A Passive Insertion as a Linearizer for ASTA?

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Q: Why is a linearizer useful?

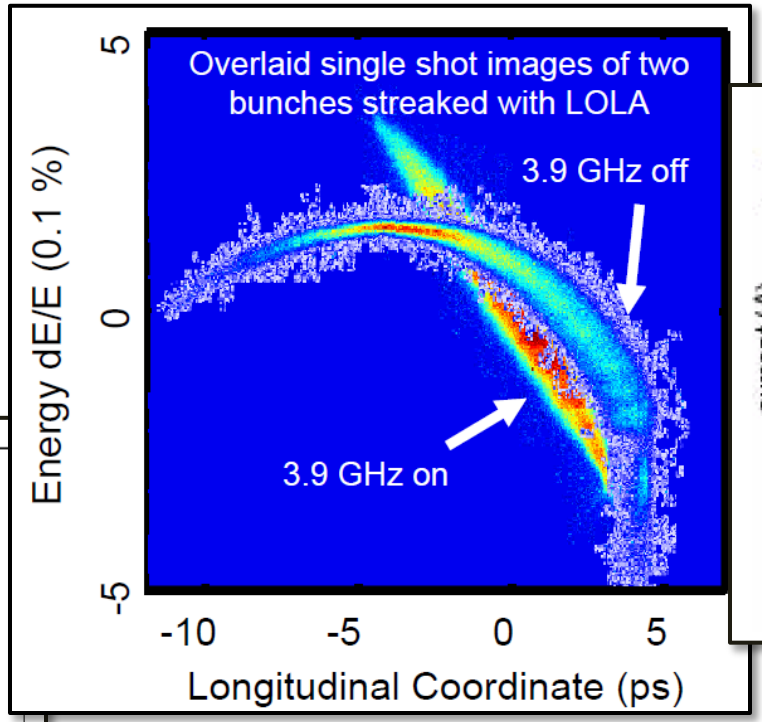
- A: to avoid development current spikes when compressing

