MERLIN
Simulations
with
Coupler Wake Fields and RF Kicks

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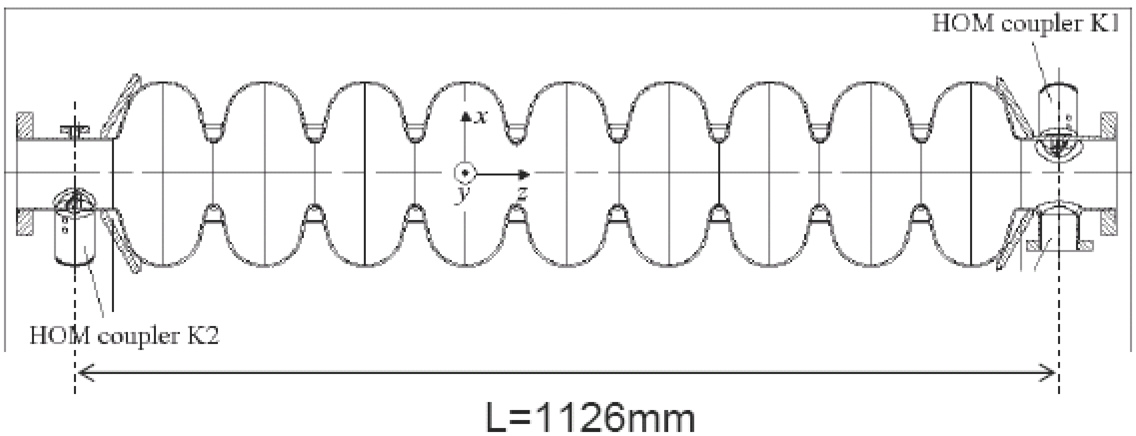
Outline of this talk:

- Introduction
- Old coupler design
- New coupler design
- RF kicks
- Discussion

Introduction

Resonator TESLA TEST Facility (DESY-HOM-Coupler)

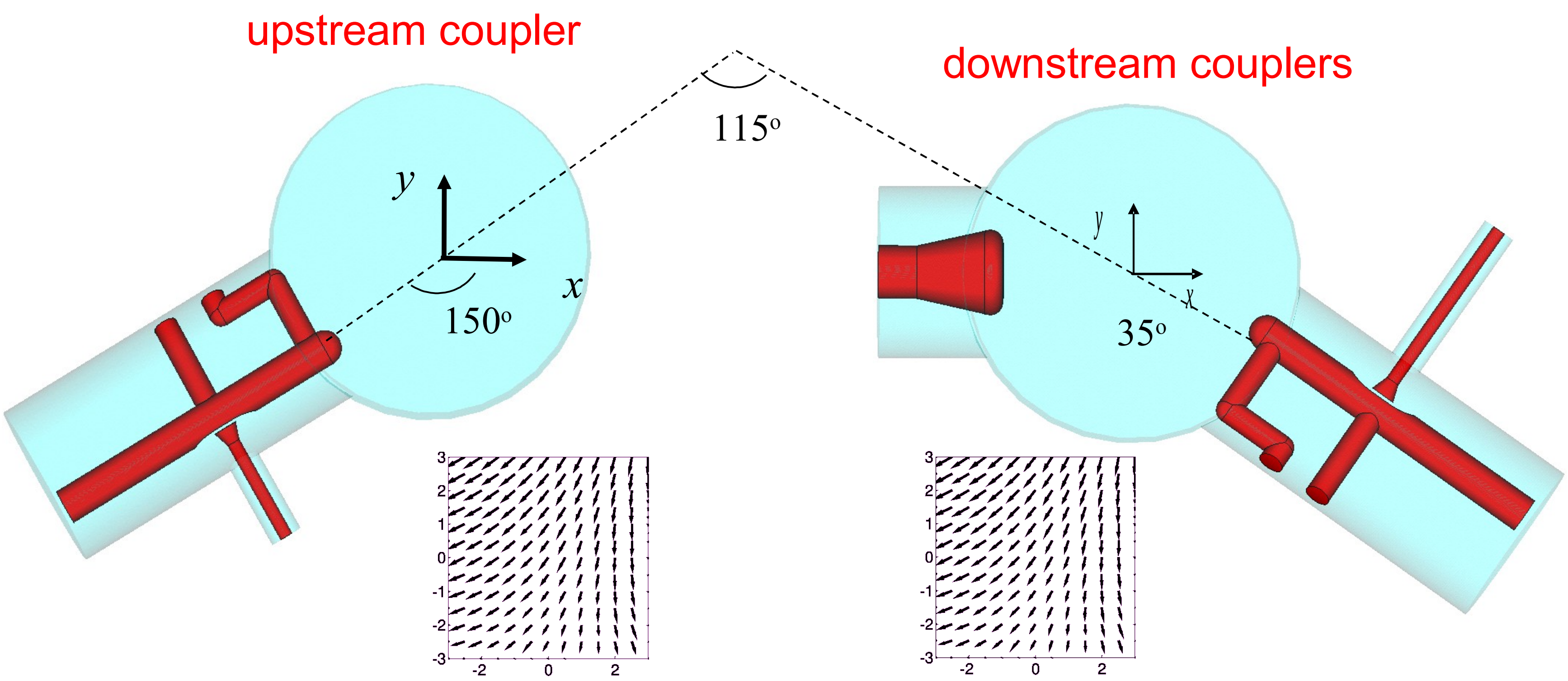


Thanks to:

