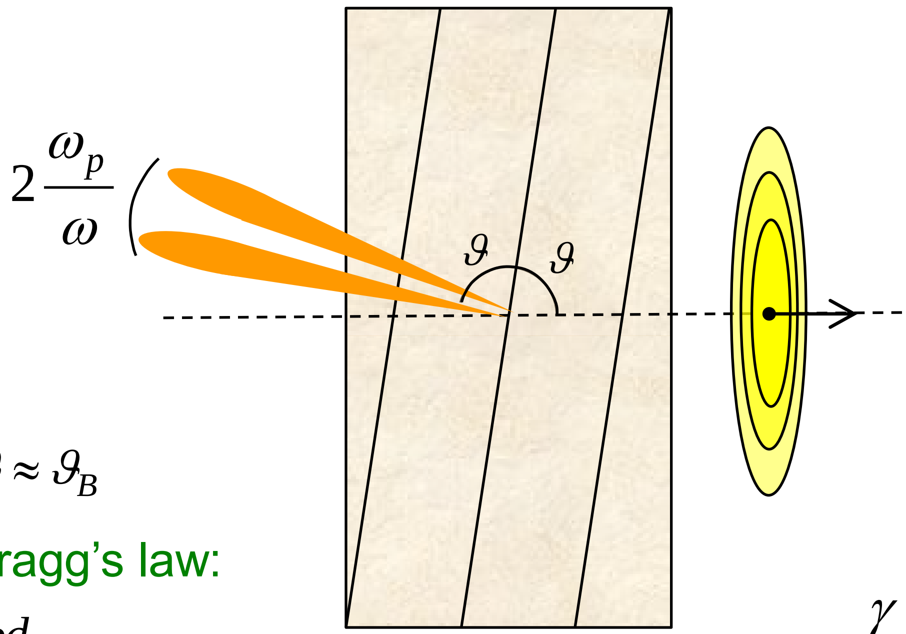
For 50 GeV electron:



δ – density effect correction (*ionization loss suppression due to polarization of substance*)

X-RAY EMISSION FROM THICK AND THIN CRYSTAL (PXR)

Thick crystal ***(d ≫1 μm)***

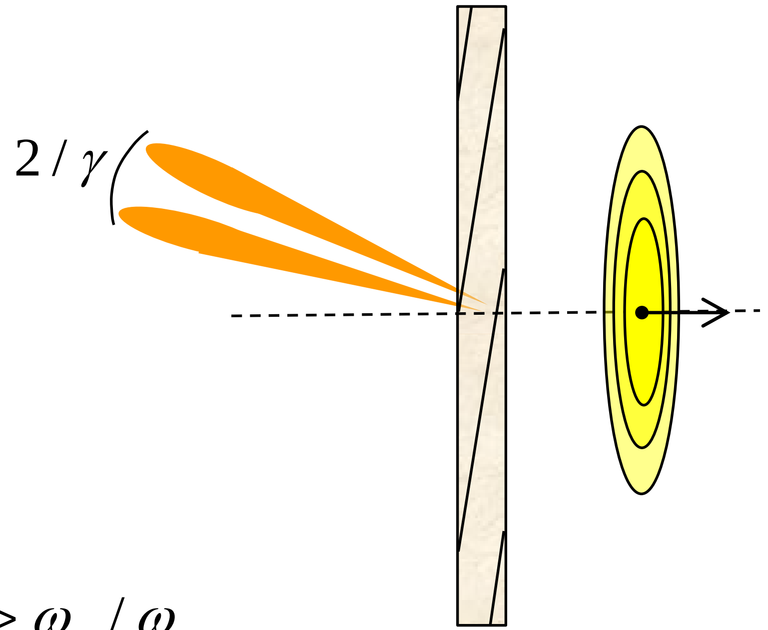


$\vartheta \approx \vartheta_B$

Bragg's law:

$$\frac{\omega d}{\pi c}\sin\vartheta_B = N$$

Thin crystal ***(d <1 μm)***



$\gamma \gg \omega_p/\omega$

Angular distribution width

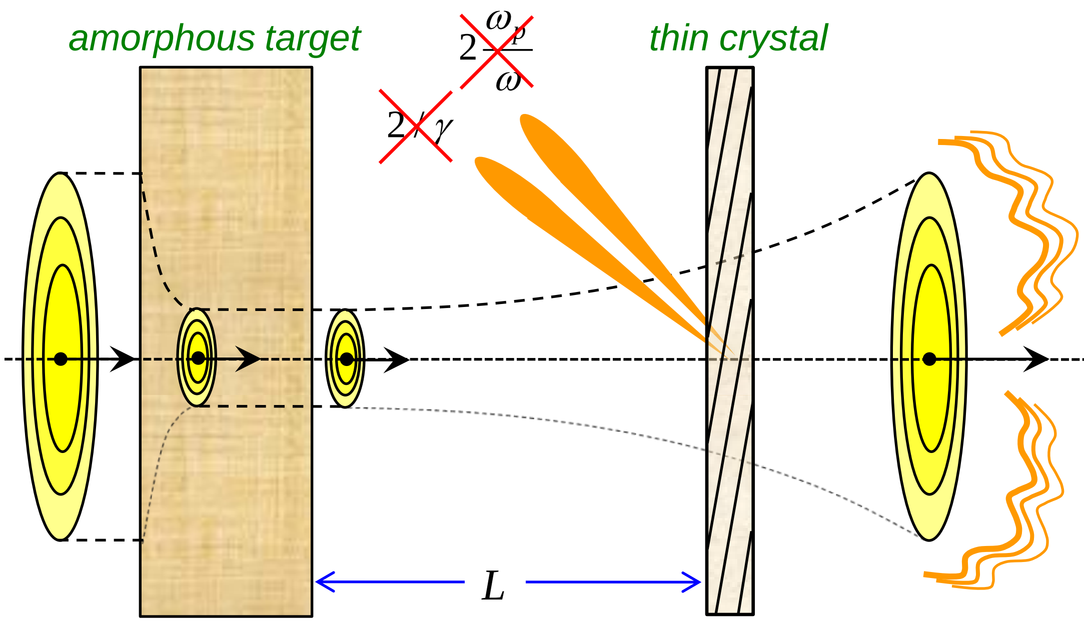
$\sim \omega_p/\omega$ $\qquad$ $\sim 1/\gamma \ll \omega_p/\omega$

