Compton polarimetry for SuperKEKB: Synchronisation

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Introduction

Reminder:

- We have draw a conceptual design with excellent expected performance
- Design relies on:

Laser:

- Integrated in accelerator: must be fully remote operated
- Operated at frequency of 250MHz: must be well synchronized to accelerator RF
- Typical acceptable (closed loop) time jitter of ~500fs (a small fraction of electron bunch/laser pulse durations

Detector:

- photon calorimeter able to cope with photons incoming every 4ns.
- The 2500 circulating bunches measured independently
- Ability to provide fast on-line info to the control room
- Embedded electronics, fast enough, with good ADC (10 bits min) and FPGA processing
- With bunch identification

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Conceptual study of a Compton polarimeter for the upgrade of the SuperKEKB collider with a polarized electron beam

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Abstract: The physics scope of the Belle II experiment currently acquiring data at the SuperKEKB collider will expand with a polarized electron beam upgrade, as recently proposed. Among the required elements for this upgrade, a real time diagnosis of the polarization is necessary to ensure it is large for all bunches in the accelerator during its regular operation. This will be realized by inserting a Compton polarimeter in the accelerator. Its conceptual design is described and no show-stopper for its integration has been identified. An estimation of the sensitivity of the polarimeter is made by means of toy Monte-Carlo studies. The proposed design accounts for the constraint to preserve the performance of the SuperKEKB accelerator and to cope with the short time separation of successive bunches. We show that the polarimeter will measure for each bunch the polarization within five minutes with a statistical precision below 1% and systematic uncertainties below 0.5%. It has the capability of providing this information online on a similar timescale. This work paves the way towards future implementation of real-time Compton polarimetry in several future projects.

Keywords: Accelerator Subsystems and Technologies; Beam-line instrumentation (beam position and profile monitors, beam-intensity monitors, bunch length monitors); Instrumentation for particle accelerators and storage rings - high energy (linear accelerators, synchrotrons)

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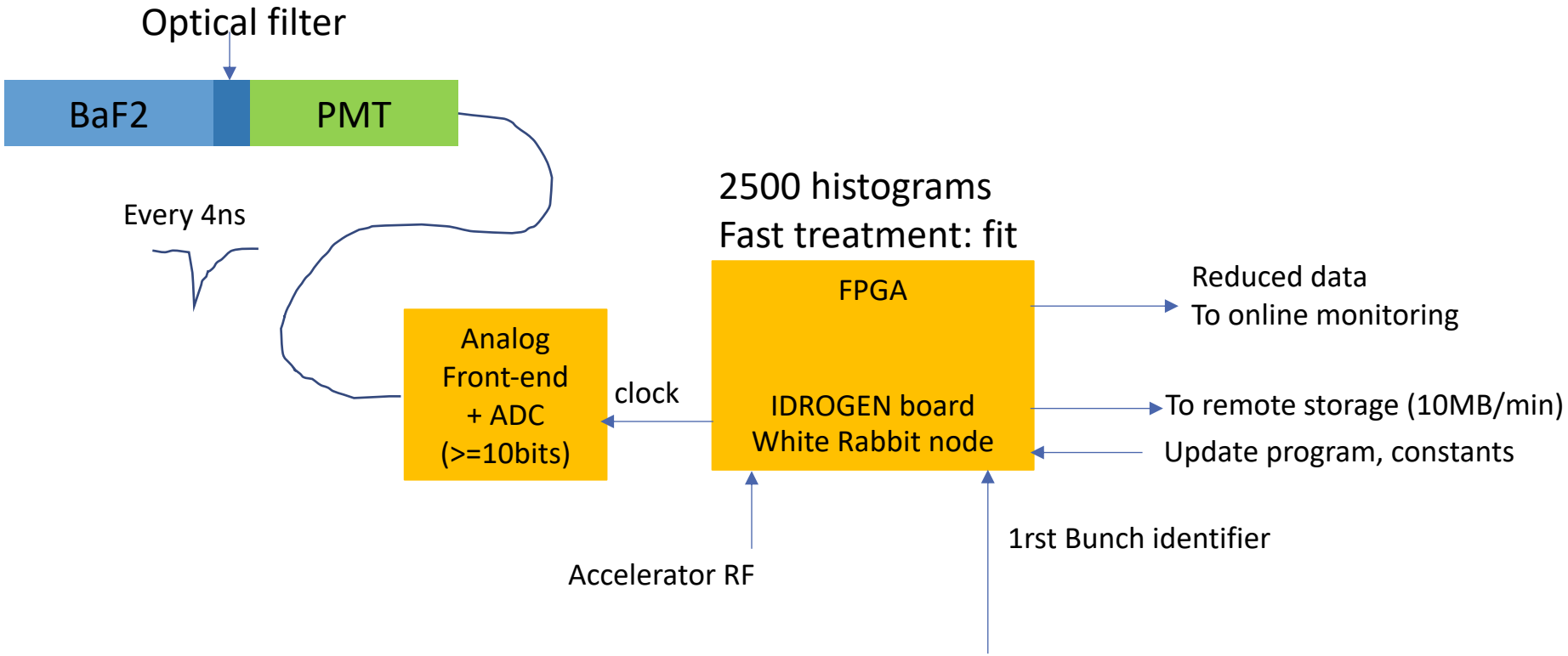
Conceptual acquisition chain