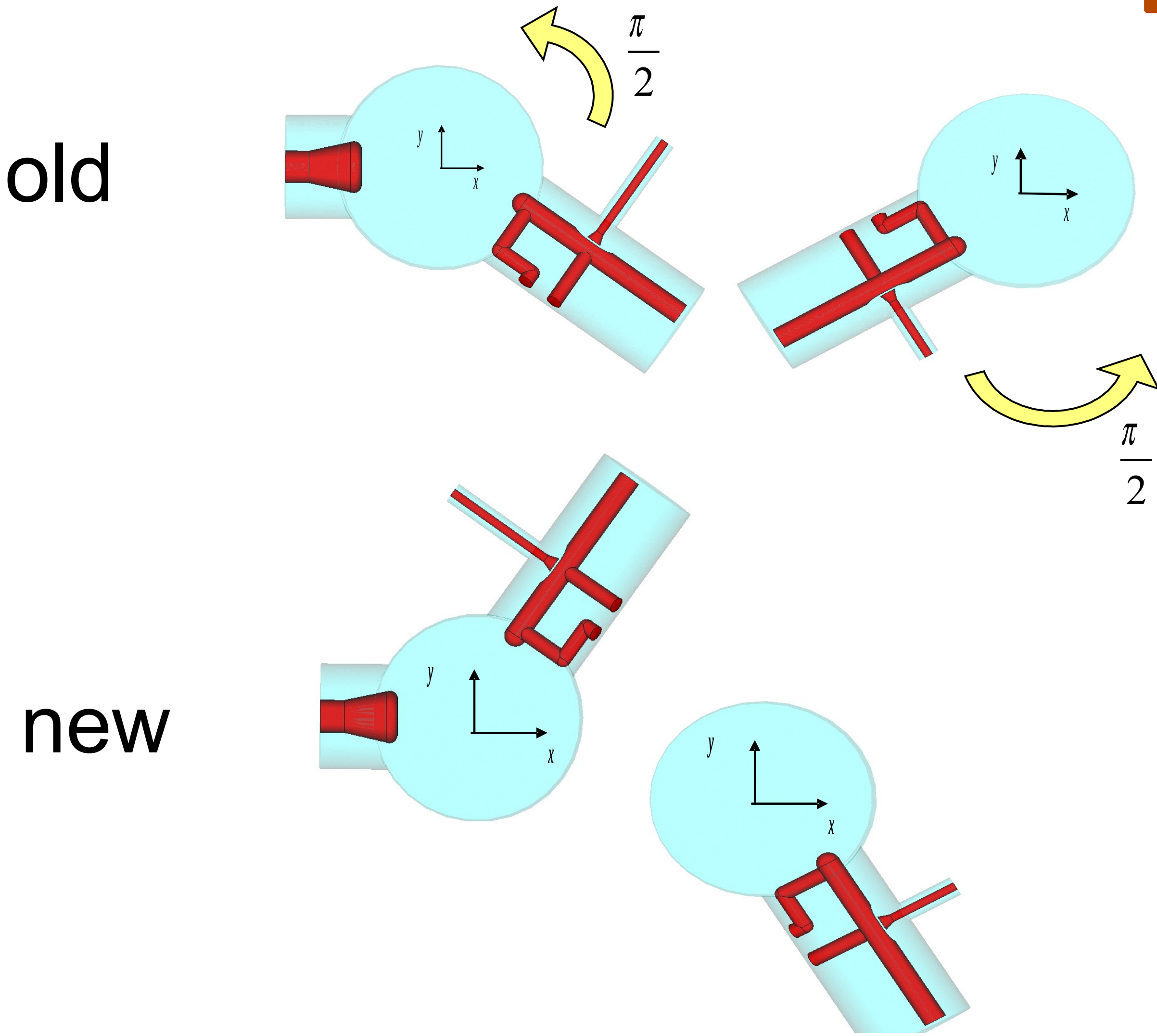
Igor Zagorodnov

and Martin Dohlus

(see talk DESY, ILC meeting. 4 May 2007)



Introduction



Kick in y can be compensated by a change in design.

Introduction

Upstream

HOM coupler

Downstream

HOM coupler
RF coupler

Asymmetric Wake Fields
+
transverse RF component

- Implemented in MERLIN as ParticleProcess
  - Old and new design
  - wake fields and RF kick

Implementation - Coupler Wake Fields

- Wake fields and RF kick in linear approximation:

old design

$$k_T = \begin{pmatrix} -0.021 \\ -0.019 \end{pmatrix} + \begin{pmatrix} 4.3 & 0.07 \\ 0.03 & -0.9 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

$$k_T \left[\frac{V}{pC} \right], \quad x[m],\ y[m]$$

new design much smaller on axis

$$k_T = \begin{pmatrix} -0.0025 \\ -0.0002 \end{pmatrix} + \begin{pmatrix} 2.33 & 0.04 \\ -0.02 & -1.1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

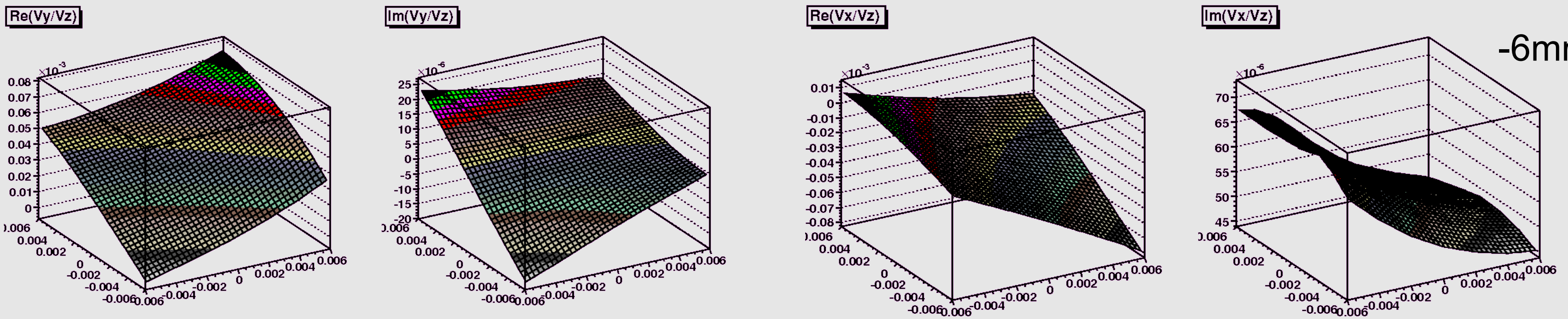
Wake fields as purely capacitive wake in coupler

$$electron:\ w_T(s), \qquad bunch\ \ distribution: g(s)$$

$$bunch: \qquad W_T(s) = \int_{-\infty}^{s} w_T(s-s')\, g(s')\, \mathrm{d}s'$$

$$capacitive: \qquad w_T = 2\mathrm{k}_T$$

Implementation - RF kicks



- MAFIA simulation exists and can be used to described the RF fields
- For the simulations presented here only a linear approximation had been used:

$$\kappa := \frac{V^{up+down}}{V_z} = 10^{-4}\begin{pmatrix}-0.82+0.59i\\0.73+0.08i\end{pmatrix} + \begin{pmatrix}-20-27i & 63+38.5i\\63+7i & +28+24i\end{pmatrix}\begin{pmatrix}x\\y\end{pmatrix}$$