Radiation yield

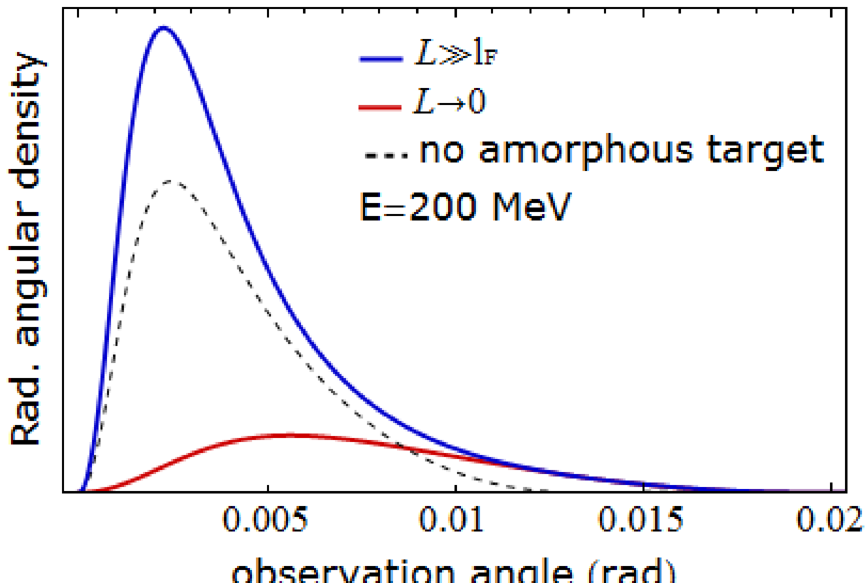
Independent on electron energy $\qquad$ $\propto \ln\gamma$

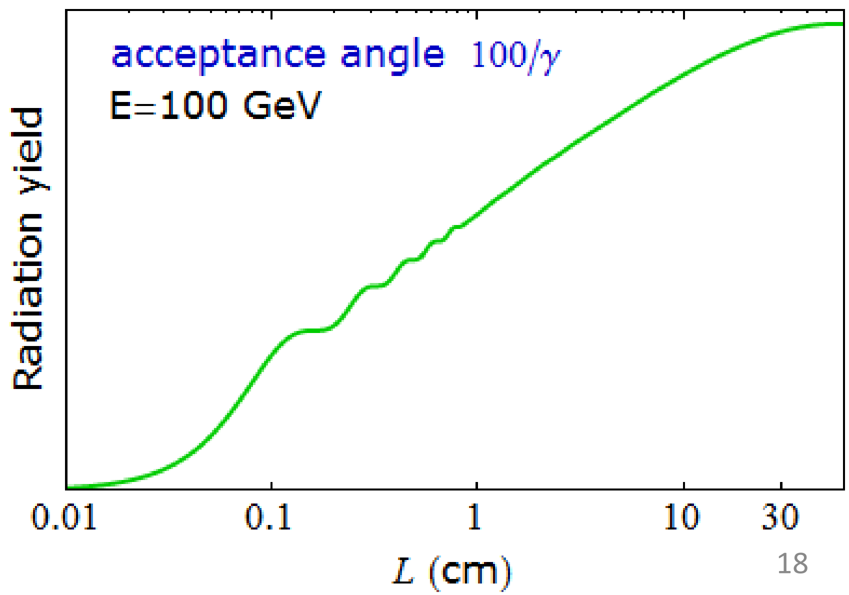
ω_p – plasma frequency $\qquad$ γ – electron Lorenz-factor

X-RAY EMISSION BY HALF-BARE ELECTRON



X-ray emission characteristics are not typical neither for thick, nor for thin crystal within macroscopically large range of L





CONCLUSIONS

Effects in 'half-bare' electron TR expected to be studied in the experiment at CLIO:

- Signal **enhancement** comparing to the case of 'dressed' electron (upstream screen absence)

- Signal **decrease** with the increase of distance between the screens

'Half-bare' electron manifestation in some other processes:

- Difference of ionization loss value in thin target from the result predicted by Bethe-Bloch formula within macroscopically large distances

- Modification of angular distribution and total yield of X-ray emission from thin crystal