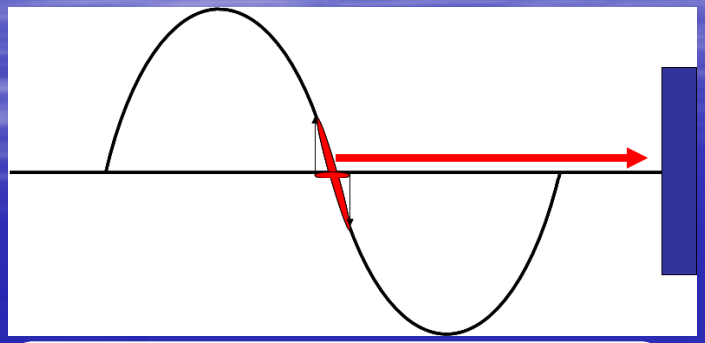
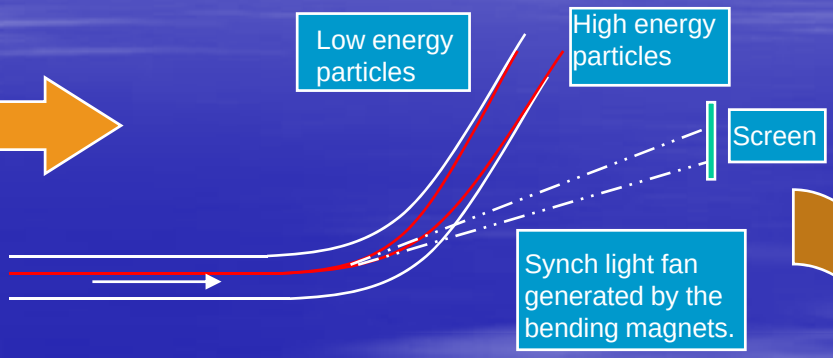
Picosecond bunch length measurements at ESA

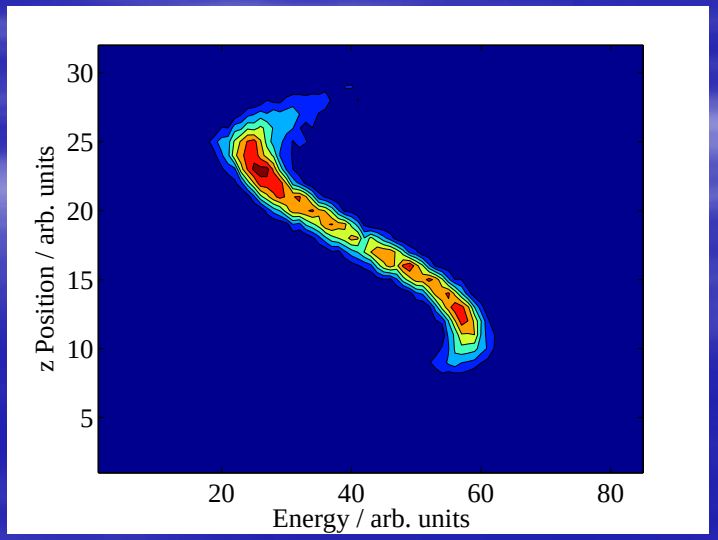
Absolute Bunch Length Measurements



S-band transverse cavity (LOLA) gives kick to particles proportional to their longitudinal position in the bunch



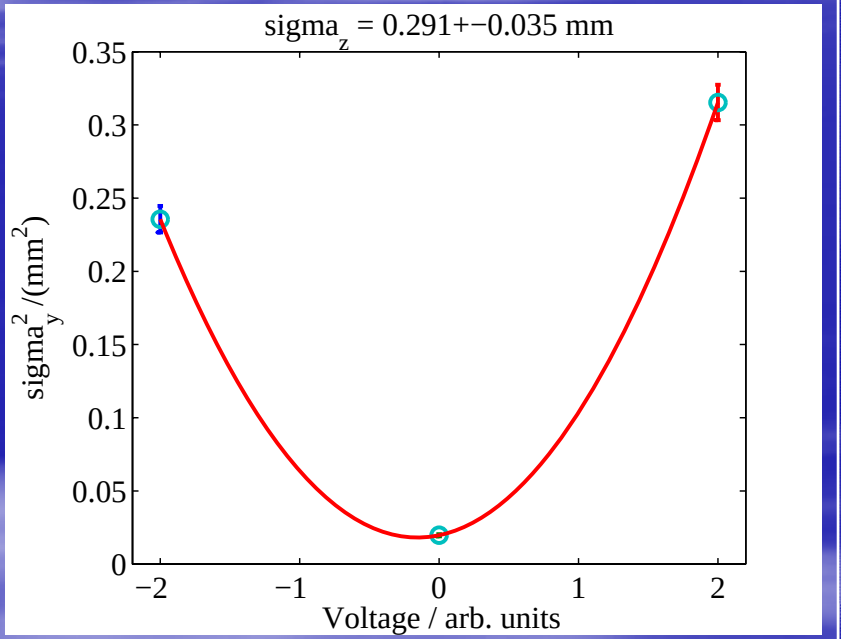
- 24.5degree A-line bend generates a synch-lite fan that is imaged on a screen.
  - Width of image gives energy spread.
- LOLA expands the beam in time along the vertical axis of the screen.
- Image is therefore an expansion in both longitudinal degrees of freedom.



