White Rabbit in Siberia: Tunka-HiSCORE

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HELMHOLTZ ASSOCIATION

DESY

Outline

- Tunka-HiSCORE -

  A new Gamma-Ray and Cosmic Ray Detector in Siberia

  - Physics, Collaboration
  - Setup: Record Cherenkov light field in stations distributed over 1-10(100)km^2

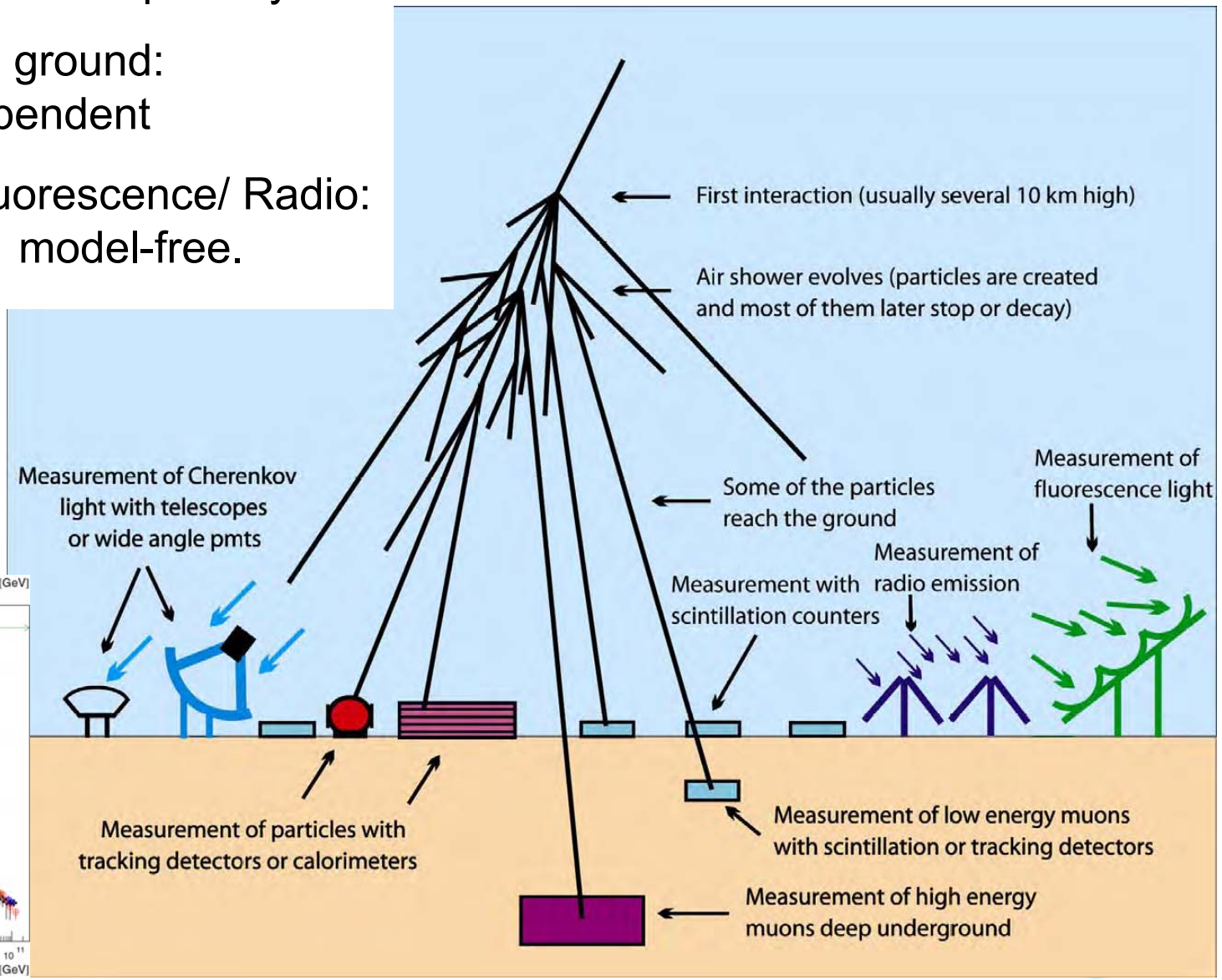
- WhiteRabbit for HiSCORE

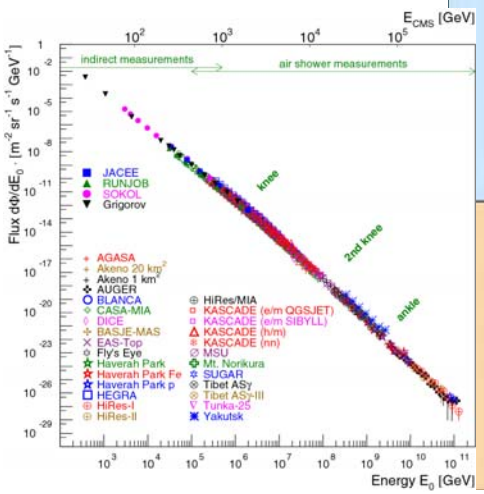
  - A natural application of WR
  - Status, plans
  - Our questions

- Summary

