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Detecting Partial Energy Modulation in a Dielectric Laser Accelerator

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Abstract

The Dielectric Laser Acceleration group at SLAC uses micro-fabricated dielectric grating structures and conventional infrared lasers to accelerator electrons. These structures have been estimated to produce an accelerating gradient up to 2 orders of magnitude greater than that produced by conventional RF accelerators. The success of the experiment depends on both the laser damage threshold of the structure and the timing overlap of femtosecond duration laser pulses with the electron bunch. In recent dielectric laser acceleration experiments, the laser pulse was shorter both temporally and spatially than the electron bunch. As a result, the laser is theorized to have interacted with only a small portion of the electron bunch. The detection of this phenomenon, referred to as partial population modulation, required a new approach to the data analysis of the electron energy spectra. A fitting function was designed to separate the accelerated electron population from the un-accelerated electron population. The approach was unsuccessful in detecting acceleration in the partial population modulation data. However, the fitting functions provide an excellent figure of merit for previous data known to contain signatures of acceleration.

Why Work on Improving Particle Accelerators?

Accelerators are not just for Particle Colliders

Applications of Particle Accelerators

X-ray Free Electron Lasers

Accelerator Driven Nuclear Fission

Radiation Sources for Cancer Therapy

Particles accelerators must be more **compact** and **economical**

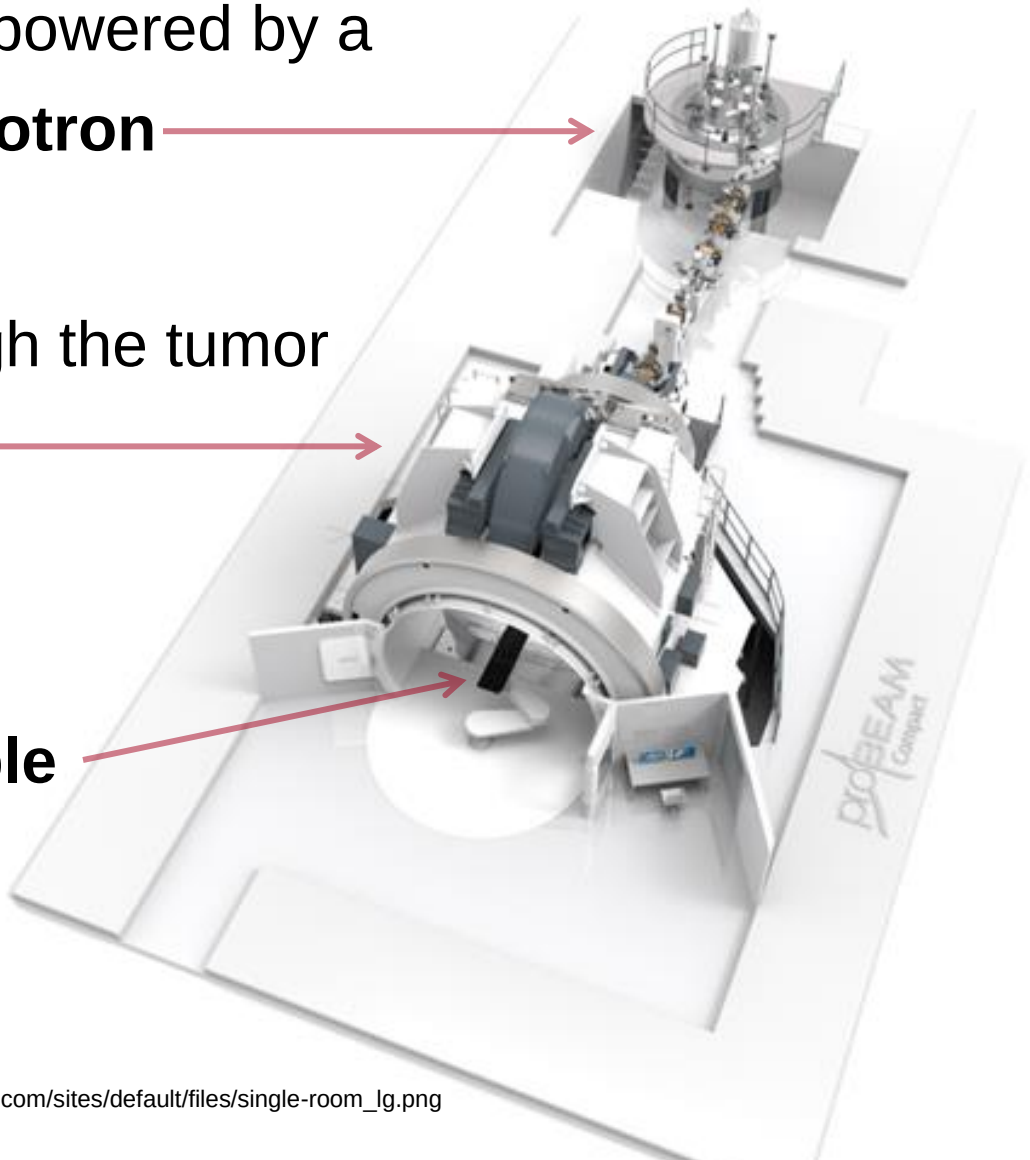
Varian ProBeam® Single-Room Proton Therapy System

