# Fast Timing in Collider Detectors

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Special thanks to Henry Frisch, Evan Angelico, and everyone on LAPPD's

# What could 1 picosecond do for us?

- Charged Particle ID
  - Jet Subparticle Measurement
- Electromagnetic Shower Profiling
- Pre-Calorimeter Sampling
- Vertexing

# What ***could*** 1 picosecond do for us?

- NEED simulation studies
- The questions are nonetheless extremely interesting!!
- I will not prove anything I’m about to say

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# Particle ID via Time of Flight

- Put glass window in front of fast timing photodetector (ie LAPPD). Charged particles will Cherenkov radiate -> Detector is sensitive in blue/near UV
- At ~1 meter, can separate pions and kaons at 20 GeV by time of flight difference with 1 ps resolution
- Dream: ID all of the different particles in a jet

$$\Delta t = \frac{L}{c}\left[\frac{1}{\sqrt{1-\left(\frac{m_K}{E}\right)^2}} - \frac{1}{\sqrt{1-\left(\frac{m_\pi}{E}\right)^2}}\right]$$

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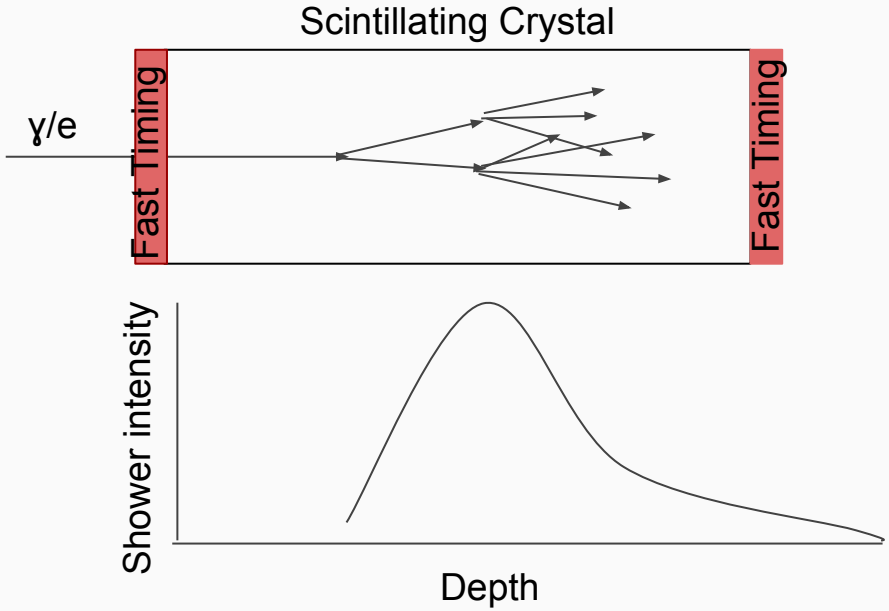
# Shower Profiling

- Place fast timing detectors on either side of a scintillating crystal.
- Difference in time of arrival of scintillation light = depth into crystal
- Brightness of scintillation light = intensity of shower at that depth
- Dream: Accurately measure entire longitudinal shower profile



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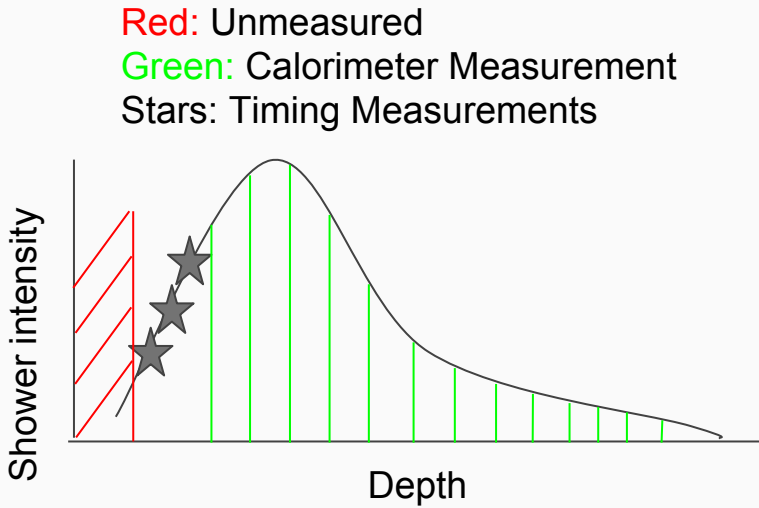
# Pre-Calorimeter Sampling

- Problem: Suppose we wanted to put the calorimeters outside of the magnetic coil. Then there is a chance the shower would begin in the coil. It is then impossible to absorb the entire shower, introducing additional uncertainty on shower energy.
- Don't need the beginning of shower if we can map the rising edge accurately and extrapolate
- Put ~3 fast timing detectors before calorimeter. Use them to map rising edge accurately.
- Dream: Calorimeters outside of magnetic coil



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- **Vertexing**

# Vertexing in Four Dimensions

- Vertices are points in 4-dimensions, they occur at different times. Always discuss vertexing via position, but could do with time additionally
- Timing in forward direction could be using for event separation in the longitudinal direction by time of flight differences. 1 ps => 300 microns
- Dream: Accurate “4-position” reconstruction of each vertex

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- Electromagnetic Shower Profiling
- Pre-Calorimeter Sampling
- Vertexing
- **??????**
  - **Many other questions one can ask**
  - **Philosophy of fast timing in colliders: Measure everything we can as accurately as we can everywhere we can**

# Open Questions

- In which of these cases is timing more accurate than other techniques?
- In which of these cases is timing worth the cost?
- Are LAPPD's feasible?
  - Event rate/occupancy?
  - Power consumption?
  - Timeline/production?
  - Radiation hardness?
- ????? Unknown unknowns

# Conclusion

Fast timing in collider detectors is a non-traditional technology that needs further study.

# Thanks!