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Compact

The Passive Dechirper

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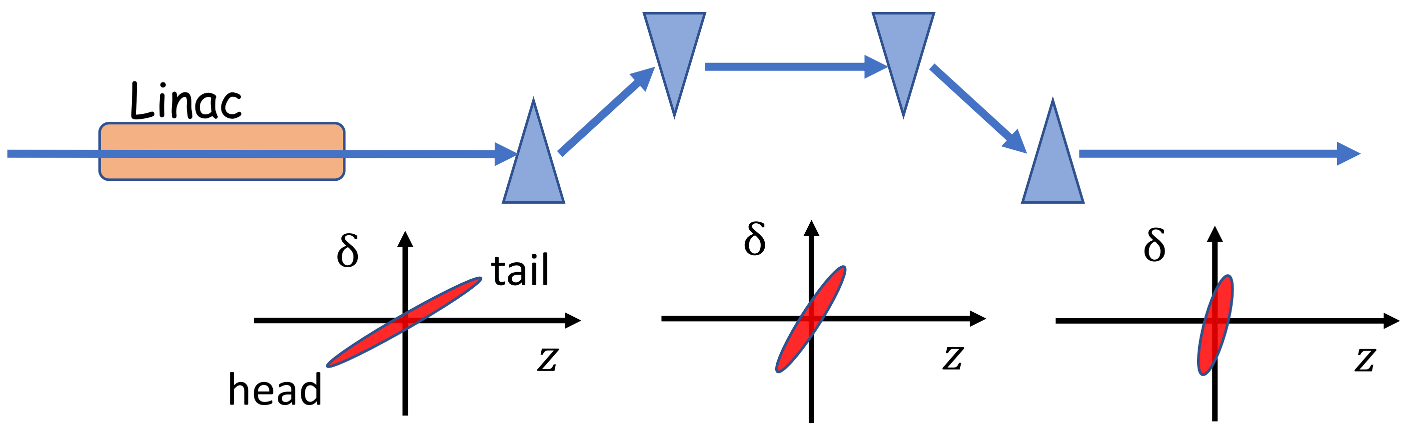
LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

Outline

- Why a passive dechirper
- Principle of dechirper
- Types of dechirper
- The Wakefield of dechirper
- Several examples
- The XLS situation
- Conclusion

Why do we need Dechirper ?

- For FEL, bunch compression typically leaves an undesired time-energy correlation
  - Broaden the FEL bandwidth and decrease FEL gain



- RF (off crest) can remove it, but this can be costly & difficult for very high frequency (e.g. 36, 48 GHz)
- Passive dechirper using self-induced wakefields to remove the chirp can be a better choice.

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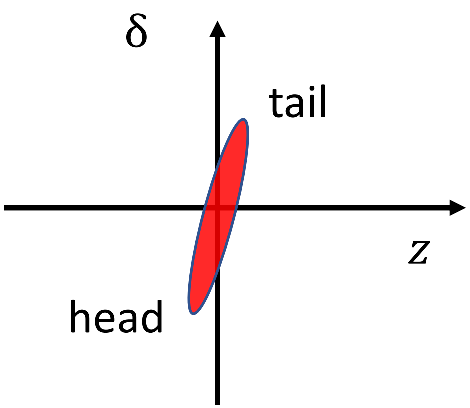
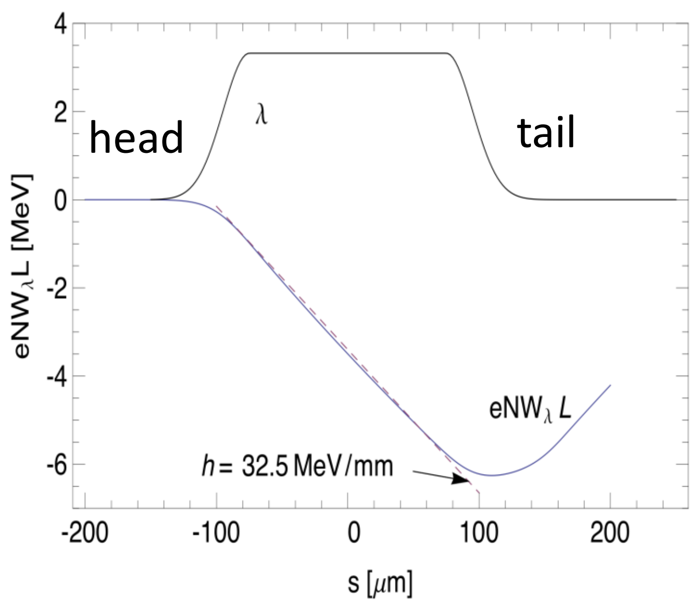
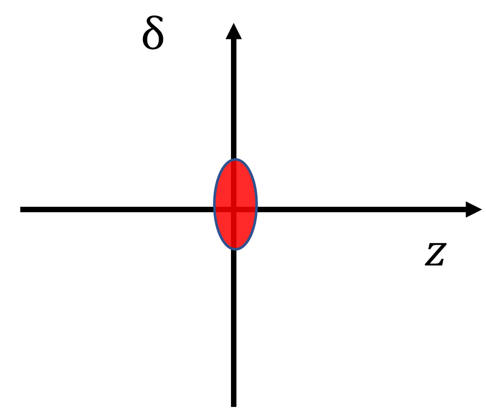
Principle of dechirper

- When beam pass through a beam pipe, the induced short range wakefield can act on the beam itself







