EFFECT OF TRANSVERSE IMPEDANCE ON LUMINOSITY MEASUREMENTS: v2

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(thanks Nicolas Mounet and Roderik Bruce)

1st version on 03/07/2013

Correction of a formula (by N. Mounet and M. Zobov) by a factor $2^{-1/4} \approx 0.84$ (see slide 7) => Many thanks!

- **Question from Witold Kozanecki (25/06/2013)**
  - **Reminder: Due to the beam-beam deflection (in fact 2/3 from deflection and 1/3 from dynamic beta) generating a systematic orbit deformation at the interaction point, the luminosities had to be re-normalised by 1-2%**
  - **Next step: Check the effect of the transverse impedance => Question: What is the transverse kick at the TCT and the orbit displacement at the IP (for ATLAS)?**

ASSUMPTIONS / CONDITIONS

- It is assumed that the beam moves essentially (significantly only) at the TCT due to the closed bump
- Conditions
  - Beta* = 11 m
  - E = 4 TeV
  - Nb = 9E10 p/b
  - Sigmaz = 10 cm
  - Qx = 64.31
  - Max. displacement at the TCT of ~ 1 mm as 6 sigmas at the interaction point means 3 sigmas / beam (as it is done symmetrically) => Taking 3 sigmas at the TCT means ~ 1 mm at the TCT => Consider a max displacement at the TCT of 1 mm
  - Opening of the TCT (half gap) = 10 mm

WHAT WE NEED TO DO / KNOW

- **1) Beta functions at the TCT**
- **2) Phase advances between TCT and IP (ATLAS)**
- **3) Transverse kick factor of the TCT (total, i.e. geometric + RW)**

Longitudinal bunch profile normalised to 1

$$\kappa_{\perp} = \iint ds\, ds'\, \rho(s)\, \rho(s')\, W_{\perp}(s - s')$$

$$= -\frac{1}{\pi} \int_{0}^{\infty} d\omega \left| \tilde{\rho}(\omega) \right|^{2} \mathrm{Im}\left[Z_{\perp}(\omega) \right]$$

For a Gaussian: $\tilde{\rho}(\omega) = e^{-\frac{\sigma_z^2 \omega^2}{2 c^2}}$

THEN, ANSWERS TO THE 2 QUESTIONS

- 1) Transverse kick at the TCT

  (to the centre of charge of the bunch)

$$<\Delta x'>_{TCT} = -\frac{N_b\; e^2\; x_0}{\beta^2\; E_{total}}\;\kappa_{\perp,TCT}$$

particles / bunch

Proton charge

Transverse displacement

Total energy

Relativistic velocity factor

- 2) Orbit displacement at the IP

Beta function at TCT

Beta function at IP

Betatron phase advance between IP and TCT

$$\Delta < x >_{IP} = <\Delta x'>_{TCT}\;\frac{\sqrt{\beta_{IP}\;\beta_{TCT}}\;\cos\left(\left|\mu_{IP}-\mu_{TCT}\right|-\pi\,Q\right)}{2\sin\left(\pi\,Q\right)}$$

Transverse tune

CASE OF A PURELY INDUCTIVE IMPEDANCE (1/2)

- **In the case of a purely inductive impedance =>** $Z_\perp(\omega) = j\, C_{Z_\perp}$

$$\kappa_\perp = -\frac{C_{Z_\perp}\, c}{2\sqrt{\pi}\,\sigma_z}$$

Speed of light

  - **Case of a round collimator with LHC parameters**

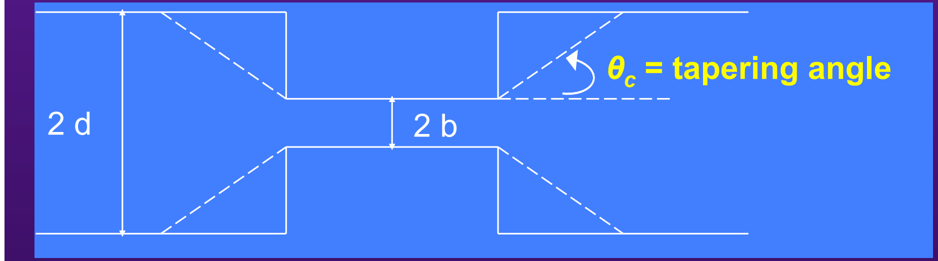
Vacuum impedance

Collimator tapering angle

$$C_{Z_\perp} = \frac{Z_0\,\theta_c}{\pi}\left(\frac{1}{b} - \frac{1}{d}\right)$$

Smaller radius

Larger radius



CASE OF A PURELY INDUCTIVE IMPEDANCE (2/2)

=>

$$\kappa_{\perp} = - \frac{\theta_c}{2\,\pi^{3/2}\,\varepsilon_0\,\sigma_z}\left(\frac{1}{b}-\frac{1}{d}\right)$$

Permittivity of vacuum

$$\boxed{< \Delta x' > = \frac{2\,N_b\,r_p\,x_0\,\theta_c}{\beta^2\,\gamma\,\sqrt{\pi}\,\sigma_z}\left(\frac{1}{b}-\frac{1}{d}\right)}$$

CASE OF A RW IMPEDANCE

- **In the case of a Resistive-Wall impedance in the classical regime (round) =>**

Length of impedance

$$Z_{\perp}(\omega) = (1 + j)\,\frac{L\,Z_0}{\pi\,b^3}\,\frac{1}{\sqrt{2\,\mu_0\,\sigma\,\omega}}$$

Permeability of vacuum

Conductivity

$\sqrt{2}$ instead of $2^{\frac{3}{4}}$
(in 1st version)

=>

$$\kappa_{\perp} = -\,\frac{\sqrt{2}\;L\,Z_0\,\Gamma\left(\frac{5}{4}\right)}{\pi^2\,b^3}\sqrt{\frac{c}{\mu_0\,\sigma\,\sigma_z}}$$

$$\boxed{<\Delta x'> = \frac{\sqrt{2}\;N_b\;r_p\;x_0\;\Gamma\left(\frac{1}{4}\right)}{\beta^2\,\gamma\,\pi\,b^3}\,\frac{L}{\sqrt{Z_0\,\sigma\,\sigma_z}}}$$

NUMERICAL APPLICATIONS (1/2)

- **Geometrical horizontal kick at the TCTH and orbit change at IP**
  - b = 10 mm
  - d = 35 mm
  - Tapering angle = 15 deg
  - Betax = 160.1 m
  - Deltamux = 123.6 deg

$$< \Delta x' >_{TCT} = 6.8\,10^{-6} \ \mu\mathrm{rad}$$

$$\Delta < x >_{IP} = 6.6\,10^{-5} \ \mu\mathrm{m}$$

NUMERICAL APPLICATIONS (2/2)

- **RW horizontal kick at the TCTH and orbit change at IP**
  - L = 1 m
  - b = 10 mm
  - Resistivity = 5.4E-8 Ωm
  - Betax = 160.1 m
  - Deltamux = 123.6 deg

instead of $2.4\ 10^{-6}$ (in 1st version)

$$<\Delta x'>_{TCT} = 2.0\ 10^{-6}\ \mu\text{rad}$$

$$\Delta < x >_{IP} = 1.9\ 10^{-5}\ \mu\text{m}$$

instead of $2.3\ 10^{-5}$ (in 1st version)