Screen Calibration

- Energy axis:
  - Move the set point of the energy feedback.
  - Digitise the image on the screen.
  - Correlate the mean of the horizontal projection with the beam energy.
- Longitudinal position axis
  - Alter the LOLA phase.
  - Digitise the image on the screen.
  - Correlate the mean of the vertical projection with LOLA's phase.
  - Use the known frequency of the LOLA RF to convert this to a correlation against z position.

Bunch length calculation



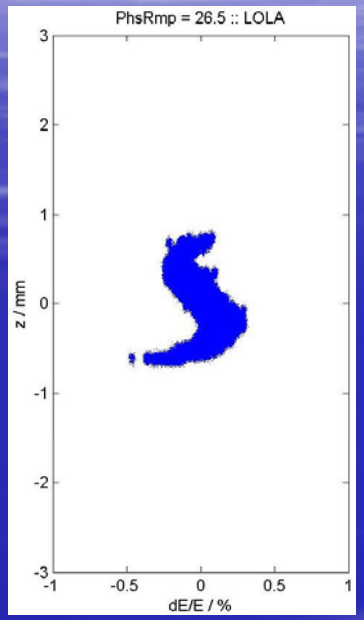
- Vertical size of image will have several components:
  - Bunch length (z).
  - Bunch height (y).
  - Bunch tilt (dy/dz).
- y may be extracted by measuring three times:
  - LOLA on
  - LOLA on at opposite phase
  - LOLA off
- A parabolic fit of the image height yields the bunch length.

Bunch length in ESA

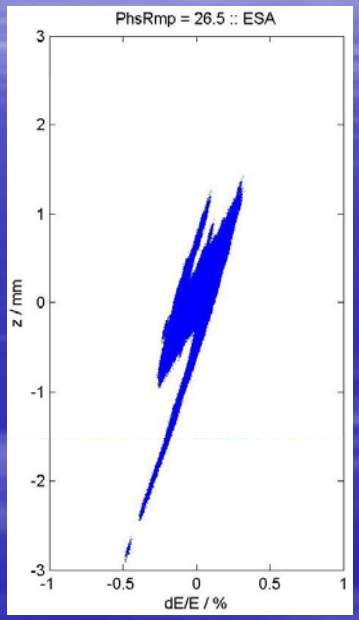
Create a several thousand particle bunch in Matlab with the measured distribution.

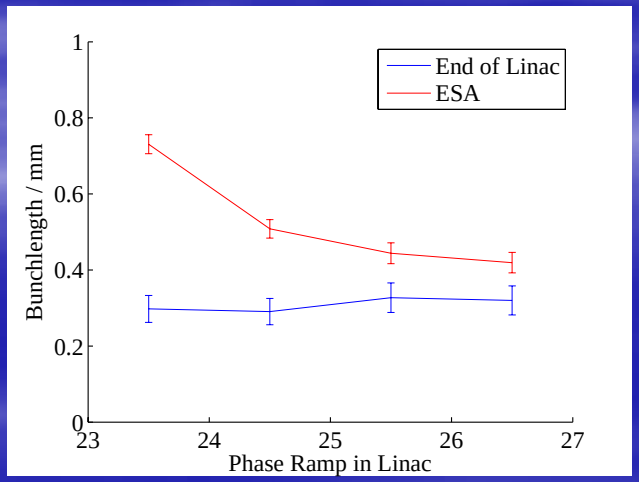
Use the R56 (0.465 m) of the A-line to calculate the distribution in ESA.