- The bunch tail loss more energy than the head

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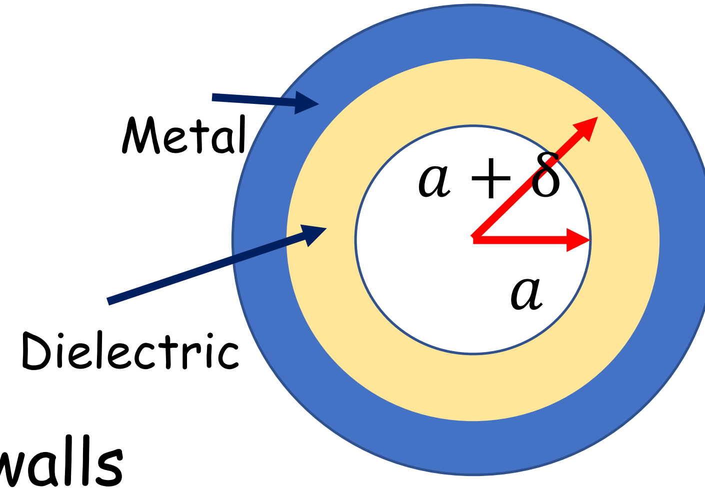
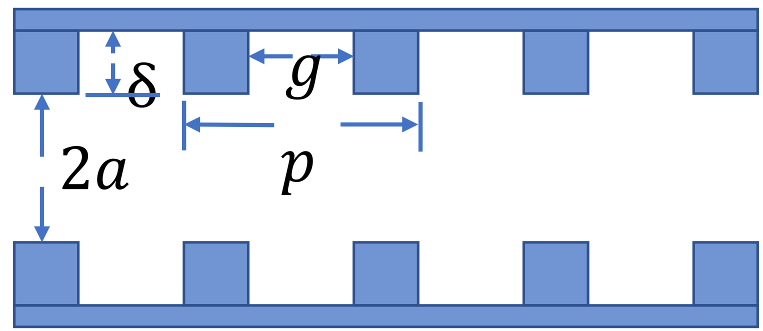
Types of Dechirper



Three types of methods:

- Metal waveguide with dielectric
- Metallic structure with corrugated walls
- RF cavity without input power



Different shapes:

- Cylinder pipe
- Rectangular pipe
- Paralle plates

	Flat	Round
Flexibilty	Eaily tunable	Difficult to tune
Longtudinal wake	$(\pi^2/16)$	1
Dipole wake	0.38	1
Quad wake	1	0

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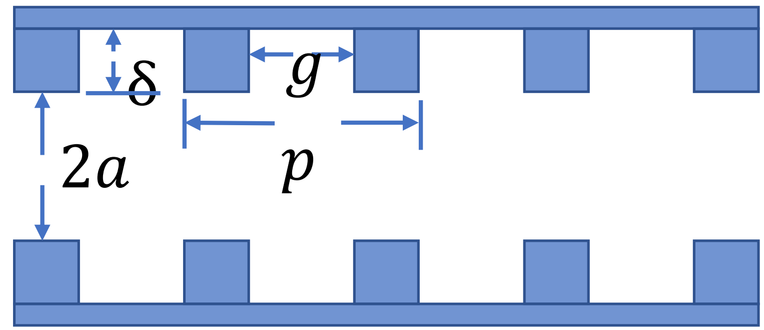
The Wakfield model - Cylinder corrugated

Cylinder corrugated pipe: $p \ll a \quad \delta \leq p$



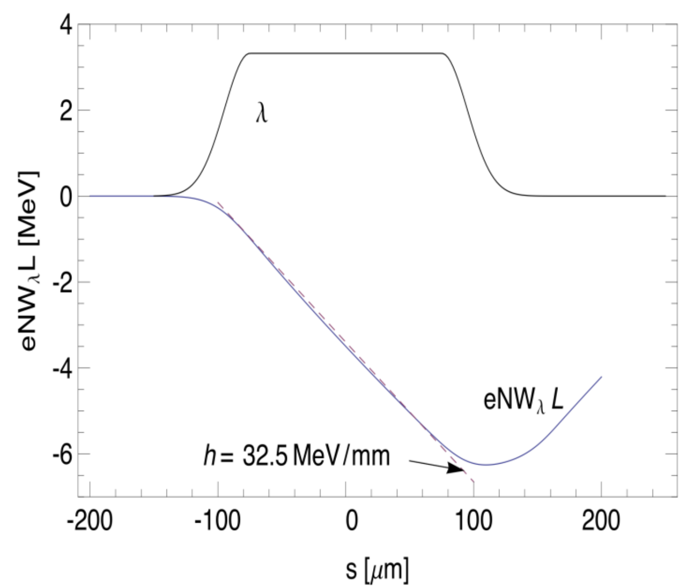
Wave number $k = \sqrt{\frac{2p}{a\delta g}}$

Loss factor $\xi = \frac{Z_0 c}{2\pi a^2}$

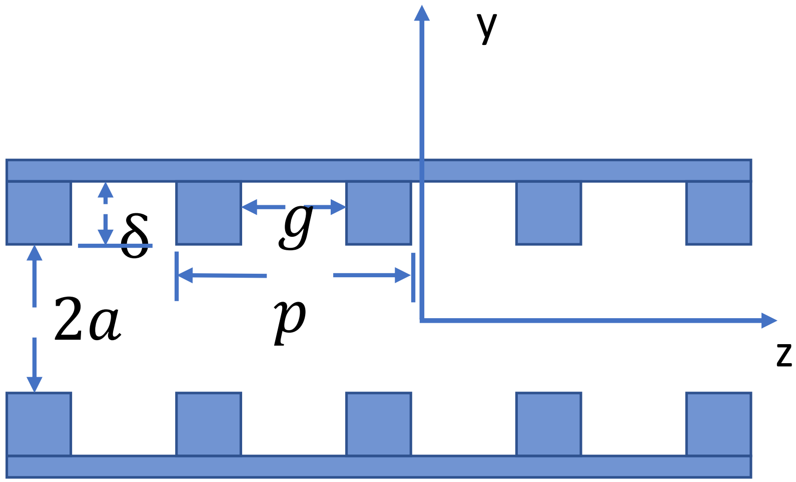
Wake function $\mathrm{W}(s) = 2\xi \mathrm{H}(s)\cos(ks)$