$$k_T = \Re\left(\kappa\, e^{i(\varphi - kz)}\right), \quad k = 2\pi f/c, \qquad z \;\; \textit{rel. particle position within the bunch}$$

$$k_T(0,0) \sim 1\,KV$$

MERLIN Simulations

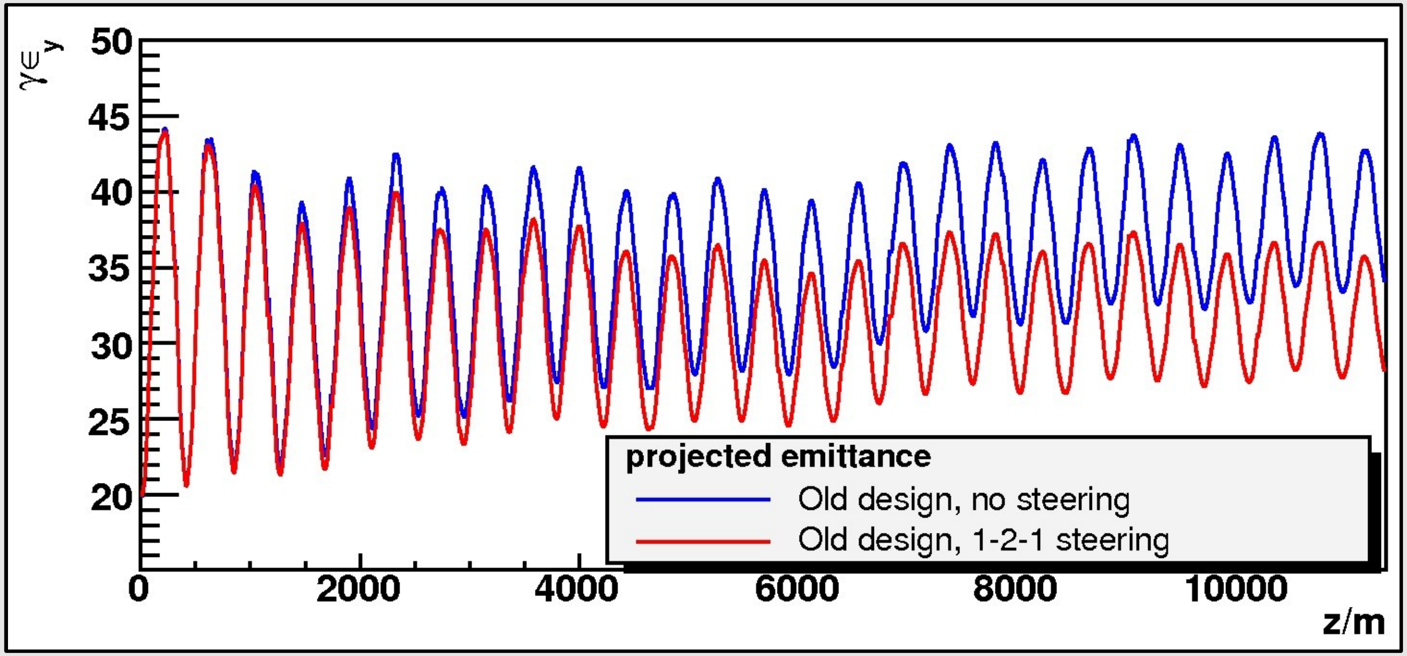
- Special lattice based on ILC2006c but without undulator (ELIN1 & ELIN2 & EBDS rematched)
  to avoid complication related to the undulator bypass
- perfect machine – no errors
- no earth curvature - straight
- One-to-one steering in ML
- Standard cavity wake fields included (TESLA)
- A FFB system is assumed to put the bunch centre to the nominal position between ML and BDS
- Linear tuning (waist,dispersion,coupling) at IP
- Lumi calculations with GUINEAPIG - see Isabell's talk
- Full particle simulation with typical 100k particles
- Gausian bunch :

$$\sigma_z = 300\mu\,, \quad \sigma_{dp} = 0.0107, \quad \gamma\epsilon_x = 8\cdot 10^{-6}, \quad \gamma\epsilon_x = 20\cdot 10^{-9}$$

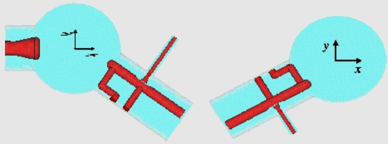
$$Q = 2\cdot 10^{10}, \quad phase = 5.3^o$$

Coupler wake fields – old design

- Projected emittance along the main linac – no undulator bypass
  - strongly oscillating emittance
  - large increase



