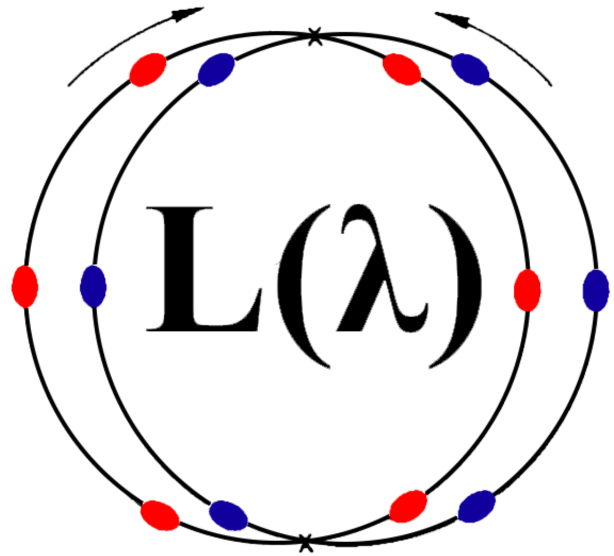

Monochromatization for Direct Higgs Production in Future Circular e+e- Colliders

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Outline

- Motivation
- Objectives
- Introduction: Accelerator Physics
- Standard Monochromatization
- Radiation Effects In FCC
- Optimized Monochromatization
- Conclusion
- Discussion

Motivation

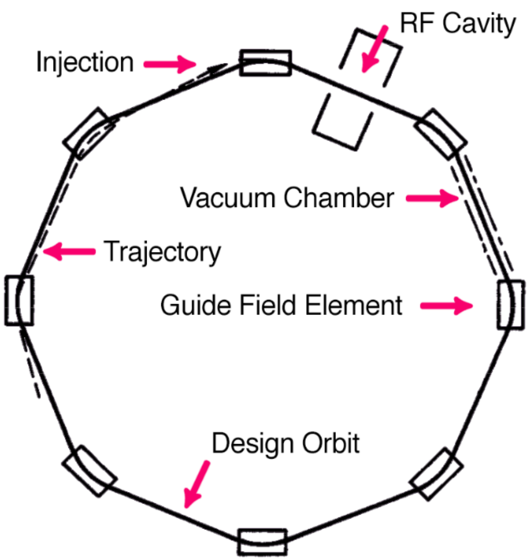
- Questions still unanswered about Higgs boson properties
- Post-LHC high energy resolution requirements
- Upcoming radiation Effects
- FCCe+e- proposal opportunity

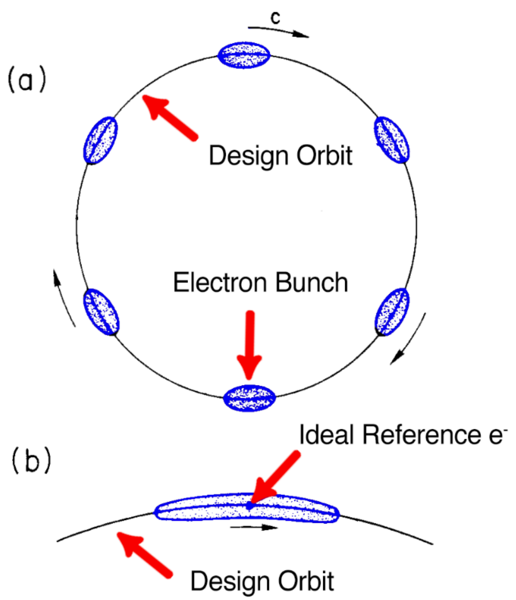
Objectives

- Characterize the radiation effects at the FCCe+e-
- Quantify the IP parameters modification due to the radiation effects.
- Define the IP parameters to produce monochromatization
- Develop an optimized monochromatization scheme for the FCCe+e-

Colliding Particles A Qualitative Description

- Particles are produced at the **source**
- Particles are injected into the **vacuum chamber**
- Stored particles loss energy by **radiation**, compensated by the **RFS**
- Particles are focused by guiding fields toward a **designed orbit**
- Accelerating field collects particles into circulating **bunches**
- Amplitud **damping** occurs due to energy loss by radiation
- Amplitude **excitation** occurs as a quantum effect
- Between damping and excitation a **balance** is reached
- Collision are produced at defined **interaction points**
- Monochromatization **requires parameters optimization**

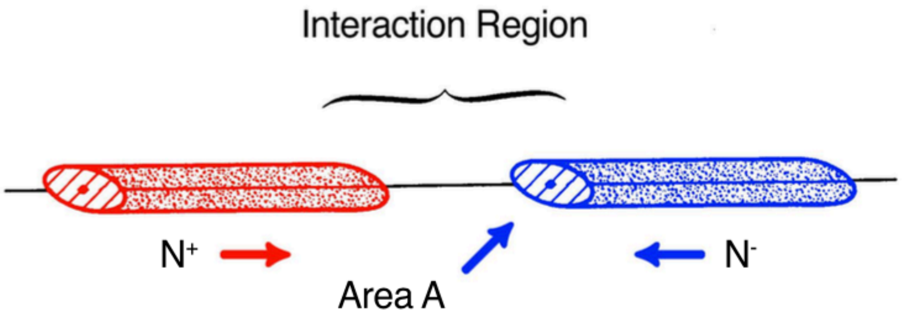


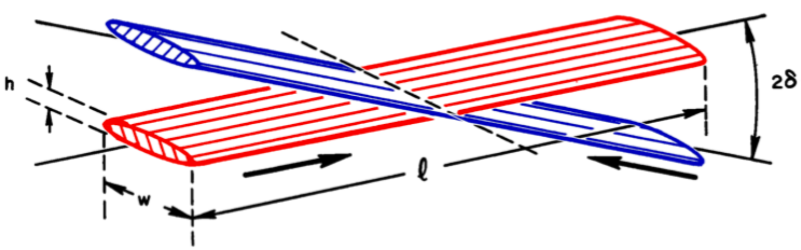


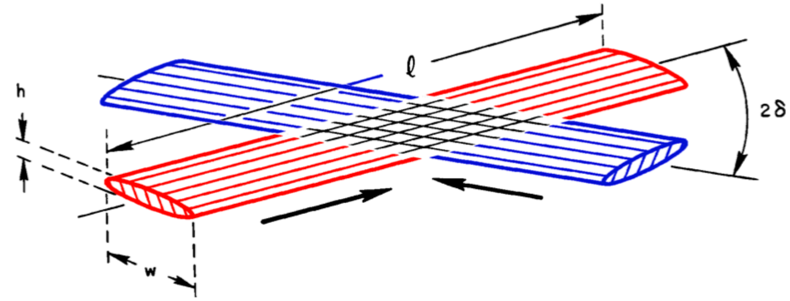
Colliders Luminosity

Luminosity $\mathcal{L} = \frac{R}{\sigma}$

Nominal Luminosity $\mathcal{L}_0 = \frac{k_b f_r N_+ N_-}{4\pi\sigma^*_{x\beta}\sigma^*_{y\beta}}$