Wake potential $\mathrm{W}_\lambda(s) = -\int_0^\infty \mathrm{W}(s')\lambda(s-s')ds'$

Bunch loss factor $\xi_\lambda = -\int_{-\infty}^\infty \mathrm{W}_\lambda(s)\lambda(s)ds$



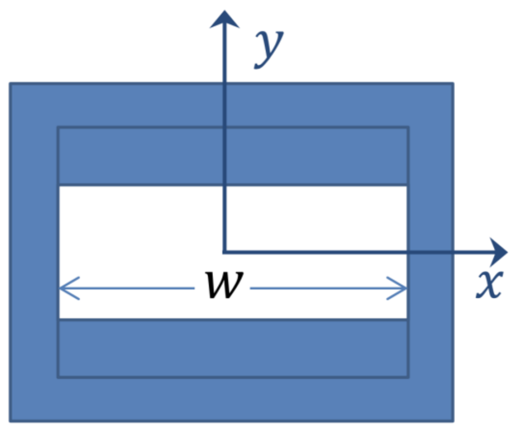
The Wakfield model - Rectangular Corrugated



Rectangular corrugated pipe: $\mathrm{w} \gg 2a$, $p, \delta \ll a$

Wave number $k = \sqrt{\frac{p}{a\delta g}}$

Loss factor $\xi = \frac{\pi^2}{16} \frac{Z_0 c}{2\pi a^2}$



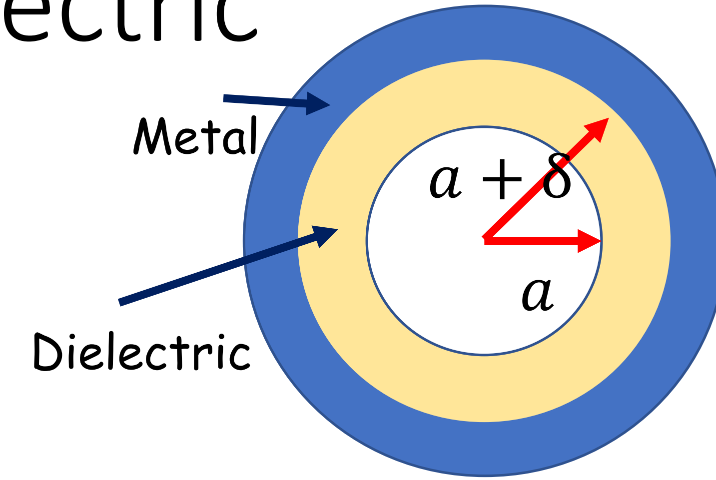
Wake function $W_{\|}(z) = \frac{\pi^2}{16} \frac{Z_0 c}{\pi a^2} H(z) \cos(kz)\ 0 < kz \lesssim 3\pi$

If $p, \delta \leq a, \delta/p \geq 0.8$

$$W_{\|}(z) = \frac{\pi^2}{16} \frac{Z_0 c}{\pi a^2} F H(z) e^{-\frac{kz}{2Q}} \cos(kz)$$