The FLASH experience

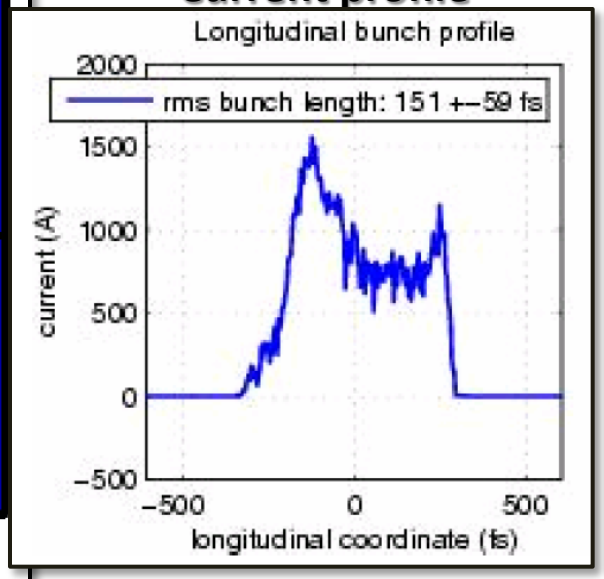
After installation of the linearizer

Before installation of the linearizer

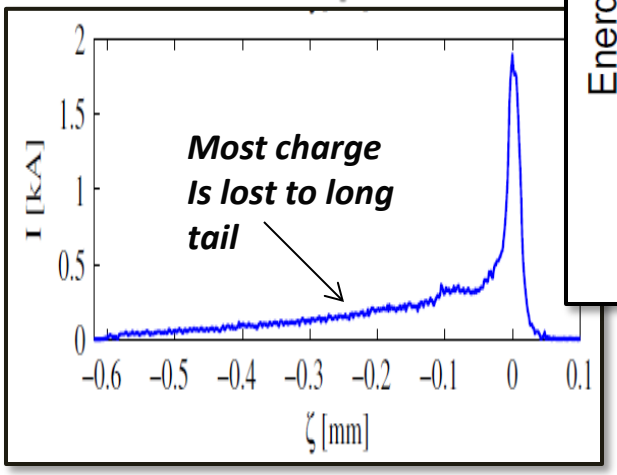
Longitudinal phase space



Current profile

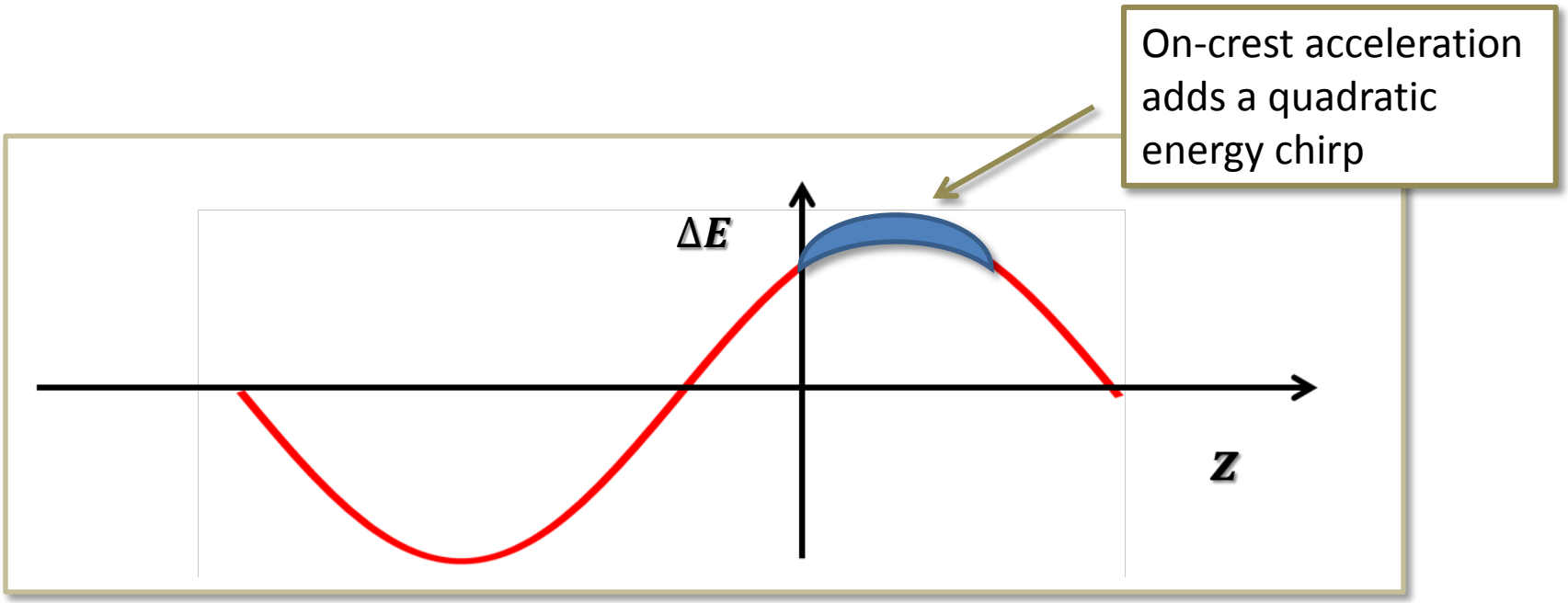


Current profile



Radiation output @13nm increased from $\sim 70\mu m$ to $\sim 400\mu m$ per bunch

RF waveform is the main cause of energy-chirp nonlinearity



- Nonlinear momentum compaction in chicanes also contributes to nonlinearity

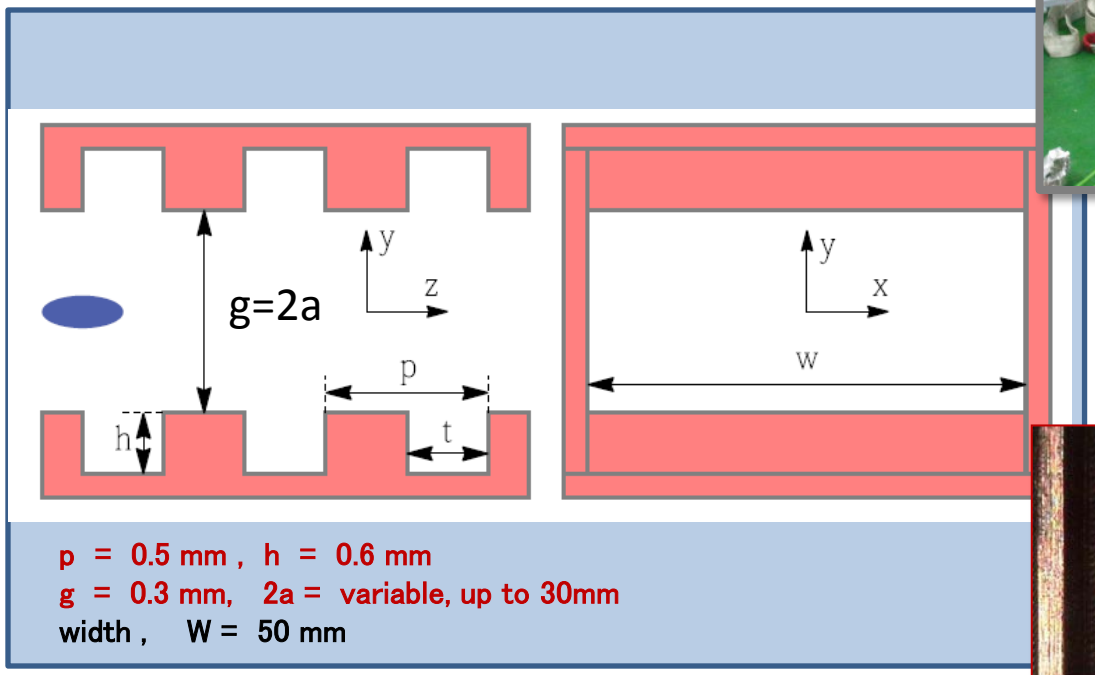
Various ways to linearize the longitudinal phase space

- **Harmonic cavities**
  - effective; method of choice in 4th generation light sources
  - expensive, somewhat inefficient (beam is decelerated)
- **Nonlinear-optics elements in dispersive section**
  - pioneered at JLAB
  - may spoil transverse emittance
- **<u>Longitudinal wake-field enhancing insertions</u>**

Recent experience with passive insertions

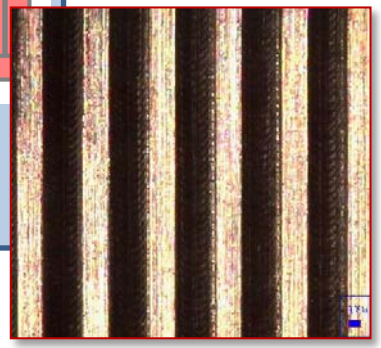
- **Recent experiments in 2013**
  - Dielectric lined tube (BNL*)
  - Corrugated metallic pipe (PAL*)
- **Tested as "dechirpers' (affecting *linear* E/z correlation)**

Mechanical support of 1m insertion (PAL)

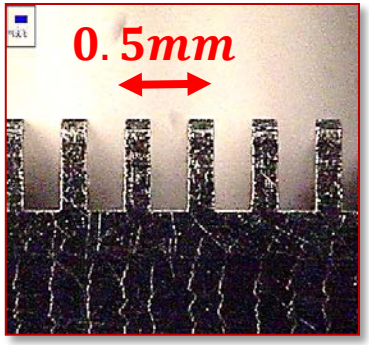


Pipe corrugations:

Top view

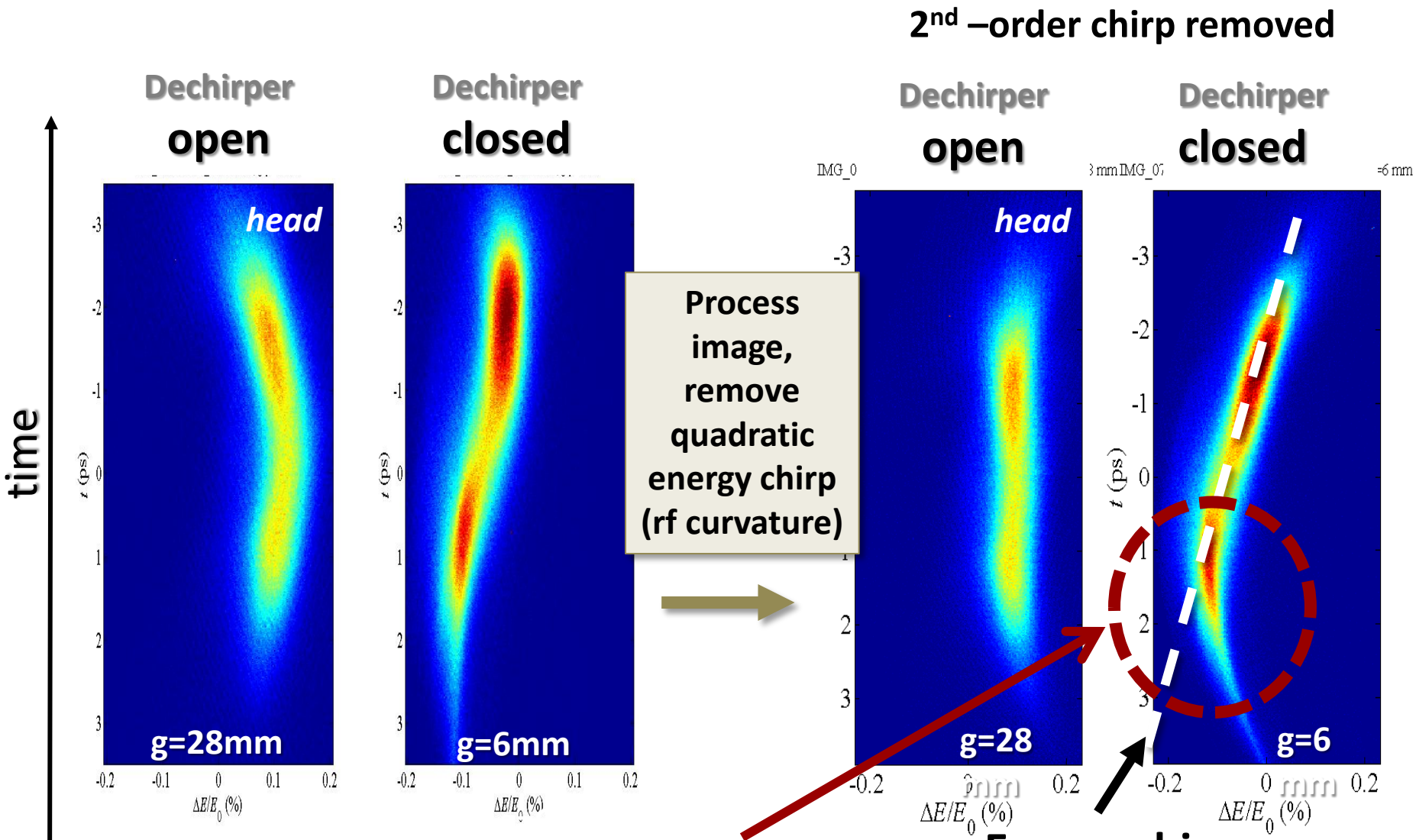


Side view



*S. Antipov, *et al.*, PRL **112** 114801 (2014)
* P.Emma, *et al.*, PRL **112** 034802 (2014)

Time-resolved beam measurements at PAL-ITF



Evidence of wake-field induced curvature (opposite sign to rf's !)

Energy chirp induced by dechiper

Voltage drop induced by corrugated-pipe insertion (rectangular aperture)

Wakefield dominated by single mode

$$w_z(z) \sim \frac{Z_0 c\pi}{16a^2}\cos\frac{2\pi}{\lambda}$$

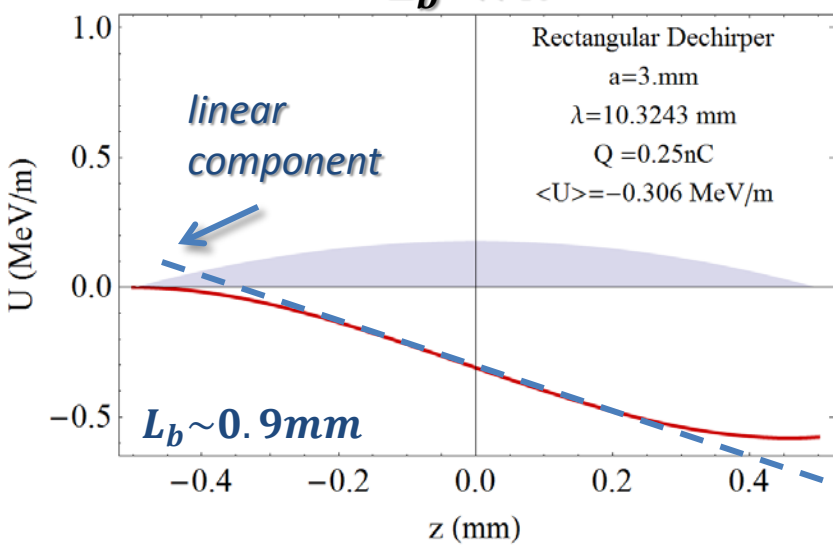
$a = 3mm$
$p = 0.5mm$
$t = 0.3mm$
$h = 1.5mm$