Let's have a look at the bunch



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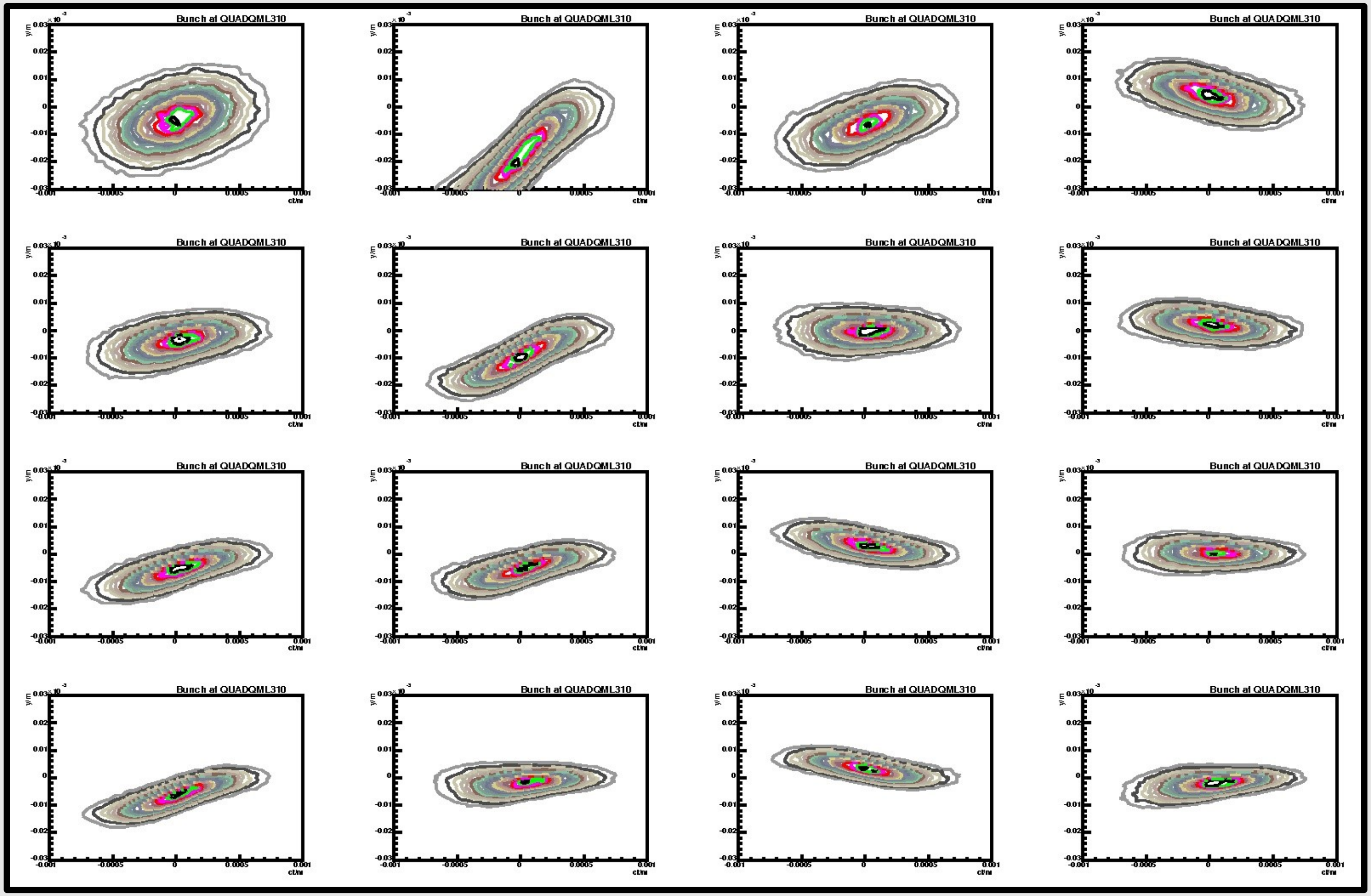

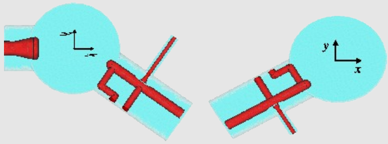