$$k = \frac{1}{a}\left(\frac{1.7096}{\sqrt{\delta/a}} - 0.5026\right)$$

The Wakfield model -dielectric

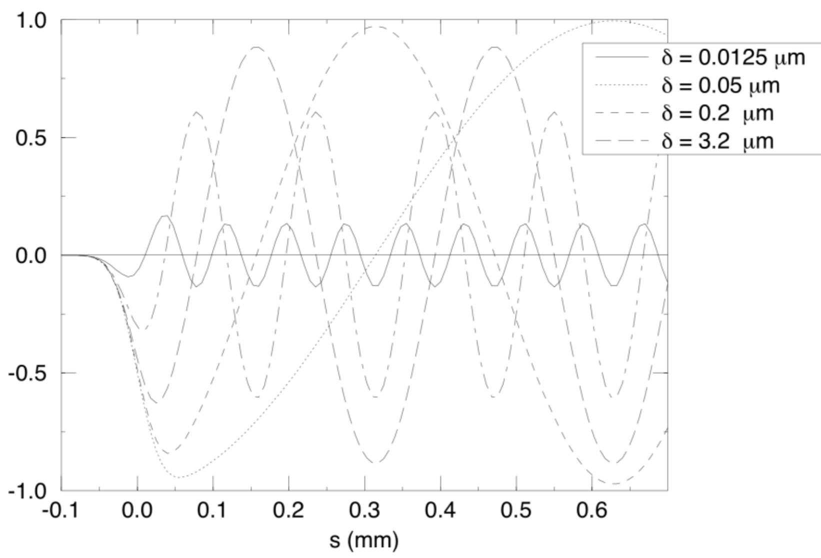


Cylinder dielectric pipe: $\sigma k_0 \leq 1$

Wave number $k_0 = \dfrac{2\epsilon}{a\delta(\epsilon - 1)}$

Loss factor $\xi = \dfrac{Z_0 c}{2\pi a^2}$

Bunch loss factor $\xi_\lambda = \dfrac{Z_0 c}{2\pi a^2} \exp(-(k_0\sigma)^2)$



$a = 50mm, \sigma = 25\mu m$

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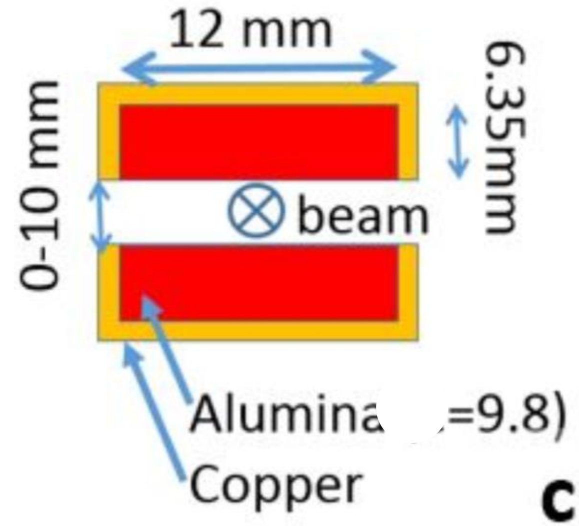
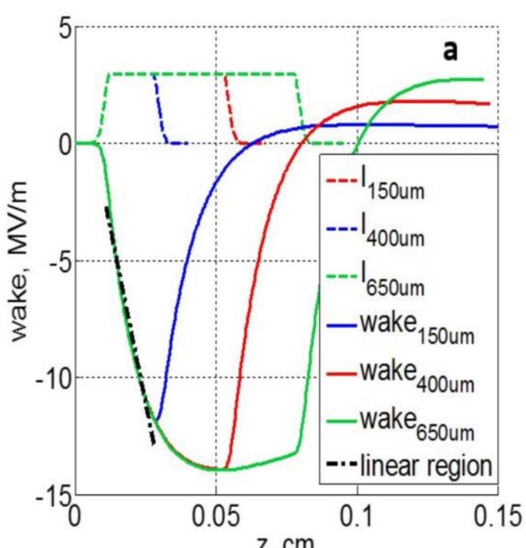
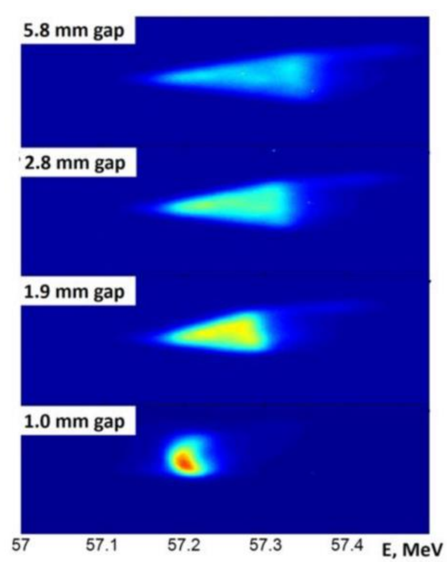
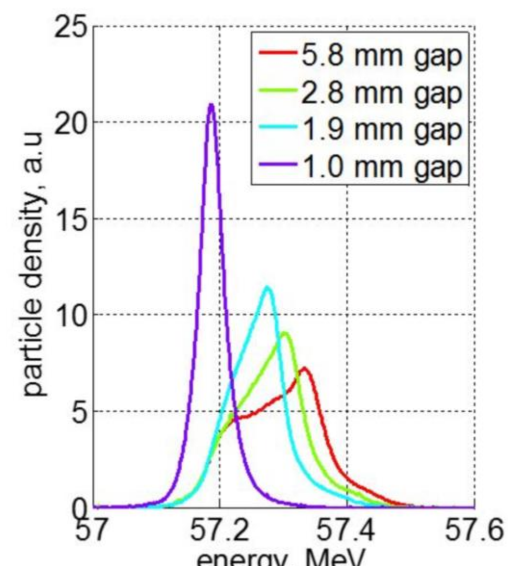
Examples- Brookhaven National Laboratory - ATF



- 60 MeV, 54 pC, 550 μm long
- Energy chirp : 330 keV/mm
- Planar tunable dechirper
  - Two 10 cm long dielectric slabs
  - The gap was changed from 5.8 mm to 1 mm

