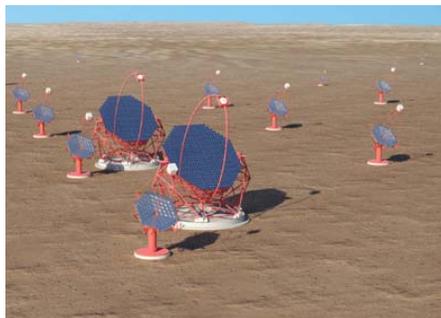


Time Synchronization and Array Trigger in CTA with WhiteRabbit



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Berlin/Zeuthen,
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Outline

- > Array Time Synchronization + Triggering : The task
- > Relation to other experiments
- > WhiteRabbit for Time Synchronization
- > First Tests of WR-performance
 - Laboratory / Field Tests
- > Summary



Array Time Synchronization : The Task

- > Time Synchronization for CTA, and other large distributed arrays
 - Experiments like CTA (few km²), HiSCORE (10km²), KM3Net, AUGERnext, LHAASO
 - Independent detector units: Cameras, PMT-DAQ-stations, Particle-Detectors
 - They generate a “local trigger” - this needs to be time-stamped with precision ~1 nsec

- > Twofold Tasks:
 - (1) **Synchronize clocks in all detector units** to a common central clock with <1 nsec precision; and do the time-stamping of the trigger signal.
Focus: the relative timing between detector units must be correct at any moment.

 - (2) **Must verify timing precision independently: long-term monitor / control in-situ,**
Verification by an independent system is as important as the synchronization; and comparable in technical challenge. Tbd. for at least a subset of all telescopes.

- > Array trigger
 - Telescopes trigger independently, and deliver time stamps
 - A central array trigger unit decides, and returns decision to Telescopes, where RO-transfer starts
 - Request: low latency messaging



White Rabbit

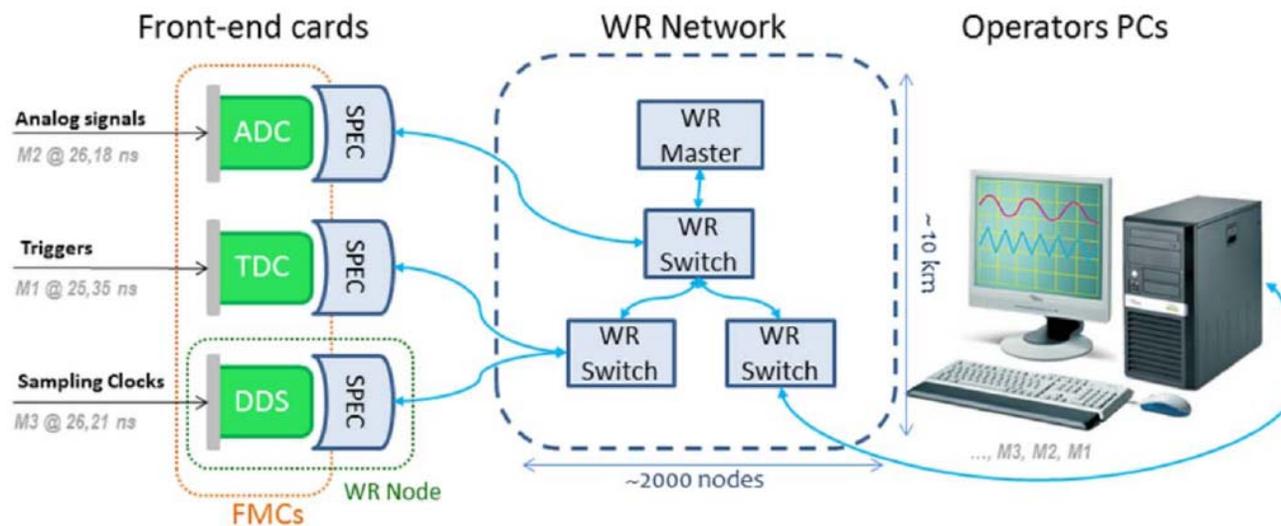


White Rabbit – a new CERN-based extension to Ethernet for :

- > Synchronous mode (precision clock synchronization)
- > Deterministic routing (package latency guaranteed)
- > ~ 1 ns precision, 20 ps jitter
- > 10 km fiber links
- > Up to 2000 nodes
- > Development for CERN & GSI accelerator complex; much external interest
- > Open Hardware Project w/ peer review (ie. open for extensions)
- > Hardware is commercially available
- > Standardization planned (IEEE...)
- > A guaranteed large user community: will be well debugged . . . (!!!)