- Funding request in preparation for submission to 'Agence Nationale de la Recherche' for building and testing this detector with the electronics
- Proposal accepted for second stage of submission process → to be submitted on the 27th of March, result in June.

Laser synchronisation – concept

D. Charlet et al., https://cds.cern.ch/record/2893372?ln=en

Master Oscillator (510MHz/51)

4km fibre link

IDROGEN, high speed DAQ
Low noise WR node
FPGA mezzanine card

- WhiteRabbit allows to minimize implementation cost
- A simple fibre to bring to the laser
- No expensive/complicated fibre length compensation system to implement

Developments made in parallel at IJCLab and KEK:

IJClab:

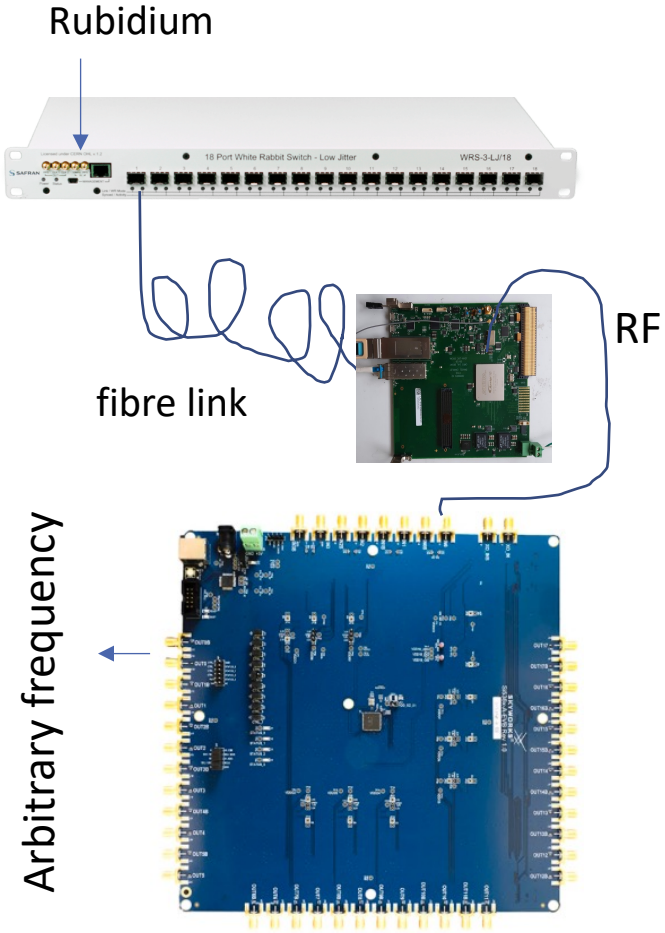
- Standalone tests with phase noise measurements
- Test new developments on the IDROGEN board quickly