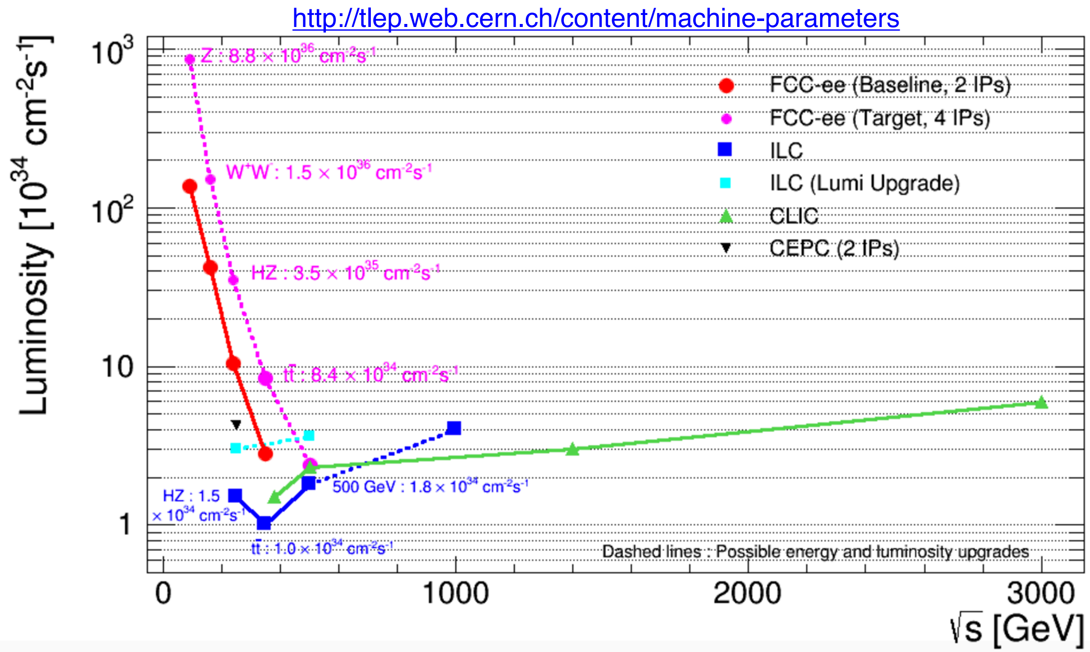






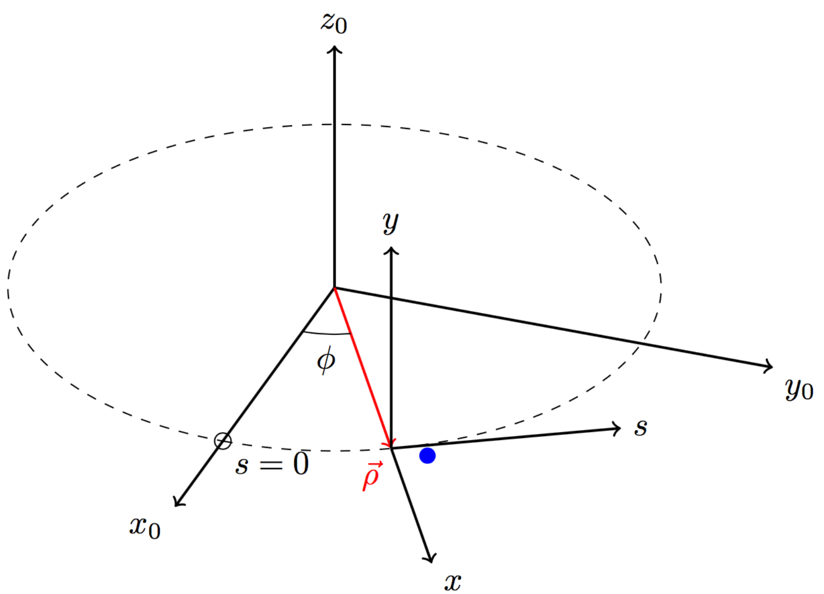
Crossing Angle $h^2_{\text{eff}} = (h^2 + l^2\delta^2)$ $w^2_{\text{eff}} = (w^2 + l^2\delta^2)$ $A_{\text{int}} = \frac{\pi}{4} B w_{\text{eff}} h_{\text{eff}}$

A proposal Future Circular e+e- Collider



- **Luminosity** is expected of order 10e36
- **Energy** range per beam should be from 40 to 175 GeV
- **Circumference** would be of 100 km
- **Energy Resolution** requires an improvement for direct Higgs production

Beam Dynamics A Quantitative Description



Horizontal Plane

$$F_x = \dot{p_x} = \frac{d}{dt}(\gamma m v_x) = \gamma m a_x$$

Vertical Plane

$$F_y = \dot{p_y} = \frac{d}{dt}(\gamma m v_y) = \gamma m a_y$$

$$B_x = \left(\frac{\partial B_y}{\partial x}\right) y$$

$$B_y = B_0 + \left(\frac{\partial B_y}{\partial x}\right) x$$

Linear Approximation + Paraxial Approximation $\quad R = \rho + x \quad x \ll \rho$

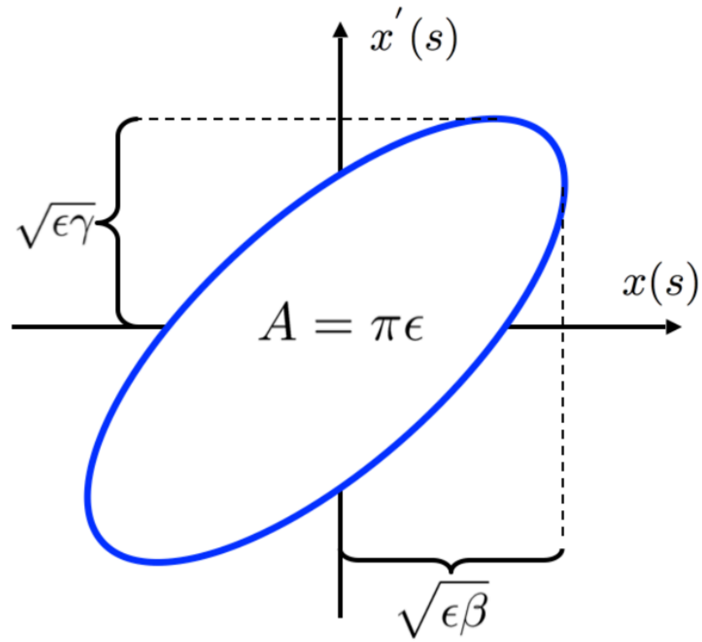
$$\frac{\partial^2 y}{\partial \theta^2} + ny = 0 \qquad \frac{\partial^2 x}{\partial \theta^2} + (1-n)x = 0 \qquad n \equiv -\frac{\rho}{B_0}\left(\frac{\partial B_y}{\partial x}\right)$$

Lattice Design Courant-Snyder Theory

Hill Differential Equation

$$x'' + K(s)x = 0 \qquad y'' - K(s)y = 0, \qquad K(s) \equiv \frac{1}{(B\rho)}\left(\frac{\partial B_y}{\partial x}\right)(s)$$

$$K(s+C) = K(s)$$



Ansatz $\quad x(s) = A\omega(s)\cos(\phi(x) + \phi_0)$

Courant-Snyder Parameters

$$\beta(s) \equiv \frac{\omega^2(s)}{k} \qquad \alpha(s) \equiv -\frac{1}{2}\beta\prime(s) \qquad \gamma(s) \equiv \frac{1+\alpha^2(s)}{\beta(s)}$$

Emittance

$$\epsilon = \pi\mathcal{W} = \pi[\gamma(s)x^2(s) + 2\alpha(s)x(s)x'(s) + \beta(s)x'^2(s)]$$

Size of the Distribution

$$\sigma_{RMS} = \sqrt{\epsilon\beta(s)}$$

Lattice Design Dispersion

Off-Momentum Particles

$$p = p_0(1+\delta)$$

Relative Momentum Deviation

$$\delta \equiv \frac{\Delta p}{p_0}$$

Momentum Contribution

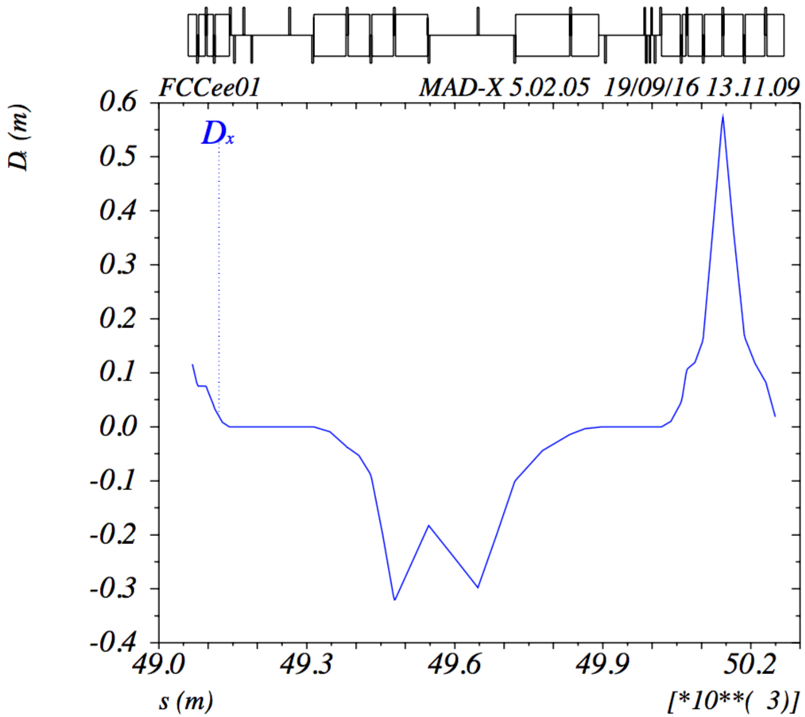
$$x(s) = x_\beta(s) + x_\delta(s)$$

Dispersion Function

$$x_\delta(s) = D(s)\delta$$

Approximations

$$x \ll \rho \qquad \delta \ll 1$$



Dipole Contribution

$$\frac{\partial^2 x}{\partial \theta^2} + (1-n)x = \rho\delta$$

Dispersion Contribution

$$x(\theta) = A\cos\sqrt{1-n}\theta + B\sin\sqrt{1-n}\theta + \frac{\rho}{1-n}\delta$$

