# HGTD Timing Calibration

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Real Time Analysis Workshop

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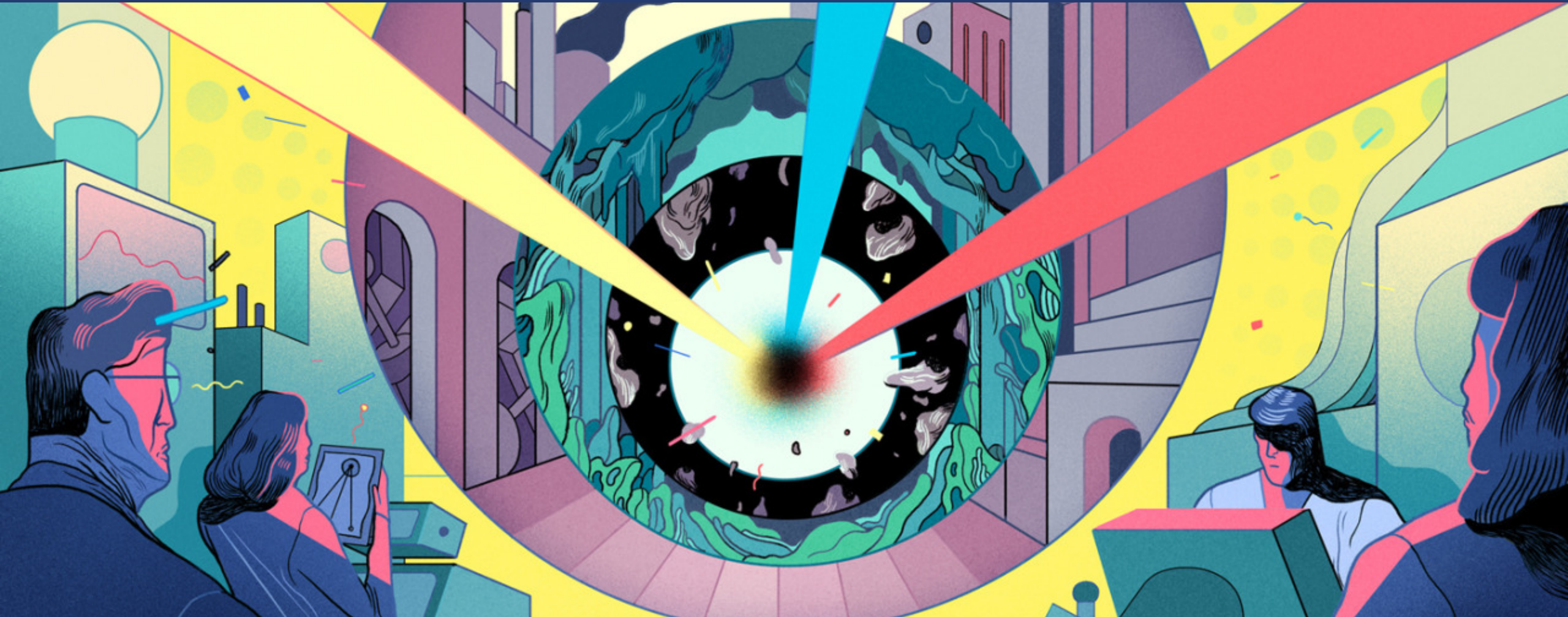
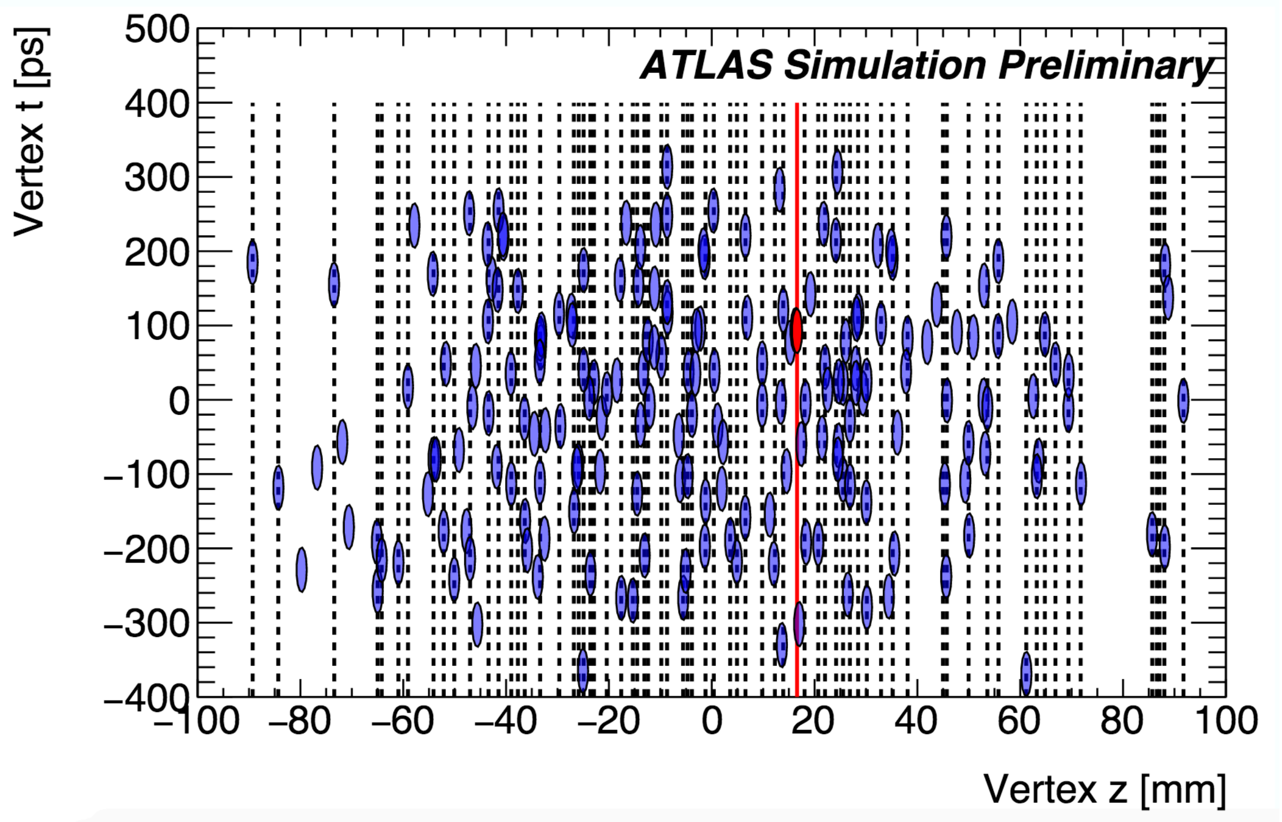
THE OHIO STATE UNIVERSITY