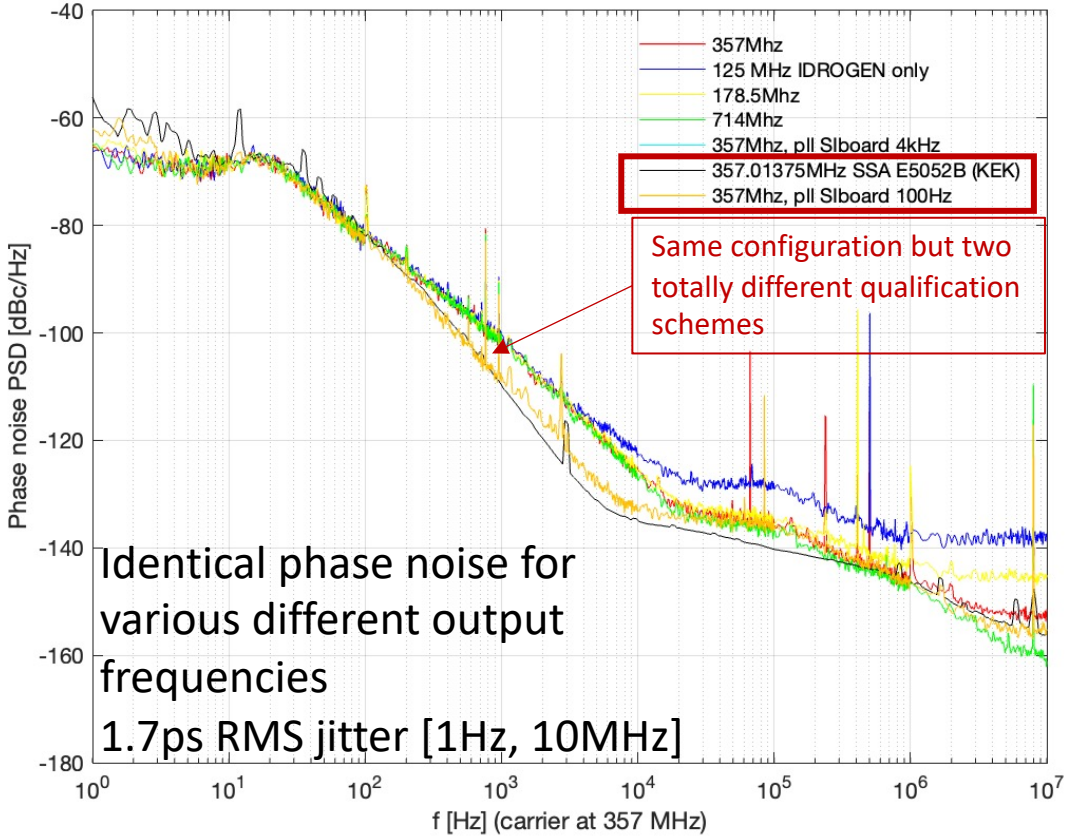
KEK:

- Test within KEK environment for instance at ATF
- Possibility to test with 4km fibre loop easily (shown in Oct'24)
- Possibility to test accelerator/laser synchronisation → rescheduled for June at ATF