General Contribution

$$x'' + K(s)x = \frac{\delta}{\rho(s)}$$

Dispersion Contribution

$$x(s) = C(s)x_0 + S(s)x'_0 + D(s)\delta_0$$

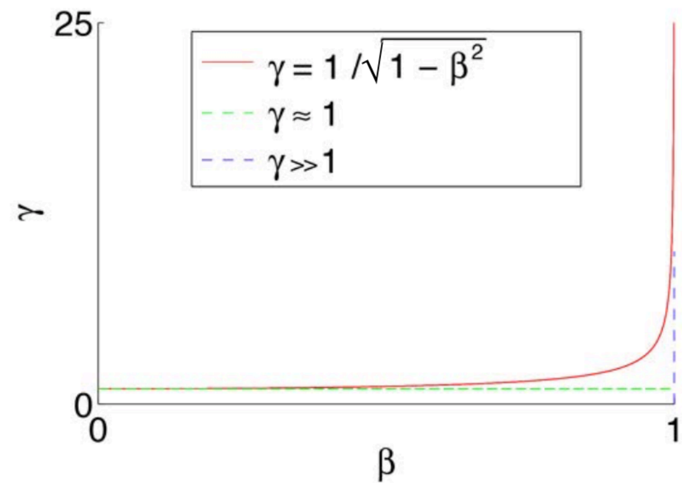
Dispersion Function

$$D(s) = S(s)\int_0^s \frac{C(\tau)}{\rho(\tau)}d\tau - C(s)\int_0^s \frac{S(\tau)}{\rho(\tau)}d\tau$$

Longitudinal Motion Energy Deviation Effects

Off-Energy Particles $E = E_0 + \epsilon$

Off-Energy Contribution $x = x_\beta + x_\epsilon$



Ultrarelativistic Limit

$$E \gg mc^2 \qquad p = \frac{1}{c}\sqrt{E^2 - (mc^2)^2} \approx \frac{E}{c}$$

$$\frac{\Delta p}{p_0} = \frac{\Delta E}{E_0} \qquad \delta = \frac{\epsilon}{E_0}$$

Off-Energy Contribution $x_\epsilon = D(s)\epsilon/E_0$

Equation of Motion for Off-Energy Particles

$$x'' = -K_x x + G\left(\frac{\epsilon}{E_0}\right)$$

Dispersion Equation $D''(s) = -K_x D(s) + G(s) \qquad G(s) = \rho^{-1}(s)$

Beam Parameters Distributions

Transverse Displacement $x = x_\beta + D_x\epsilon_0, \qquad y = y_\beta + D_y\epsilon_0 \qquad \epsilon_0 = \frac{\epsilon}{E_0}$

Average at the IP $\langle \mathcal{A} \rangle^\pm = \int f^\pm(X^\pm)\mathcal{A}(X^+, X^-)dX^\pm \qquad \langle \mathcal{A} \rangle^* = \Big\langle \langle \mathcal{A} \rangle^+ \Big\rangle^- = \Big\langle \langle \mathcal{A} \rangle^- \Big\rangle^+$

$$f^\pm(x,y,\epsilon) = \frac{f^\pm(p_x,p_y,z)}{\sqrt{8\pi^3\beta_x^*\epsilon_{xc}\beta_y^*\epsilon_{yc}\sigma_\epsilon^2}} \exp\left\{-\frac{(x_\beta + D_x\epsilon_0)^2}{2\beta_x^*\epsilon_{xc}} - \frac{(y_\beta + D_y\epsilon_0)^2}{2\beta_y^*\epsilon_{yc}} - \frac{\epsilon^2}{2\sigma_\epsilon^2}\right\}$$

Average over distribution

$$\sigma_x^* = \sqrt{\langle x^2 \rangle^\pm} = \sqrt{\beta_x^*\epsilon_{xc} + D_x^{*2}\sigma_\epsilon^2}$$

$$\sigma_y^* = \sqrt{\langle y^2 \rangle^\pm} = \sqrt{\beta_y^*\epsilon_{yc} + D_y^{*2}\sigma_\epsilon^2}$$

$$\sigma_\epsilon^* = \sqrt{\langle \epsilon_0^2 \rangle^\pm}$$

Position-Energy Correlation

$$\boxed{\begin{aligned} \langle x\epsilon_0 \rangle^\pm &= D_x^{*\pm}\sigma_\epsilon^2 \\ \langle y\epsilon_0 \rangle^\pm &= D_y^{*\pm}\sigma_\epsilon^2 \end{aligned}}$$

Notes

- **Relative Momentum Deviation** of particles differs from ideality
- **Dispersion** quantifies the effects on displacement due to off-momentum particles
- **Emittance** is a measure of how far our distribution is from ideal orbit
- **Beta Function** is related to the physical transverse size of bunches

Monochromatization Standard Monochromatization

Collision Energy Spread

$$\sigma_w = \sqrt{2}E_0\sigma_\epsilon$$

Beam Energy Spread

$$\sigma_\epsilon{}^2 \propto \frac{55\hbar c E_0{}^2}{32\sqrt{3(mc^2)^3}} \frac{I_3}{I_2} \frac{1}{J_\epsilon}$$

Function of radius and J_ϵ

$$\sigma_w \propto (\rho J_\epsilon)^{-1/2}.$$

$$J_\epsilon \in [0.5, 2.5]$$

Typical Options

$$\left.\begin{array}{l} \rho >> \rho_0 \\ J_\epsilon > J_{0\epsilon} \end{array}\right\} \Rightarrow \sigma_w < \sigma_{0w}$$

Baseline Scheme

$$D^*_{x+} = -D^*_{x-} = 0$$

$$D^*_{y+} = D^*_{y-} = 0$$

$$\mathcal{L} = \mathcal{L}_0$$

Average over distribution

$$\sigma^*_x = \sqrt{\langle x^2 \rangle^\pm} = \sqrt{\beta^*_x \epsilon_{xc} + D^{*2}_x \sigma^2_\epsilon} \qquad \langle x\epsilon_0 \rangle^\pm = D^{*\pm}_x \sigma^2_\epsilon$$

$$\sigma^*_y = \sqrt{\langle y^2 \rangle^\pm} = \sqrt{\beta^*_y \epsilon_{yc} + D^{*2}_y \sigma^2_\epsilon} \qquad \langle y\epsilon_0 \rangle^\pm = D^{*\pm}_y \sigma^2_\epsilon$$

Monochromatization principle A “simple explanation”

Standard collision Dispersion has the same sign in the IP

$$\begin{array}{ccccc} & \xrightarrow{E+\Delta E} & & \xleftarrow{E+\Delta E} & \\ e^- & \xrightarrow{E} & & \xleftarrow{E} & e^+ \\ & \xrightarrow{E-\Delta E} & & \xleftarrow{E-\Delta E} & \end{array}$$

$$w = 2(E_0 + \epsilon)$$

Monochromatization Dispersion has opposite sign in the IP

$$\begin{array}{ccccc} & \xrightarrow{E+\Delta E} & & \xleftarrow{E-\Delta E} & \\ e^- & \xrightarrow{E} & & \xleftarrow{E} & e^+ \\ & \xrightarrow{E-\Delta E} & & \xleftarrow{E+\Delta E} & \end{array}$$

$$w = 2E_0 + 0(\epsilon)^2$$

Monochromatization Standard Monochromatization

Monochromatization Factor

$$\lambda \equiv \frac{\mathcal{L}_0}{\mathcal{L}}$$

Both Opposite Sign

$$D^*_{x+} = -D^*_{x-} = D^*_x \qquad D^*_{y+} = -D^*_{y-} = D^*_y$$

$$\mathcal{L} = \frac{\mathcal{L}_0}{\sqrt{1+\sigma_\epsilon^2\left(\frac{D_x^{*2}}{\sigma_{x\beta}^{*2}}+\frac{D_y^{*2}}{\sigma_{y\beta}^{*2}}\right)}} \qquad \Sigma_w = \frac{\sqrt{2}E_0\sigma_\epsilon}{\sqrt{1+\sigma_\epsilon^2\left(\frac{D_x^{*2}}{\sigma_{x\beta}^{*2}}+\frac{D_y^{*2}}{\sigma_{y\beta}^{*2}}\right)}} \qquad \lambda = \sqrt{1+\sigma_\epsilon^2\left(\frac{D_x^{*2}}{\sigma_{x\beta}^{*2}}+\frac{D_y^{*2}}{\sigma_{y\beta}^{*2}}\right)}$$

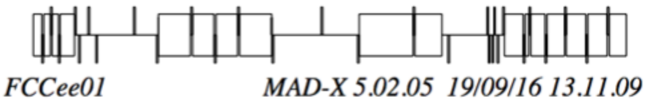
Horizontal Plane Oposite Sign

$$D^*_{x+} = -D^*_{x-} = D^*_x \qquad D^*_{y+} = D^*_{y-} = D^*_y$$

$$\Sigma_w = \frac{\sqrt{2}E_0\sigma_\epsilon}{\sqrt{1+\sigma_\epsilon^2\left(\frac{D_x^{*2}}{\sigma_{x\beta}^{*2}}\right)}} \qquad L = \frac{L_0}{\sqrt{1+\sigma_\epsilon^2\left(\frac{D_x^{*2}}{\sigma_{x\beta}^{*2}}\right)}\boxed{\sqrt{1+\sigma_\epsilon^2\left(\frac{D_y^{*2}}{\sigma_{y\beta}^{*2}}\right)}}} \qquad \lambda = \sqrt{1+\sigma_\epsilon^2\left(\frac{D_x^{*2}}{\sigma_{x\beta}^{*2}}\right)}$$