ATLAS EXPERIMENT



# Motivation

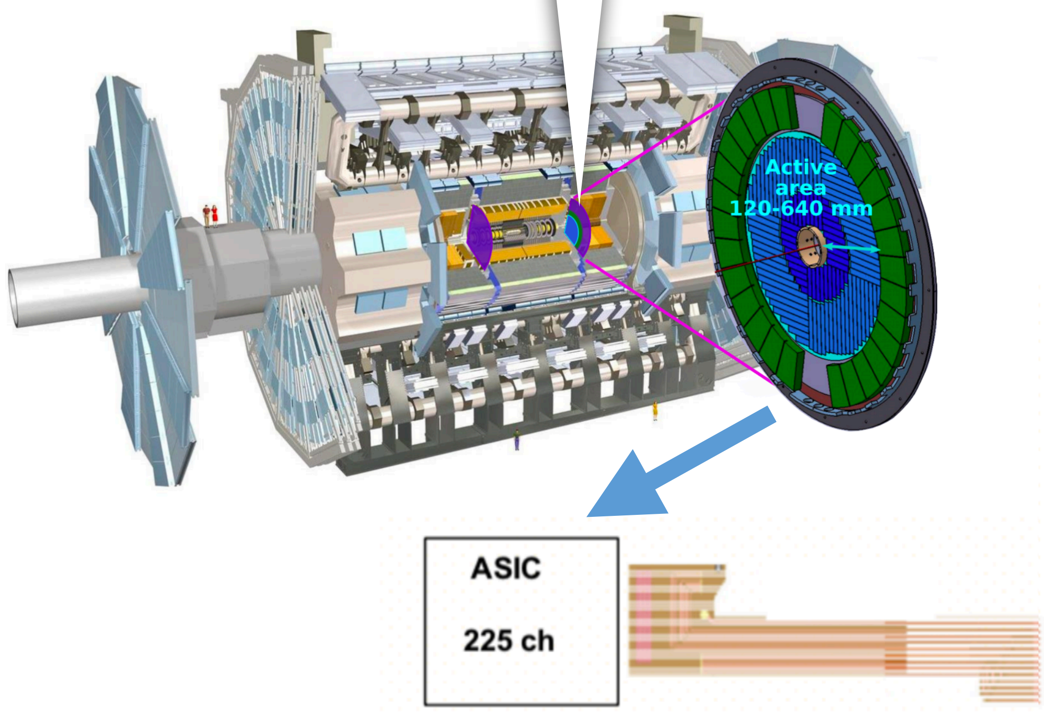
- Pileup is one of the most difficult challenges at high luminosity
  - Additional fake jets
  - Reduced accuracy of physics objects
- Can exploit the time spread of collisions to improve track-to-vertex association and reduce pileup contamination
- High Granularity Timing Detector (HGTD)



