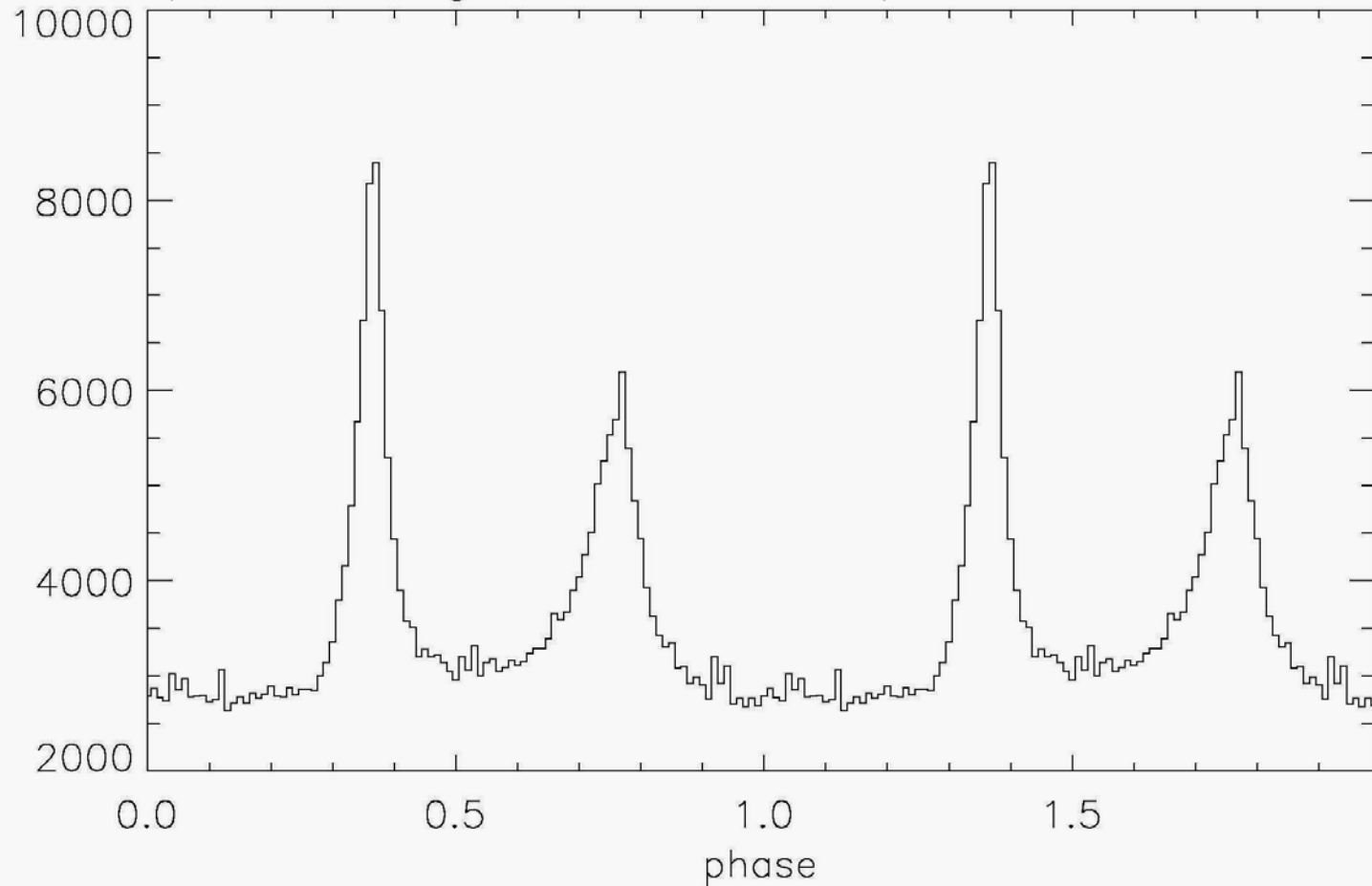


Pre-launch timing calibration standards

Eckhard Kendziorra
IAA Tübingen

Crab pulse profile measured with EPIC pn

Pulse profile of light curve with a period of 0.033510217 s



Lessons learned from XMM-Newton

- **Relative timing** of EPIC pn verified pre-launch (but only for relatively short intervals, relative timing verified shortly after launch but **second jumps** of experiment clock only detected **after** launch)
- **Absolute** timing for EPIC pn **NOT** verified pre-launch (low priority)
we still are working on in orbit verification



Pre-launch timing calibration/verification essential

Recommendation

- Verify **relative** timing by long exposures with **periodic** and **stable** X-ray beam
Errors in relative timing will show up in periodogram and folded light curve
- Also verify **absolute** timing with entire satellite
(easy, has been done for ABRIXAS)