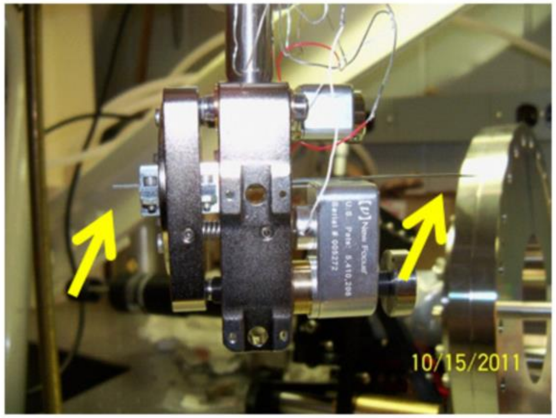


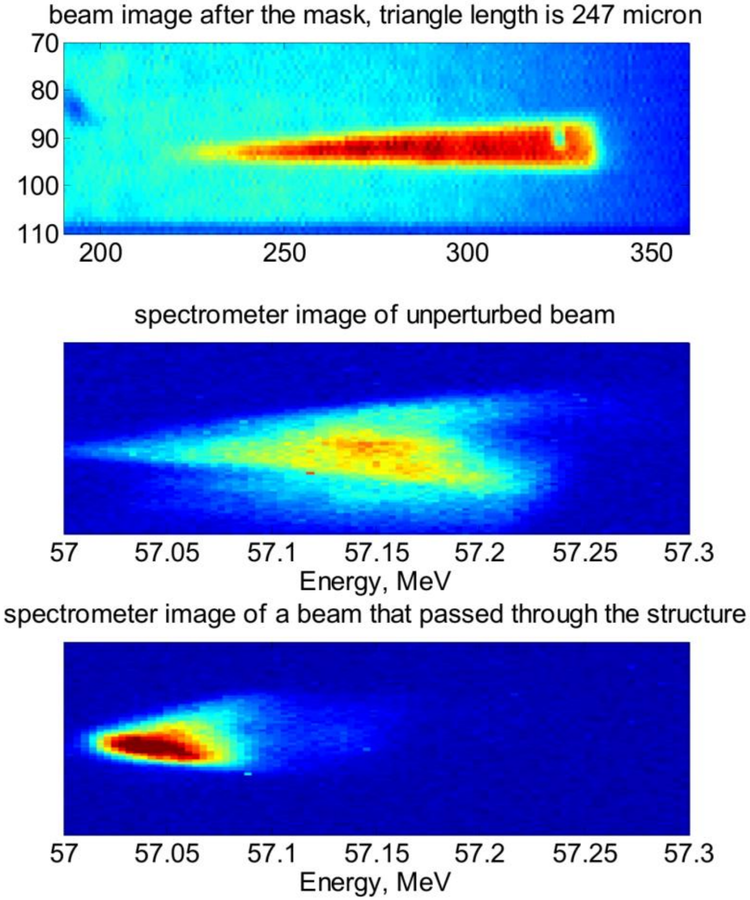




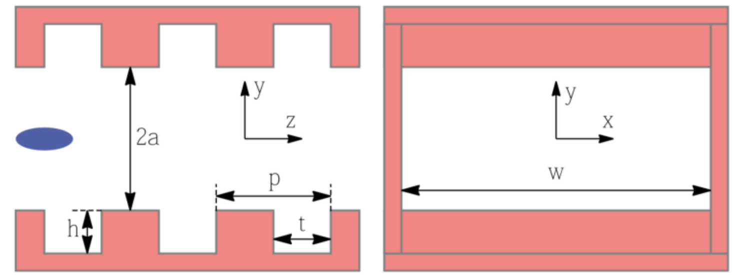
Examples- BNL ATF

- 57 MeV, 54 pC, 550 μm long
- Energy spread: 200 -> 70 keV
- Dielectric tube
  - Inner radius: 330 mm
  - Length: 5 cm



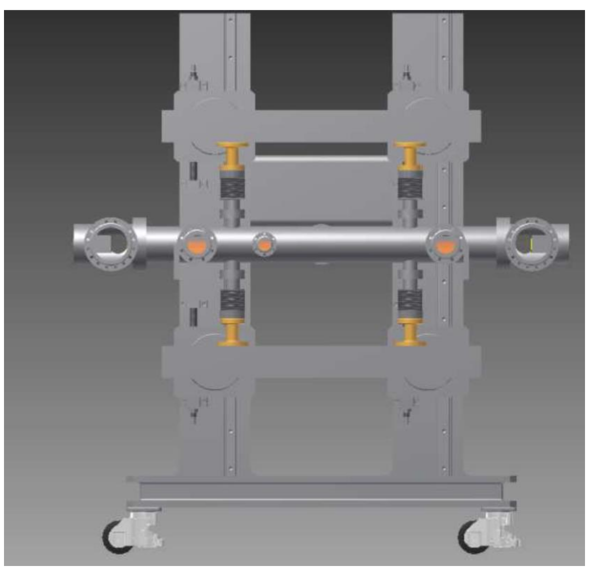


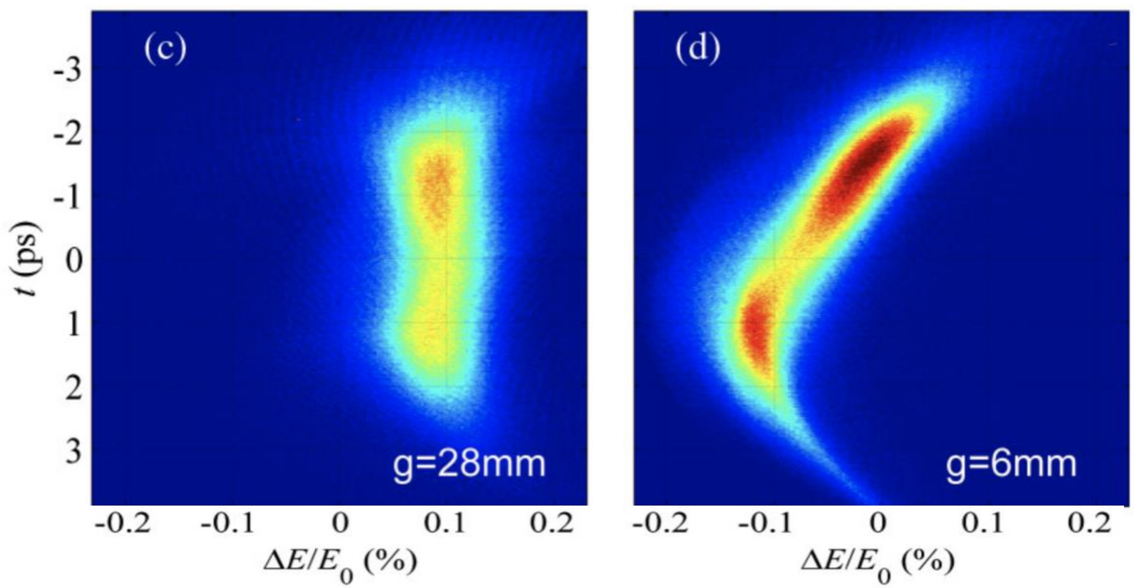
Examples- Pohang Accelerator Laboratory - ITF