Cosmic Ray Detection Techniques

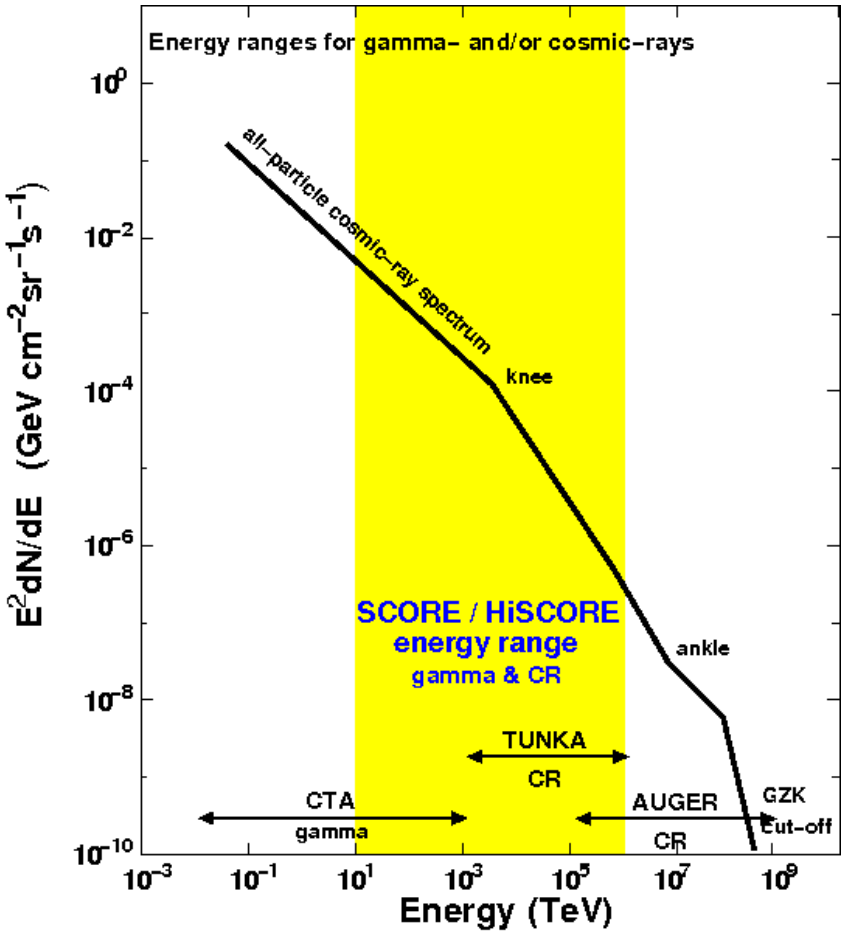
- Measure: E, mass of primary CR
- Particle flux on ground: very model dependent
- Cherenkov/ Fluorescence/ Radio: calorimetric → model-free.





The HiSCORE Detector

HiSCORE = **H**undred***i** **S**quare-km **C**osmic **OR**igin **E**xplorer



- Gamma-rays:
- $E_\gamma > 10$ TeV
- Cosmic-rays:
- $100\ \text{TeV} < E_{CR} < 1\ \text{EeV}$

- Large area: up to few 100 km^2
- Large field of view: ~0.6 sr
- Non-imaging technique