White Rabbit



■ For concept + details, see eg:

Cern-WR-site <http://www.ohwr.org/projects/white-rabbit/wiki> ;

(also <http://znwiki3.ifh.de/TUNKA/>)



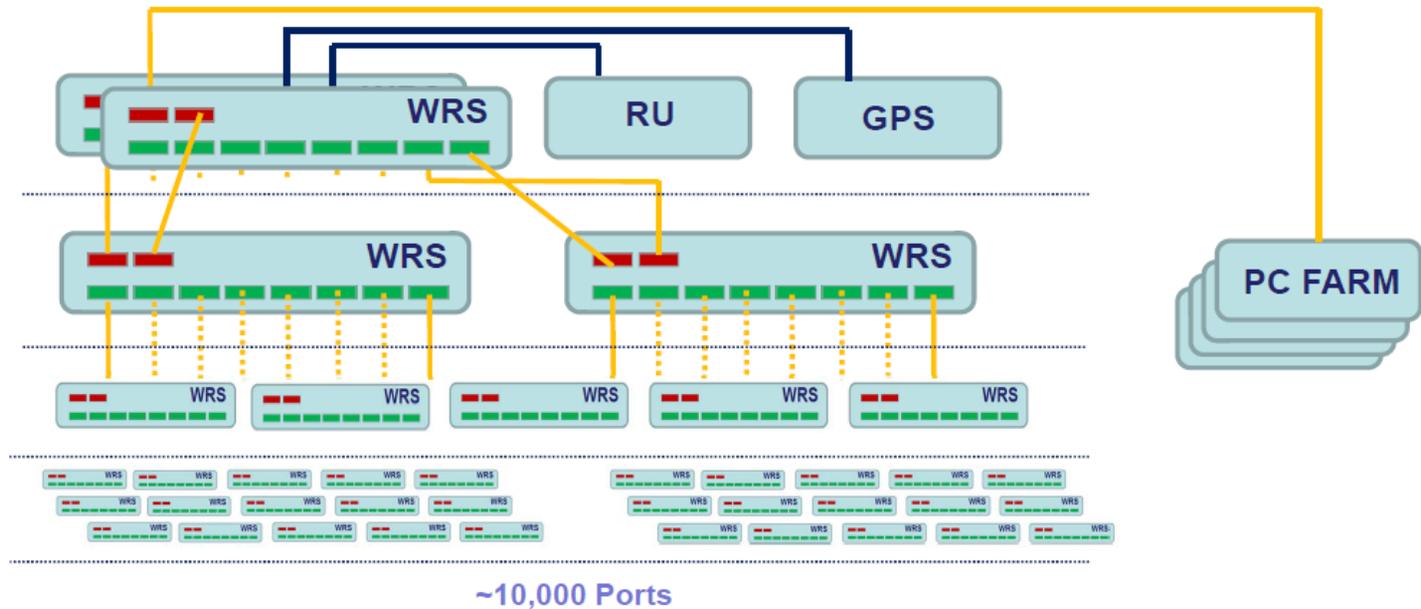
A large-scale application: LHAASO - WhiteRabbit plans

- > Other WR-application proposals:
 - LHAASO : ~10000 nodes to synchronize

Design study
G.Gong, ICALEPCS, 2011.

WR-Switches

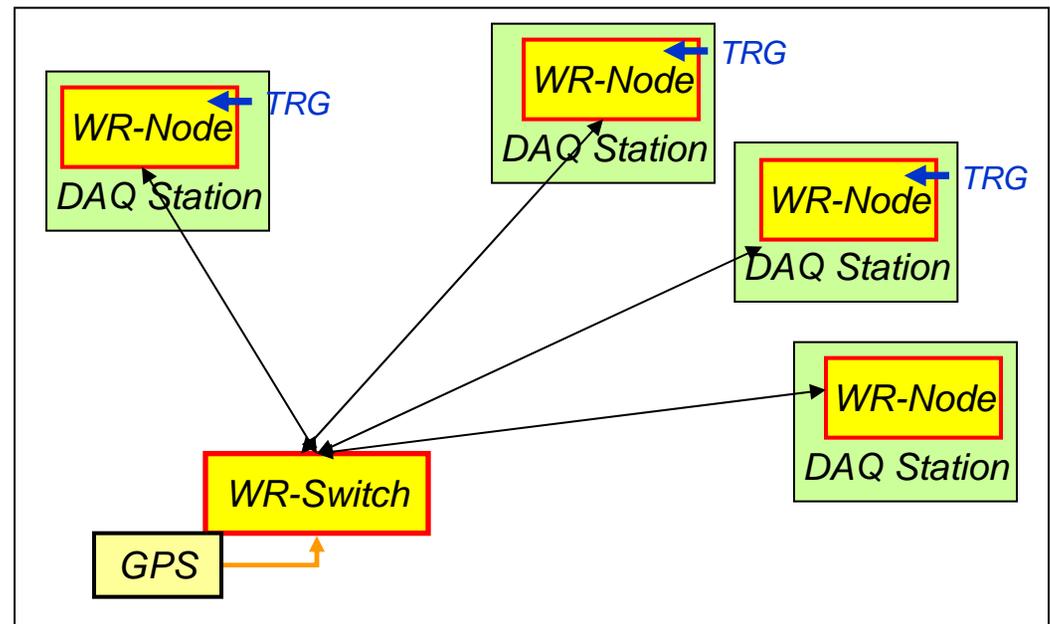
WR-Nodes
(DAQ stations)