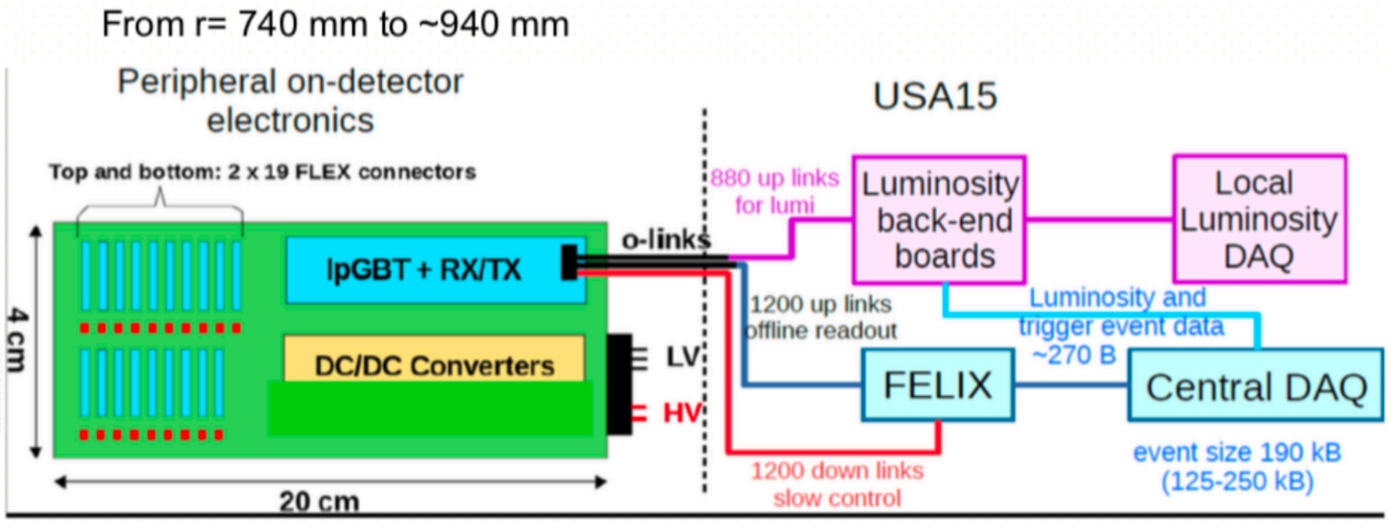
# HGTD Overview

Pseudorapidity coverage: 2.4<|η<4.0

Radial extension: 12 cm < R < 64 cm

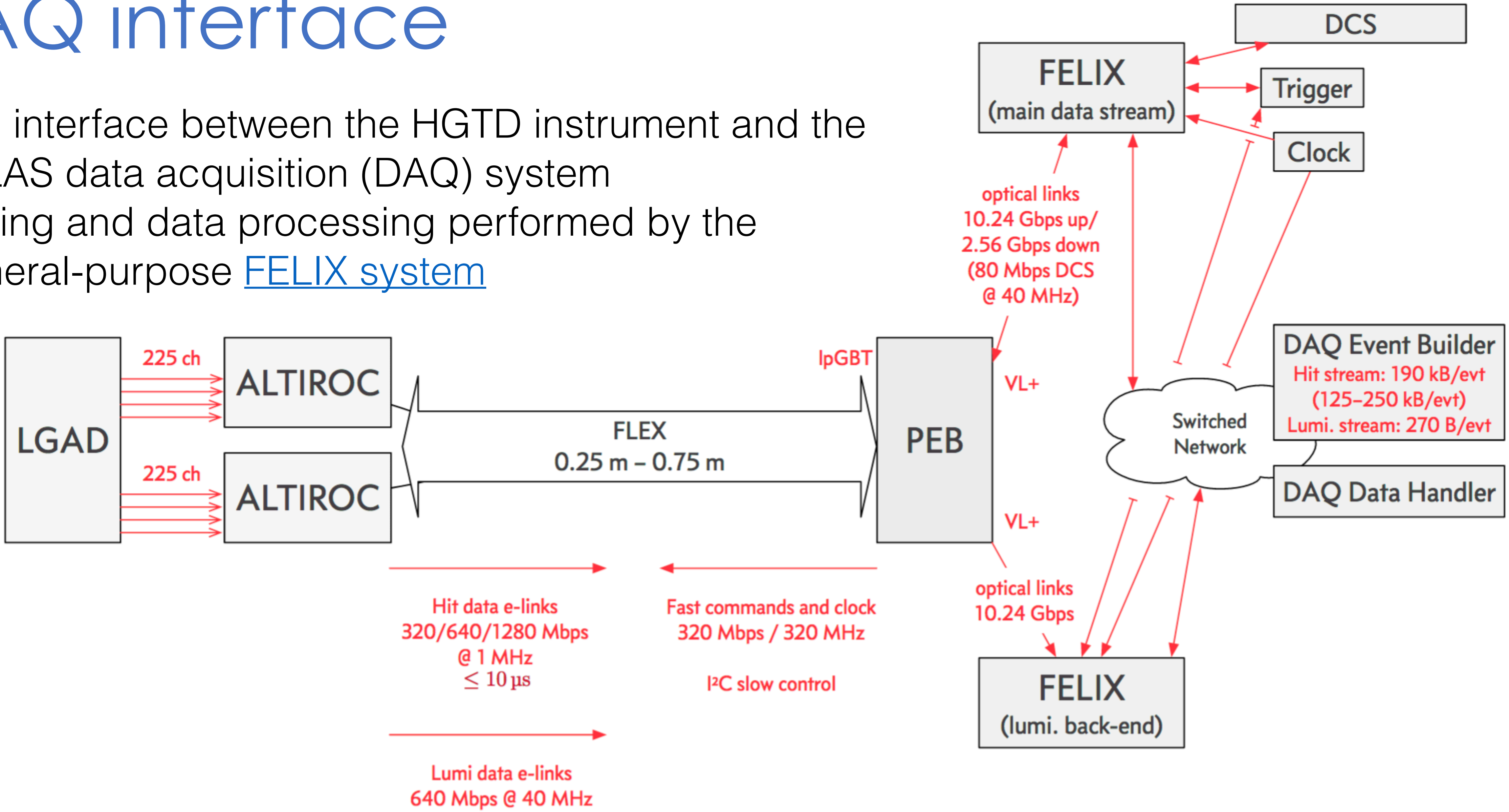



- Thin Low Gain Avalanche Detectors (LGADs): pixel detector with coarse spatial resolution but precision timing (30 ps per track)
    - 2 double planar layers in each endcap
    - overlapping sensors for each layer (larger overlap at inner radii)
- Specially-designed ASIC ALTIROC front-end



# DAQ interface

- The interface between the HGTD instrument and the ATLAS data acquisition (DAQ) system
- Timing and data processing performed by the general-purpose [FELIX system]