What is need for timing calibration

- Relative timing
 - Periodically modulated X-ray beam
 - directly modulated source (I of X-ray tube)
 - mechanically chopped beam
 - chopper wheel
 - step motor
 - stable oscillator $\Delta f/f \sim 10^{-9}$
(compare 1 Hz pulse from oscillator with GPS)
 - monitoring of frequency is essential

- Absolute timing

- GPS clock with digital interface

- Stimulus

- LED for low energy detectors

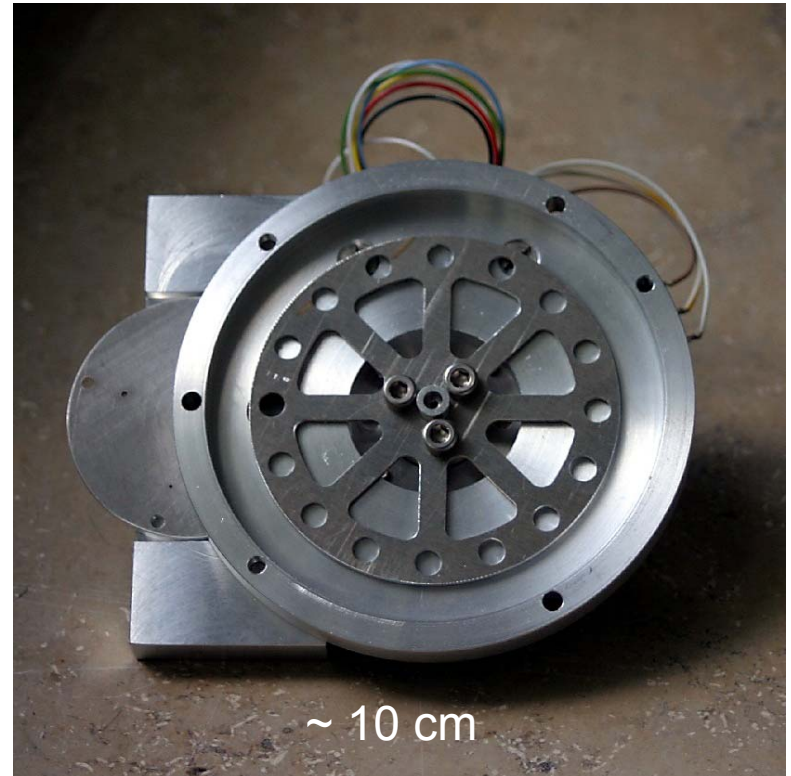
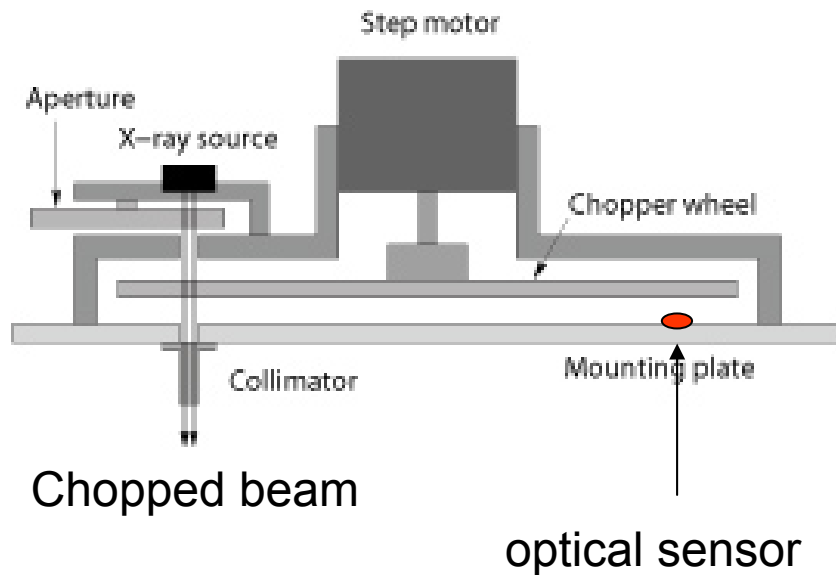
- X-ray source with mechanical shutter