SLAC

250MeV Proton source powered by a **Superconducting Cyclotron**

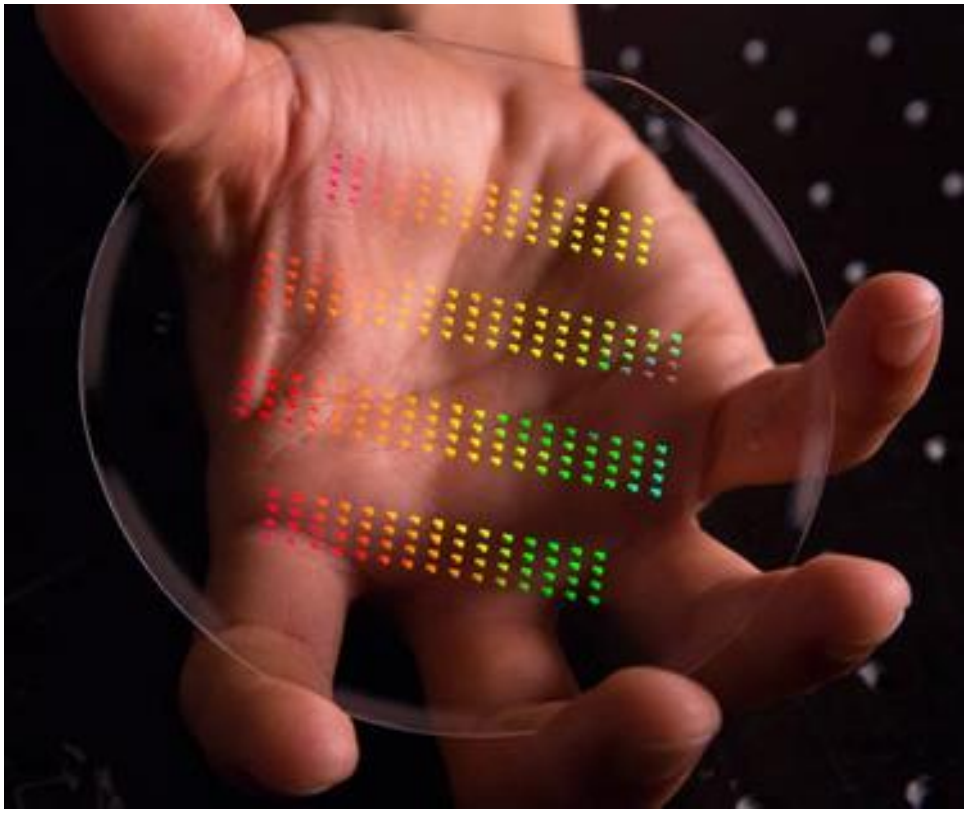
Beam is scanned through the tumor via a **Gantry**

The patient lays on a **Robotic Treatment Table**



https://www.varian.com/sites/default/files/single-room_lg.png

Particle Accelerator on a Chip



http://www.nanowerk.com/news2/id32510.jpg

Transitioning from RF to optical wavelengths

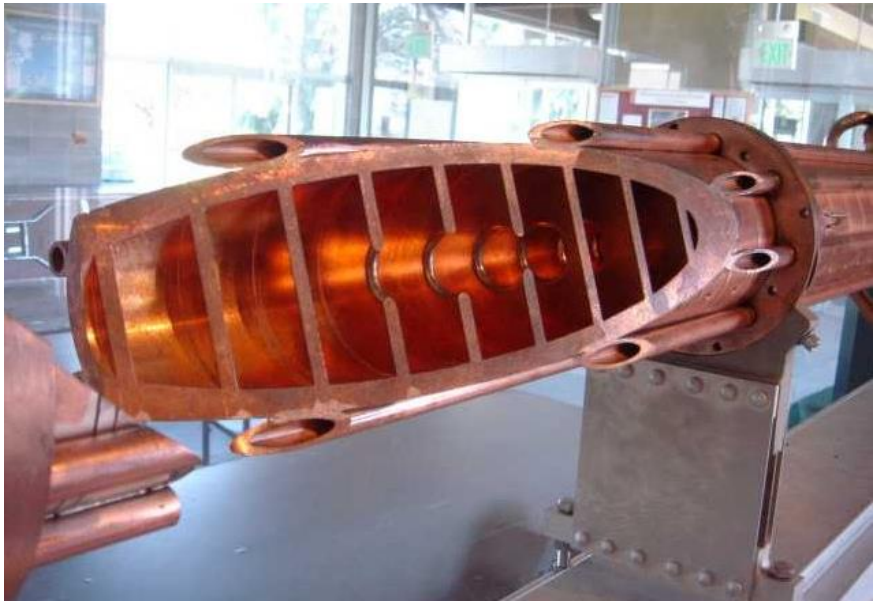
Characteristic scale of accelerating structure reduced to optical wavelengths

Lasers produce **large electric fields** and are **commercially available**

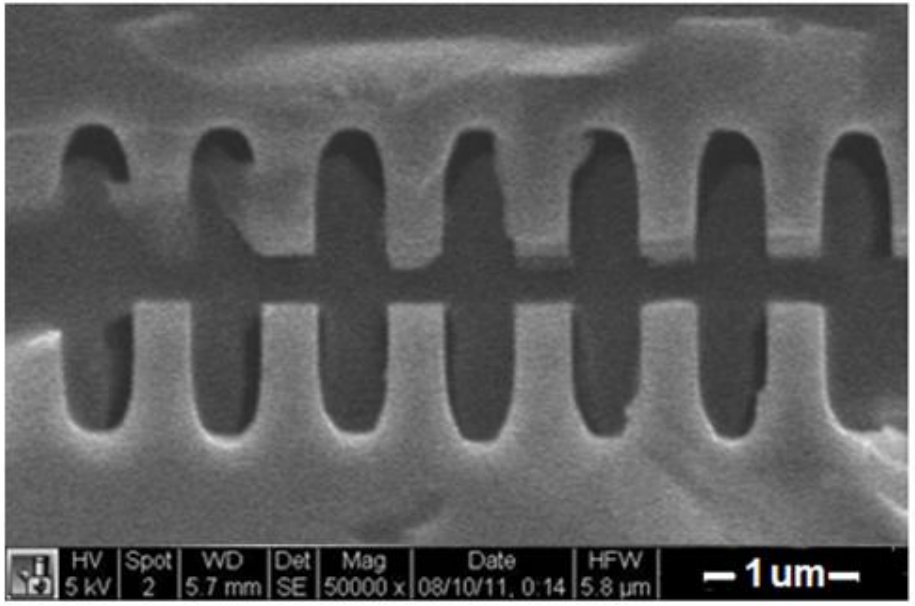
Radiofrequency accelerator structures breakdown at electric fields around 100 MV/m and are **expensive** to **construct** and maintain

Dielectrics have **High Damage Threshold**: 1 GV/m!