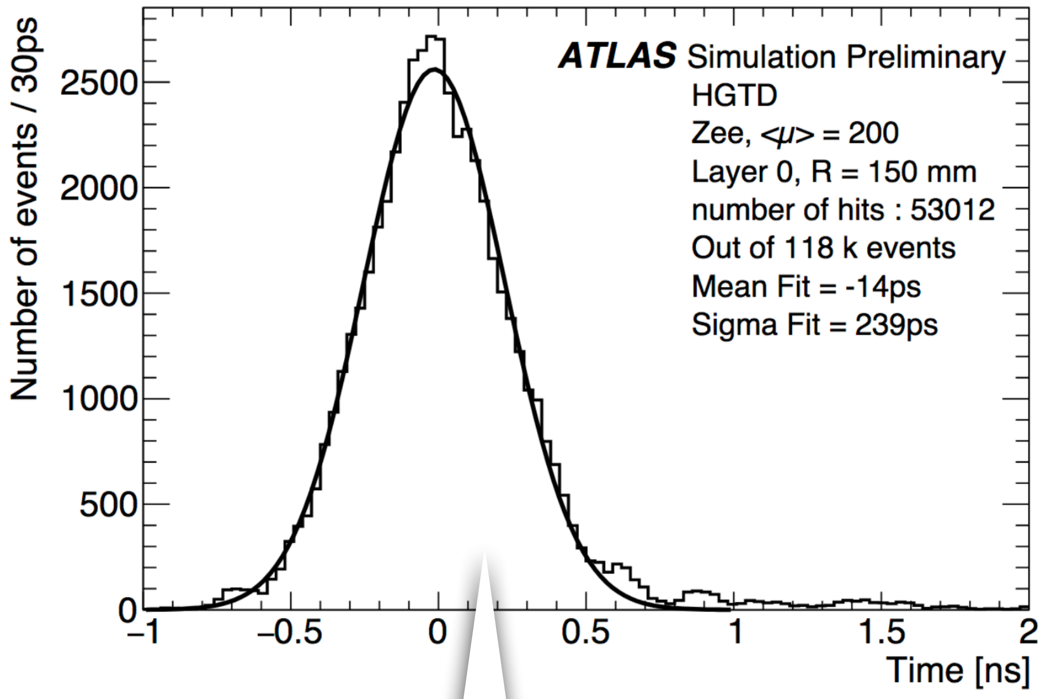


# Precision Timing

- **Timing in the system will be determined by a master clock**
  - Clock will be distributed to the lpGBT downlinks and then to the individual ALTIROC readout chips
  - Inside the ALTIROC, a clock tree will be used to distribute the clock as uniformly as possible
- **Any temporal variation in the time clock distribution may compromise the ultimate resolution of the detector**
  - The sensors themselves will have a resolution of ~40 ps per hit
  - The contributions to the time resolution from the on-detector electronics (UX15) and from the clock distribution (USA15) must be made much smaller than this.
- Goal to have clock dispersion for HGTD less than 10 ps across a wide range of frequencies and over the detector acceptance

# Calibration for the HGTD

- The hit time of arrival $t_{hit}$ is measured with respect to the clock, but this reference may drift
  - Need calibration to keep expected time resolution of 30–50 ps
- **Static variations** — ie ToF, flex cable length, etc
- **Dynamic variations** — slower than the event rate, ie day/night variation
- Plot timing distribution of simulated hits
  - Can calibrate pixel $t_{hit}$ using mean of distribution



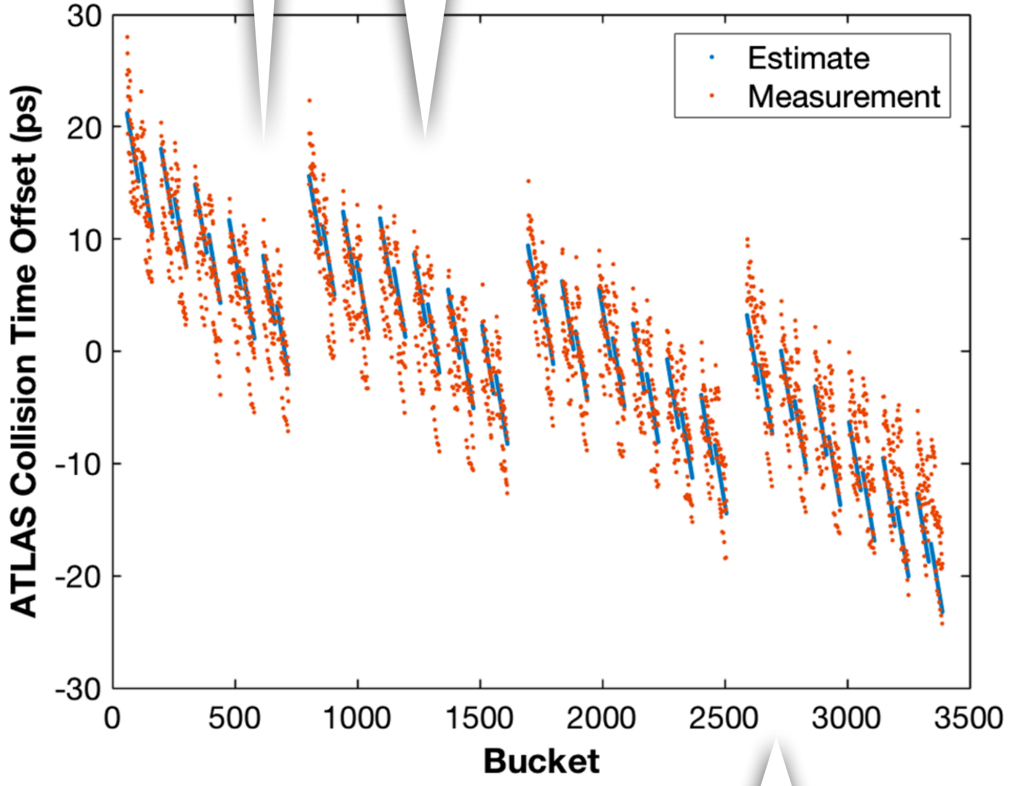

Gaussian core derived from the time dispersion of the LHC collision in convolution with hit time resolution

# Timing Variation

- **LHC per-bunch variation**: using ATLAS collision time offset from RF system (right)
- **Felix jitter**: expected time jitter of ~5.19ps jitter from
- Three separate random Gaussian 5ps jitter to model **IpGBT, FLEX,** and **ASIC**
  - Preliminary numbers
- Static radially-dependent ToF variation of 0-70 ps
  - No significant impact on these per-sensor hit distributions