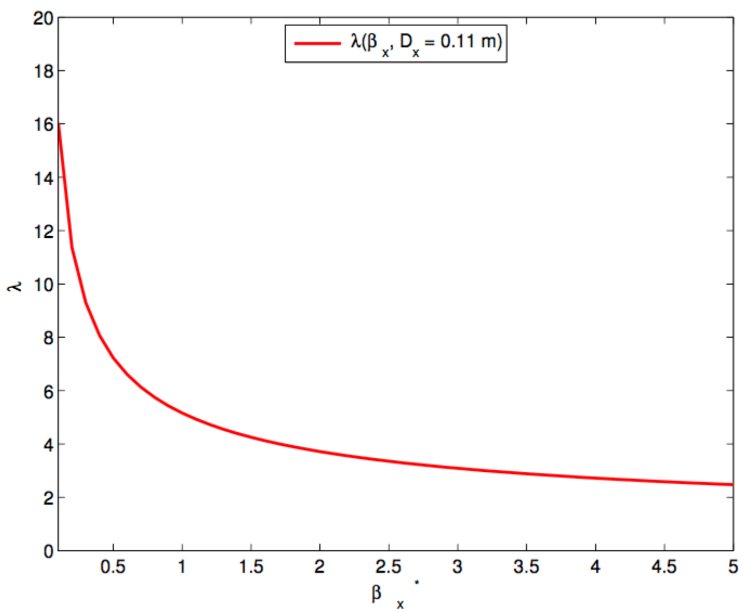
Monochromatization Factor λ

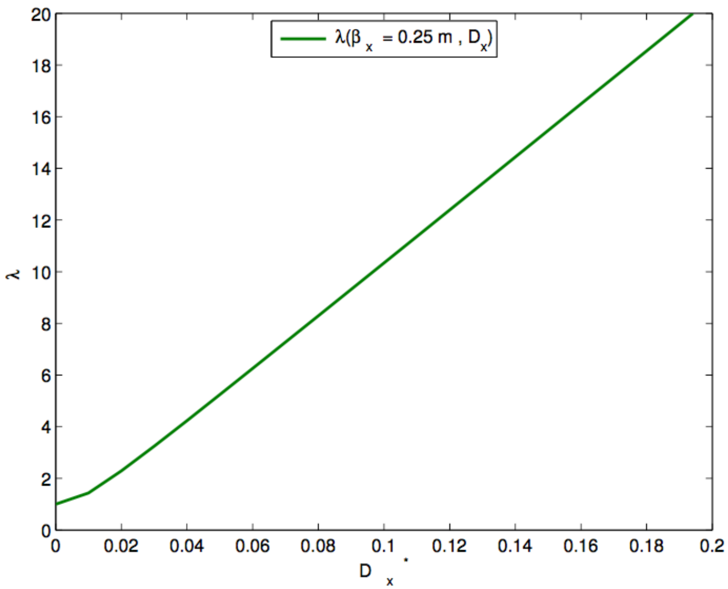
Standard Monochromatization $D^*_{y^+} = D^*_{y^-} = 0$



Monochromatization Factor

$$\lambda = \sqrt{1 + \sigma_\epsilon^2 \left(\frac{D_x^{*2}}{\sigma_{x\beta}^{*2}} \right)}$$





Luminosity

$$\mathcal{L} \propto \frac{1}{\lambda}$$

Energy Resolution

$$(\Sigma_w)_\lambda = \frac{\sigma_\delta}{\sqrt{2}} \frac{1}{\lambda}$$

Physical Size

$$\sigma_{RMS} = \sqrt{\epsilon \beta(s)}$$

Notes

- **Baseline Parameters** fail to produce the required center-of-mass energy resolution for direct Higgs production at 125 GeV
- **Higgs Width** of ~4.2 MeV requires an improvement in resolution by at least a factor of 10 since baseline produced a ~40 MeV width distribution
- **Double Ring System** of the FCCee may produced dispersion at the interaction point as required for monochromatization.
- **Radiation Effects** could compromise the performance of a monochromatization scheme

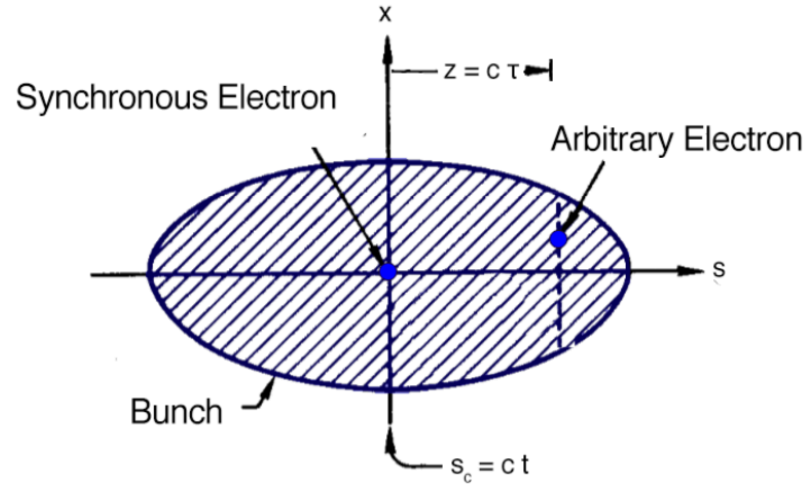
Radiation Effects: Synchrotron radiation Radiation Damping

Azimuthal Displacement

$$z(t) = s(s) - s_c(s)$$

Time Displacement

$$\tau = \frac{s(s) - s_c(s)}{c}$$



Length Increment

$$\delta l_\epsilon = \oint G(s) x_\epsilon ds = \frac{\epsilon}{E_0} \oint G(s) D_x(s) ds$$

Dilation Factor

$$\frac{\delta l_\epsilon}{L} = \alpha \frac{\epsilon}{E_0}$$

$$\alpha = \frac{1}{L} \oint G(s) D_x(s) ds$$

Relative Revolution Time Increment

$$\frac{\delta t}{T_0} = \frac{\delta l}{L} = \alpha \frac{\epsilon}{E_0}$$

Time Displacement Evolution

$$\delta z = -\alpha \frac{\epsilon}{E_0} L$$

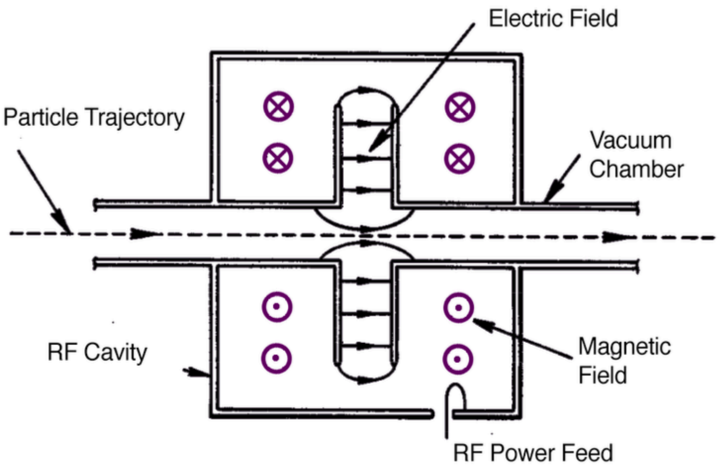
$$\boxed{\frac{d\tau}{dt} = -\alpha \frac{\epsilon}{E_0}}$$

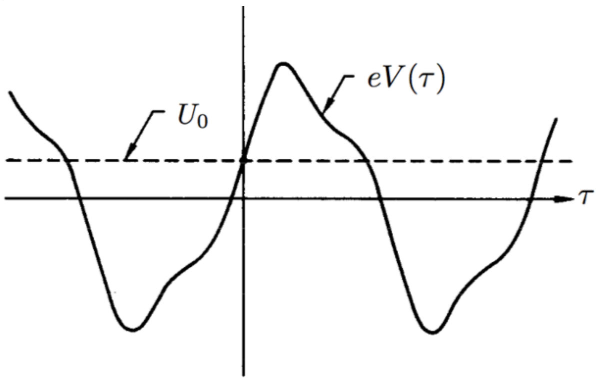
Synchrotron radiation Radiation Damping

RF Energy Supply $eV(\tau) = U_{rf}(\bar{t}_s - \tau)$

Energy Change $\delta U = eV(\tau_1) - U_{rad}(\epsilon)$

$$U_{rad} = U_0 + D\epsilon, \qquad D = \left(\frac{dU_{rad}}{d\epsilon}\right)_{E_0}$$