- 70 MeV, 200 pC, 700 μm(σ_z)
- Corrugated rectangular pipe
  - a = 28,6 mm, h = 0.6 mm, p = 0.5 mm, g = 0.3 mm
  - Length: 1 m

g = 2a

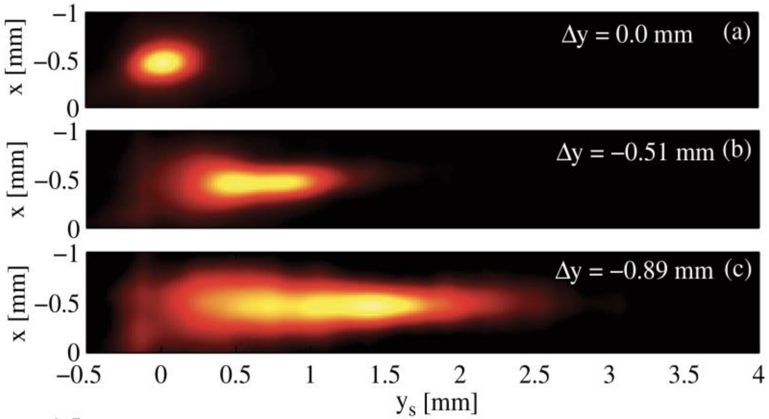


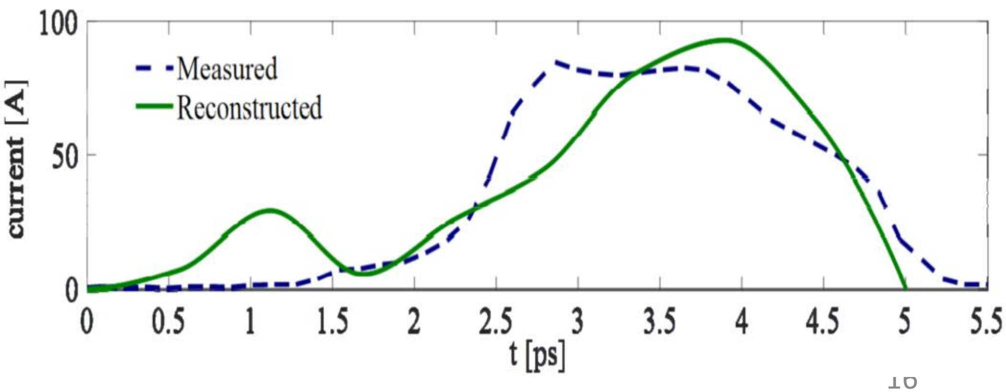


Examples- PSI - passive streaker

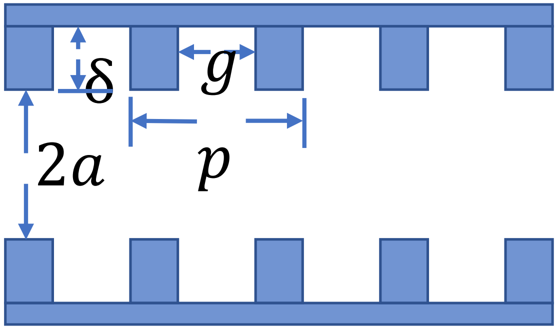
Temporal profile measurements

- 140 MeV, 200 pC, 1 ps (rms)
- Dielectric cylinder pipe
    - Alumina with Copper
    - Inner radius: 1.65 mm
    - Length: 9.5 cm

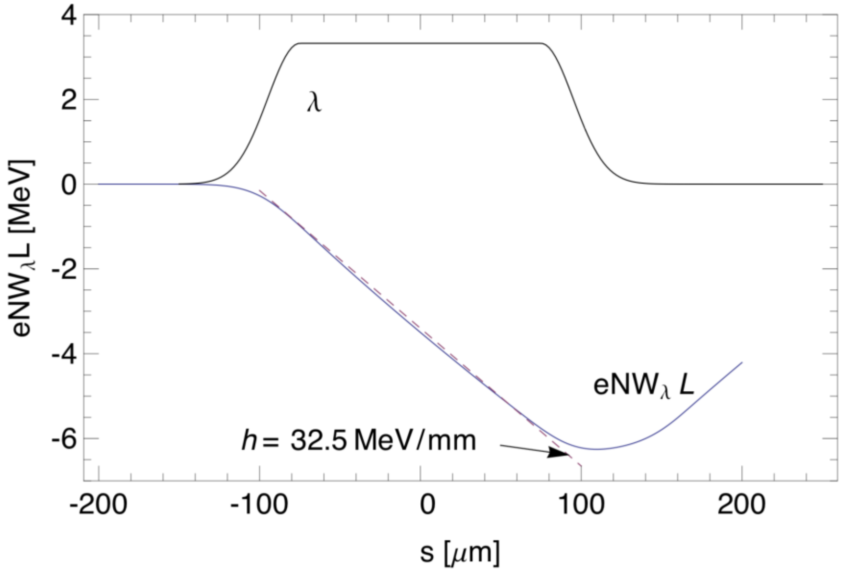




Examples- Berkeley National Laboratory - NGLS



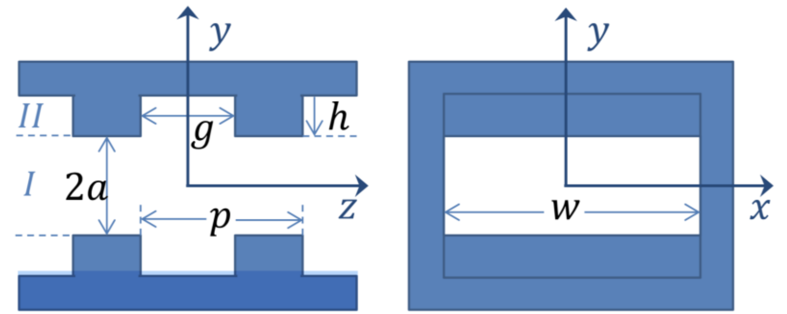
- 350 MeV, 300 pC, 150 μm long
- Energy chirp : 40 MeV/mm
- Corrugated cylinder pipe
  - a = 3 mm, δ = 450 μm, p = 1000 μm, g = 750 μm
  - Length: 6.65 m



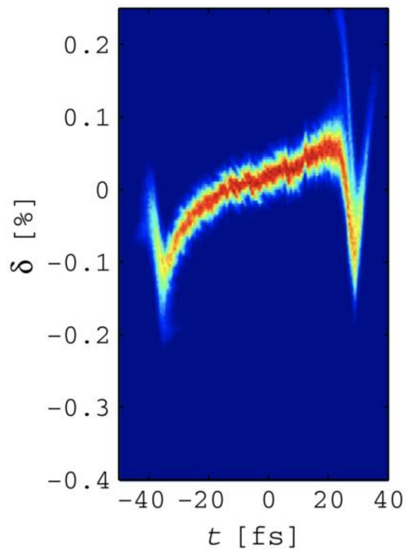
Due to the deviation between numerical and analytical results, the generated energy chirp is small than 40 MeV/mm. The 8.2 m structures is need.