Basic Layout of a WhiteRabbit based timing DAQ

White Rabbit DAQ architecture:

- (1) A WR-network :
WRSwitch(es) + GPS/RbCl
- (2) Many WR-Nodes ('endpoints')
for time-stamping



Components

- WhiteRabbit Switches (WRS)
- White-Rabbit Nodes
eg. SPEC (Simple PCIe FMC Carrier)
(or build your own board: OWHR)



from June/2012



available

Price: ~1200 EUR/Station

CTA : DAQ and control network with White Rabbit

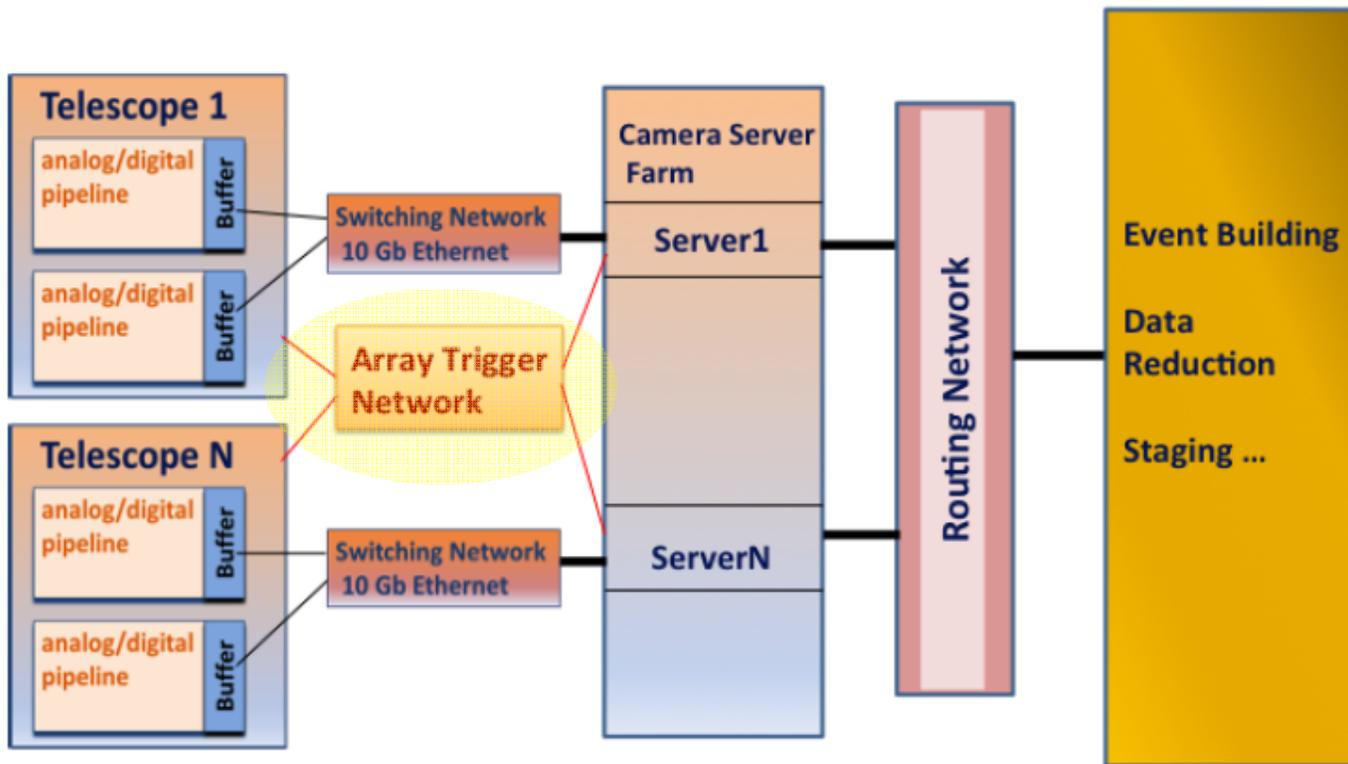
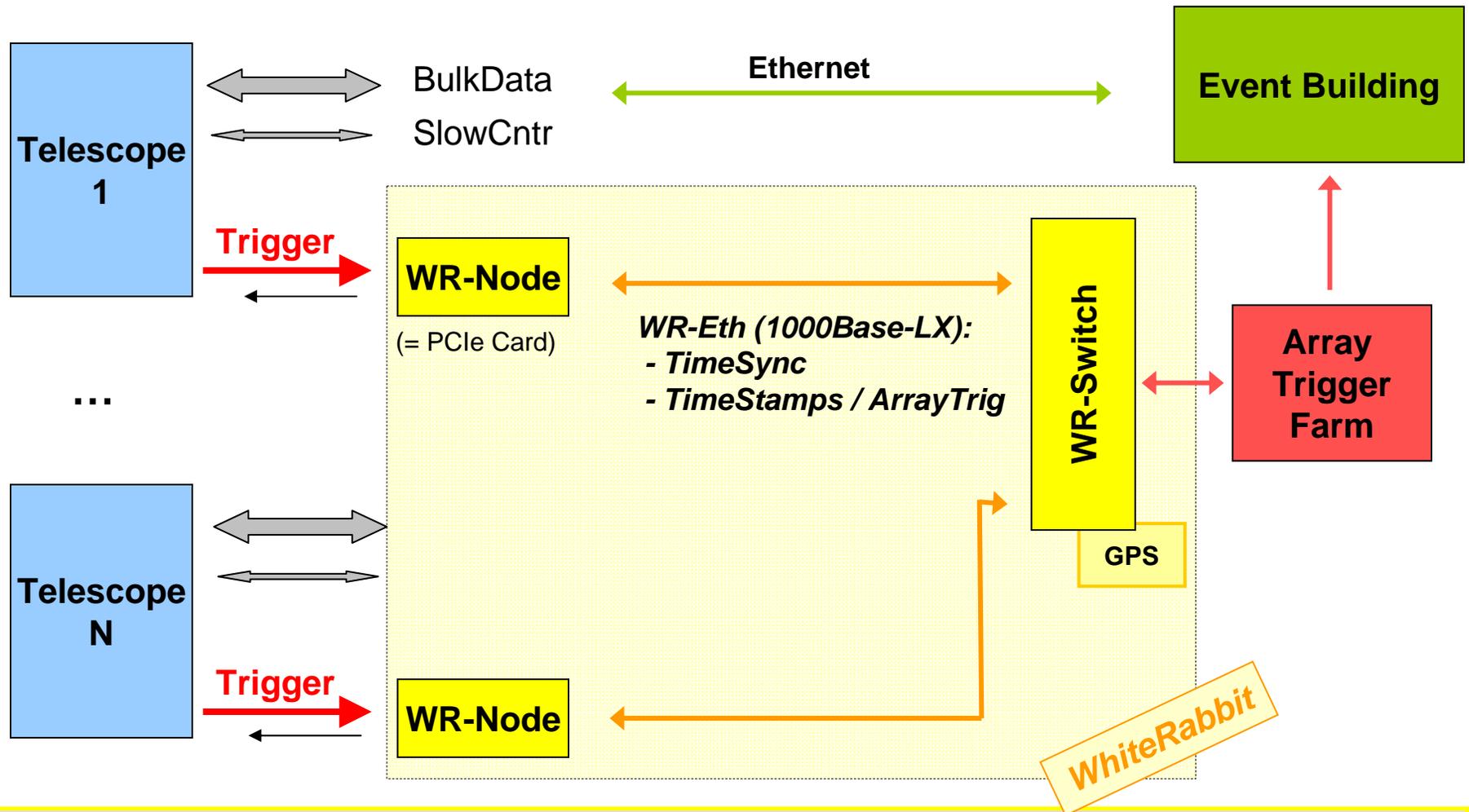