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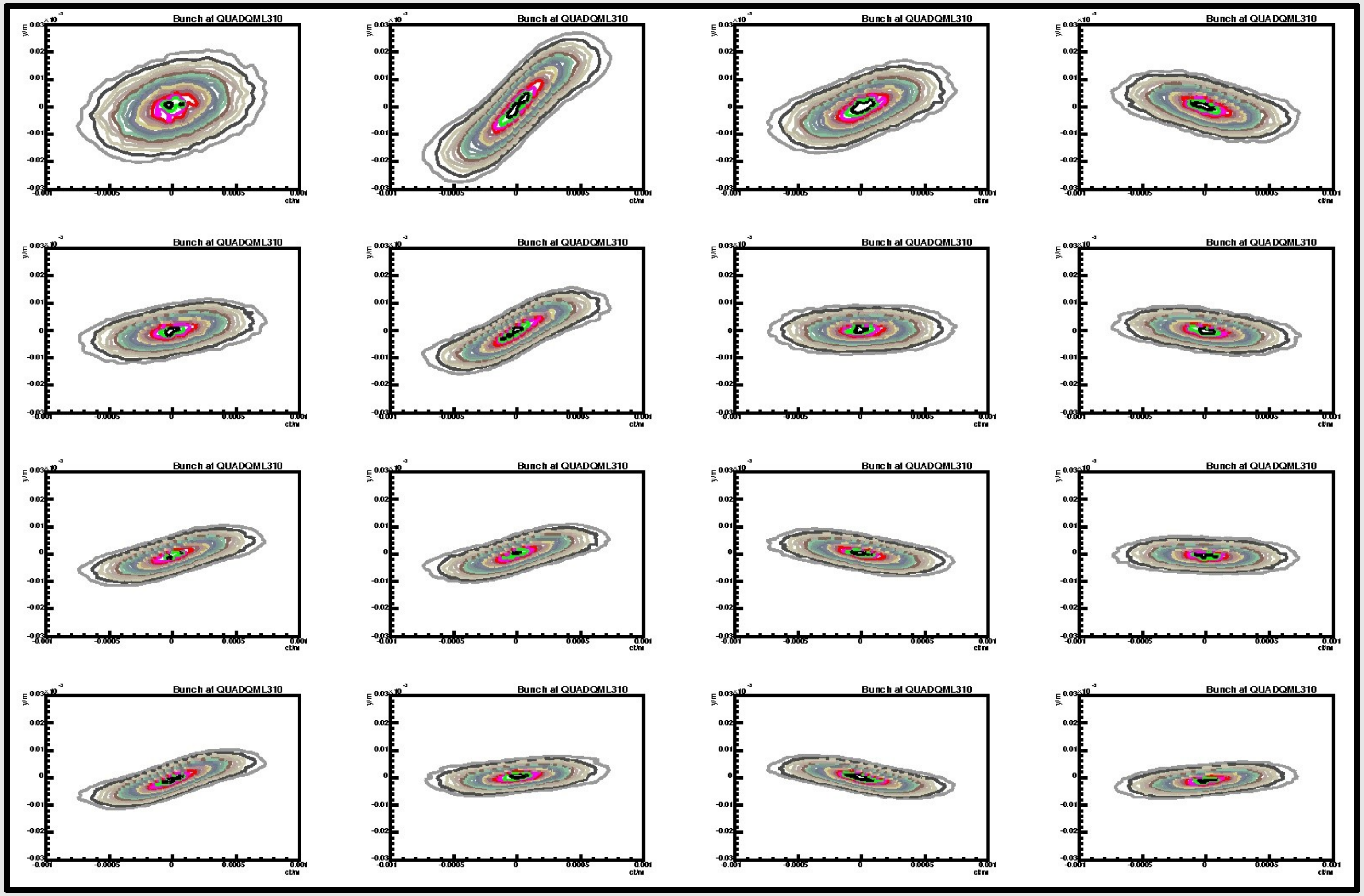
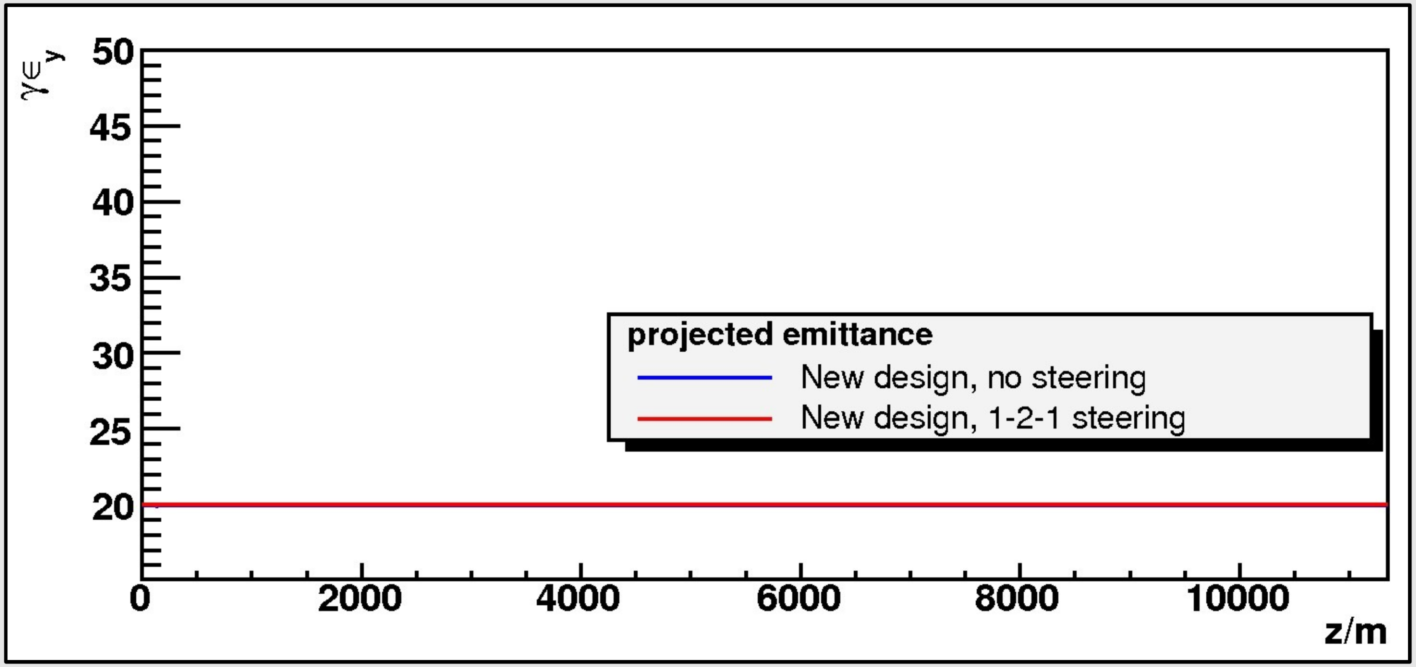