Taking measurement as offset for full smear

measurement - estimate as offset for calibrated hit time



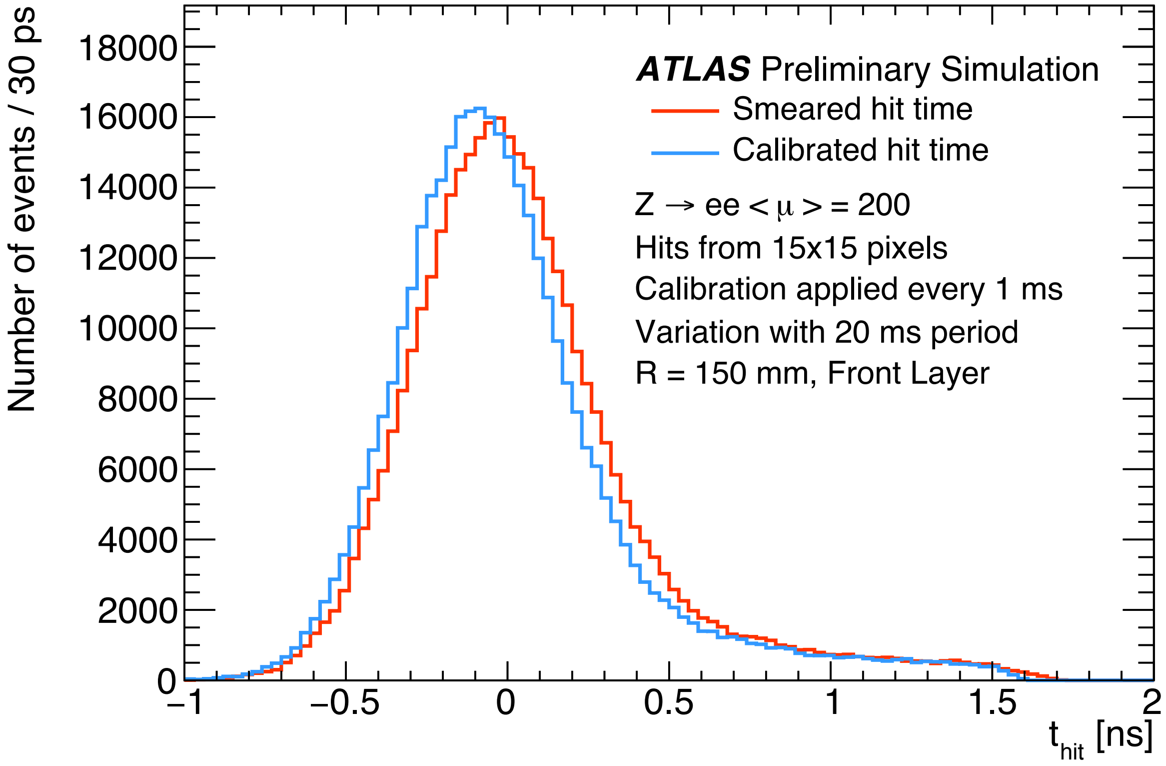

Collision point time shift for the ATLAS detector

# Timing Variation

- **Can't calibrate away event-by event random fluctuations**
- Performance of calibration procedure will depend on how many longer-term variations (heat cycles or other effects) affect the time measurement , but these are largely unknown…
    - Instead parameterize these long-term variations and study how large / fast they could be and still meet our targets
    - Sinusoidally varying 100ps time offset with period of 100µs - 1day

# Calibration Procedure

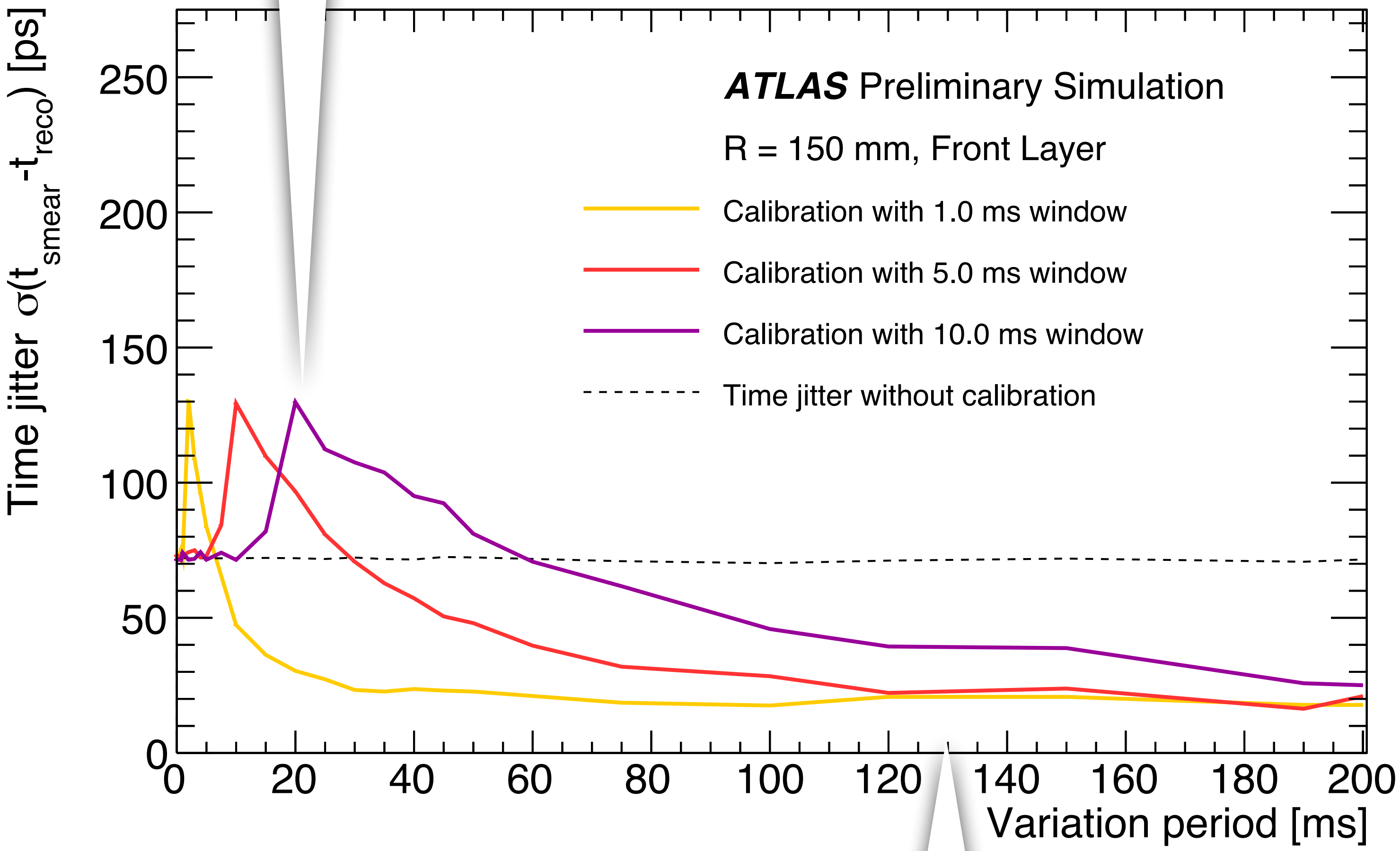
- Assuming event readout rate of 1MHz
- Derive t0 correction on a subset of MC events
- Apply to independent dataset and evaluate performance
- Measure the resolution