D. Charlet (IJCLab) et al., H. Kaji (KEK SKB),
K. Popov, A. Aryshev (KEK ATF)

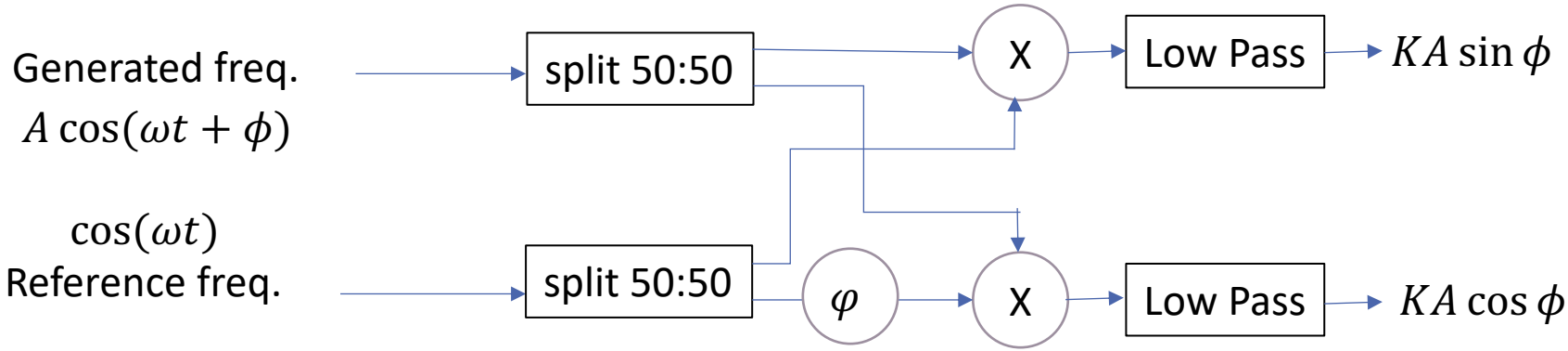
Arbitrary frequency generation

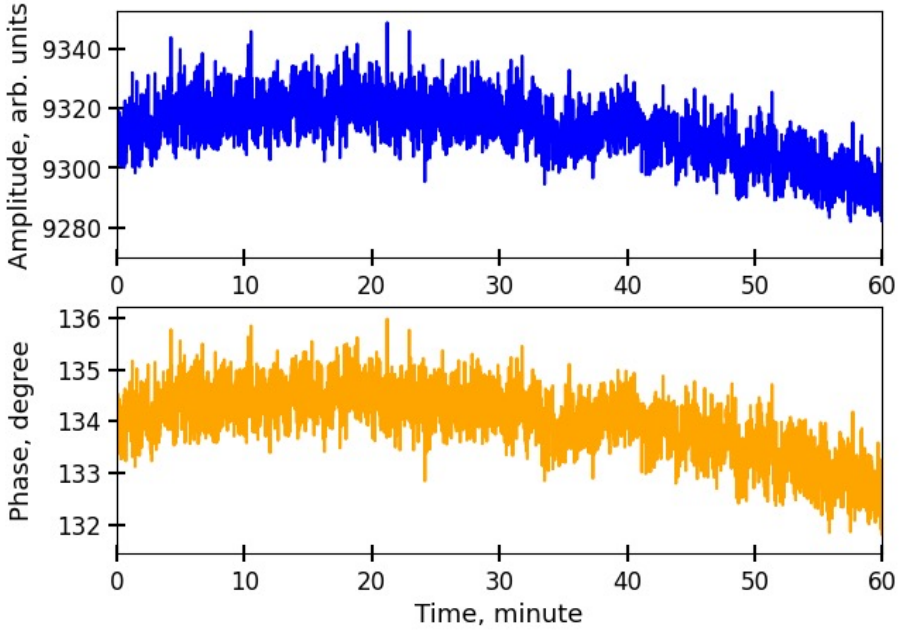


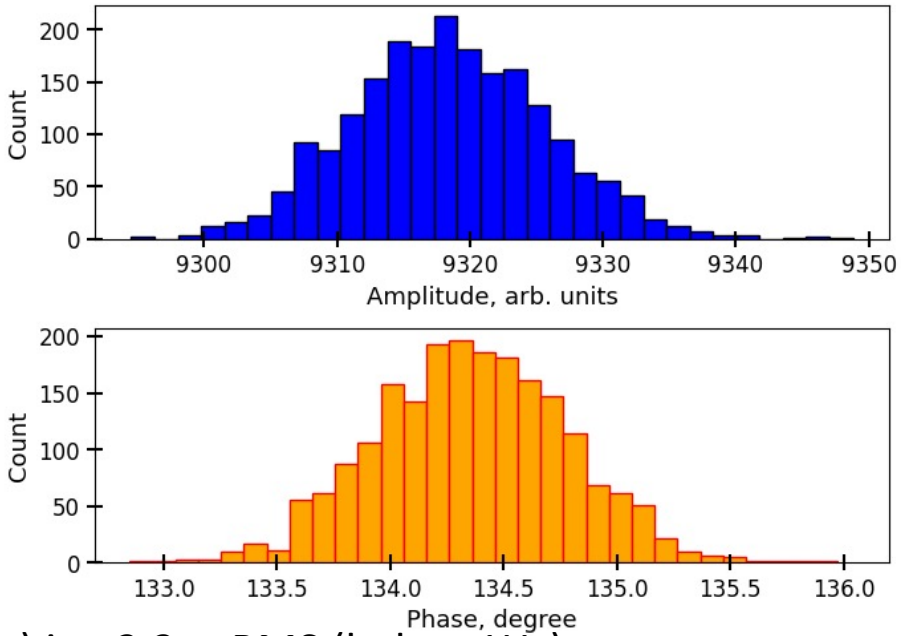


Precision of 1 Hz, accuracy excellent (no drift over several hours)
Consistency of KEK and IJCLab measurements.

Long term drift







~0.3degree RMS phase jitter (at 357MHz) i.e. 2.3ps RMS (below 1Hz)

NB: measurements made in a regular office, no thermal stabilization

Next steps

Synchronisation of laser (and data acquisition) is part of essential elements for the implementation of Compton polarimeter

- Very encouraging results 2.4 ps RMS (<1Hz); 1.7ps RMS (>1Hz)
- Work ongoing to understand
    1. drift component of phase noise (temperature ?)
    2. Noise in intermediate region [1Hz, 100Hz] → White Rabbit protocol related ?
- Laser +accel synchro test not yet done (not possible in October) → June ‘25 at KEK ATF
- Integrate SI5362 chip on the IDROGEN board (avoid some spurs)
- Replace commercial switches by home made, well configured IDROGEN board (first results being analyzed)
- ADC mezzanine card at 1GHz prepared first tests being performed at IJCLab and KEK
- Possibility to measure absolute frequency with colleagues from metrology lab (SYRTE, Paris)

NB:

- These results are only concerning the added jitter induced by the RF transport.
- Electron beam jittering itself against absolute RF reference may be of similar scale already