Figure 2. DAQ and Control network layout



White Rabbit : A Layout for Array-Timing & Trigger

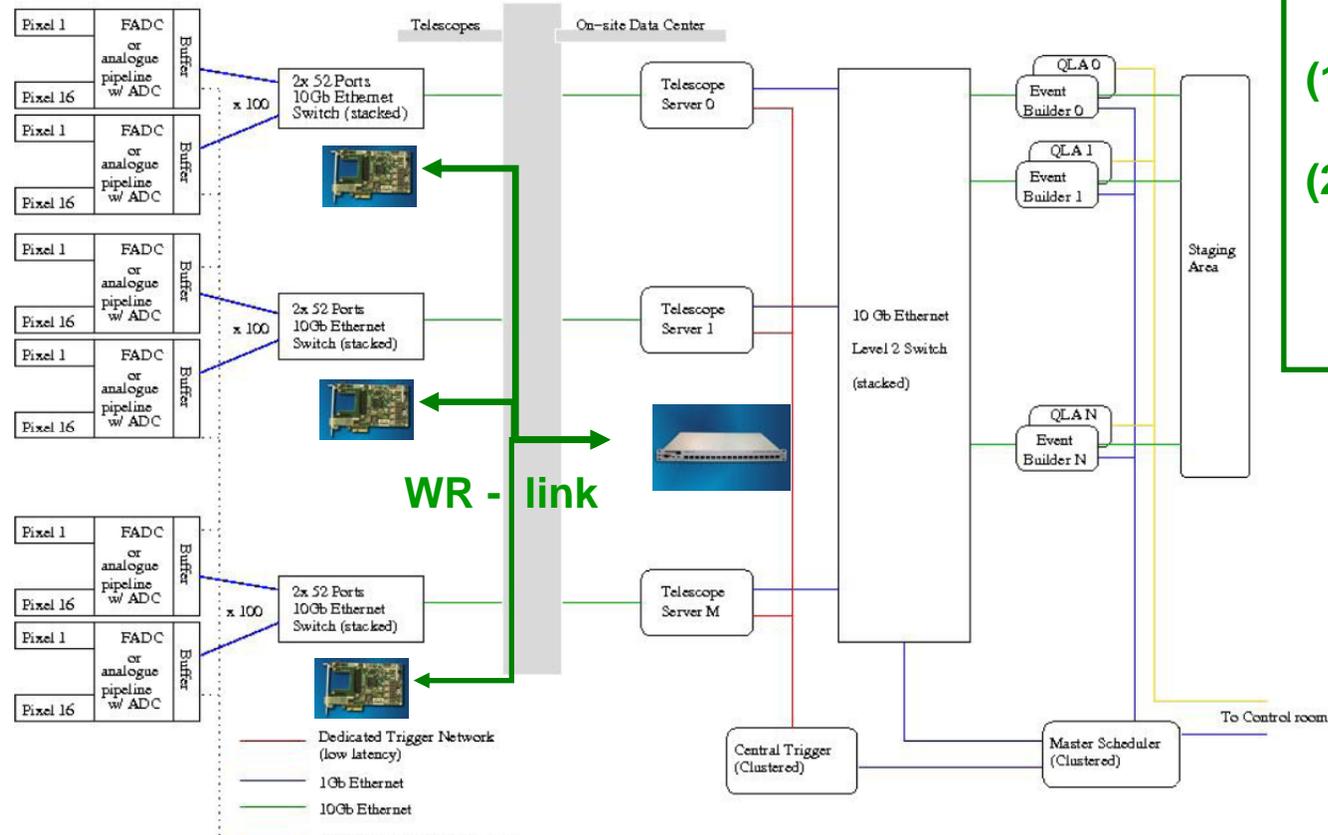


Only a few components are needed:

- per telescope : 1 x WhiteRabbit Node (PCIe) + 1 standard fiber (SM;1390/1510nm)
- per array : 1...n WhiteRabbit Switches

CTA : DAQ with White Rabbit for Timing & ArrayTrigger

DAQ Architecture



Use the WR-link for

- (1) nsec-timing cameras
- (2) Array-trigger request / confirm messages (1Gbs) with guaranteed latency.

Here, we considered just the baseline functionality: Time-stamping of Camera trigger. There many are more options, including development of CTA-WR boards; Which could integrate FE/DAQ components with WR-cores. E.g.: a WR-Mezzanine with DRS4 (or NecTar).



The White-Rabbit SPEC Card

- **SPEC (“Simple PCIe FMC Carrier”) is the WR node currently available.**
- **For tests, it can also be configured as WR-Master.**
- **It carries the mezzanine-card for your DAQ:**
 - available/planned**
 - **Digital InpOutFMC / FMC DEL / FMC FADC(100MHz) / TDC;**
 - **eg. possible: design a DRS4-based mezzanine for HiSCORE/CTA**