LiTrack was used, but a simple matrix multiplication suffices.



$$\begin{pmatrix} L_2 \\ dP_2/P_2 \end{pmatrix} = \begin{pmatrix} 1 & R_{56} \\ 0 & 1 \end{pmatrix} \begin{pmatrix} L_1 \\ dP_1/P_1 \end{pmatrix}$$

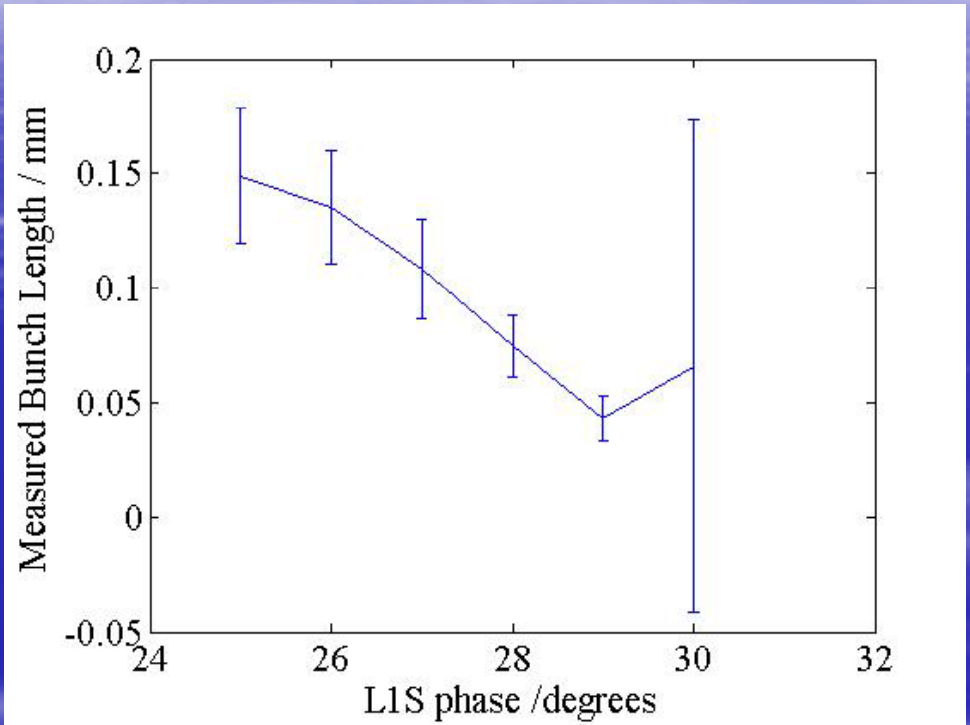




The measurements were made for a series of linac phase settings to change the E-z correlation.

Bunch lengths of ~400 -> 800 microns were achieved.

Lower range of measurement



- LCLS is capable of compressing bunches to the point at which coherent synch radiation breaks them up.
- Brought LCLS beam into ESA, and measured the bunch length with LOLA for various settings of their compressor.
- Measured down to ~50 microns.

Relative Measurements

- Direct bunch length measurements in ESA are based on measuring the radiation emitted as the beam passes a ceramic gap.
- The spectrum is determined by the bunch shape,
  - Shorter bunches will contain more power at high frequencies.

$$P(\omega) \propto Q^2 \exp\left(-\frac{\omega^2 \sigma_z^2}{c^2}\right)$$

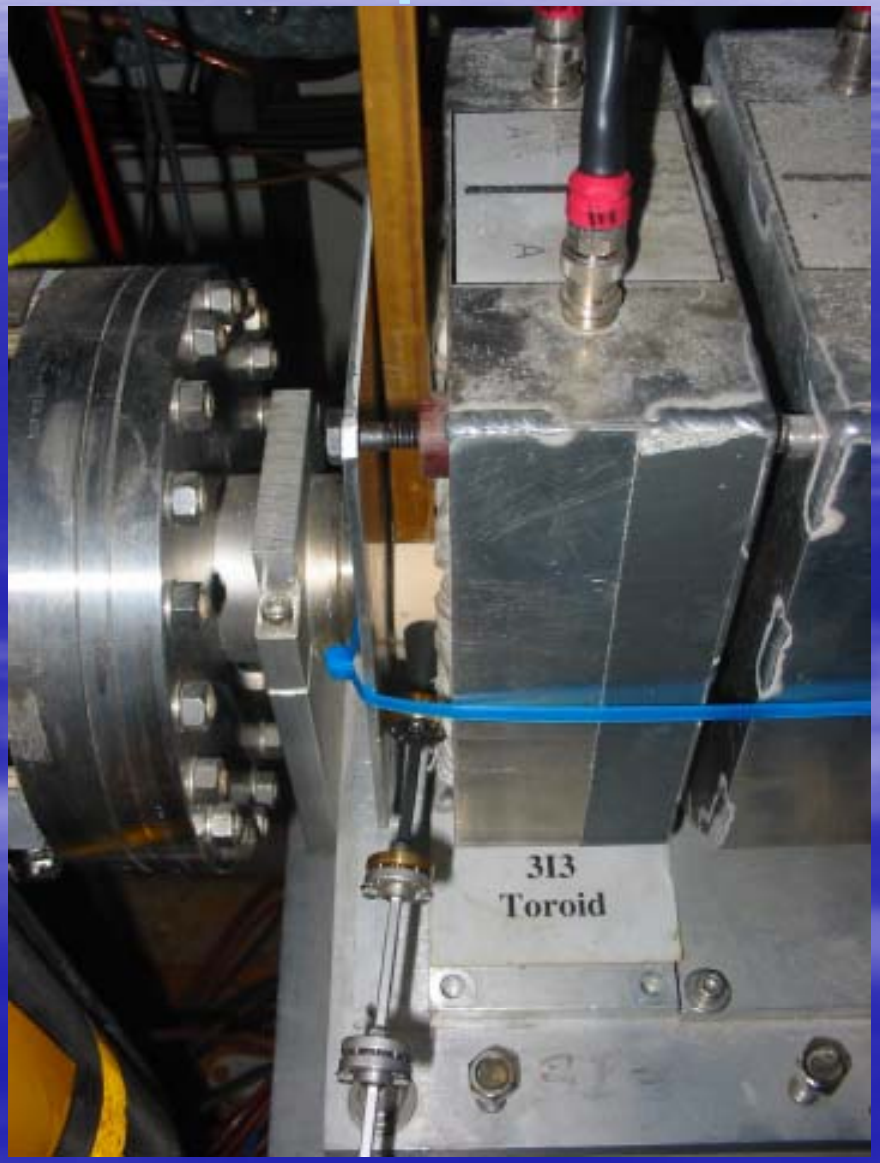
- Measure the power at frequencies with a large dependence on the expected length range.