$$\lambda = 2\pi\sqrt{\frac{aht}{p}} = 10.3\ mm$$

$Q = 250pC$

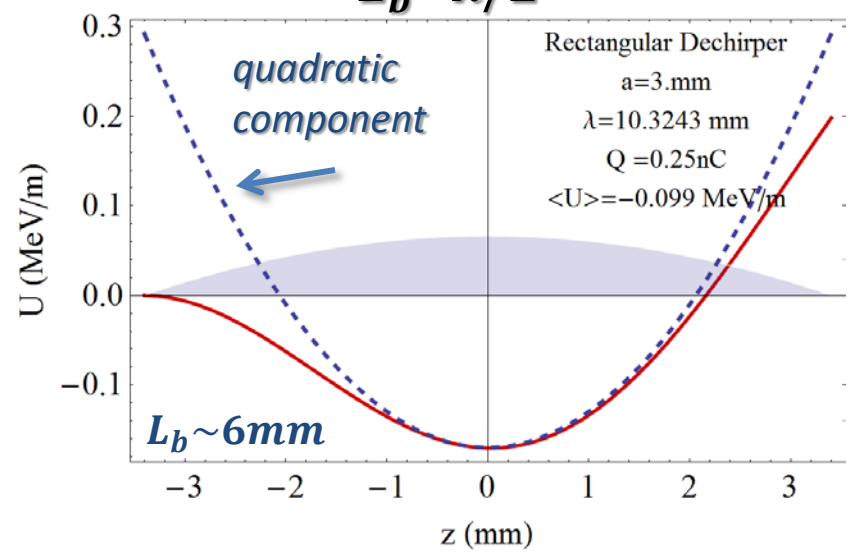
Dechirper regime: *short bunch*

$L_b \ll \lambda$

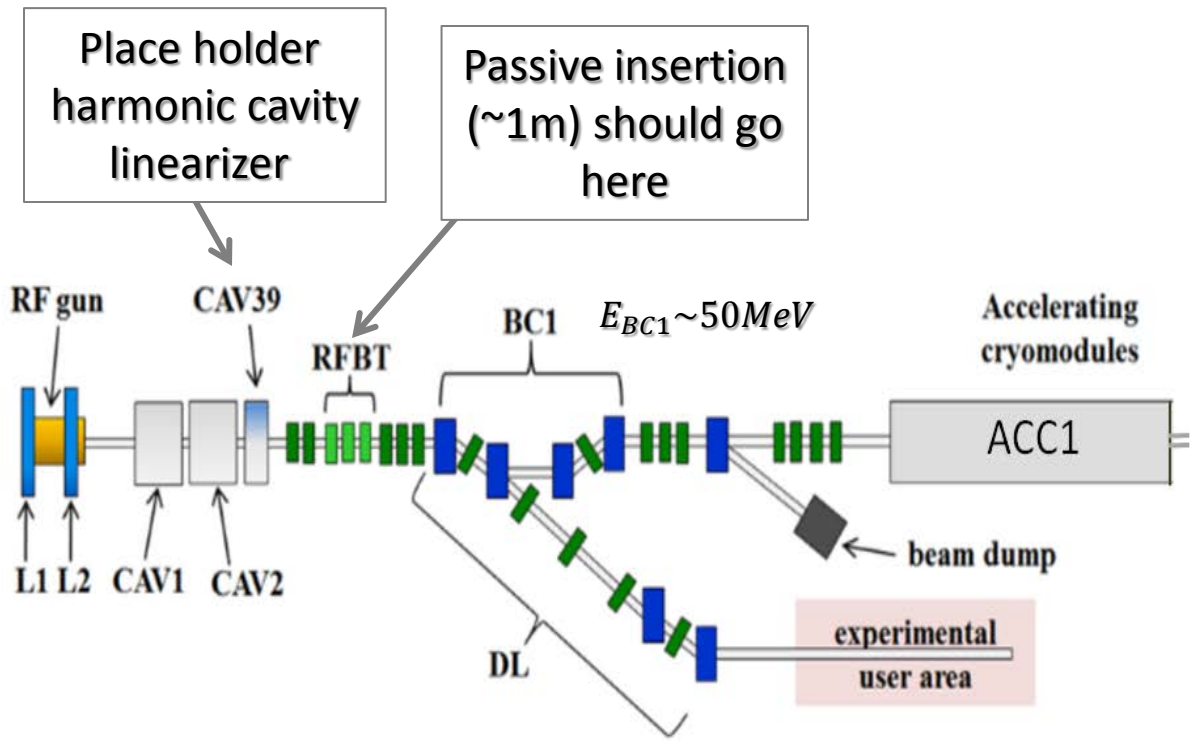


Linearizer regime: *long bunch*

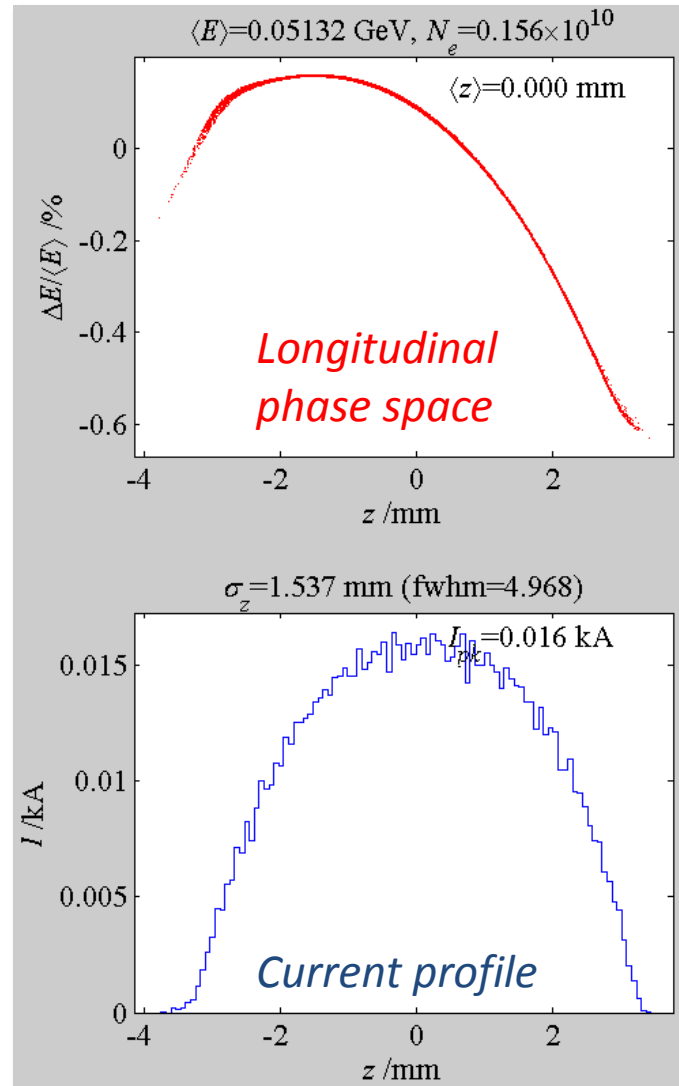
$L_b \sim \lambda/2$



Could a passive insertion linearizer work for ASTA?



Injected beam ($Q = 250pC$)



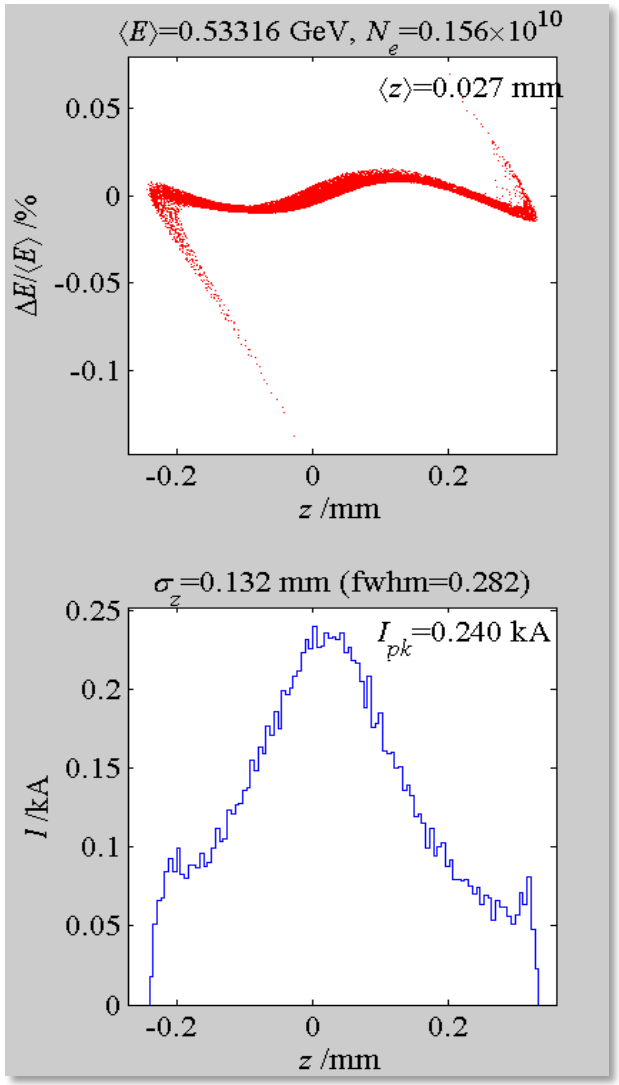