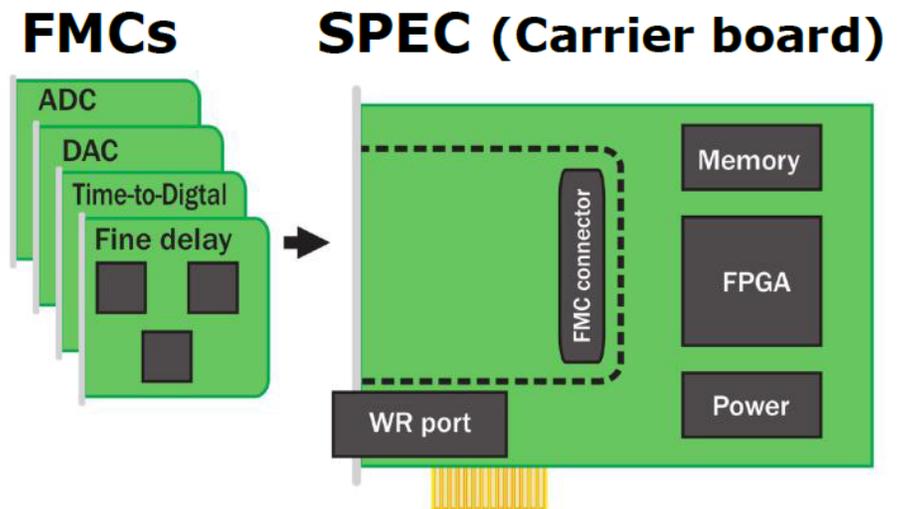
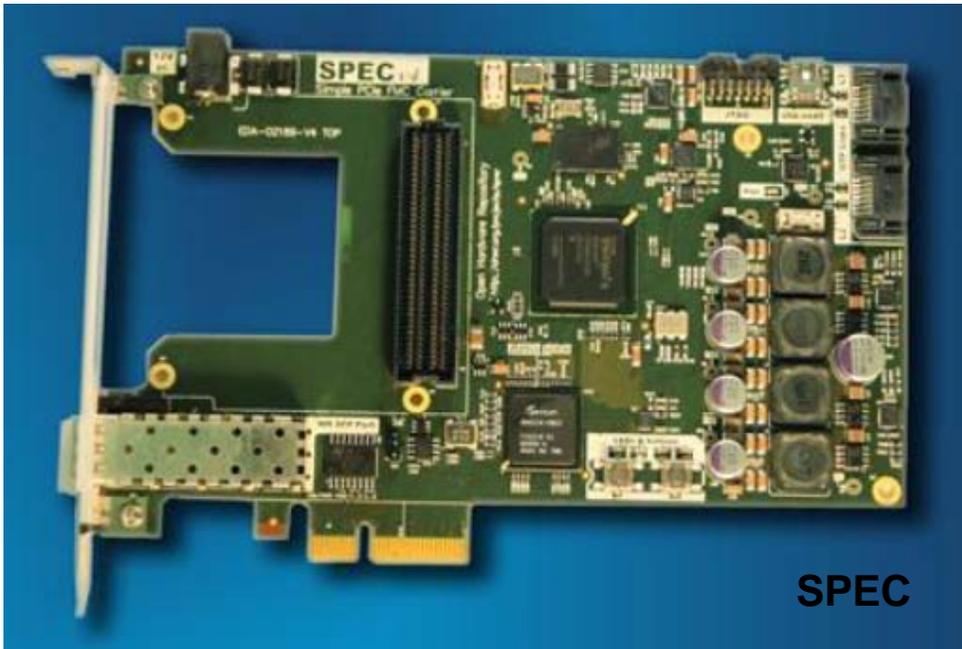
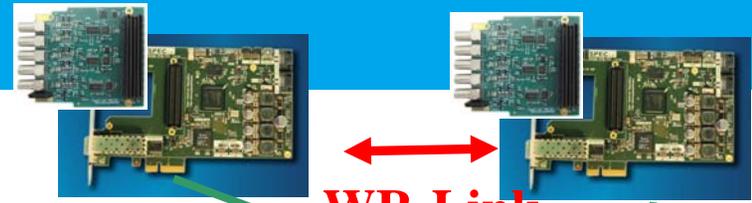


Illustration of the connection of SPEC with FMCs

Test Setup + Results



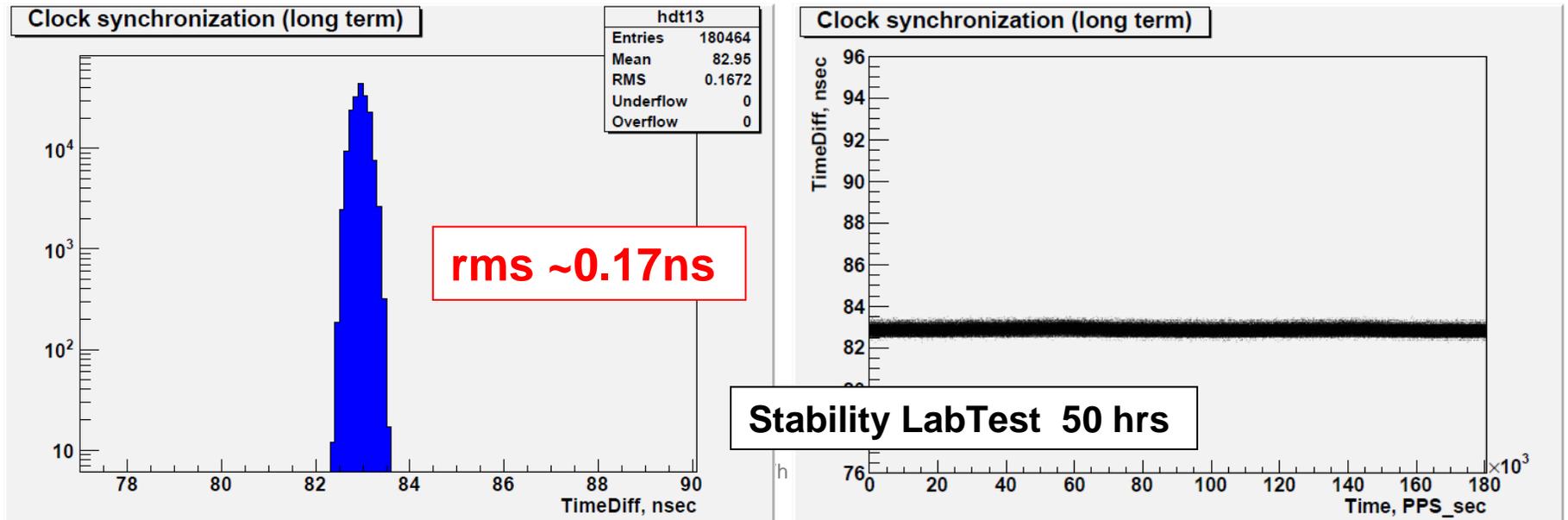
> Setup:

- 2 WR-SPECs: Master-Slave WR-link + 50m SM/G.652
- Time tests: comparing the master/slave 1-PPS output
- Setup emulates the basic element: WRS+SPEC

1 PPS timing
(DRS4 5GS/s)

Not sensitive to (1) fluctuations at $\ll 1$ sec scale, and (2) clocks in neighbouring nodes

> Result: **TimeDiff (Master-Slave) rms < 0.2 ns !!** (~ measurement precision)



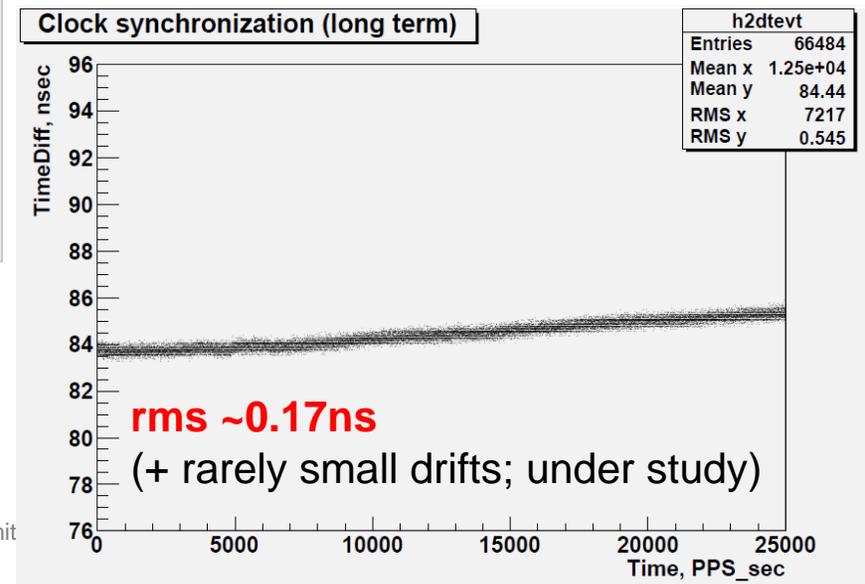
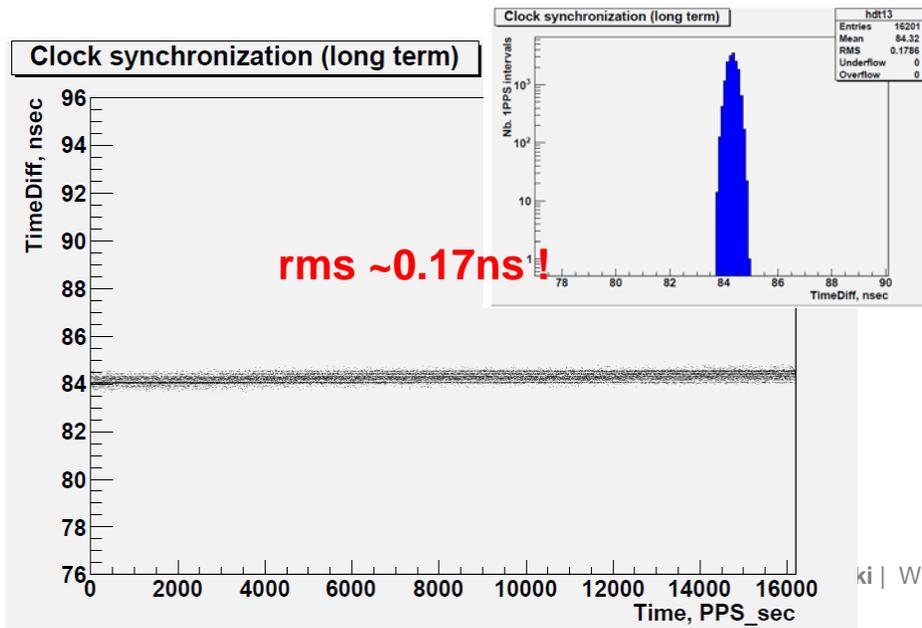
Test at Tunka/HiSCORE

> Field tests at Tunka/HiSCORE site

- April 2012: use DESY-Lab-setup
- use the real 1+1 km Tunka-fibers

> Confirmed Lab-result: rms <0.2 ns

- Routine operation/tests in summer 2012;
Rarely: slow drifts (temperature?).
(As any in-situ verification of a new system).