Radiofrequency vs. Optical Waveguides



SLAC Main Linac
~10cm



SEM of Grating Structure
~1um

How the Dielectric Laser Accelerator Works

https://www.youtube.com/watch?feature=player_embedded&v=V89qvy8whxY

Search for Acceleration

Time of Arrival of Laser Pulse is scanned

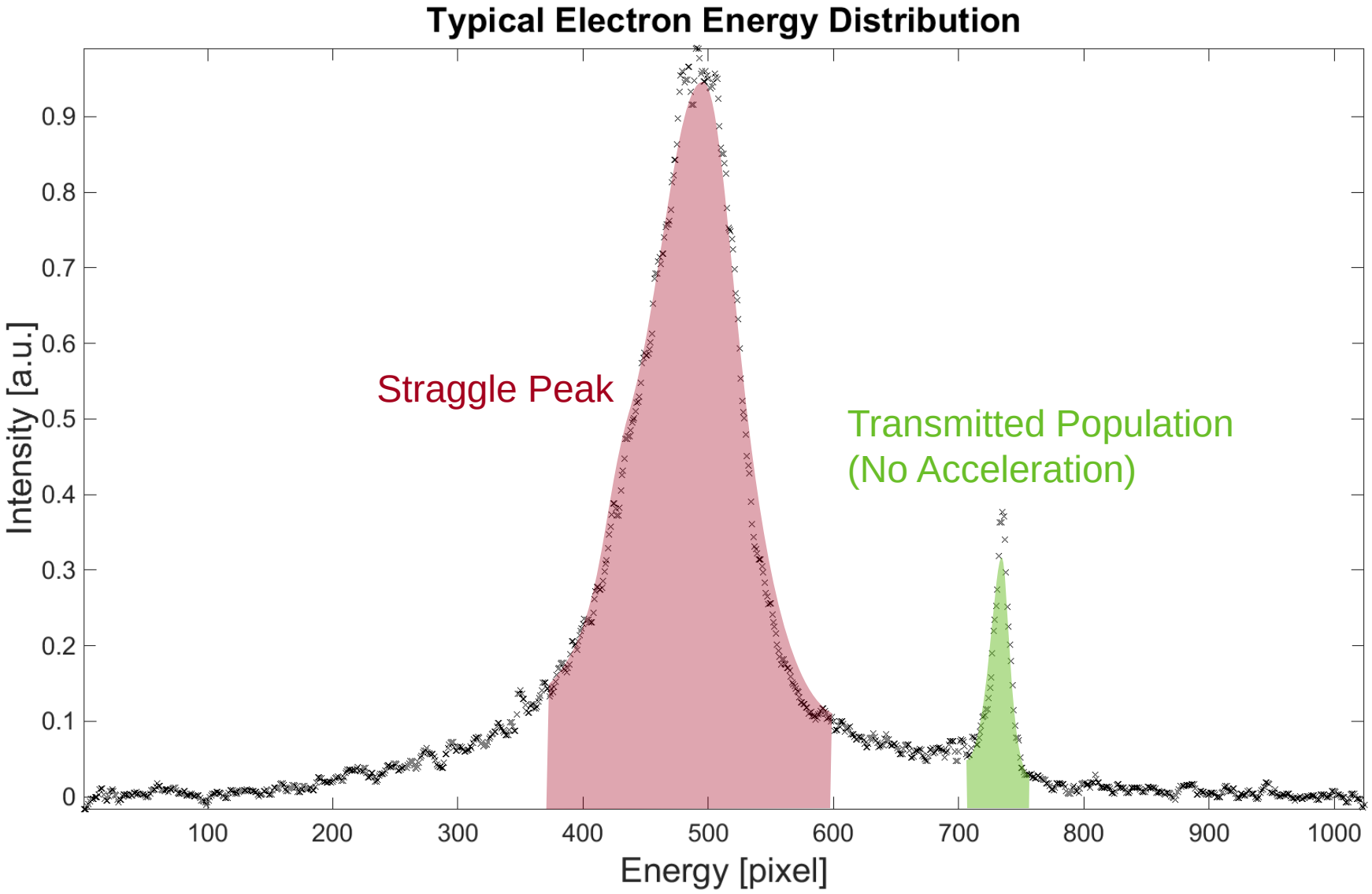
Laser On events are compared to **Laser Off** events

Spectrometer records the energy distribution of each shot of electrons sent through the accelerator