# Calibration Performance

- Calibration performance depends on timescale of effects being calibrated away
- As variation timescale gets smaller, calibration provides worse resolution

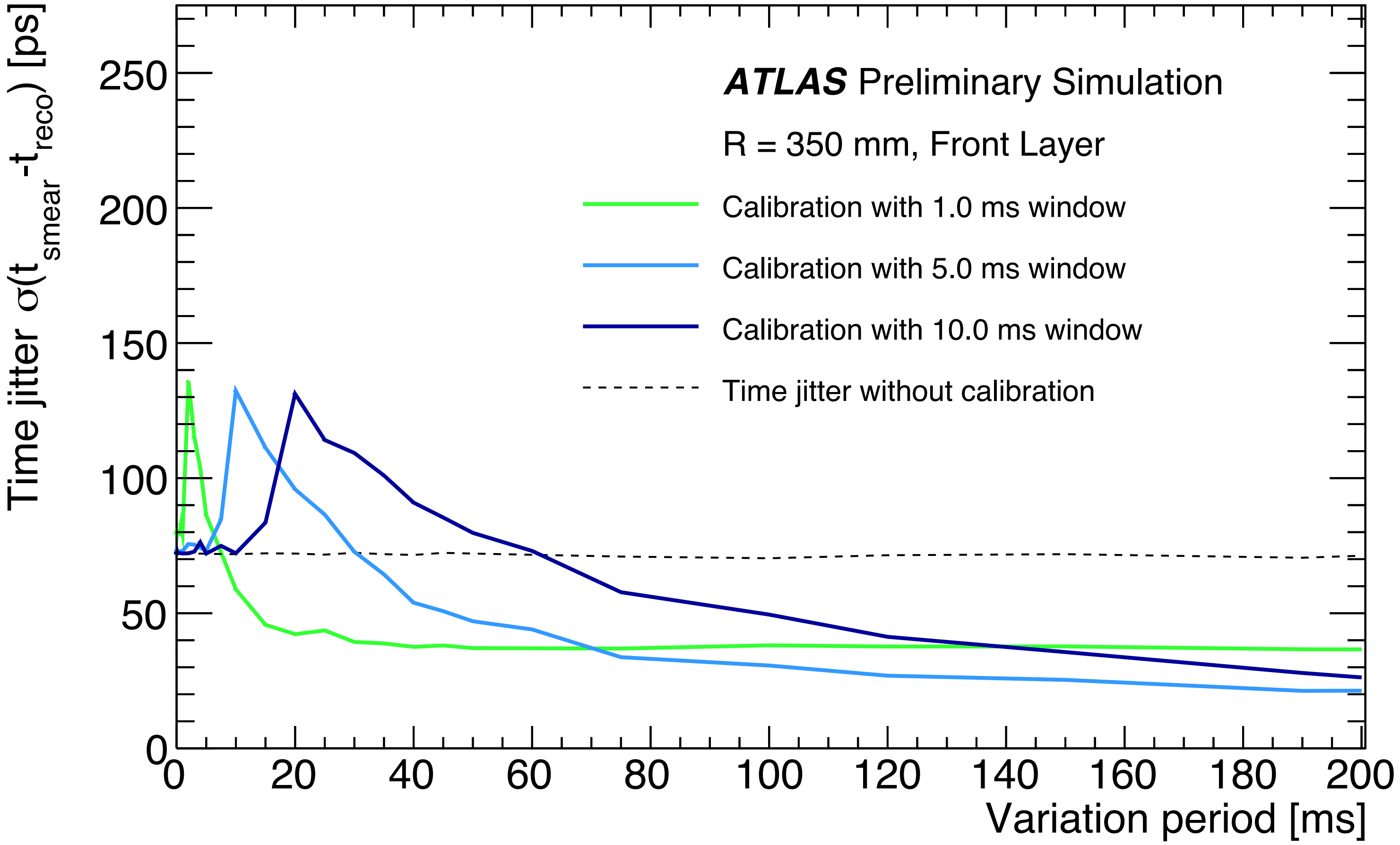
calibration timescale = 2*variation timescale maximally incorrect