Energy Evolution

$$\boxed{\frac{d\epsilon}{dt} = \frac{1}{T_0}(e\dot{V}_0\tau - D\epsilon)}$$

Time Displacement Evolution

$$\frac{d\tau}{dt} = -\alpha\frac{\epsilon}{E_0}$$

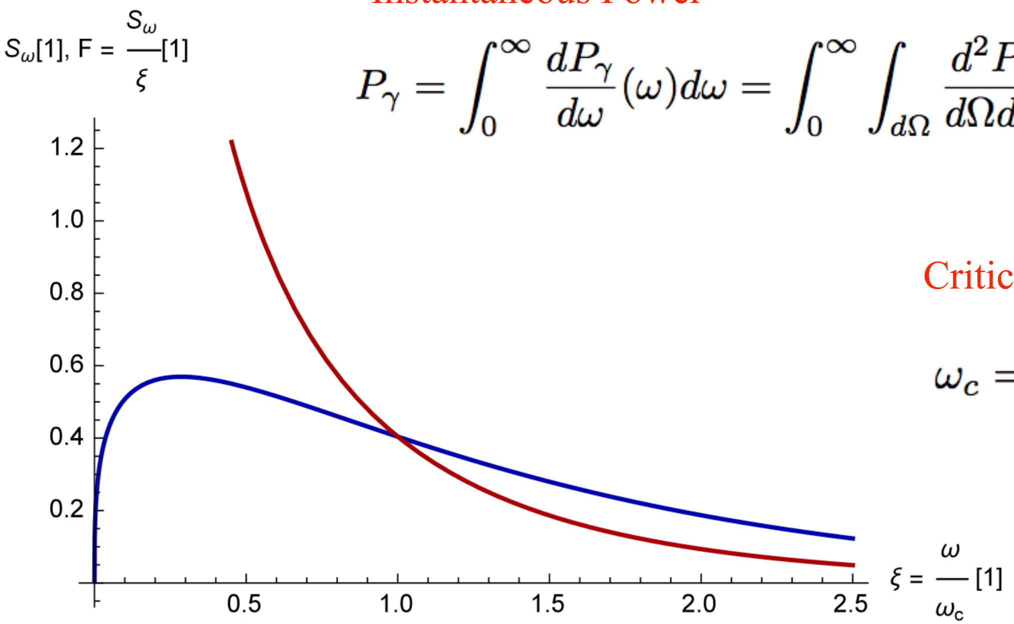
In Complex Notation

$$\tilde{\epsilon} = -i\frac{\Omega E_0}{\alpha}\tilde{\tau}$$

Time Displacement Evolution

$$\boxed{\frac{d^2\tau}{dt^2} + 2\alpha_\epsilon\frac{d\tau}{dt} + \Omega^2\tau = 0 \qquad \alpha_\epsilon = \frac{D}{2T_0} \qquad \Omega^2 = \frac{\alpha e\dot{V}_0}{T_0 E_0}}$$

Synchrotron radiation Quantum Radiation Effects



Instantaneous Power

$$P_\gamma = \int_0^\infty \frac{dP_\gamma}{d\omega}(\omega)d\omega = \int_0^\infty \int_{d\Omega} \frac{d^2P_\gamma}{d\Omega d\omega}(\Omega,\omega,)d\Omega d\omega$$

Spectrum Function

$$\frac{dP_\gamma}{d\omega}(\omega) = \frac{P_\gamma}{\omega_c} S\left(\frac{\omega}{\omega_c}\right)$$

$$S(\xi) = \frac{9\sqrt{3}}{8\pi}\xi \int_\xi^\infty K_{5/3}(\bar{\xi})d\bar{\xi}$$

Critical Frequency

$$\omega_c = \frac{3}{2}\frac{c\gamma^3}{\rho}$$

Photon Spectrum Rate

$$\frac{dn_\gamma}{dt}(u) = \frac{P_\gamma}{u_c^2} F\left(\frac{u}{u_c}\right)$$

$$F(\xi) = S(\xi)/\xi$$

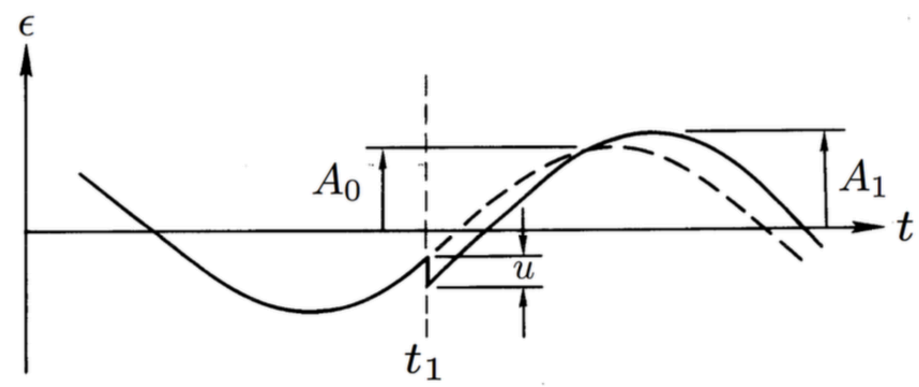
$$\frac{dN_\gamma}{dt} = \int_0^\infty \frac{dn_\gamma}{dt}(u)du \qquad < u >= \left(\frac{dN_\gamma}{dt}\right)^{-1} \int_0^\infty u\frac{dn_\gamma}{dt}du. \qquad < u^2 >= \left(\frac{dN_\gamma}{dt}\right)^{-1} \int_0^\infty u^2\frac{dn_\gamma}{dt}du$$

$$\frac{dN_\gamma}{dt} = \frac{15\sqrt{3}}{8}\frac{P_\gamma}{u_c} \qquad < u >= \frac{8}{15\sqrt{3}}u_c \qquad < u^2 >= \frac{11}{27}u_c^2$$

Synchrotron radiation Quantum Radiation Effects

Energy Deviation Oscillation

$$\epsilon = A_0 \exp^{i\Omega(t-t_0)}$$



Photon Emission

$$\epsilon = A_0 \exp^{i\Omega(t-t_0)} - u \exp^{i\Omega(t-t_i)}$$

$$\epsilon = A_1 \exp^{i\Omega(t-t_1)}$$

New Amplitude

$$A_1^2 = A_0^2 + u^2 - 2A_0 \cos\Omega(t_i - t_0)$$

Probable Amplitude Change

$$< \delta A^2 >=< A_1^2 - A_0^2 >= u^2$$

Probable Amplitude Squared

$$\frac{d\langle A^2\rangle}{dt} = -2\frac{\langle A^2\rangle}{\tau_\epsilon} \qquad \left\langle \frac{dA^2}{dt} \right\rangle = \frac{d\langle A^2\rangle}{dt} = \frac{dN_\gamma}{dt}u^2$$

Excitation Term

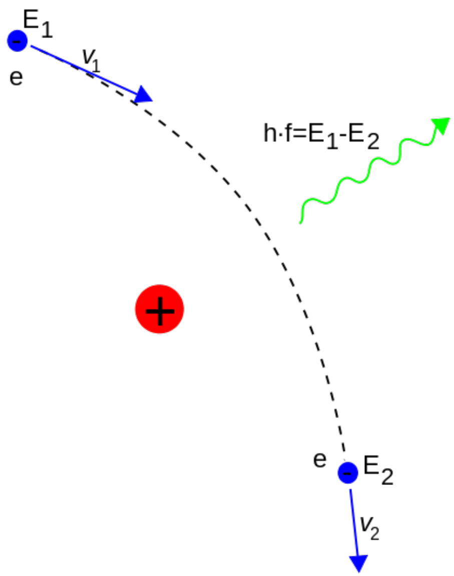
$$\boxed{< u^2 > \left(\frac{dN_\gamma}{dt}\right) = \frac{55}{24\sqrt{3}} r_e \hbar m c^4 \frac{\gamma^7}{\rho^3}}$$

For Sinusoidal Energy Oscillation

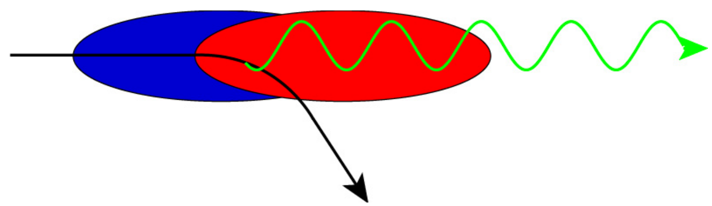
$$\langle A^2\rangle = \frac{1}{2}\tau_\epsilon \frac{dN_\gamma}{dt}u^2 \qquad \sigma_\epsilon^2 = \langle \epsilon^2\rangle = \frac{\langle A^2\rangle}{2} = \frac{1}{4}\tau_\epsilon \frac{dN_\gamma}{dt}u^2$$

Beamstrahlung Sokolov-Ternov Theory

Breamsstrahlung



Beamstrahlung



Lorentz Invariant

$$\Upsilon \equiv \frac{e}{m_e^3}\sqrt{|(F_{\mu\nu}p^\nu)^2|} = \frac{B}{B_c} = \frac{2}{3}\frac{\hbar\omega_c}{E_e}$$