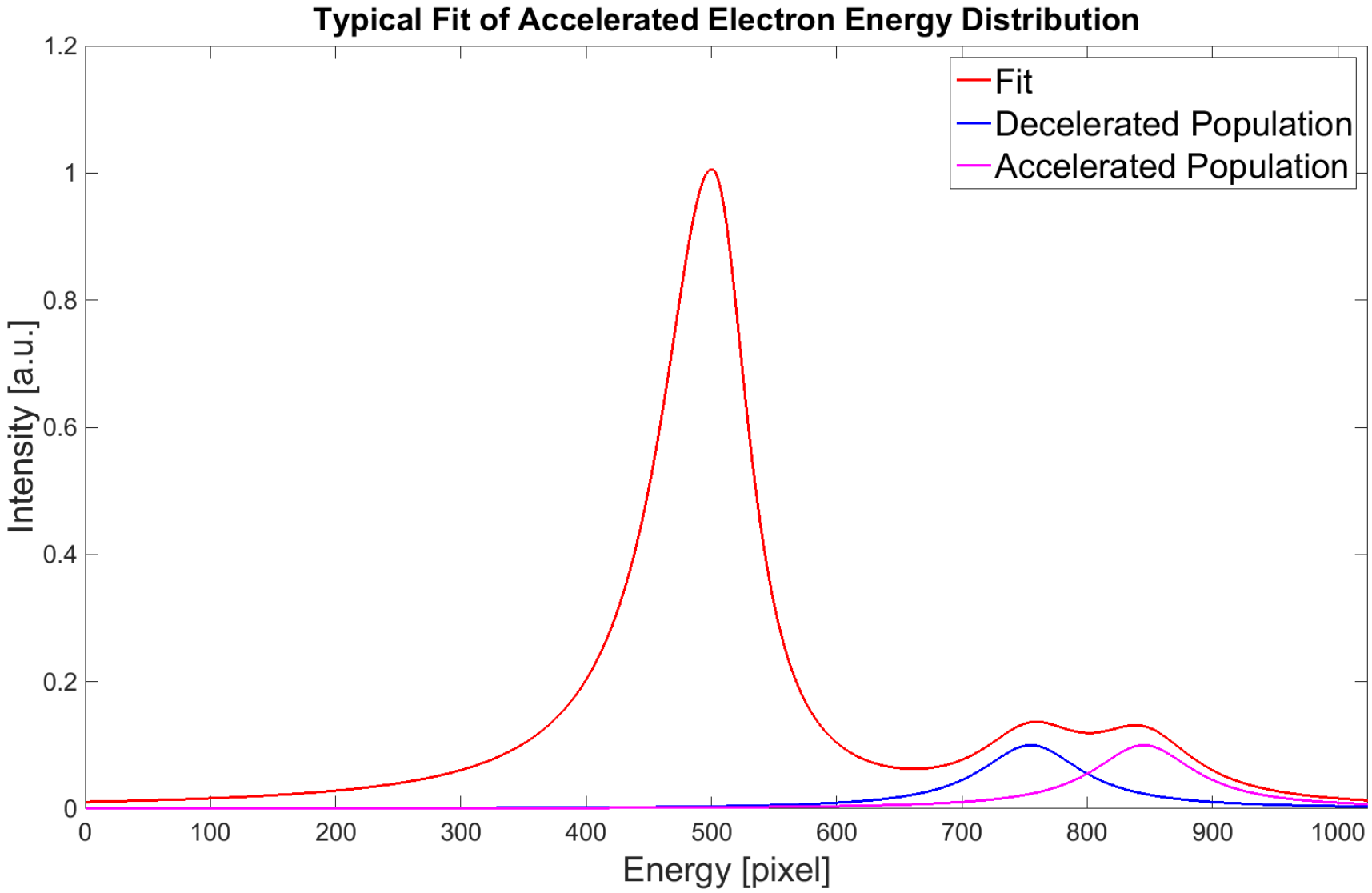
Fitting functions are used to create figures of merit for spectrometer data

Figures of Merit used during experiment for optimization

Typical Single Shot Electron Energy Distribution



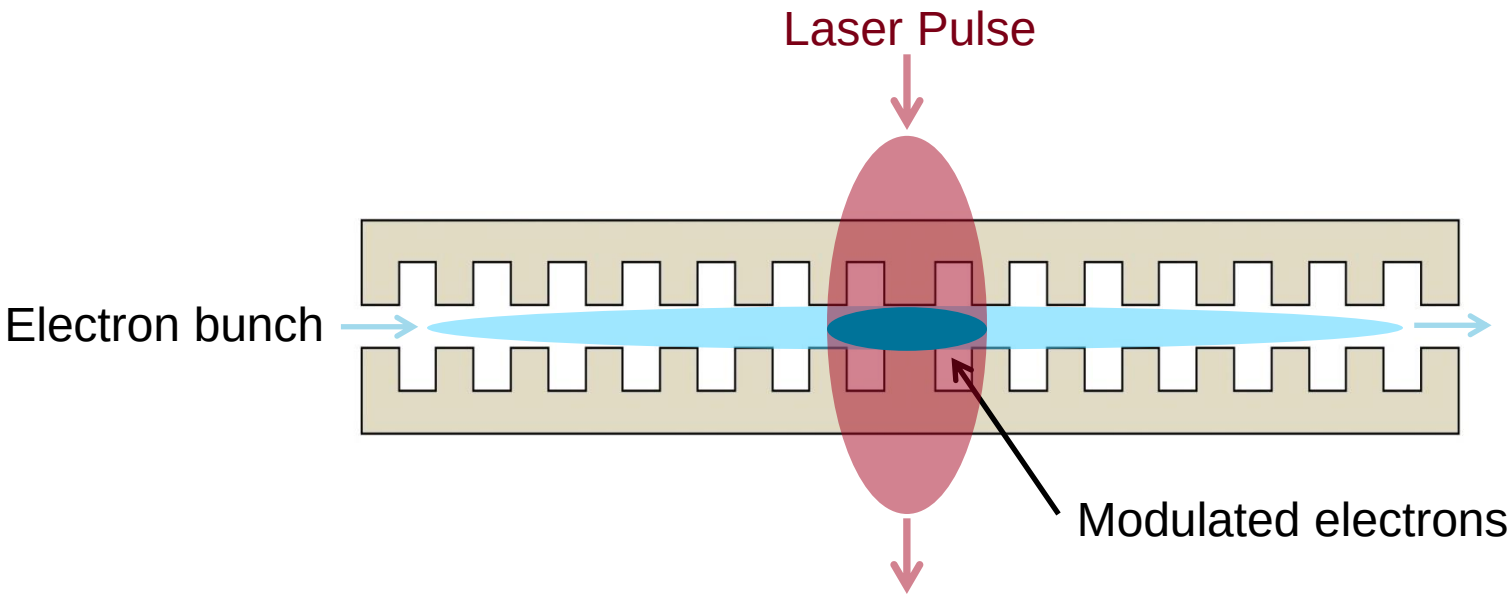
Fit Assumed for Previous Experimental Runs