- or electrical stimulus

- Trigger stimulus at selected time, compare event time with trigger time

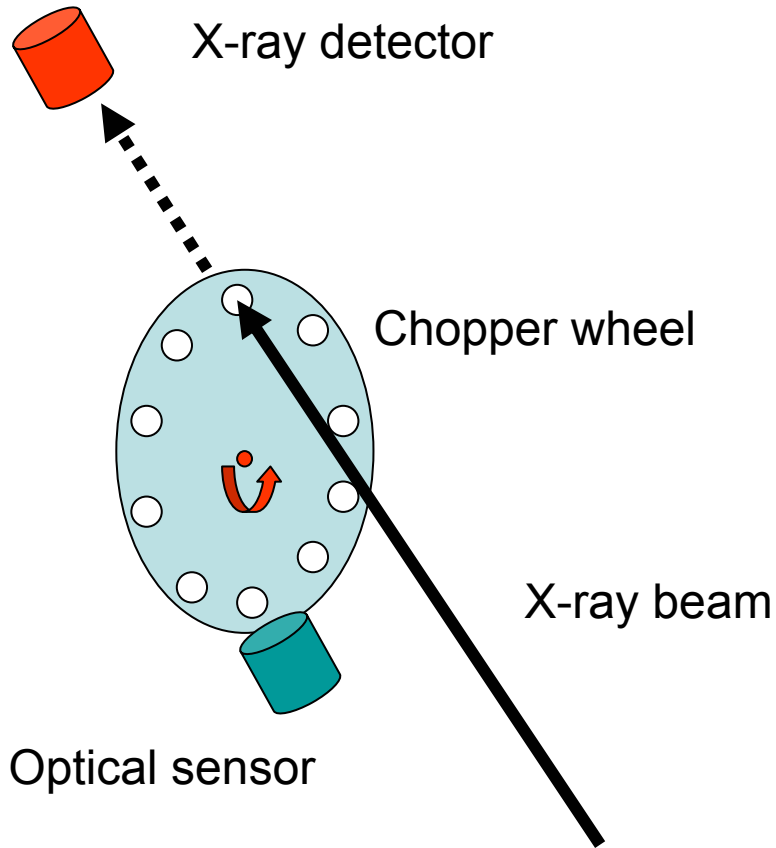


Generation of periodic X-ray signal with chopper wheel



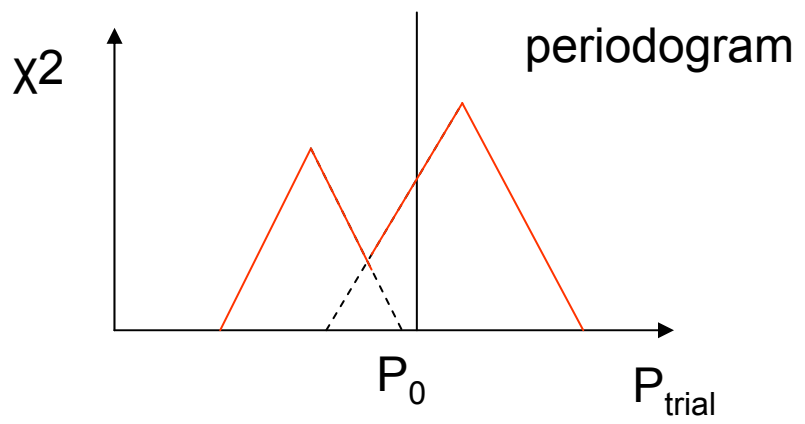
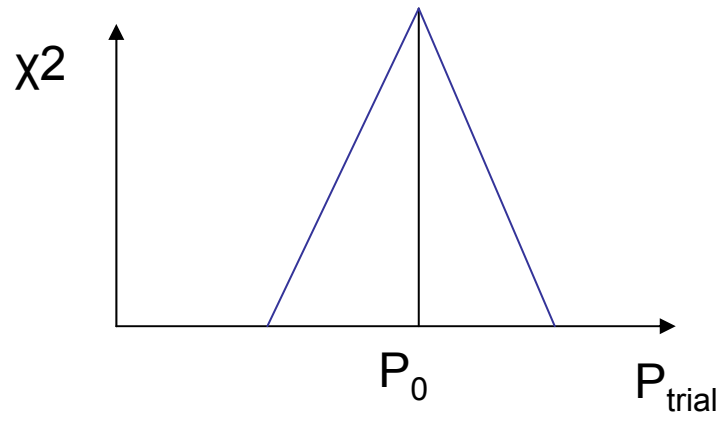
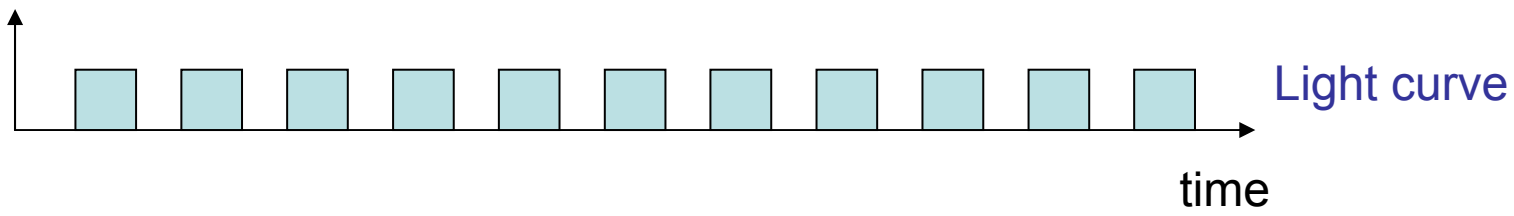
- Chopper wheel driven by step motor, controlled from **stable** oscillator
 $\Delta f/f \sim 10^{-9}$
- Stability of rotation must be monitored with e.g. optical sensor or Hall sensor