- **Consider moderate charge bunches out of CAV2 (Q=250pC)**
  - ASTRA simulations (P.Piot, et al.)
- **Include 3 CMs (up to 600sMeV)**
- **LiTrack simulation**

ASTA: Compressing with 3.9GHz harmonic cavity

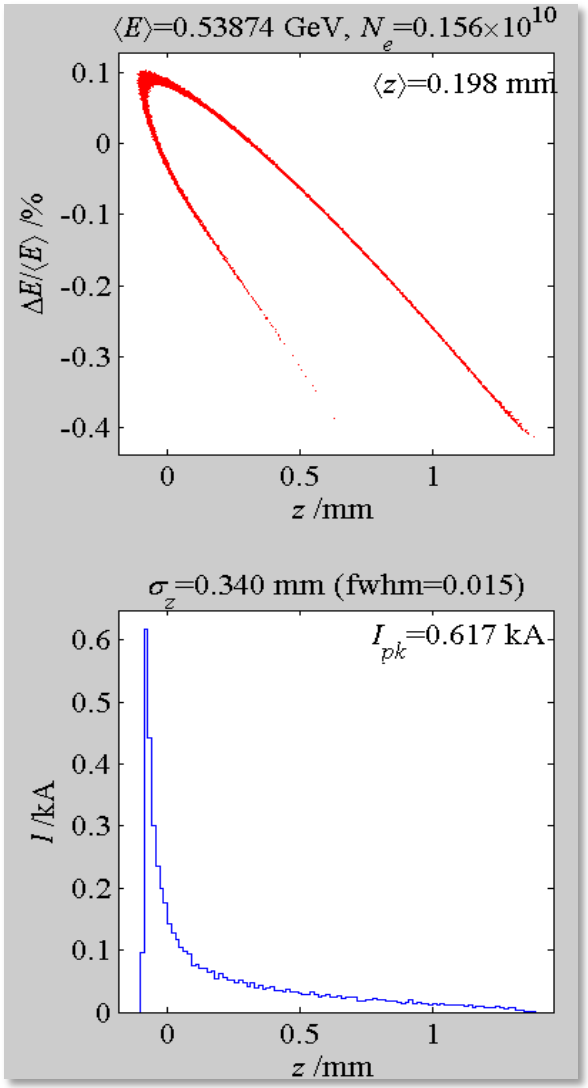
- **We are interested in moderate compressions to limit emittance growth**
  - We may want to compress even less
- Simulation does not include space charge