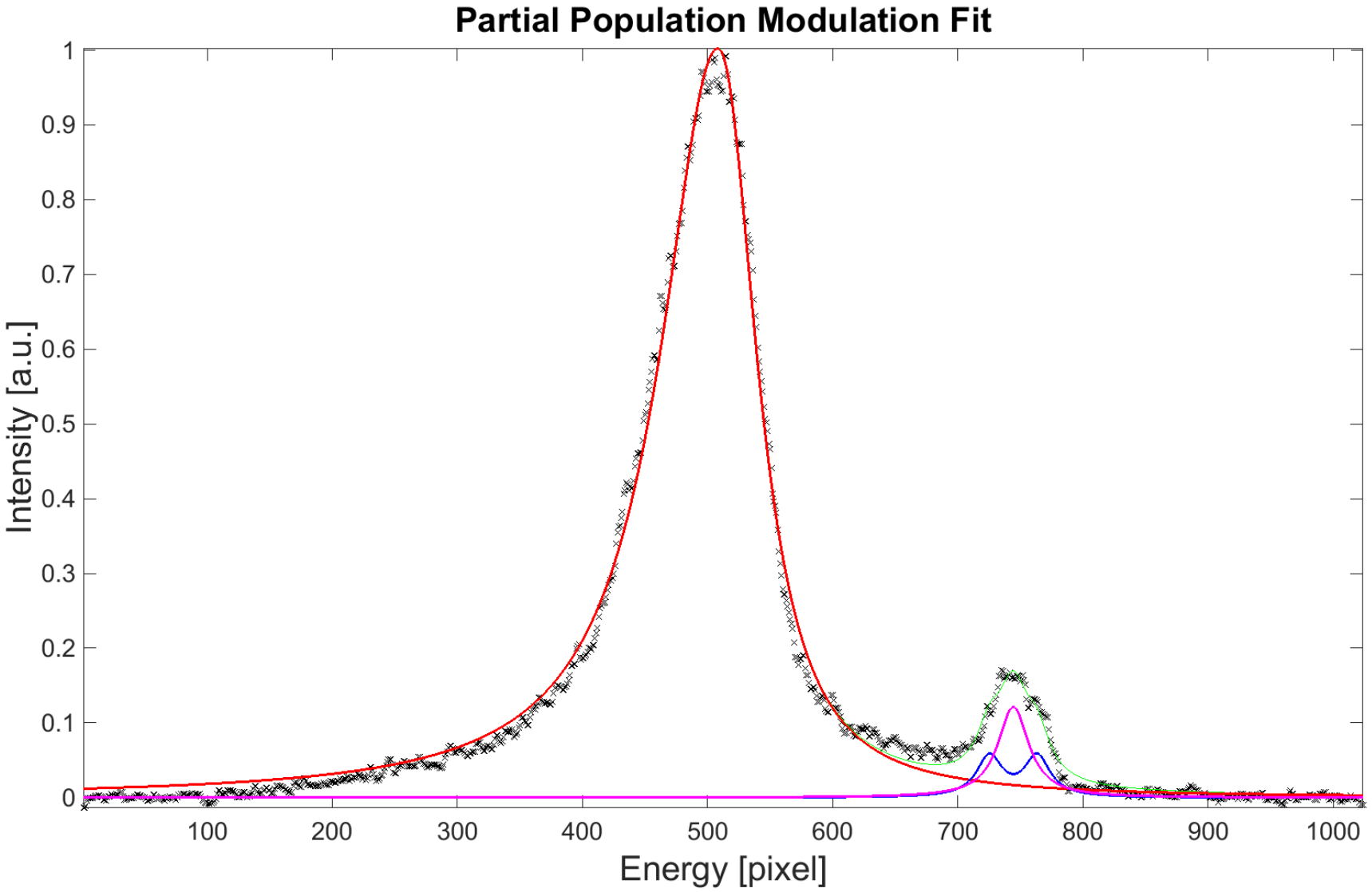
Partial Population Modulation

Recent experiments used a laser pulse that was shorter both **spatially** and **temporally** than the electron beam

Partial modulation: Only a fraction of the electron beam is accelerated by the laser interaction