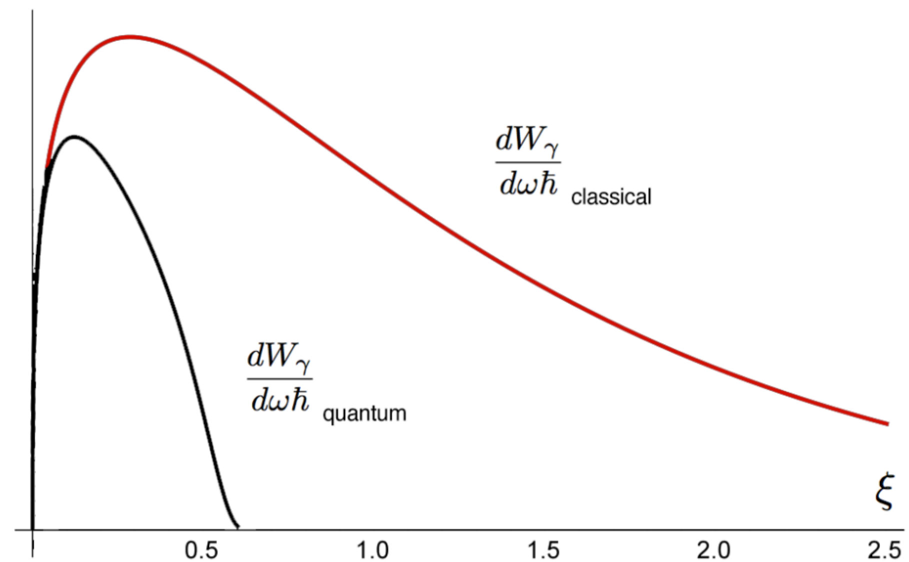
$$\Upsilon_{\max} = 2\frac{r_e^2\gamma N_b}{\alpha\sigma_z(\sigma_x^* + \sigma_y^*)}$$

$$\Upsilon_{\mathrm{ave}} \approx \frac{5}{12}\Upsilon_{\max} = \frac{5}{6}\frac{r_e^2\gamma N_b}{\alpha\sigma_z^*(\sigma_x^* + \sigma_y^*)}$$

Quantum Spectrum Formula

$$\frac{dW_\gamma}{d\omega\hbar} = \frac{\alpha}{\sqrt{3}\hbar\pi\gamma^2}\left(\int_\xi^\infty K_{5/3}(\xi')\,d\xi' + \frac{y^2}{1-y}K_{2/3}(\xi)\right)$$

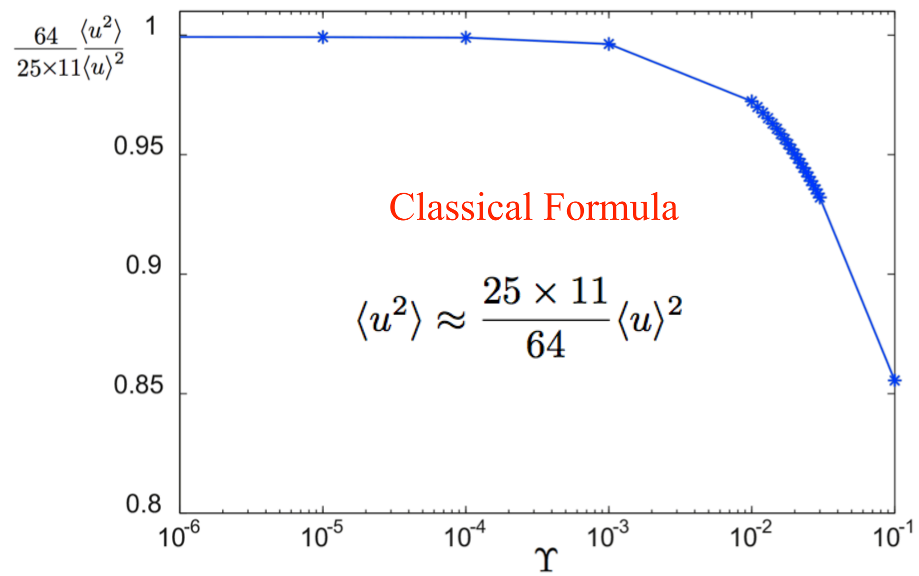
$$\xi = \frac{2\hbar\omega}{3\Upsilon(E-\hbar\omega)} \qquad y \equiv \omega/E_e$$



Beamstrahlung Sokolov-Ternov Theory

Excitation Term

$$n_\gamma \langle u^2 \rangle \approx 1.4 \, \frac{r_e^5 N_b^3 \gamma^2}{\alpha \sigma_z^2 (\sigma_x + \sigma_y)^3} \approx 192 \, \frac{r_e^5 N_b^3 \gamma^2}{\sigma_z^2 \sigma_x^3}$$



Total Energy Spread

$$\sigma_{\rm tot}^2 = \sigma_{\delta,\rm SR}^2 + \sigma_{\delta,\rm BS}^2$$

$$\sigma_{\delta,\rm tot}^2 - \sigma_{\delta,\rm SR}^2 = A \left(\frac{\sigma_{\delta,\rm SR}}{\sigma_{\delta,\rm tot}} \frac{1}{\sigma_{z,\rm SR}} \right)^2$$

Self-Consistent Equations

$$\epsilon_{x,\rm tot} = \epsilon_{x,\rm SR} + \frac{\tau_x n_{\rm IP}}{4T_{\rm rev}} \{ n_\gamma < u^2 > \} \mathcal{H}_x^*$$

$$\sigma_{\delta,\rm tot}^2 = \sigma_{\delta,\rm SR}^2 + \frac{n_{\rm IP} \tau_{E,\rm SR}}{4T_{\rm rev}} \{ n_\gamma < u^2 > \}$$

Bunch Length

$$\sigma_{z,\rm tot} = \frac{\alpha_{\rm C} C}{2\pi Q_s} \sigma_{\delta,\rm tot}$$

Dispersion Invariant

$$\mathcal{H}_x^* \equiv \frac{\left(\beta_x^* {D'_x}^* + \alpha_x^* D_x^*\right)^2 + {D_x^*}^2}{\beta_x^*}$$

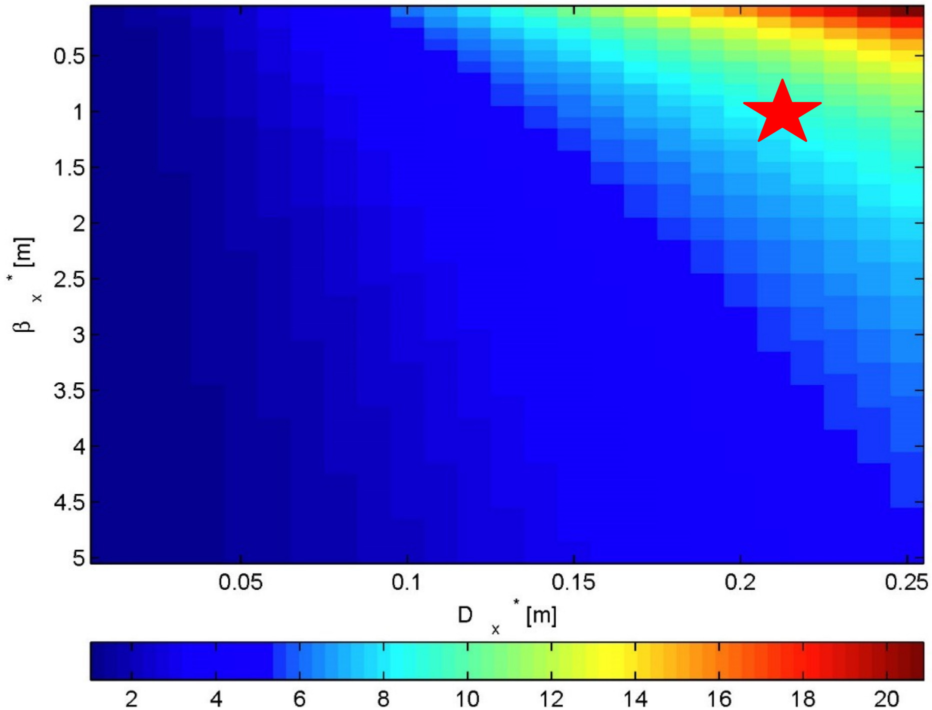
Baseline monochromatization

E_e [GeV]	62.5
scheme	m.c. basel.
I_b [mA]	408.3
N_b [10^{10}]	3.3
n_b [1]	25760
n_{IP} [1]	2
β_x^* [m]	1.0
β_y^* [mm]	2
D_x^* [m]	0.22
$\epsilon_{x,\mathrm{SR}}$ [nm]	0.17
$\epsilon_{x,\mathrm{tot}}$ [nm]	0.21
$\epsilon_{y,\mathrm{SR}}$ [pm]	1
$\sigma_{x,\mathrm{SR}}$ [μm]	132
$\sigma_{x,\mathrm{tot}}$ [μm]	144
σ_y [nm]	45
$\sigma_{z,\mathrm{SR}}$ [mm]	1.8
$\sigma_{z,\mathrm{tot}}$ [mm]	1.8
$\sigma_{\delta,\mathrm{SR}}$ [%]	0.06
$\sigma_{\delta,\mathrm{tot}}$ [%]	0.06
θ_c [mrad]	0
circ. C [km]	100
α_C [10^{-6}]	7
f_{rf} [MHz]	400
V_{rf} [GV]	0.4
$U_{0,\mathrm{SR}}$ [GeV]	0.12
$U_{0,\mathrm{BS}}$ [MeV]	0.01
τ_E/T_{rev}	509
Q_s	0.030
Υ_{max} [10^{-4}]	0.3
Υ_{ave} [10^{-4}]	0.1
θ_c [mrad]	0
ξ_x [10^{-2}]	1
ξ_y [10^{-2}]	4
λ [1]	9.2
L [10^{35} cm^{-2}s^{-1}]	1.0
σ_w [MeV]	5.8