$$R_{56} = -19cm$$
$$V_{HL} = 6MV$$

Linearizer ON

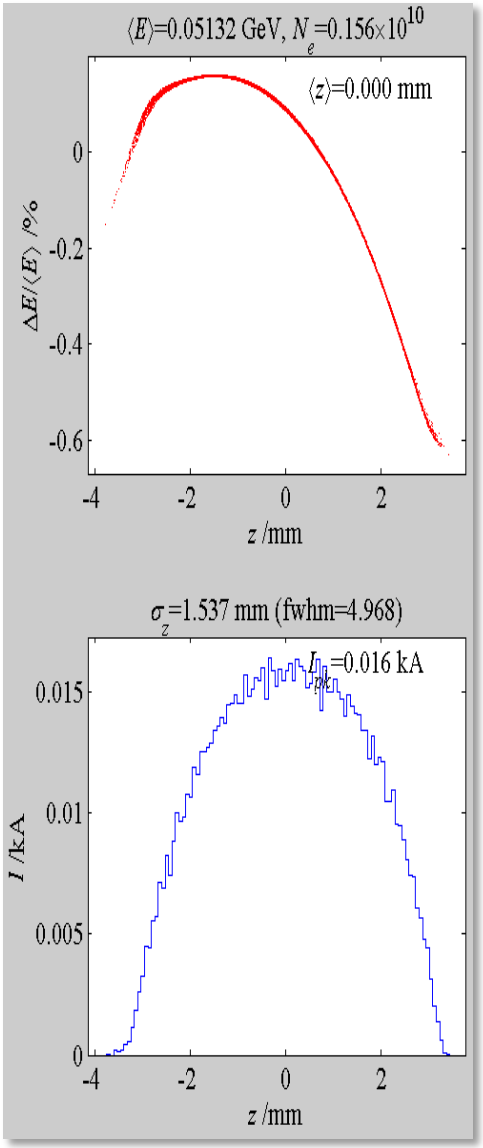


Linearizer OFF

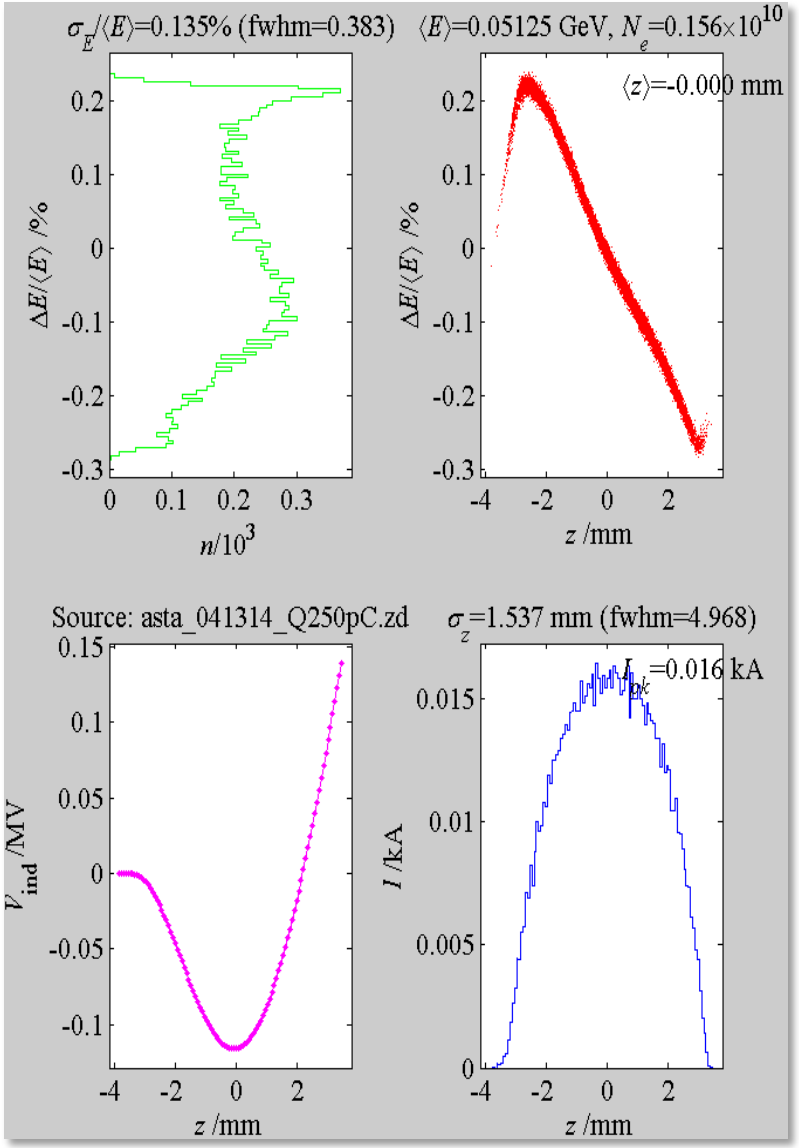


Replace harmonic cavity with corrugated 0.7m pipe