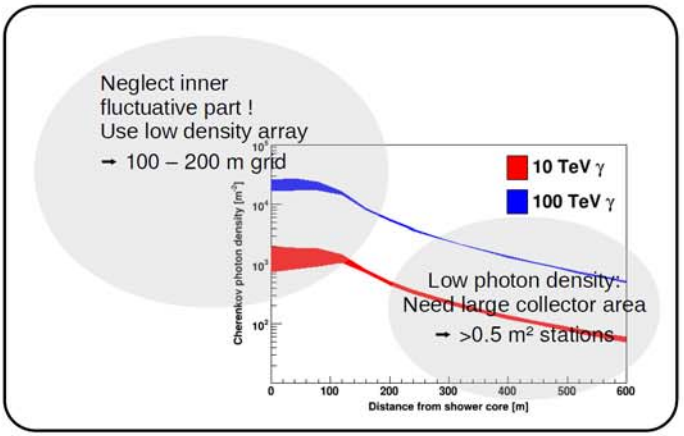
ASPERA recognizes the importance of *"development of ground-based wide-angle gamma-ray detectors"*

ASPERA

Complementary in energy range, physics + technique wrt CTA (E~0.01–100 TeV)

HiSCORE: Design principles

- Large instrumented area: 10 – 100 km^2 - sensitivity to low fluxes
- Large station area: 0.5-1m^2 - photons far off-axis
- Wide station spacing: 100-200m - low cost; reconstr. lever-arm
- Fast electronics/sampling: Photon arrival times for X_{max} and direction



Ground based array of detector stations

HiSCORE: A staged approach

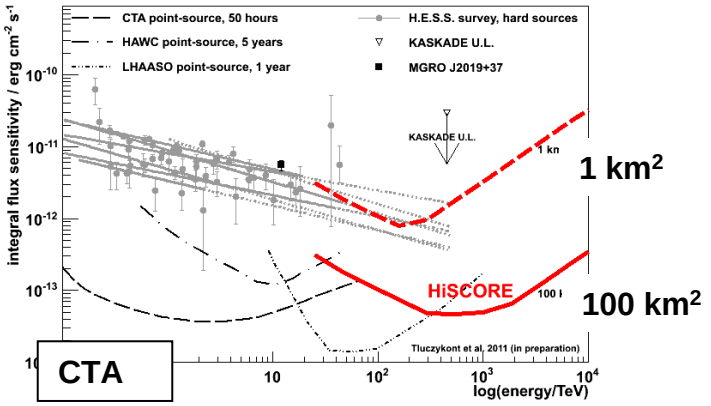
- Stage 1: 1 km^2 Engineering Array @ Tunka by fall 2013
  - Proof-of principle
  - First physics ~2013 !

    M87: 127hr / yr (tilted-south mode)
    → 50 γ-ray events/yr with Engineering Array