Width of standard model Higgs 4-5 MeV requires $\lambda \geq 10$

$N_b = 3.3\times10^{10}$ $n_b = 25760$ $\beta_y^* = 2$ mm

Monochromatization Factor



★: $\lambda = 9.2$, $L = 1 \times 10^{35}$ cm^{-2}s^{-1}

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E_e [GeV]	62.5
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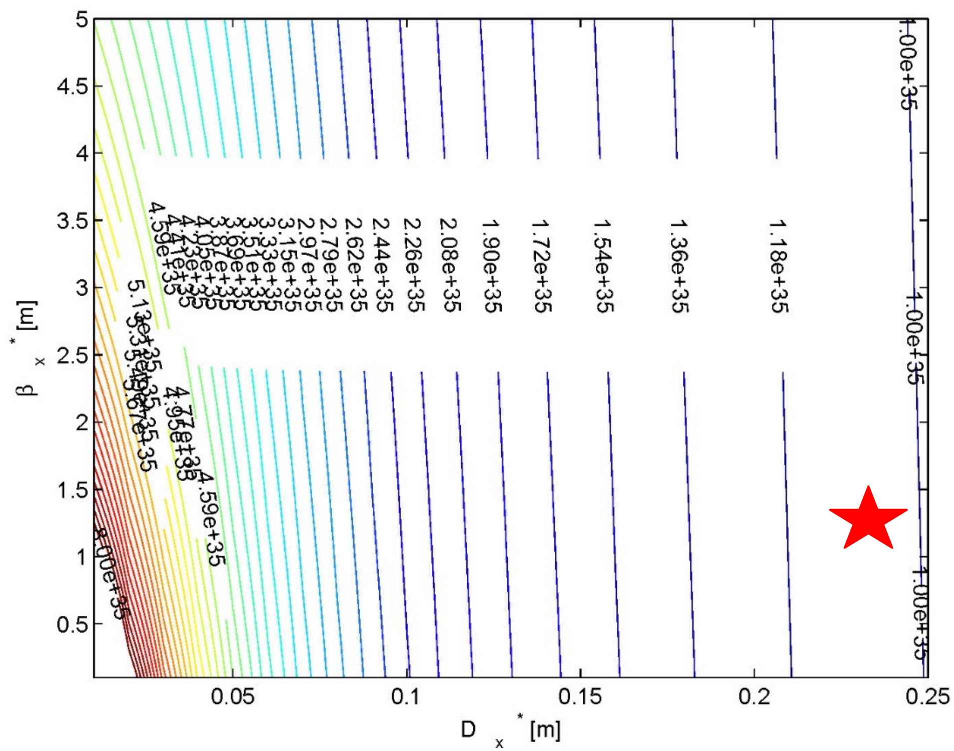
Luminosity contours



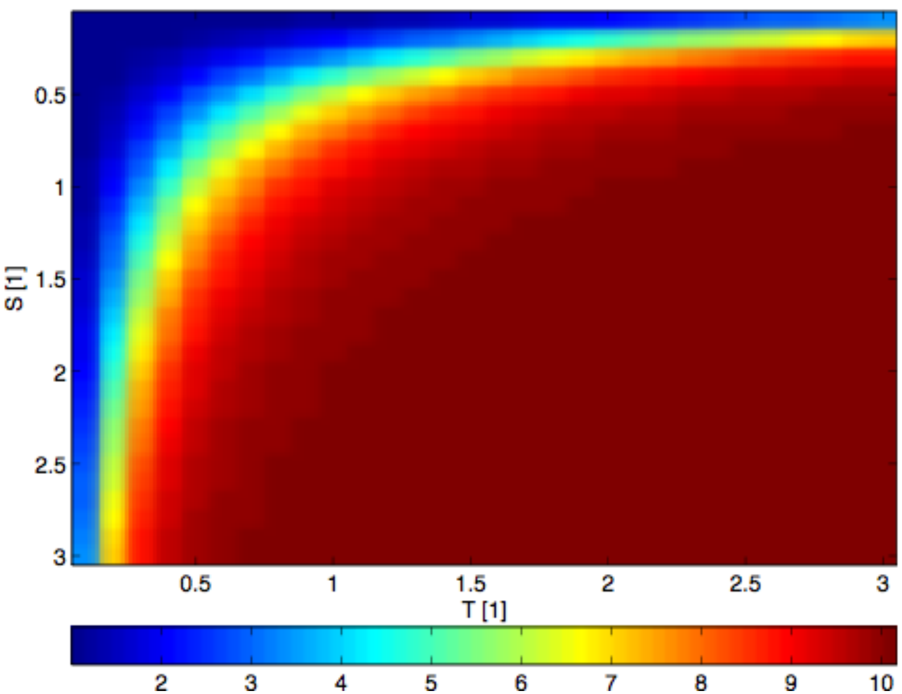
★: $\lambda = 9.2$, $L = 1 \times 10^{35}$ cm^{-2}s^{-1}

Optimized Monochromatization Luminosity_max and λ

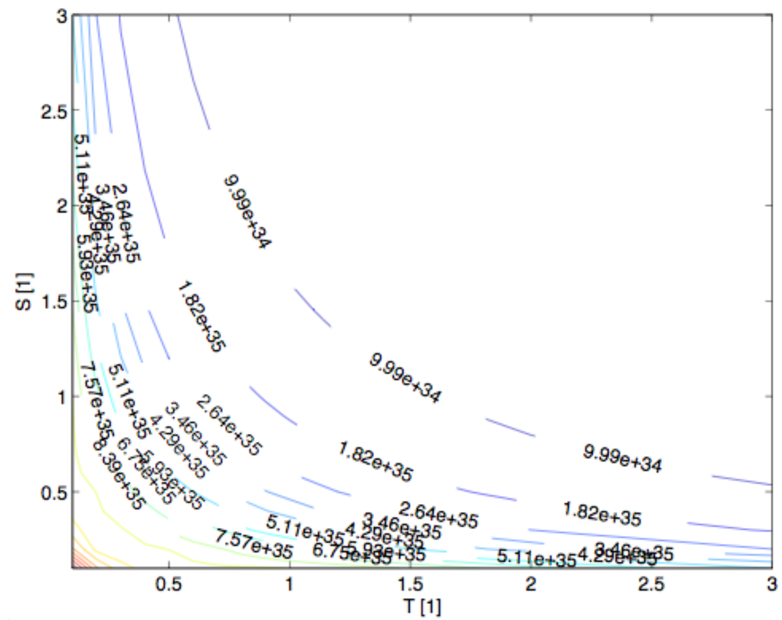
$S = [\,0.1\,,\,3\,]$, $T = [\,0.1\,,\,3\,]$; $\beta_x = \beta_{0x} * S^2$, $D_x* = D_{0x} * S$; $N_b = N_{0b} / T$, $n_b = n_{0b} * T$

$\beta_{0x} = 1.0$ m, $\beta_{0y} = 1.0$ mm, $D_{0x} = 0.22$ m, $N_{0b} = 3.3\text{x}10^{10}$, $n_{0b} = 25760$ ★ : $\lambda_0 = 10.17321$

Monochromatization Factor



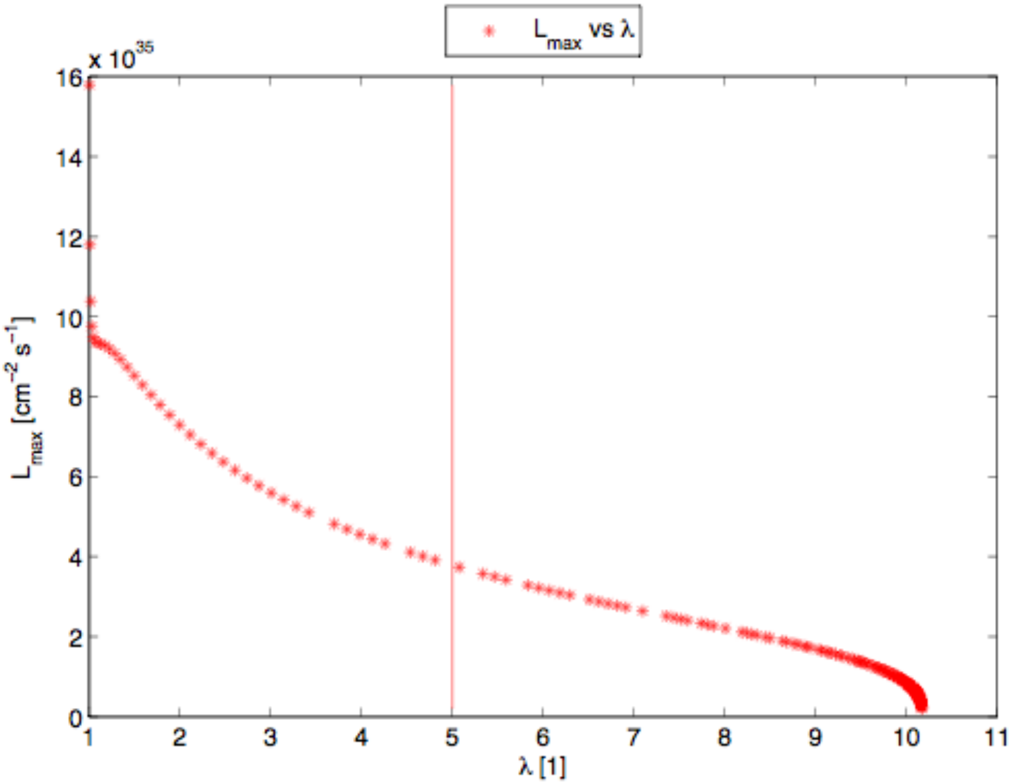
Luminosity contours



Optimized Monochromatization Luminosity_max and λ

$S = [\ 0.1\ ,\ 3\ ]$, $T = [\ 0.1\ ,\ 3\ ]$; $\beta_x = \beta_{0x} * S^2$, $D_x{}^* = D_{0x} * S$; $N_b = N_{0b} / T$, $n_b = n_{0b} * T$