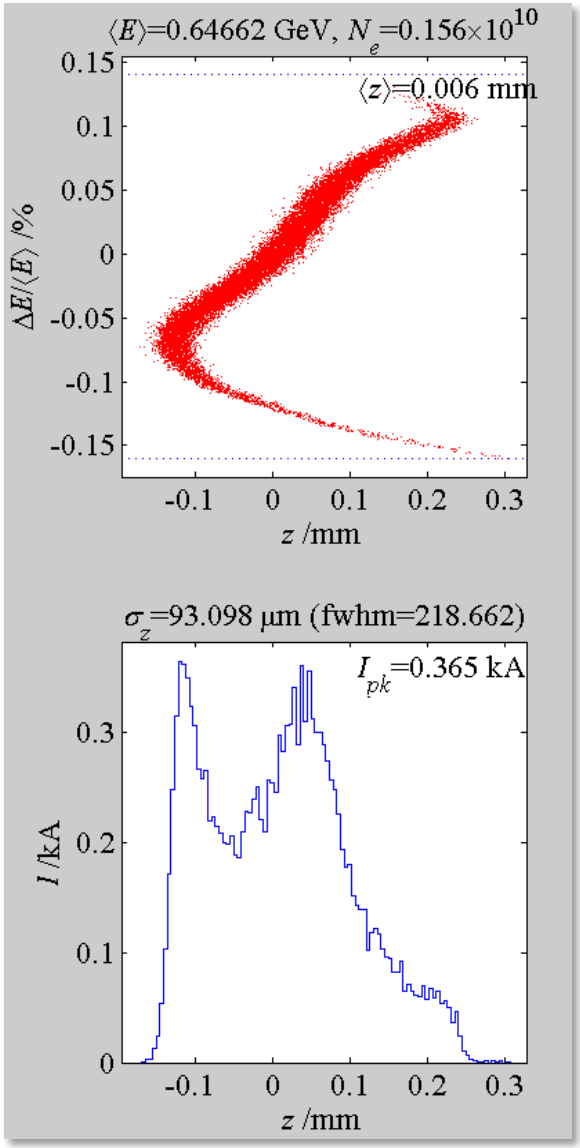
Injected beam



Exit of Insertion



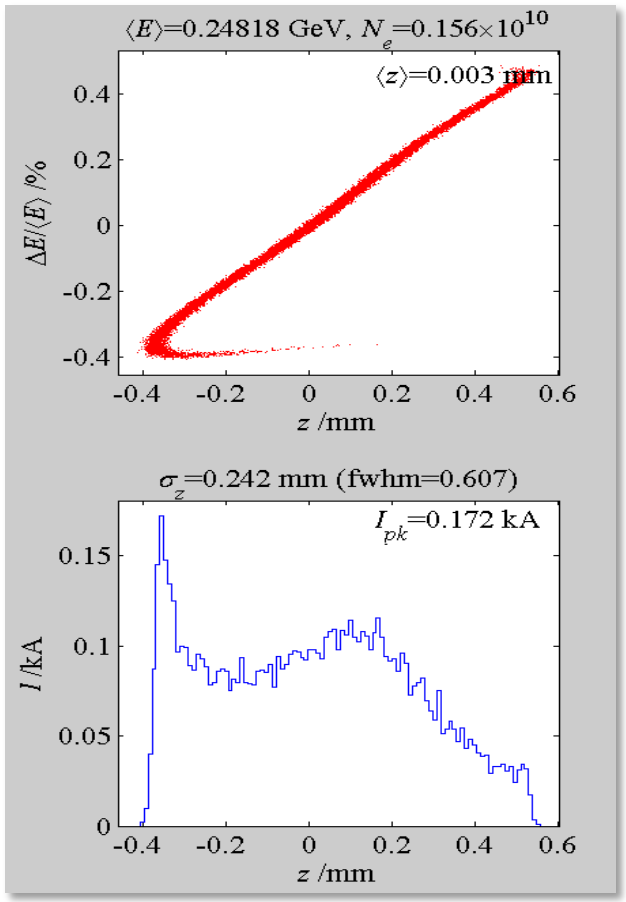
Exit of machine



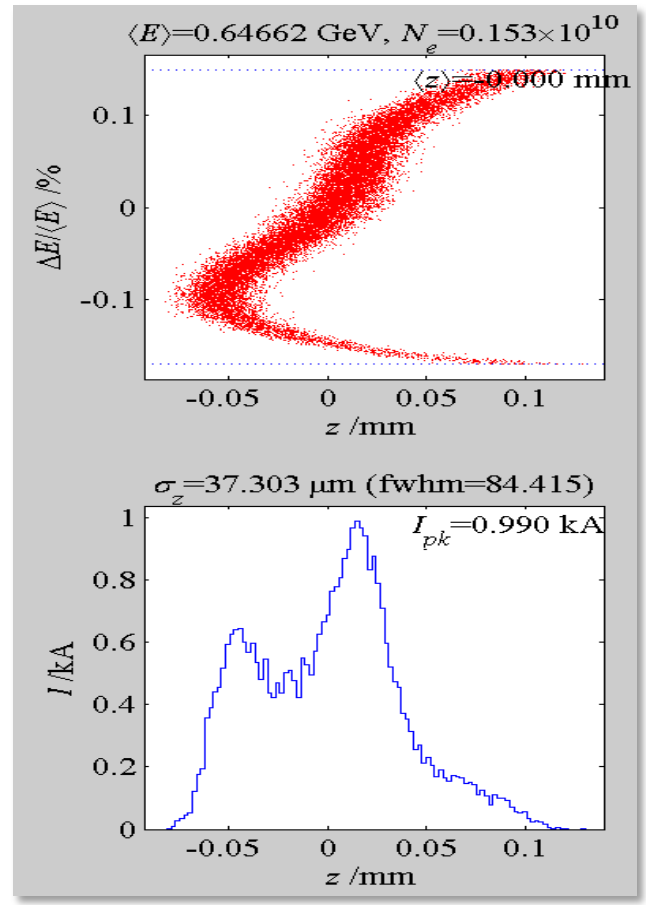
Introducing a 2nd bunch compressor (at ~250MeV)