- Stage 2: 10 km^2 in >2014
- Stage 3: 100 km^2

  → important: southern skies

- HiSCORE sensitivity better CTA >>10TeV →



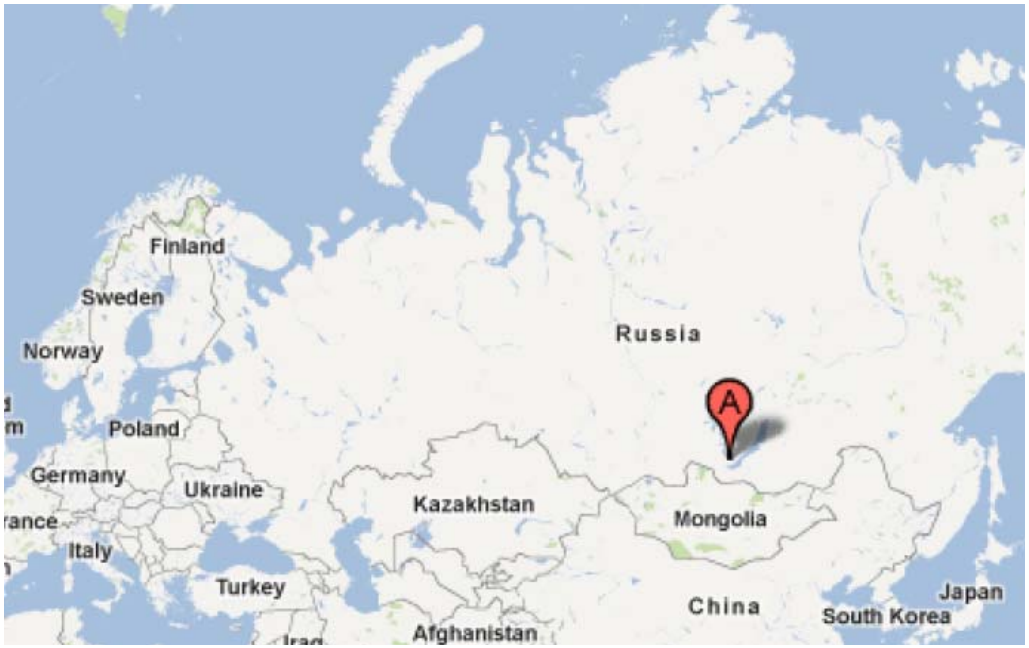
Tunka-HiSCORE : Collaboration, Location

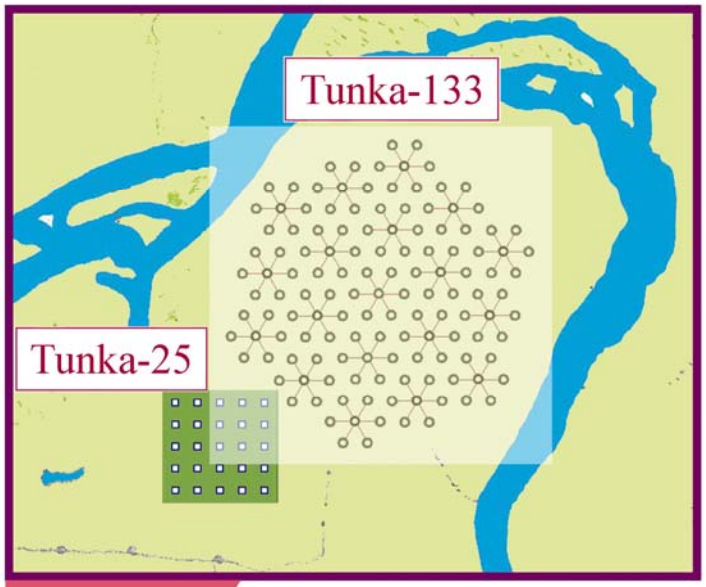
> MoscowStateUniv/ INR-RAS / ISU (Russia) + Univ.Hamburg / DESY (Germ)

supported by Helmholtz as 'Helmholtz Russia Joint Research Group' (2012-15)

> Tunka-Valley / Siberia

- 50km off Lake Baikal
- At the site of Tunka-133 – An Air Cherenkov Array of 1 km2;
  operating since 2009 (Russia/INFN/DESY)