$\beta_{0x} = 1.0$ m, $\beta_{0y} = 1.0$ mm, $D_{0x} = 0.22$ m, $N_{0b} = 3.3\text{x}10^{10}$, $n_{0b} = 25760$



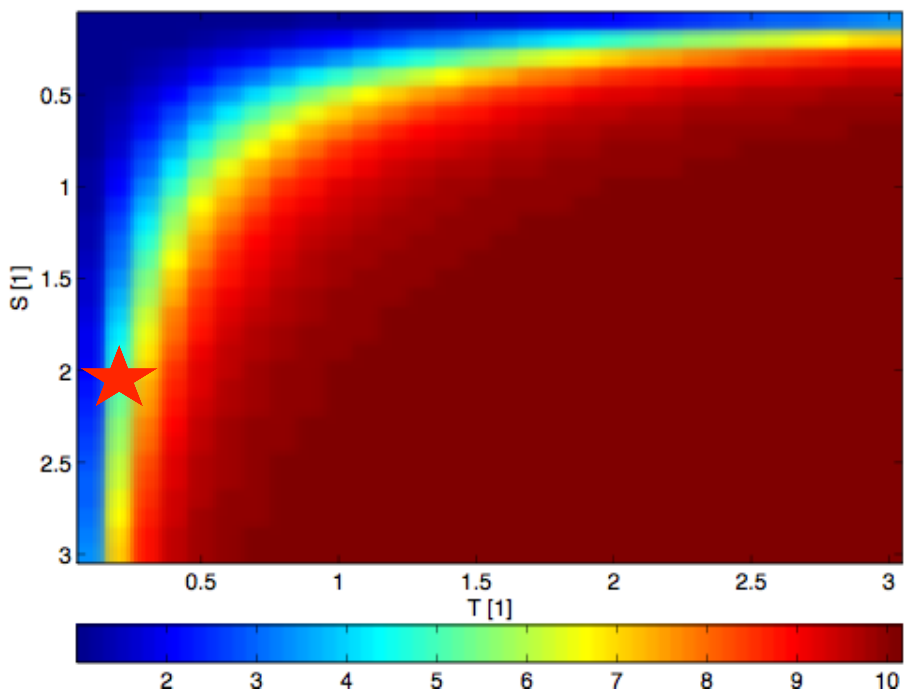
★ : $\lambda_0 = 10.17321$, $L \sim 1 \text{ x } 10^{36}\ cm^{-2}s^{-1}$

Optimized Monochromatization Luminosity_max and λ

$S = [\,0.1\,,\,3\,]$, $T = [\,0.1\,,\,3\,]$; $\beta_x = \beta_{0x} * S^2$, $D_x{}^* = D_{0x} * S$; $N_b = N_{0b} / T$, $n_b = n_{0b} * T$

$\beta_{0x} = 1.0$ m, $\beta_{0y} = 1.0$ mm, $D_{0x} = 0.22$ m, $N_{0b} = 3.3\mathrm{x}10^{10}$, $n_{0b} = 25760$

Monochromatization Factor



★ : $\lambda = 5.07$, $\beta = 1.96$ m, $D_x = 0.308$ m, $L = 3.736 \times 10^{35}\ \mathrm{cm^{-2}s^{-1}}$

Optimized Monochromatization Conclusions

E_e [GeV]	45.6	62.5	62.5	62.5	80
scheme	CW	h.-o.	m.c. basel.	m.c. opt'd	CW
I_b [mA]	1450.3	408.3	408.3	408.3	151.5
N_b [10^{10}]	3.3	1.05	3.3	11.1	6.0
n_b [1]	91500	80960	25760	7728	5260
n_{IP} [1]	2	2	2	2	2
β_x^* [m]	1	1.0	1.0	1.96	1
β_y^* [mm]	2	2	2	1	2
D_x^* [m]	0	0	0.22	0.308	0
$\epsilon_{x,\mathrm{SR}}$ [nm]	0.09	0.17	0.17	0.17	0.26
$\epsilon_{x,\mathrm{tot}}$ [nm]	0.09	0.17	0.21	0.70	0.26
$\epsilon_{y,\mathrm{SR}}$ [pm]	1	1	1	1	1
$\sigma_{x,\mathrm{SR}}$ [μm]	9.5	9.2	132	185.7	16
$\sigma_{x,\mathrm{tot}}$ [μm]	9.5	9.2	144	188.5	16
σ_y [nm]	45	45	45	32	45
$\sigma_{z,\mathrm{SR}}$ [mm]	1.6	1.8	1.8	1.8	2.0
$\sigma_{z,\mathrm{tot}}$ [mm]	3.8	1.8	1.8	1.8	3.1
$\sigma_{\delta,\mathrm{SR}}$ [%]	0.04	0.06	0.06	0.06	0.07
$\sigma_{\delta,\mathrm{tot}}$ [%]	0.09	0.06	0.06	0.06	0.10
θ_c [mrad]	30	0	0	0	30
circ. C [km]	100	100	100	100	100
α_C [10^{-6}]	7	7	7	7	7
f_{rf} [MHz]	400	400	400	400	400
V_{rf} [GV]	0.2	0.4	0.4	0.4	0.8
$U_{0,\mathrm{SR}}$ [GeV]	0.03	0.12	0.12	0.12	0.33
$U_{0,\mathrm{BS}}$ [MeV]	0.5	0.05	0.01	0.01	0.21
τ_E/T_{rev}	1320	509	509	509	243
Q_s	0.025	0.030	0.030	0.030	0.037
Υ_{max} [10^{-4}]	1.7	0.8	0.3	0.85	4.0
Υ_{ave} [10^{-4}]	0.7	0.3	0.1	0.35	1.7
θ_c [mrad]	30	0	0	0	30
ξ_x [10^{-2}]	5	12	1	2.22	7
ξ_y [10^{-2}]	13	15	4	6.76	16
λ [1]	1	1	9.2	5.08	1
L [10^{35} cm^{-2}s^{-1}]	9.0	2.2	1.0	3.74	1.9
σ_w [MeV]	58	53	5.8	10.44	113

- **Monochromatization** scheme can be implemented
- **Beamstrahlung** effects may be predicted
- **Simulation** (!) supports predictions
- **Lattice** designed is still in progress and the required modification should be possible
- **Theory** confirmation could be achieved at the FCCe+e-
- **Alternative** optimization techniques under study

Participations

2017 IMC17: *Talk,* Cancún City

2017 Seminario IFUNAM:' *Talk*, IF-UNAM, Mexico City

2017 División de Partículas y Campos *Meeting, Talk, (Co-Author) Poster (2)*, CINVESTAV, Mexico City

2016 IPAC (Author) *Poster (1) Contribution Paper (1)* to Proceedings Conference, Copenhagen, Denmark

2016 Red FAE *Meeting & Talk* Pachuca, Hidalgo

2016 CERN-BINP Workshop *Talk* / *Contribution Paper* to Proceedings Workshop Geneva, Switzerland

2016 Latin-American Conference High Energy Physics: Particle and Strings *Talk*, Havana, Cuba

2016 IPAC (Presenter) Poster (2) Contribution Paper (2) to Proceedings Conference, Busan, Korea

2016 USPAS; Fundamentals of Accelerator Physics and Technology, *School* Austin, Texas, USA

2015 Mexican Particle Accelerator *School & Talk*; Guanajuato, Guanajuato, México

2015 FCC-ee Optics Design 33rd meeting *Talk,* CERN, France/Switzerland.

2015 Summer project at CERN as associated member of the personnel, CERN, *Talk* France/Switzerland.

2014 Seminario DCI (IFUG); *Talk*, León, Guanajuato.

2014 Science Undergraduate Summer Laboratory Internships; lectures on HEP School León, Guanajuato.

Monochromatization for Direct Higgs Production in Future Circular e+e- Colliders

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