- As a way to increase compression, preserve beam quality
- Same 0.7m long passive insertion

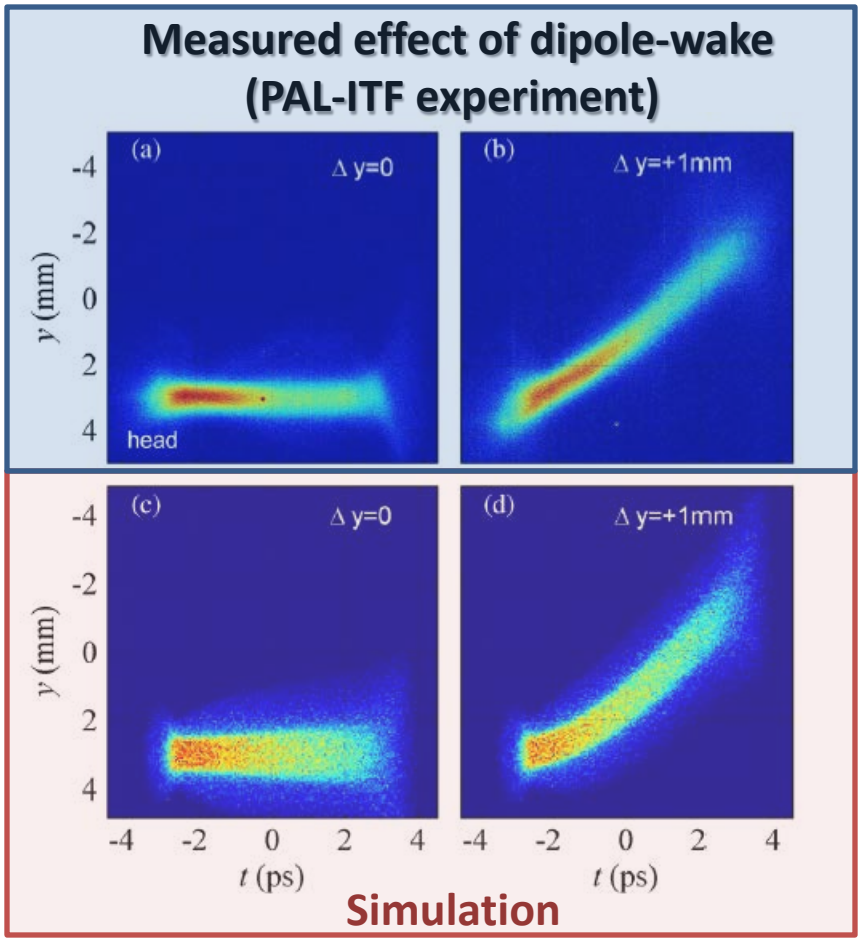
Exit of BC1

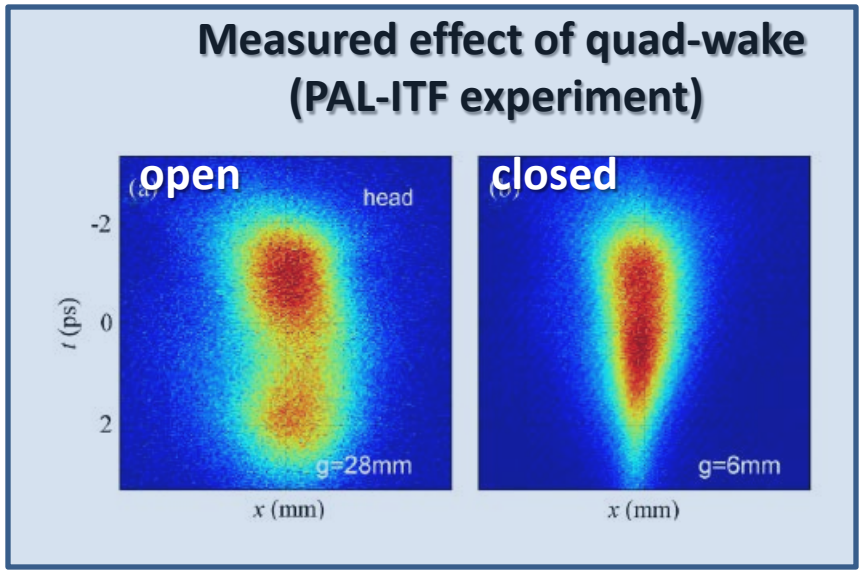


Exit of machine



Perturbation to transverse dynamics





- **Good control of beam needed to avoid dipole-like kicks**
- **Quad-wake (characteristic of rectangular aperture geometry) will cause projected emittance growth even if beam is well centered**
  - Use a circular aperture insertion (at cost of tunability)?

Conclusions

- **Linearization by passive insertion may work for ASTA.**
  - Cheap!
- **Not 'as clean' as linearization by harmonic cavities:**
  - higher order-nonlinearities cause appearance of current spikes
  - It may be adequate for moderate compression
- **Effects on transverse dynamic to be considered in a serious feasibility study**
  - Include space charge
- **To avoid quad-wake effects a circular aperture insertion may be used instead**
  - at cost of tunability

Acknowledgments

- P.Piot for providing the macroparticle file off the ASTA injector