One-to-one steering

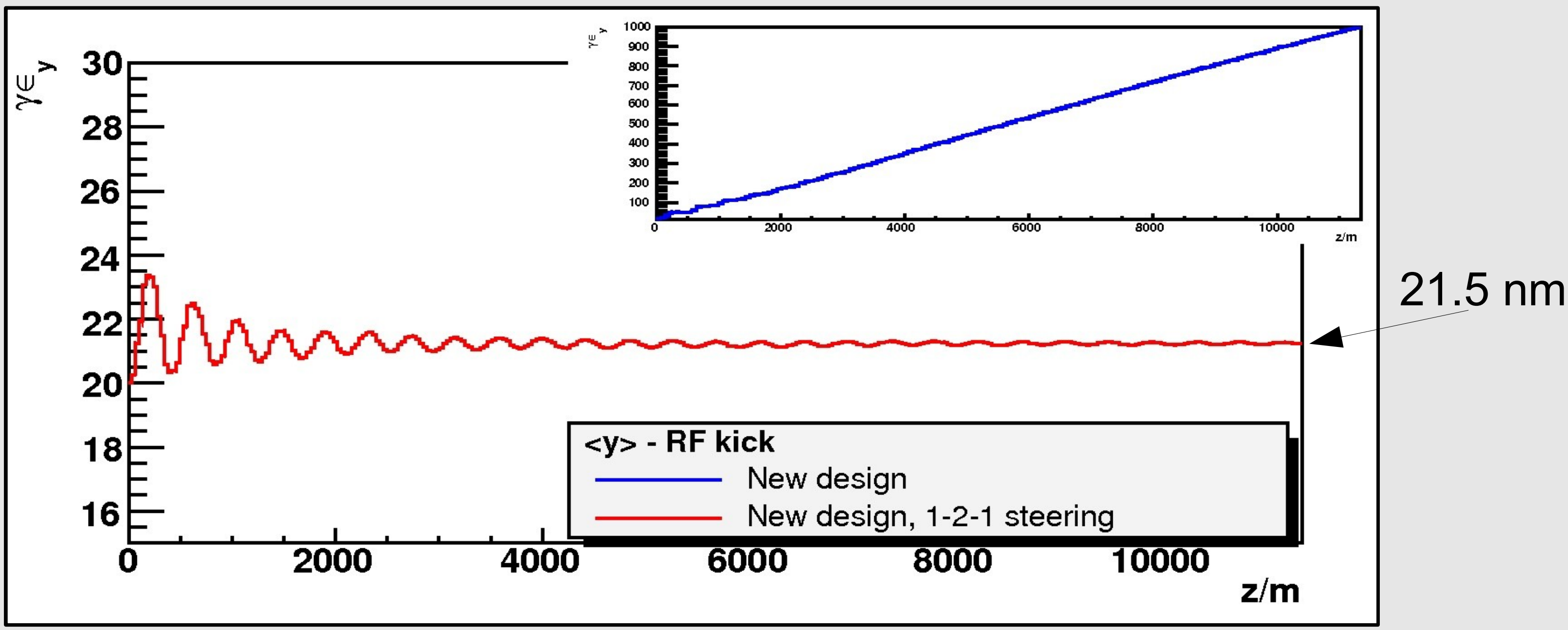
Coupler wake fields – new design



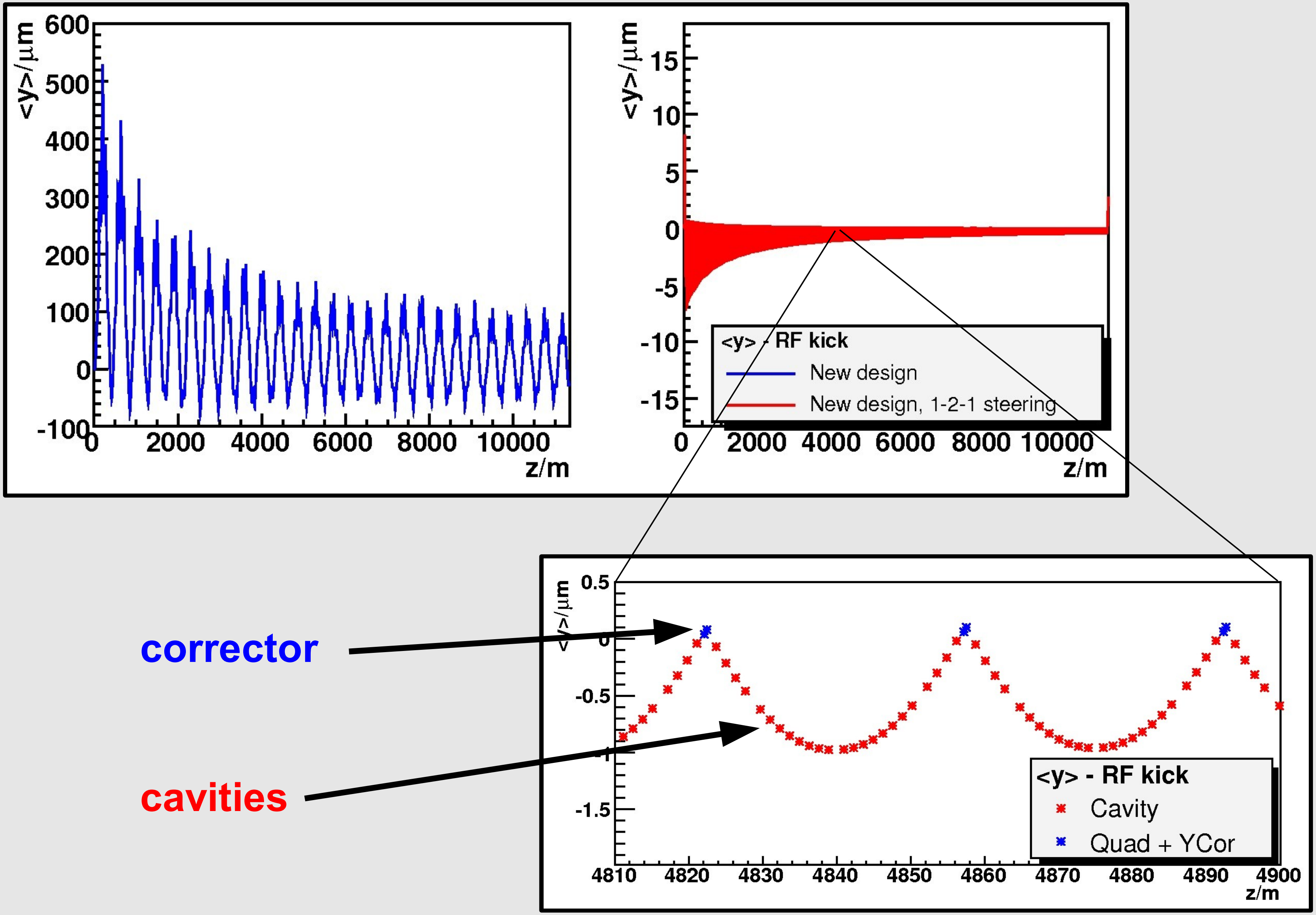
- Projected emittance
  - Negligible effect – see below

Coupler RF kicks - Emittance

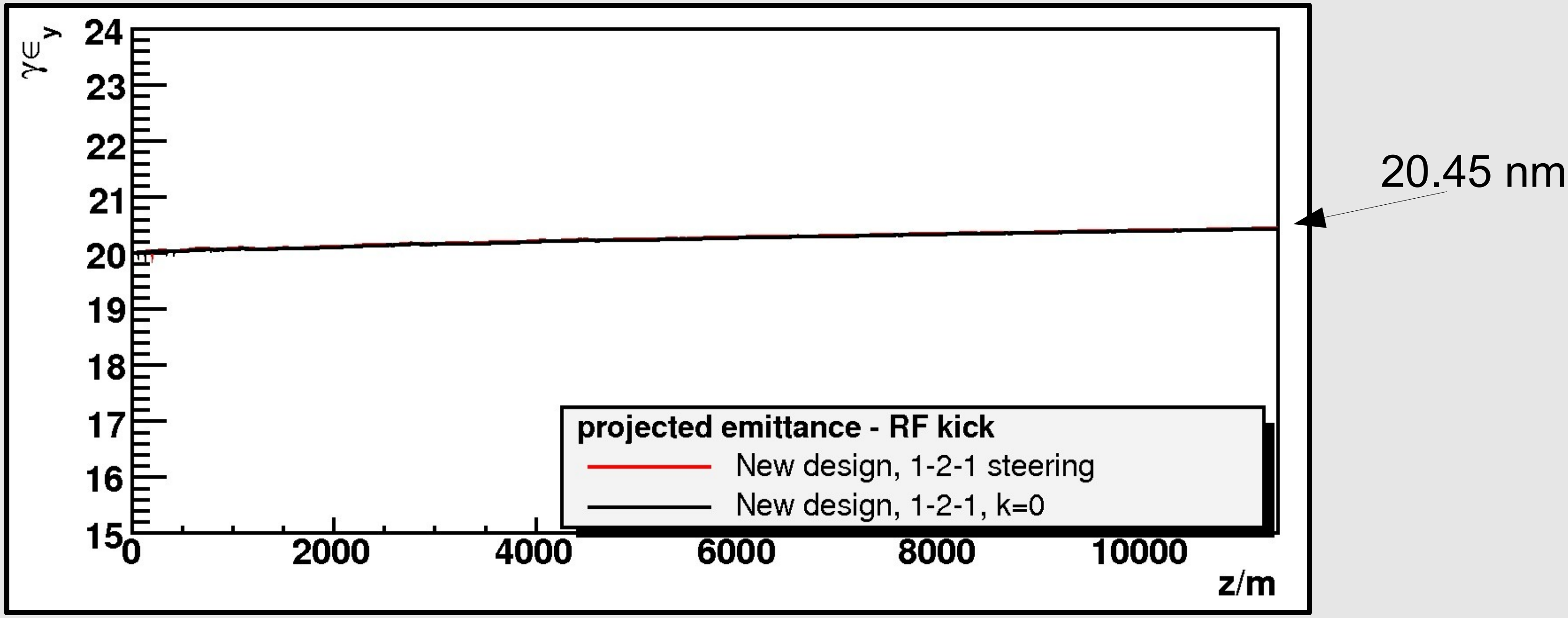
- Projected emittance along the main linac
  - Strong transverse kick 1KV/cavity –
  - correctors (at each quads) preset to compensate + 1-2-1
  - Net increase of 1.5 nm in