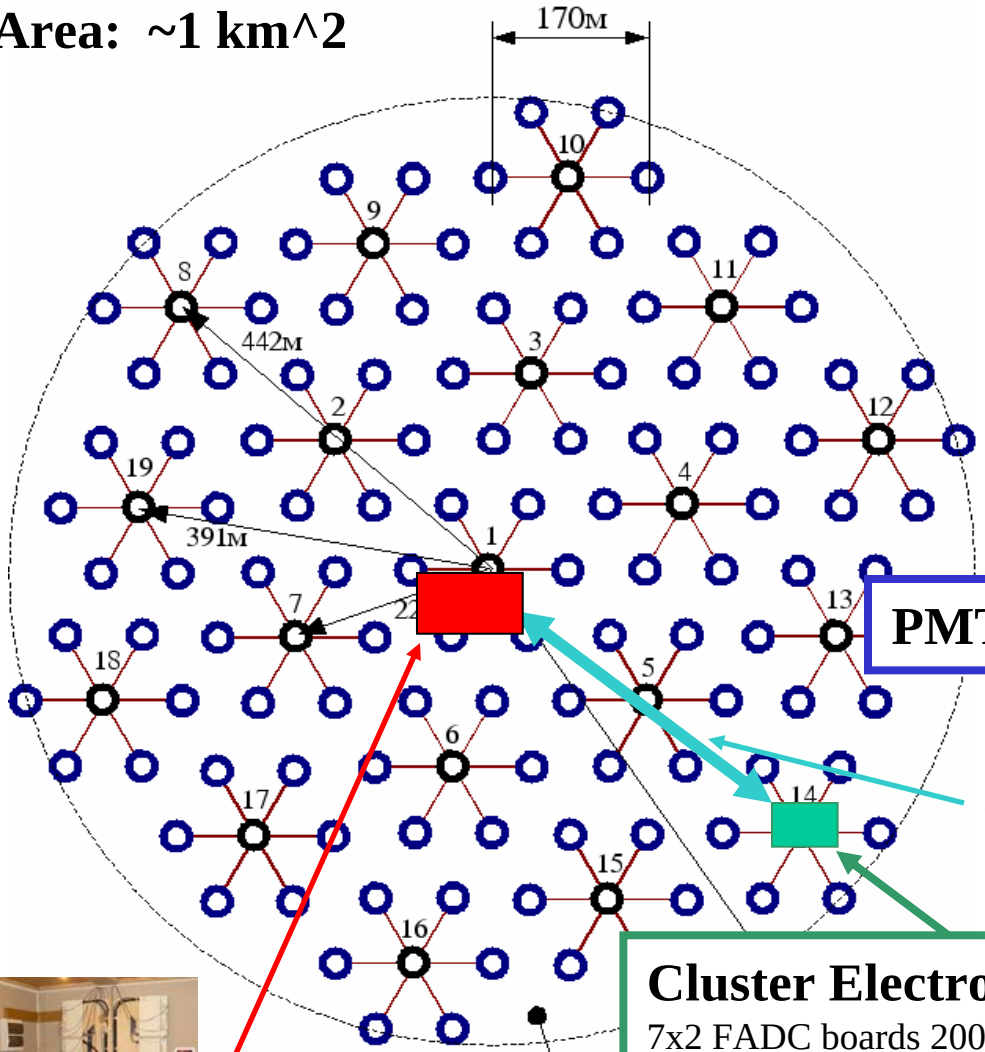


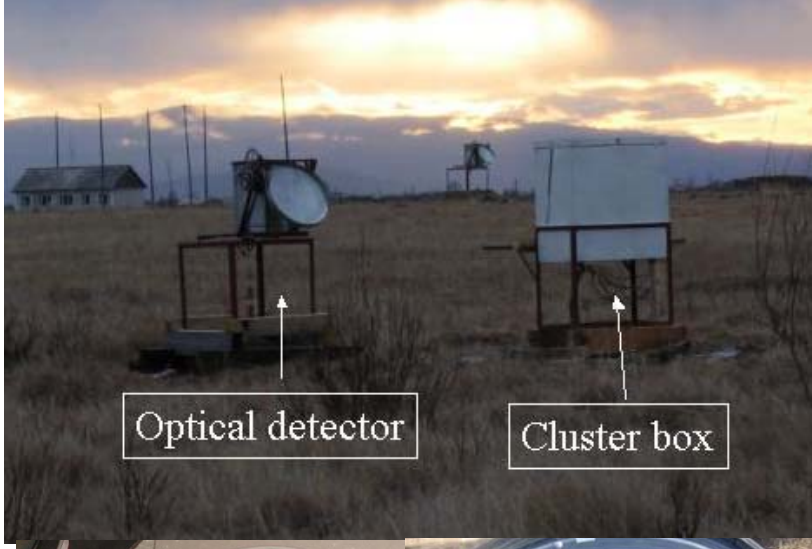


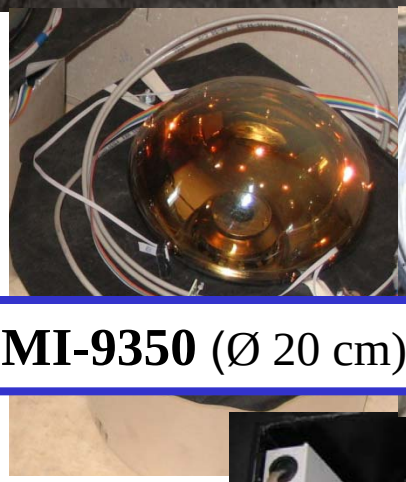
51° 48' 35" N
103° 04' 02" E
675 m a.s.l.

