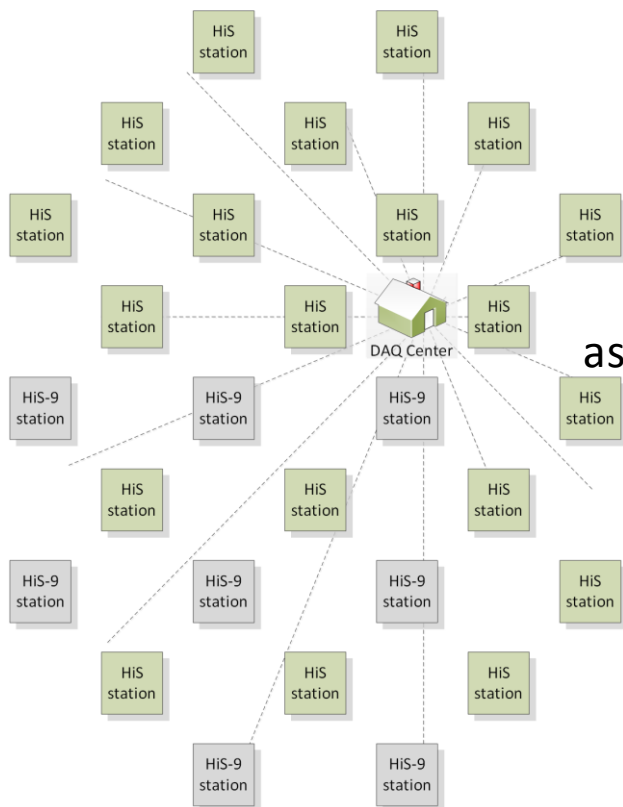
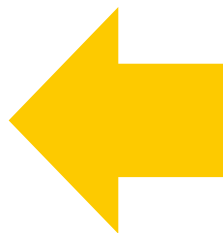


White Rabbit based sub-nsec time synchronization, time stamping and triggering in distributed large scale astroparticle physics experiments

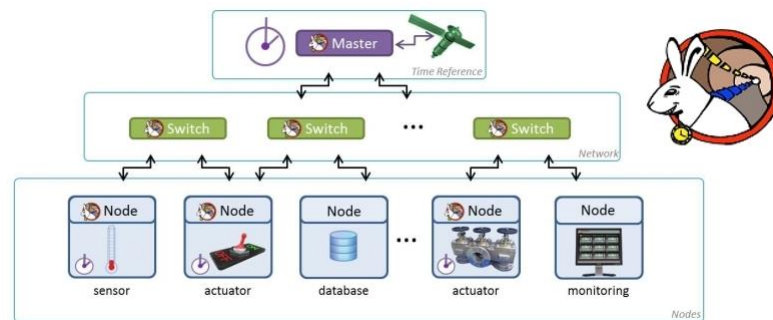


HiSCORE experiment in Siberia

- Distributed over several km²
- Needs 1ns time stamps



Integrating WR into
astroparticle experiments
like HiSCORE
with time stamping



White Rabbit
Time Synchronisation System
Developed at CERN

Sub-nsec precision
Ethernet fiber based

PAUL SCHERRER INSTITUT PSI DESY

White Rabbit based sub-nsec time synchronization, time stamping and triggering in distributed large scale astroparticle physics experiments

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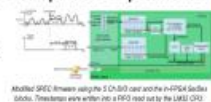
Wir schaffen Wissen – heute für morgen