Experimental Setup

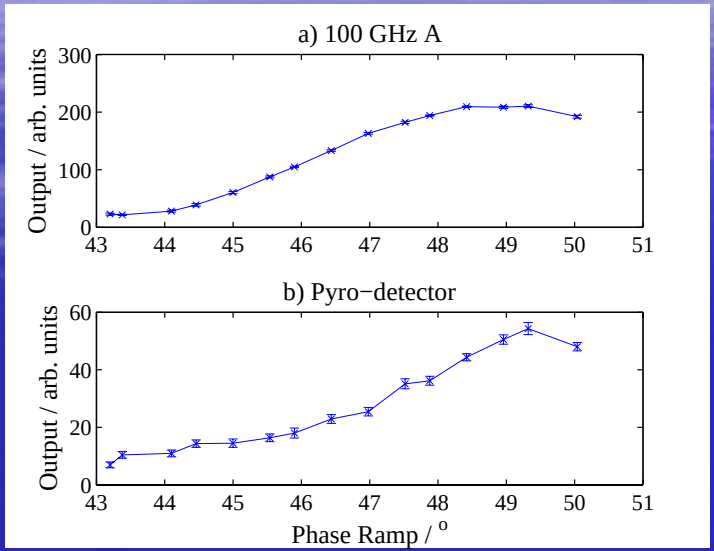
Bring the power from the gap to the detector diodes using appropriate waveguide.

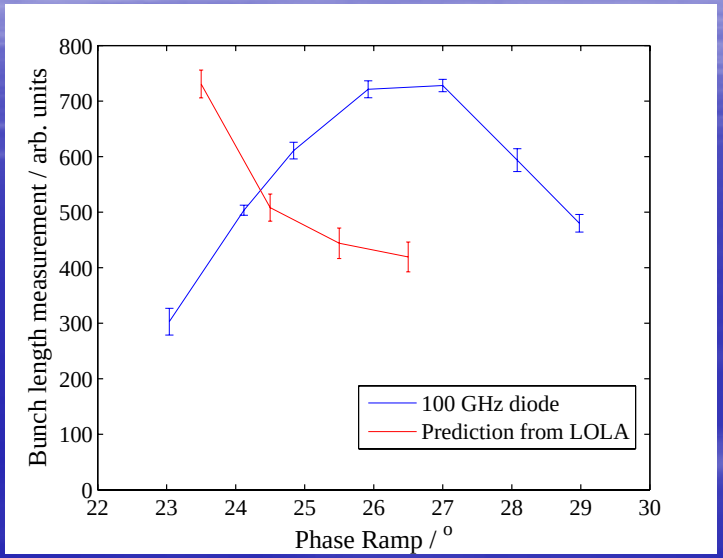
Sampled the RF at 16 GHz, 23 GHz, and 100 GHz.

Downstream of this point, a pyro-detector was used to monitor a second ceramic gap.



Results, and Conclusions





The 100 GHz diode and pyro-detector have a clear dependence on linac phase.

The pyro-detector peaks later as its wideband sensitivity allows it to measure shorter bunch lengths.

As expected, the 16 and 23 GHz showed no dependence due to their low frequency.

Comparison of the LOLA results with the 100 GHz results, showing sensitive range of the diode is ~0.4 -> 1 mm.

This is consistent with the theory.