Example of a Partial Population Modulation Fit

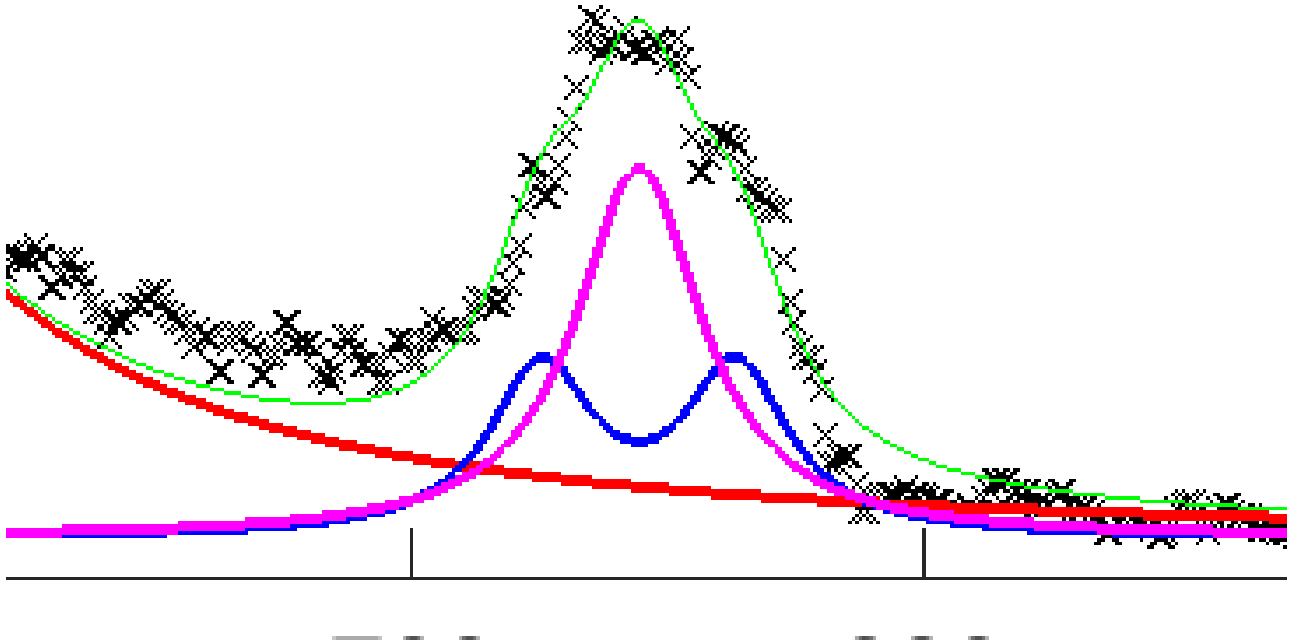


Close Up of Transmitted Peaks

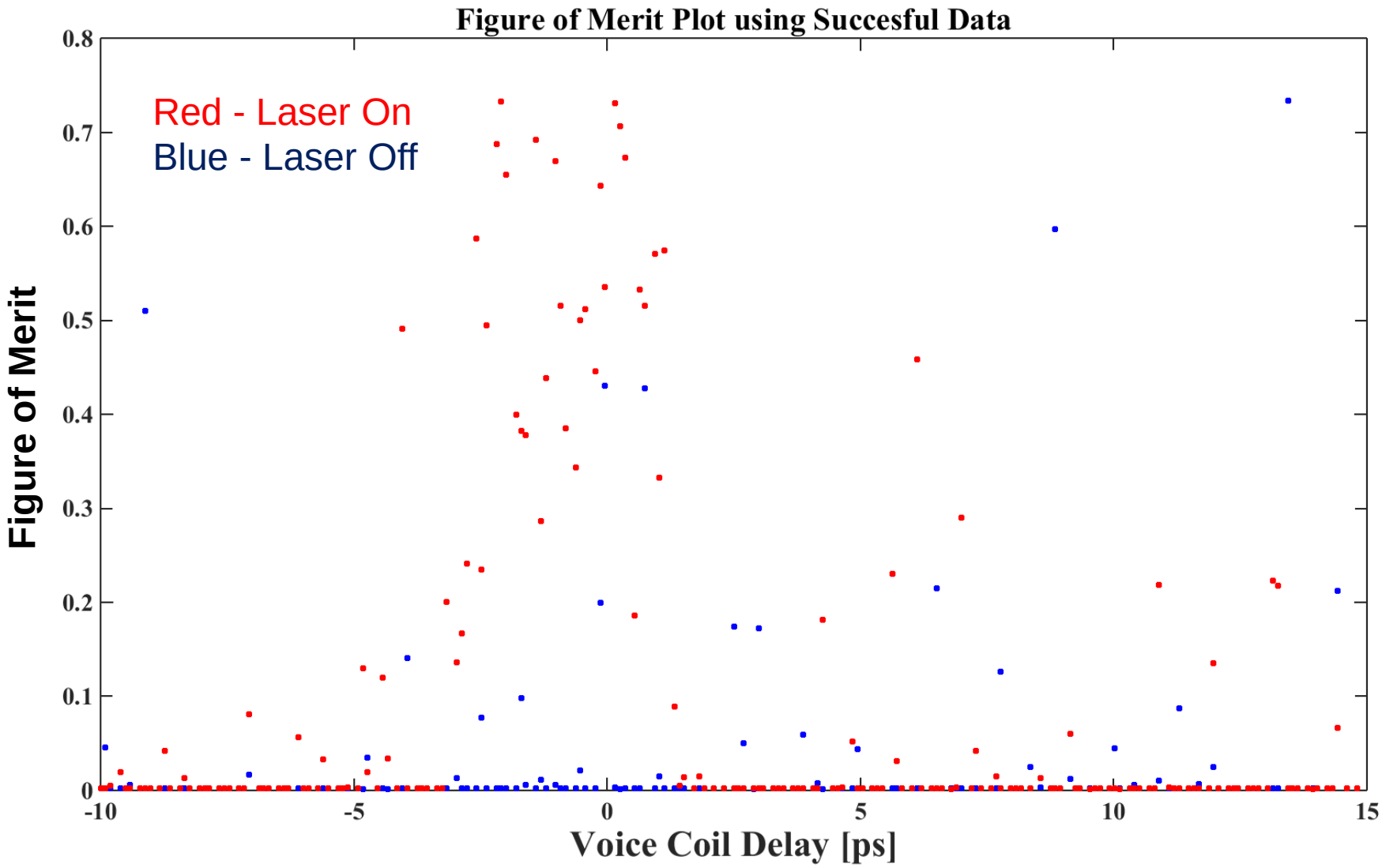
Blue: Modulated Peaks