Time Synchronization to sub-nsec precision between detector subsystems in large scale astroparticle physics experiments can efficiently be provided by White Rabbit (WR) [1], a new Ethernet-based technology for time and frequency transfer. We discuss principles and advantages of WR for distributed detector arrays, which allows clock synchronization and trigger timestamping of sub-nanosecond precision, as well as for complex and flexible topological trigger strategies, based on Ethernet-routed triggerlines. We illustrate a White Rabbit system for the Gamma-Ray Imaging (GRIGO) [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34] [35] [36] [37] [38] [39] [40] [41] [42] [43] [44] [45] [46] [47] [48] [49] [50] [51] [52] [53] [54] [55] [56] [57] [58] [59] [60] [61] [62] [63] [64] [65] [66] [67] [68] [69] [70] [71] [72] [73] [74] [75] [76] [77] [78] [79] [80] [81] [82] [83] [84] [85] [86] [87] [88] [89] [90] [91] [92] [93] [94] [95] [96] [97] [98] [99] [100] [101] [102] [103] [104] [105] [106] [107] [108] [109] [110] [111] [112] [113] [114] [115] [116] [117] [118] [119] [120] [121] [122] [123] [124] [125] [126] [127] [128] [129] [130] [131] [132] [133] [134] [135] [136] [137] [138] [139] [140] [141] [142] [143] [144] [145] [146] [147] [148] [149] [150] [151] [152] [153] [154] [155] [156] [157] [158] [159] [160] [161] [162] [163] [164] [165] [166] [167] [168] [169] [170] [171] [172] [173] 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[506] [507] [508] [509] [510] [511] [512] [513] [514] [515] [516] [517] [518] [519] [520] [521] [522] [523] [524] [525] [526] [527] [528] [529] [530] [531] [532] [533] [534] [535] [536] [537] [538] [539] [540] [541] [542] [543] [544] [545] [546] [547] [548] [549] [550] [551] [552] [553] [554] [555] [556] [557] [558] [559] [560] [561] [562] [563] [564] [565] [566] [567] [568] [569] [570] [571] [572] [573] [574] [575] [576] [577] [578] [579] [580] [581] [582] [583] [584] [585] [586] [587] [588] [589] [590] [591] [592] [593] [594] [595] [596] [597] [598] [599] [600] [601] [602] [603] [604] [605] [606] [607] [608] [609] [610] [611] [612] [613] [614] [615] [616] [617] [618] [619] [620] [621] [622] [623] [624] [625] [626] [627] [628] [629] [630] [631] [632] [633] [634] [635] [636] [637] [638] [639] [640] [641] [642] [643] [644] [645] [646] [647] [648] [649] [650] [651] [652] [653] [654] [655] [656] [657] [658] [659] [660] [661] [662] [663] [664] [665] [666] [667] [668] [669] [670] [671] 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WR+Timestamp firmware for Astroparticle Experiments

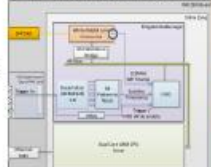
SPEC board with modified design

- Intended to be used as PCIe card inside a PC
- Modified design timestamps with a resolution of 1ns
- SCH DIO has adjustable input of three/folds
- In standalone mode limited network/software capabilities due to the software m32 cpu
- Time stamp read out rate at 1MHz



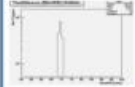
ZEN board (Zynq based) by 79als

- Intended to be used as standalone device
- White Rabbit Core running in Programmable Logic
- Linux has access to the White Rabbit core register over the AXI bus (e.g. monitoring)
- Linux can read out the time stamp FIFO
- WR link can be used as network interface for sending/receiving network packages



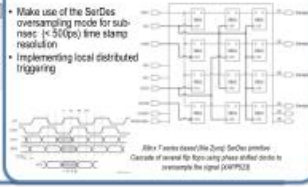
With this firmware / hardware

- WR stable 125MHz clock
- WR trigger input and output
- WR time stamps
- With ZEN local distributed trigger decisions possible
- Or global array trigger decision over WR link



Future Work

- Make use of the SerDes oversampling mode for sub-nsec 1-5k(Sps) time stamp resolution
- Implementing local distributed triggering



Conclusions

- Large scale astroparticle experiments need nsec-timing
- WR perfectly fits these requirements (Clock distribution, Trigger time stamping, ...)
- WR has been implemented and operating in HiSCORE
- Zynq board has more possibilities as a standalone device (Analyzing time stamps on the fly in firmware and software, receiving neighboring time stamps)

White Rabbit [1]

- Fully deterministic Ethernet-based network for data transfer and synchronization
- Subnanosecond accuracy
- Open Source Hard-, Firm-, and Software
- Developed at CERN
- Standard GbE compatible



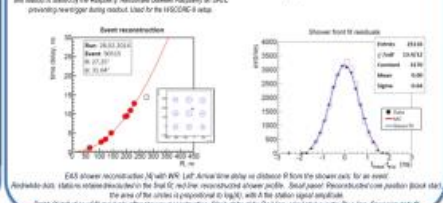
HiSCORE experiment [5]

- Cosmic- and gamma rays emit Cherenkov light and radio pulses in the atmosphere
- Multiple detectors distributed over a large area 1km²-100km²
- 20 station prototype (0.25km²) installed in Turku, Siberia
- Each station detects Cherenkov light with 4 PMTs
- For an angular resolution of 0.1 degree timestamps with 1ns resolution is needed



Station readout electronic

- PMT inputs recorded on a DR54 5GHz sampling eval board (B) triggered by the SPEC board
- Raspberry reads out the DR54 boards
- Ready Flag as Handshake between SPEC and Raspberry
- WR Fiber for timestamps
- Raspberry Ethernet for DR54 data



References

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 [6] DR54 evaluation board, DSI, Inc., 2014. <http://www.dsi.com/products/boards>

Integrating WR into HiSCORE

WR itself

HiSCORE experiment in Siberia with modified WR firmware