

EFFECT OF TRANSVERSE IMPEDANCE ON LUMINOSITY MEASUREMENTS

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(thanks Nicolas Mounet and Roderik Bruce)

- ◆ **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

$$\begin{aligned}\kappa_{\perp} &= \iint ds ds' \rho(s) \rho(s') W_{\perp}(s - s') \\ &= -\frac{1}{\pi} \int_0^{\infty} d\omega |\tilde{\rho}(\omega)|^2 \text{Im}[Z_{\perp}(\omega)]\end{aligned}$$

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

THEN, ANSWERS TO THE 2 QUESTIONS

- ◆ 1) Transverse kick at the TCT
(to the centre of charge of the bunch)

$$\langle \Delta x' \rangle_{TCT} = - \frac{N_b e^2 x_0}{\beta^2 E_{total}} K_{\perp, TCT}$$

particles / bunch

Proton charge

Transverse displacement

Total energy

Relativistic velocity factor

- ◆ 2) Orbit displacement at the IP

Beta function at IP

Beta function at TCT

Betatron phase advance
between IP and TCT

$$\Delta \langle x \rangle_{IP} = \langle \Delta x' \rangle_{TCT} \frac{\sqrt{\beta_{IP} \beta_{TCT}} \cos(|\mu_{IP} - \mu_{TCT}| - \pi Q)}{2 \sin(\pi Q)}$$

Transverse tune

CASE OF A PURELY INDUCTIVE IMPEDANCE (1/2)

- ◆ In the case of a purely inductive impedance =>

$$Z_{\perp}(\omega) = j C_{Z_{\perp}}$$

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

Speed of light

- Case of a round collimator with LHC parameters

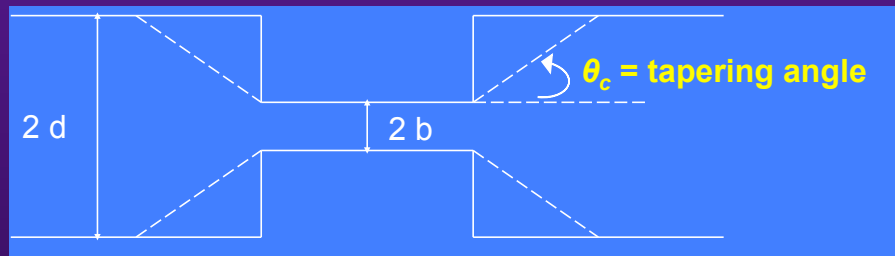
Vacuum impedance

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)

$$\Rightarrow \kappa_{\perp} = - \frac{\theta_c}{2 \pi^{3/2} \epsilon_0 \sigma_z} \left(\frac{1}{b} - \frac{1}{d} \right)$$

Permittivity of vacuum

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

CASE OF A RW IMPEDANCE

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

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

Length of impedance

Permeability of vacuum

Conductivity

=>

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

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

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**

$$\langle \Delta x' \rangle_{TCT} = 6.8 \cdot 10^{-6} \mu\text{rad}$$

$$\Delta \langle x \rangle_{IP} = 6.6 \cdot 10^{-5} \mu\text{m}$$

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**

$$\langle \Delta x' \rangle_{TCT} = 2.4 \cdot 10^{-6} \mu\text{rad}$$

$$\Delta \langle x \rangle_{IP} = 2.3 \cdot 10^{-5} \mu\text{m}$$