calibration works well when calibration timescale << variation timescale

# Calibration Performance

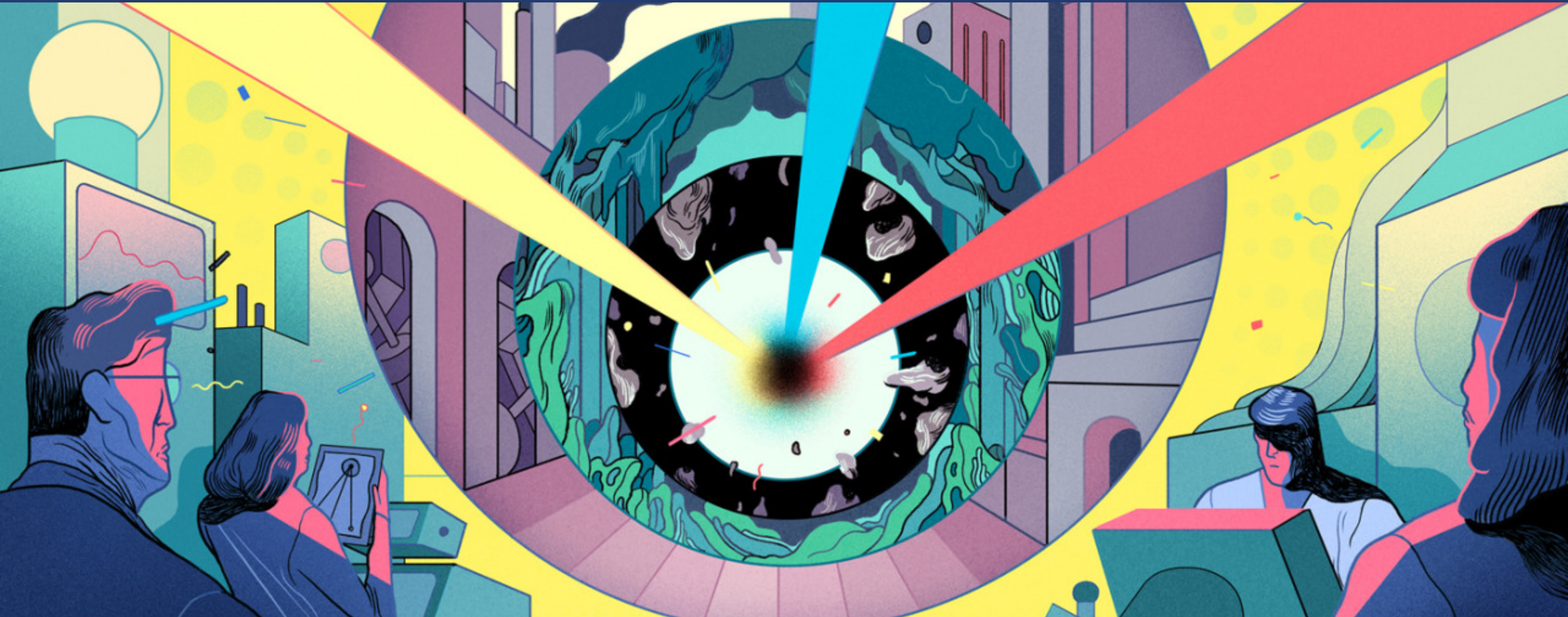
- Different statistics and different radii
- Optimal calibration window changes



# Open Questions

- How would the performance look after applying some reasonable trigger selection?
- Could a calibration across more ASICs be used for a more precise calibration? What about a calibration for individual sensors to correct for the ASIC clock tree jitter?
- Is a dynamic timing calibration possible?
    - Can calibration corrections be applied on an event-by-event basis?