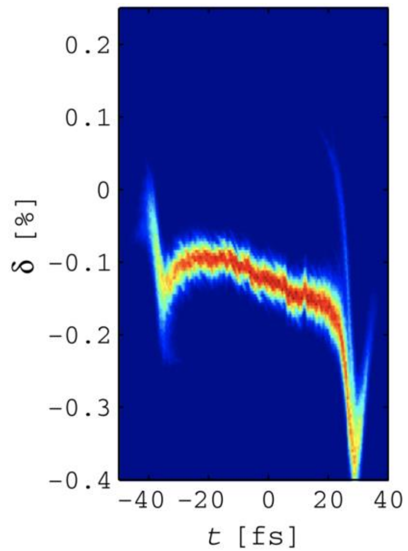
Examples- LCLS at SLAC

- 6.6 GeV, 150 pC, 15 μm long
- Energy chirp : 1333 MeV/mm
- Corrugated rectangular pipe
    - a = 0.7 mm, h = 0.5 mm, p = 0.5 mm, g = 0.25 mm
    - Length: 4 m



Before the dechirper





After the dechirper

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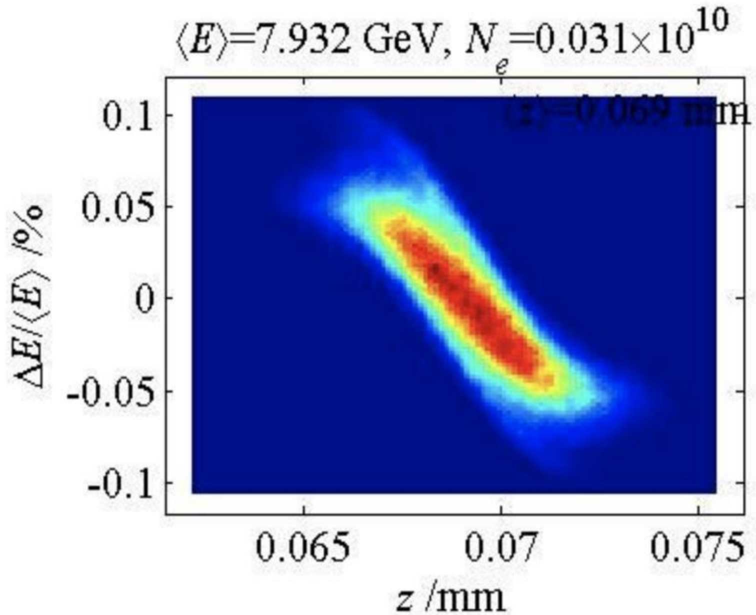
The XLS situation

Q	50 pC
E	8 GeV
σ_t	5 fs

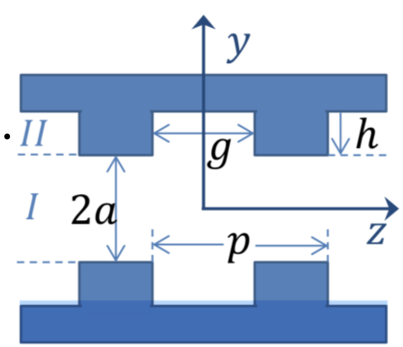


Report by S. Di. Mitri at WP6 meeting

Required energy chirp: ~ 1800 MeV/mm

The dechirper at LCLS of SLAC can be a good start point.

- Corrugated rectangular pipe
- a = 0.7 mm, h = 0.5 mm, p = 0.5 mm, g = 0.25 mm
- Length: 4 m
- Energy chirp : 1333 MeV/mm for 6.6 GeV beam



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Conclusion

- The different types of wakefield for the dechiper are reviewed
- There are already serveral successful applications of the pasisve dechirper
- It is very promising using the passive dechirper in the XLS project.

Reference

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Backup

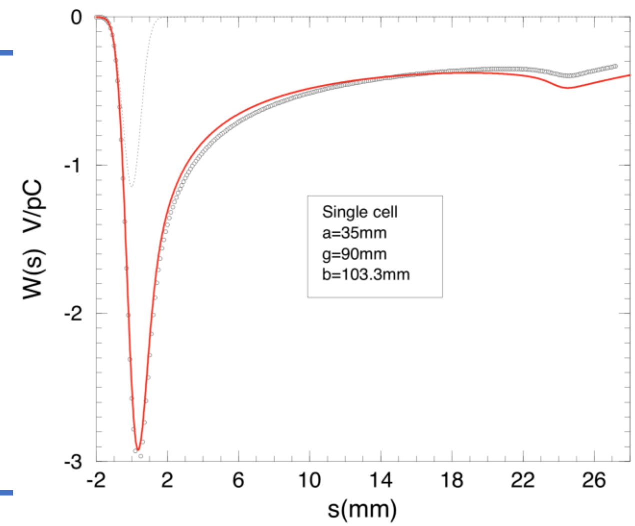
The Wakfield model – Cylinder cavity

Cylinder cavity pipe:

Single cells

$$w(s) = \frac{Z_0 c}{a\pi^2}\{\frac{s+g}{\sqrt{s(s+2g)}}F(\frac{\sqrt{s(s+2g)}}{a}) - F(\frac{s}{a})\}$$

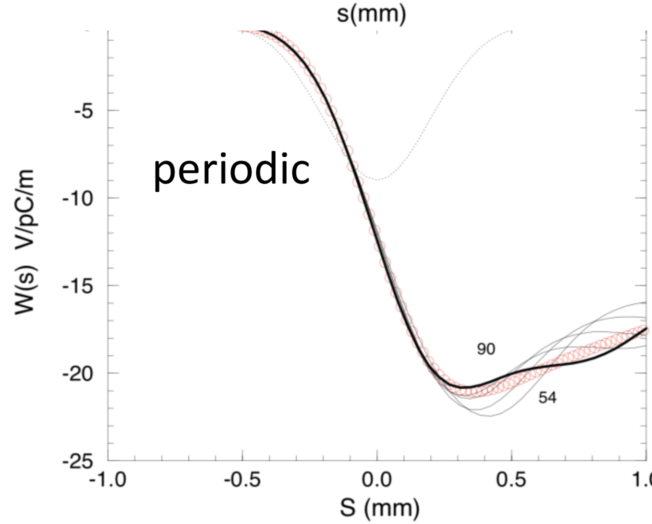
$$F(x) = \begin{cases} (2/x)\arcsin(x/2) & \text{if } x \leq 2 \\ (\pi/x) & \text{if } x > 2 \end{cases}$$



Periodic cells

$$w(s) = \frac{Z_0 c}{\pi a^2}((1+\beta)\exp(-\sqrt{\frac{s}{s_0}}) - \beta)$$

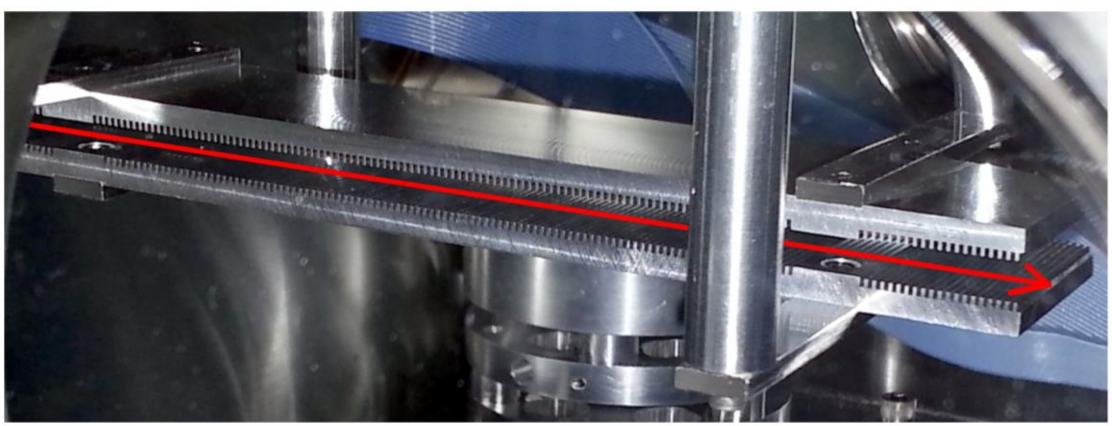
$$\beta = 0.16, s_0 = a^2/2L$$

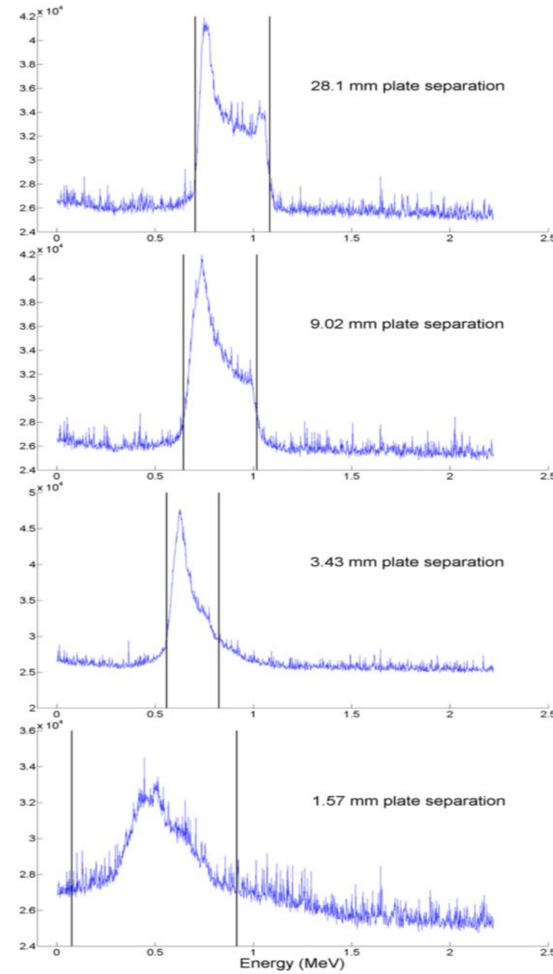


Examples – Radiabeam Technologies

Remove residual energy chirp: Manufacture & Experiment

- BNF ATF beam
  - 57 MeV, 340 pC, 3.5 ps
  - Intial chirp: 400 keV/mm
- Rectangular dechirper
  - Length: 18.1 mm, Width: 38.1 mm
  - Gap: 1 -30 mm





Examples- Shanghai Jiao Tong U.

Nonlinear-Energy chirp Compensation

- 3.3 MeV, 6 pC, 8 ps (FWHM)
- Two Paralle Corrugated Plates
  - Aluminum
  - Length: 16 cm; Width: 3.2 cm
  - Gap: 3 mm