Chopper for Panter test facility



Chopper wheel for Panter

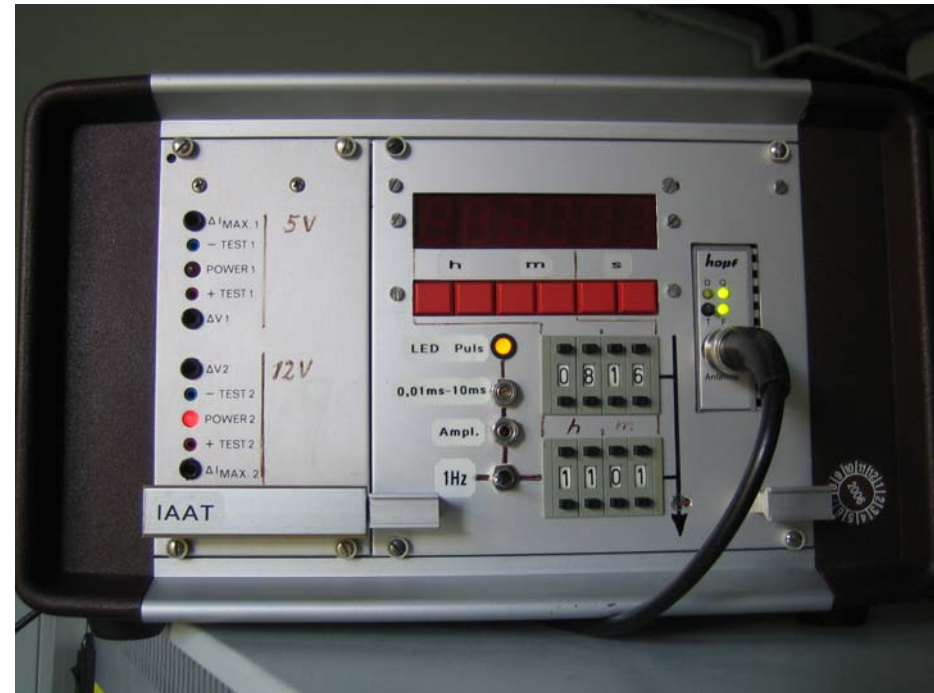
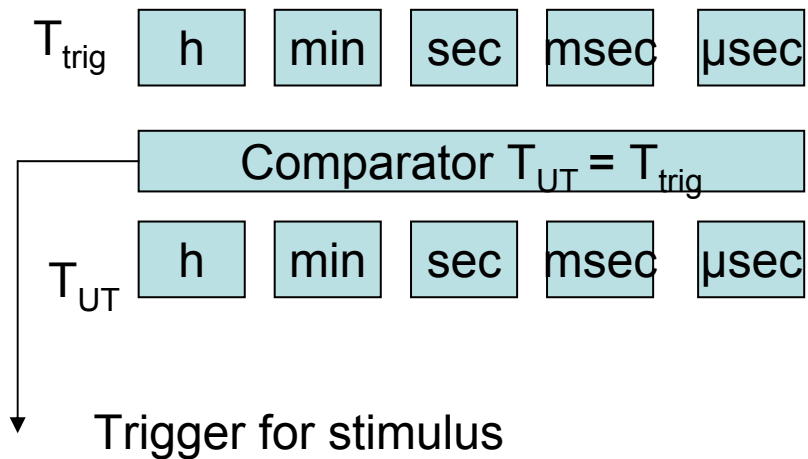
- Periods from $\sim 1\text{ms}$ to 1sec



Absolute time

Generate stimulus at selected time T_{trig}

Compare measured event time with trigger time T_{trig}



DCF77 Receiver & Trigger Unit

Jitter of time standards

Terrestrial time standards, DCF77, IRIG: **several msec**

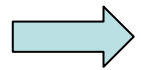
Satellite based systems, GPS, Galileo: **< 0.1 μ sec**

 **use GPS (NOT DCF77, IRIG)**

Conclusion

Pre-launch calibration/verification of event timing is

- cheap and easy
- takes only some days
- saves a lot of effort after launch



should be part of pre-launch calibration/verification plan for future missions