# Backup Slides



# Phase Noise & Jitter

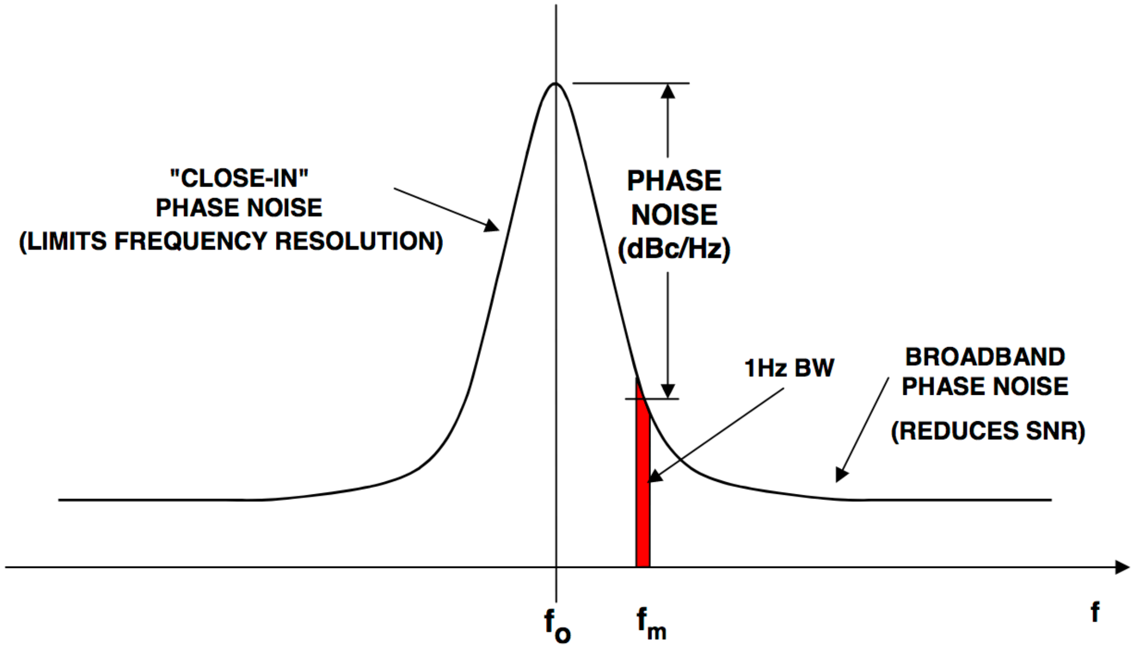



***Figure 1: Oscillator Power Spectrum Due to Phase Noise***

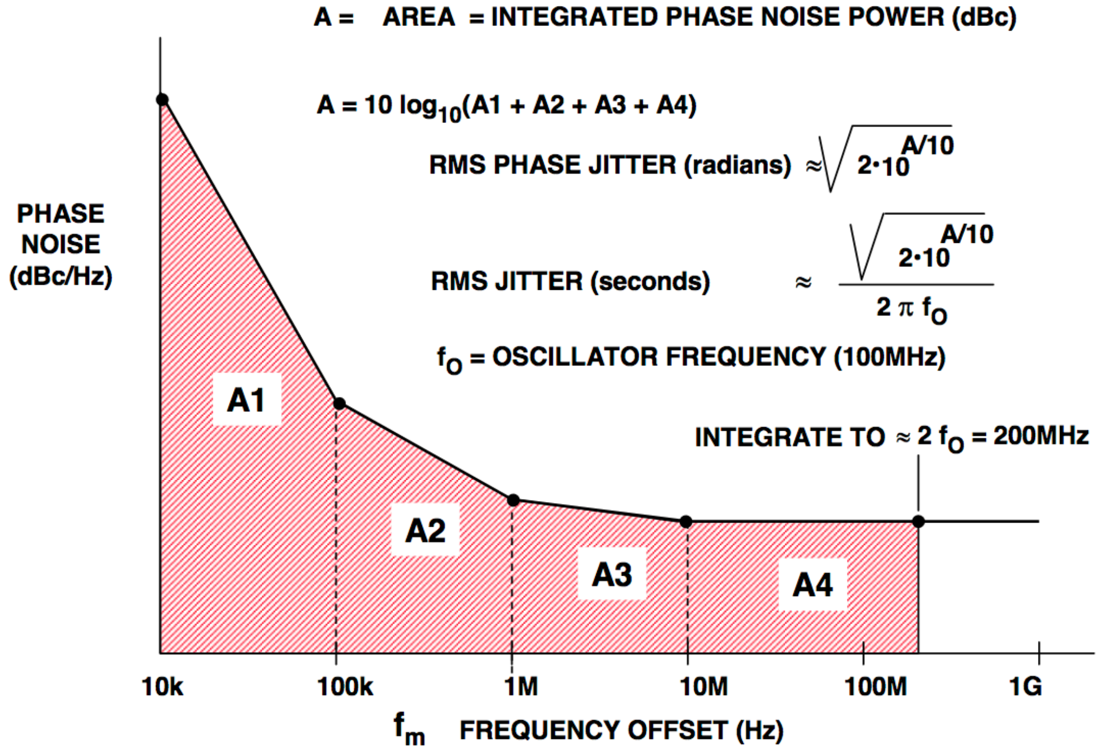
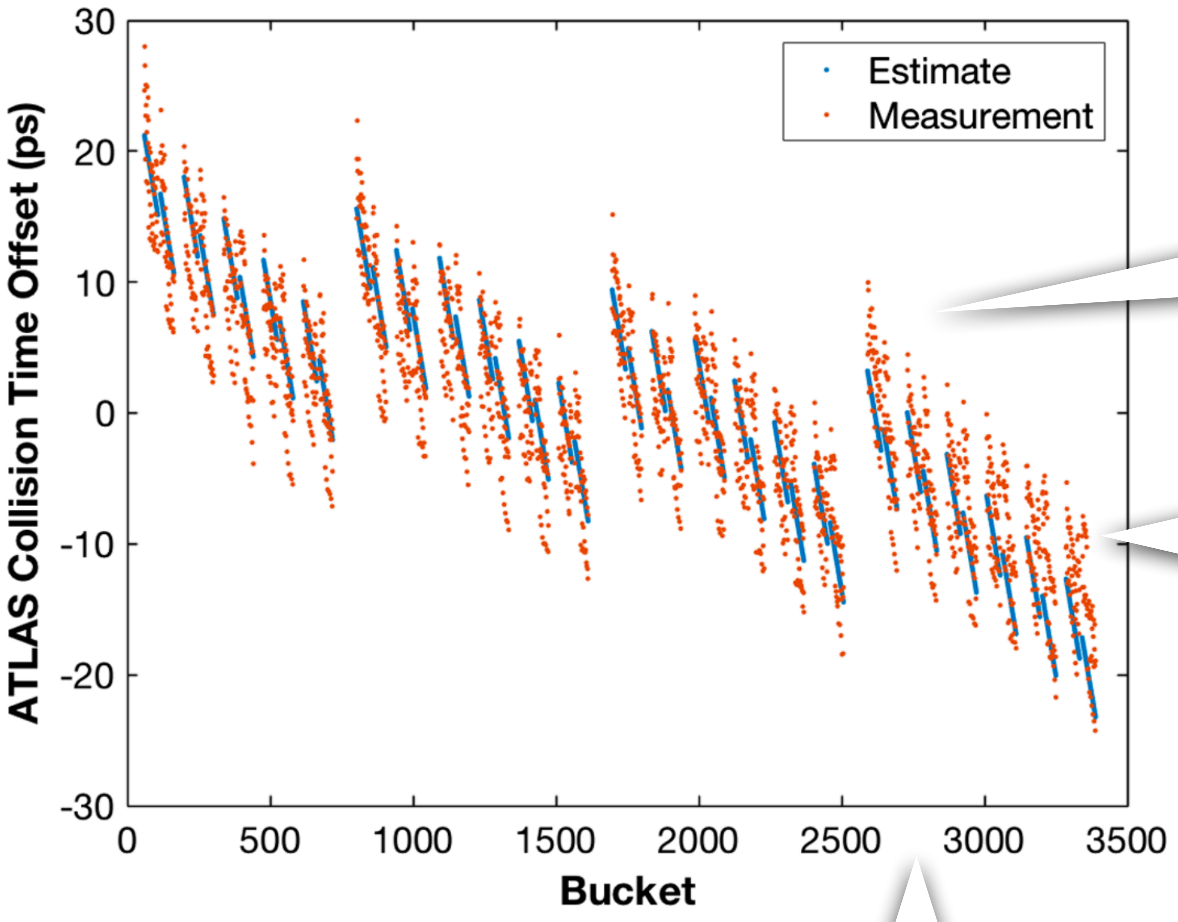



***Figure 4: Calculating Jitter from Phase Noise***

https://www.analog.com/media/ru/training-seminars/tutorials/MT-008.pdf

# LHC Variation




Taking measurement as offset for full smear

measurement - estimate as offset for calibrated hit time

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https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.20.101003

# FELIX Jitter

FELIX clock test setup