Purple: Unmodulated Peaks

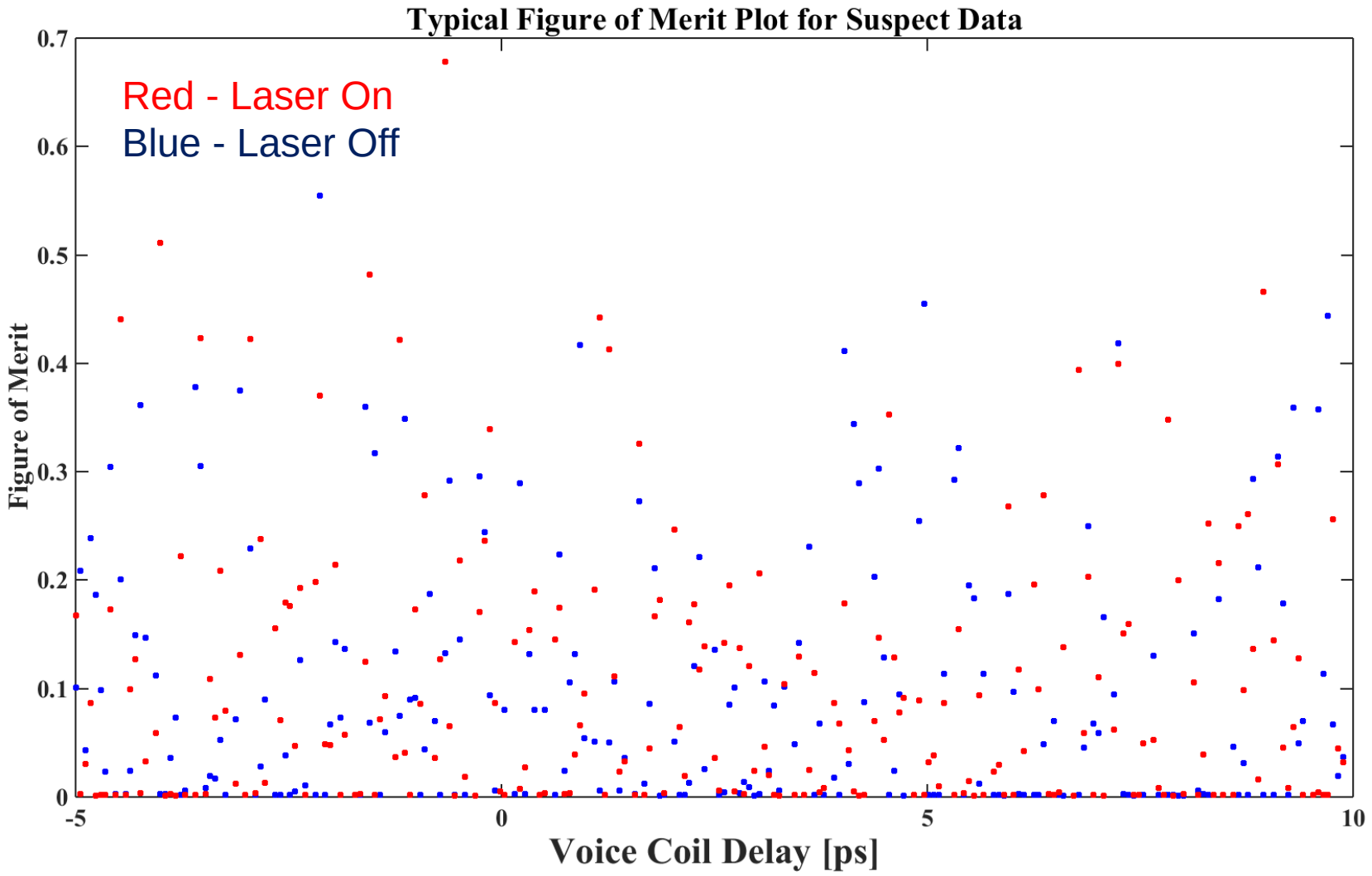
Red: Straggle Peak



Testing the Fit on Good Data



Trying to Fit New Data



What Did We Learn?