Coupler RF kicks - Trajectory



RF kicks – Dispersion Corrected Emittance

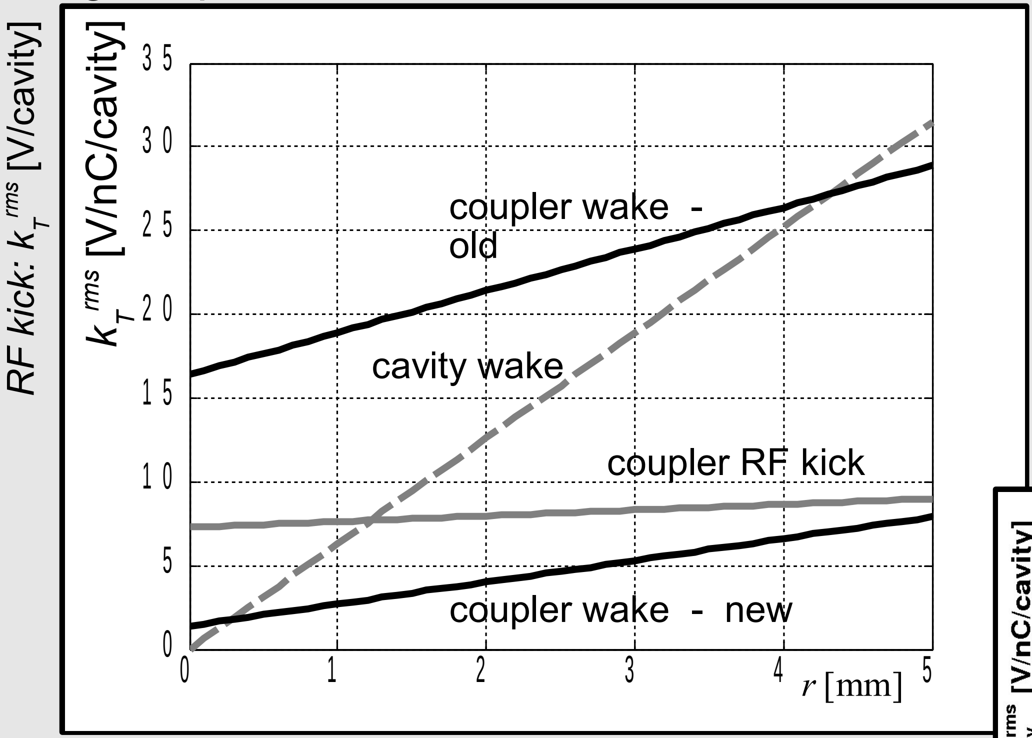


$$\gamma\epsilon_y^c=\gamma\sqrt{[\langle y^2\rangle-\langle y\delta\rangle^2/\langle\delta^2\rangle][\langle y'^2\rangle-\langle y'\delta\rangle^2/\langle\delta^2\rangle]-[\langle yy'\rangle-(\langle y\delta\rangle)(\langle y'\delta\rangle)/\langle\delta^2\rangle]}$$

- The emittance growth is almost purely dispersive
- for a perfect linac and a perfect 1-2-1 steering
  - No strong effect within a bunch by the cos(φ-kz)-term

Discussion

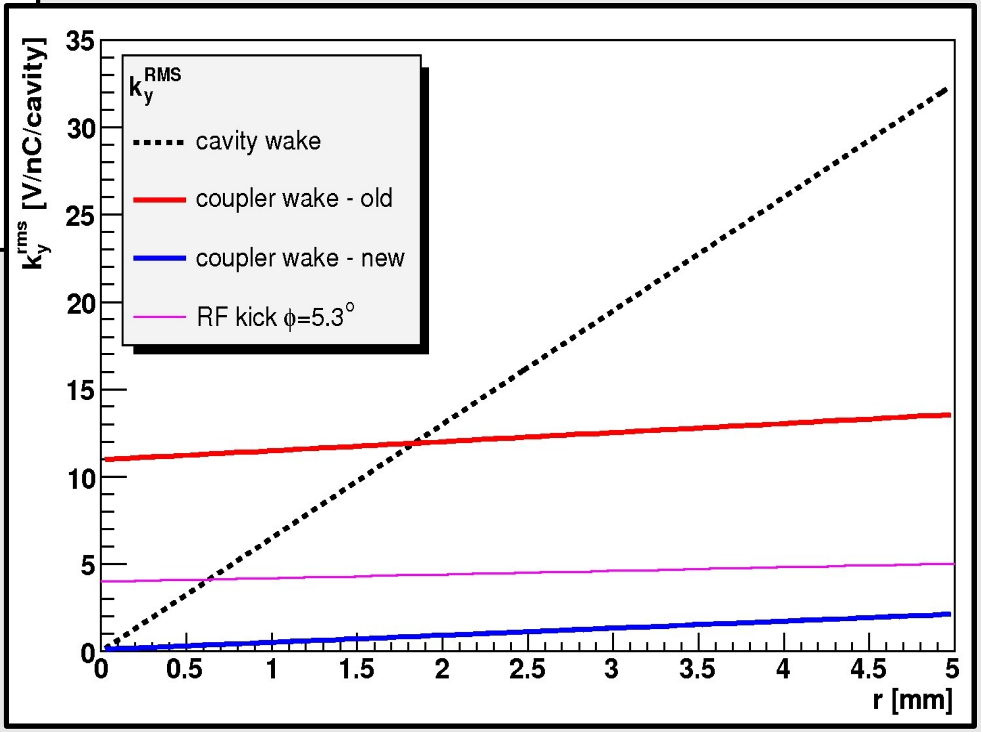
Igor's plot:



$$kick: \ k_{x,y} = \int_{-\infty}^{\infty} W_{x,y}(s) g(s) \mathrm{d}x$$

$$k_{x,y}^{rms} = \sqrt{\int_{-\infty}^{\infty} (W_{x,y}(s) - k_{x,y})^2 g(s) \mathrm{d}x}$$

$$k_T^{rms} = \sqrt{(k_x^{rms})^2 + (k_y^{rms})^2}$$



- The simulations presented here look into the y-plane separately → all values are smaller
- ILC bunch 3.2 nC
  - RF kick is independent

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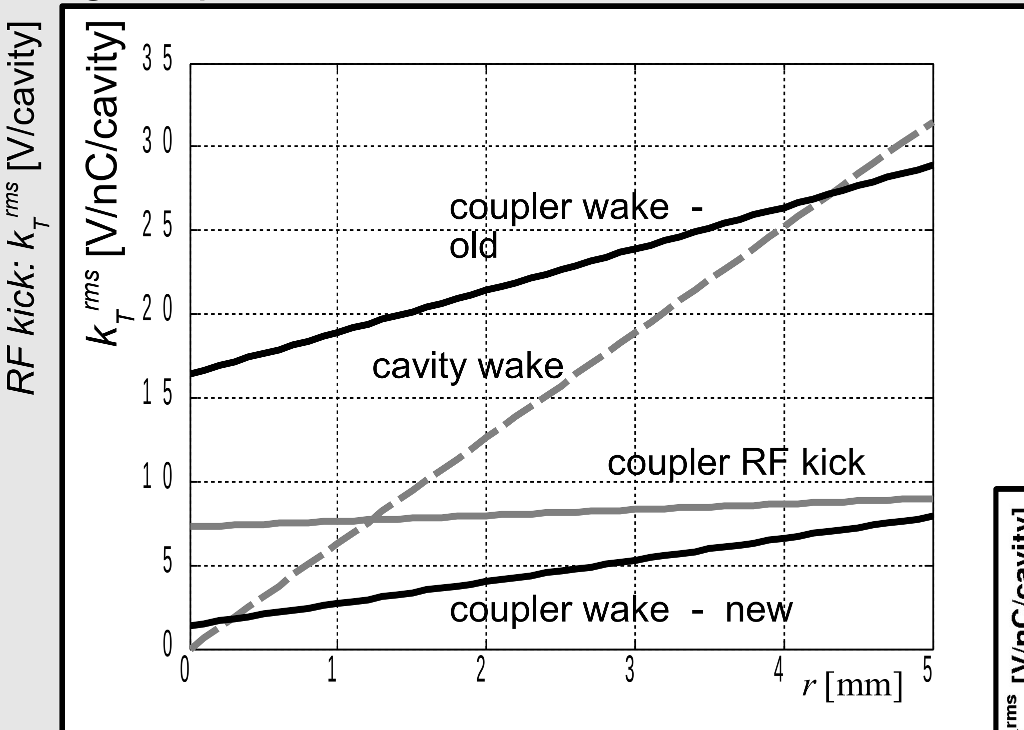
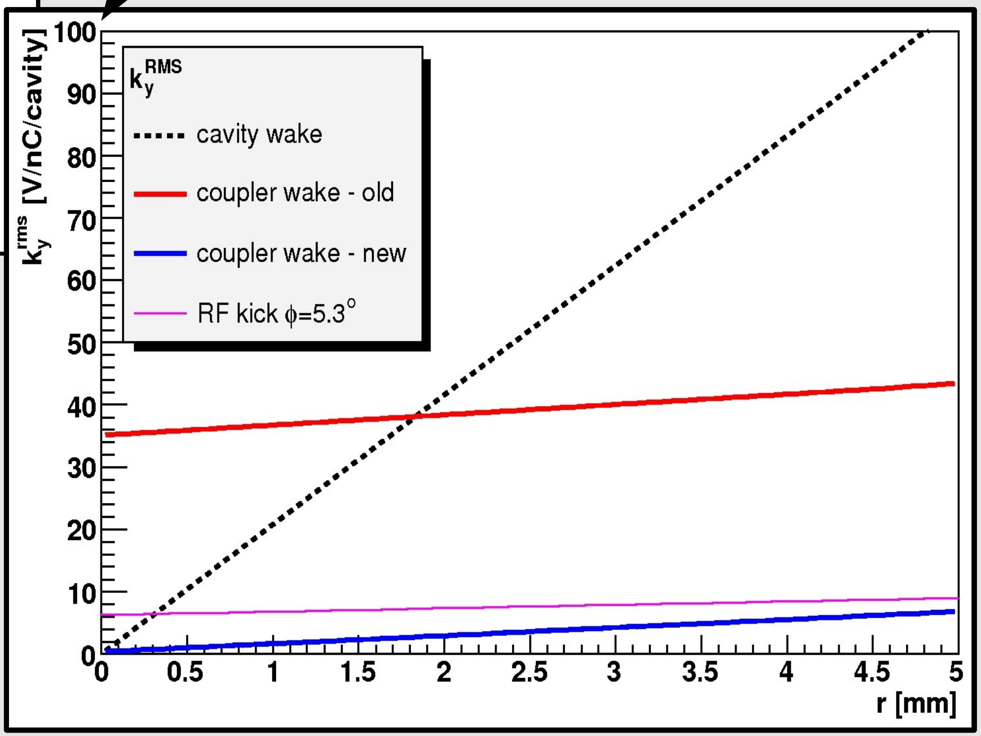


scale!



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Conclusion

- The coupler wake fields and coupler RF kick has been implemented in MERLIN
- Old coupler design: Critically large wake fields
- New design: Negligible coupler wake fields (1/100 smaller in y, 1/10 order in x)
- Transverse kick at RF coupler similar to a 100 μrad cavity tilt
  - Dispersive emittance growth
- Additional studies necessary
  - alignment errors, DFS etc.
  - alternative configurations (alternating cavities)?