Summary

- > **First Tests of White Rabbit elements at DESY are very encouraging:**
 - **Clock stability (longterm) < 0.2 ns rms**

- > **For CTA, White Rabbit is an excellent candidate for**
 - **Time-synchronization: specs are fulfilled**
 - **Array trigger : favourable network architecture for time-stamp based coincidences**

- > **Advantages, that make WR a top candidate for CTA:**
 - **Real standard, commercial support, Open source HW/SW**
 - **Reliability, easy maintenance, cost effective, scalability, field-applicable**
 - **Used for timing in : HiSCORE, LHAASO, ...**

- > **Full performance verification in the field**
 - **A challenge that can be made a common effort with other projects**

- > **DESY is committed to HiSCORE WR-DAQ; and thinks about a related CTA initiative**

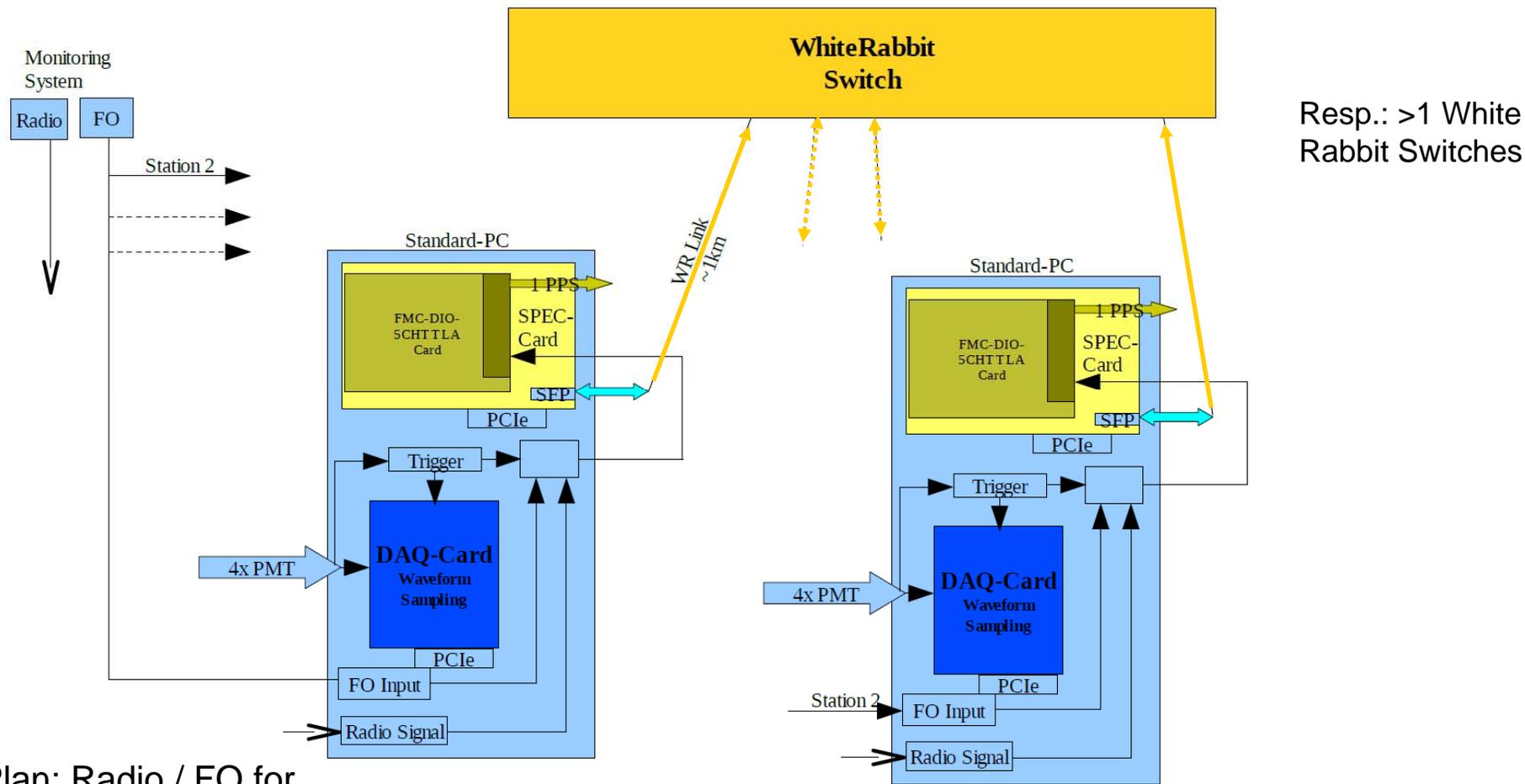
- > **Application in ASTRI is realistic and a logical preparation for CTA**



> Thanks.



HiSCORE : DAQ Station + White Rabbit



Resp.: >1 White Rabbit Switches

Plan: Radio / FO for verification of timing

(still under development)



Example Layout: CTA / HiSCORE

HiSCORE / EA : 20-40 DAQ-Stations

CTA : 50-100 Telescopes

1. Array center:

WR-switches (18 x out) - with $N=4 \rightarrow 67$ Stations / Telescopes
(+ central GPS; or Rub.Clock)



2. Dedicated SM-fiber to every Station / Telescope

3. Every Station / Telescope houses 1 WR-SPEC time-latching unit

> Price: $O(1300\text{Eur})$ per station

= 1100 (SPEC+DIO) + $1/17 \times 3500$ (WRS)

(very conservative)