Small signals are difficult to detect

Future experiments: Laser should cover the whole beam

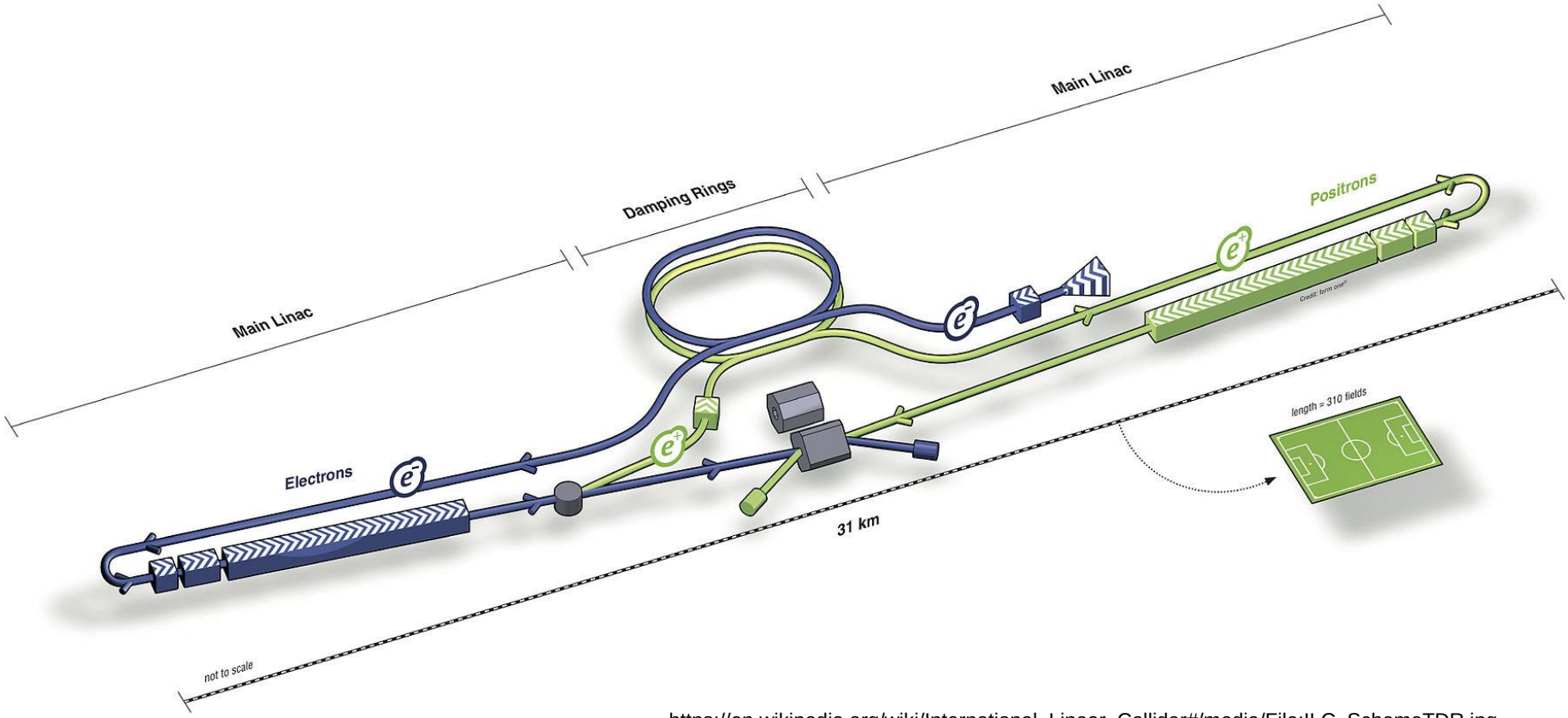
Electron gun is **Unstable**

Poor Transmission create high **Noise Floor**

The new fitting routine is still useful for previous or future **Good Data**

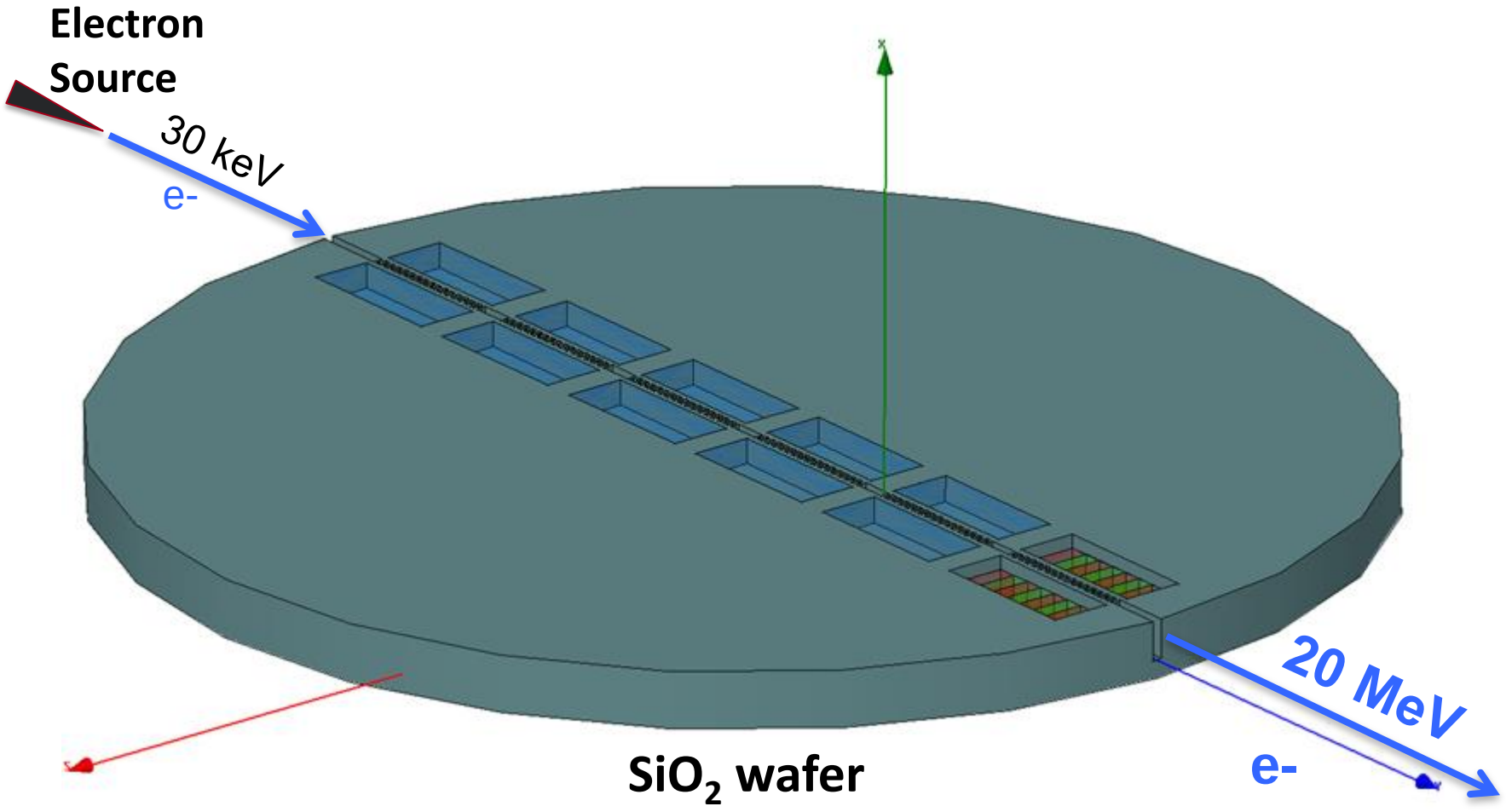
Particle Accelerators Need to Get Smaller

International Linear Collider planned to be 31km long!



https://en.wikipedia.org/wiki/International_Linear_Collider#/media/File:ILC_SchemeTDR.jpg

Multi-MeV Accelerator Integrated on a Single Wafer



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