The existing Tunka-133 Array: 19 Clusters with 7 PMTs each

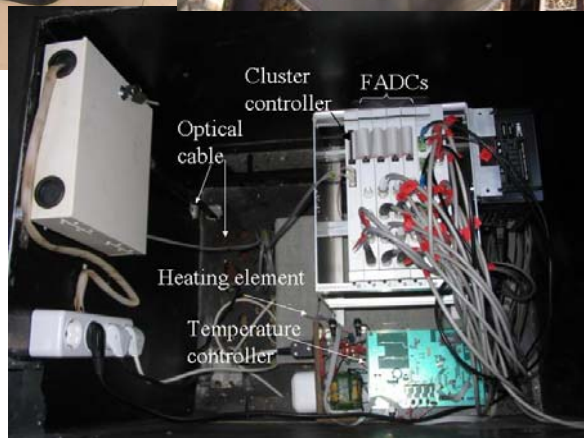
Area: ~1 km^2







PMT EMI-9350 (Ø 20 cm)



Optical cable

Cluster Electronic Box

7x2 FADC boards 200 MHz, 12 bit

Central DAQ

HiSCORE : Local trigger time stamping

- HiSCORE Engineering Array (2013)
- 20-40 DAQ stations, distributed over ~1 km^2
- Each Station:
  - generates local trigger
  - digitizes PMT waveform
  - 0.1-10kHz, few MB/s, GHz sampling

- Need: Precise relative time synchronization between stations

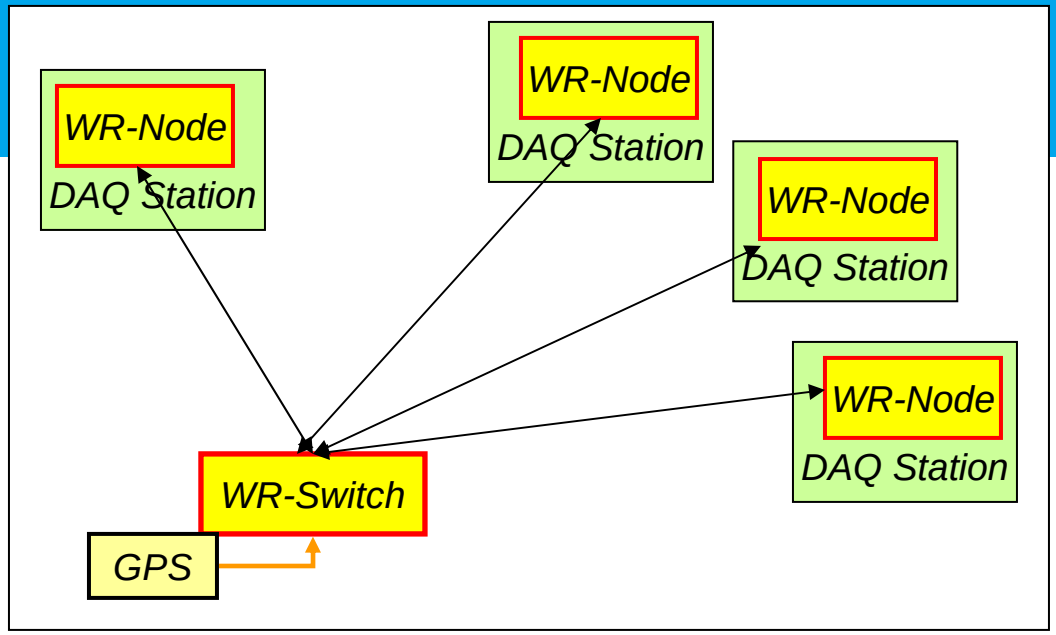
  → Station trigger time stamps with 1nsec relative time-error;

  (for: shower direction, shower front reconstruction (particle type) …)

- TimeSynchronization inside a distributed DAQ-System on nsec-scale

  → White Rabbit is a natural candidate

Baseline Design



- Central Switch(es)

  ←→ 20…40 Stations

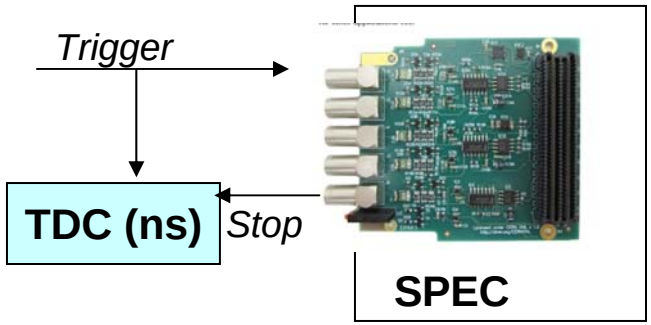
- Each Station:

  1 SPEC with “nsec-timestamp capability”

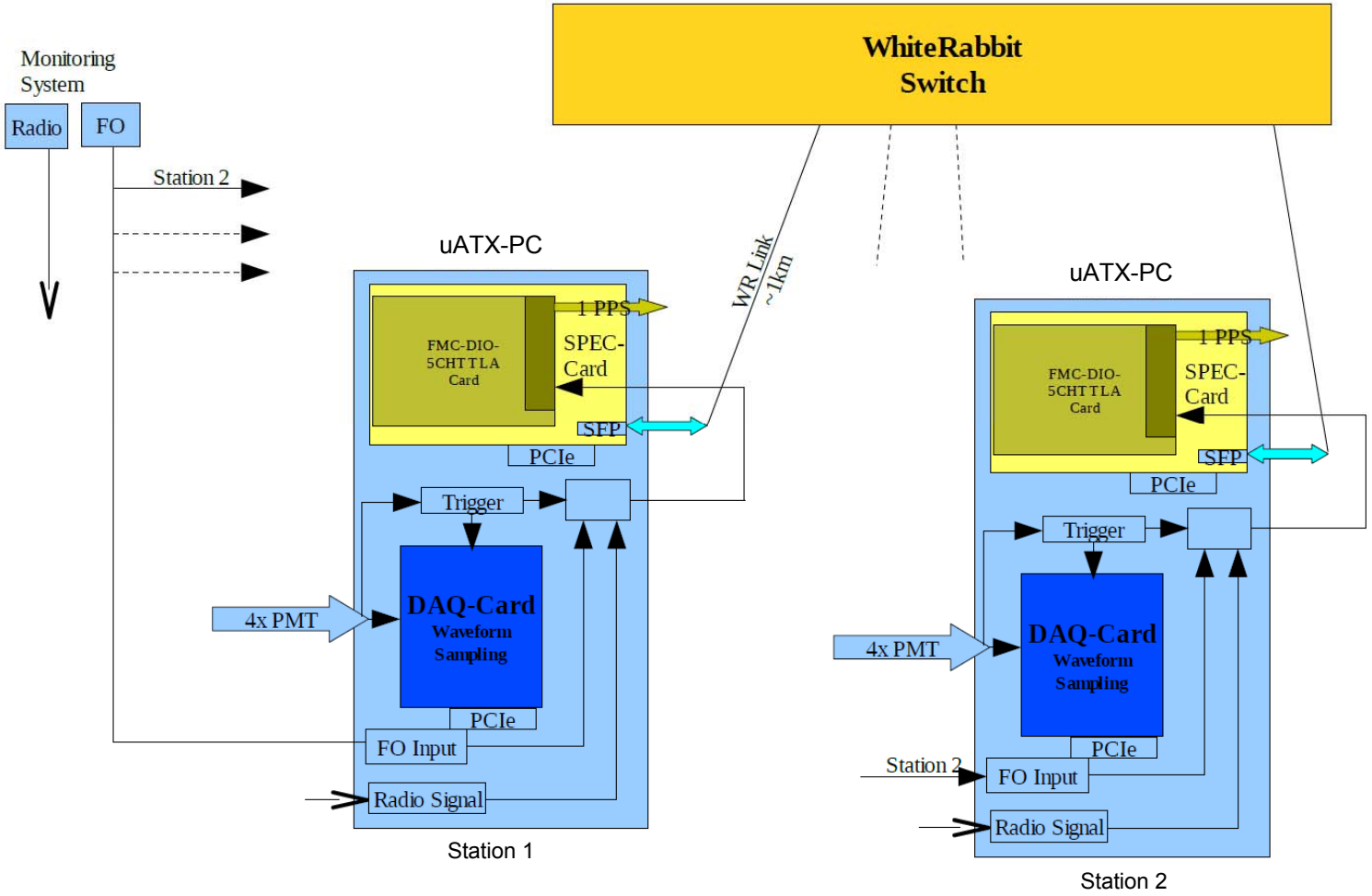
  - SPEC + FMC-5ChDIO with external TDC
  - SPEC + FMC-DEL, …
  - SPEC + custom-FMC (DRS4 Waveform sampling)

- SPEC+ 5CHDIO-FMC + TDC

  - A simple way to get fine-time <8ns
  - Trigger: Input to FMC-5ChDIO + to external TDC
  - SPEC latches 8nsec GPS time
  - Outputs the “next 125 MHz clock” → as Stop for TDC



Baseline Design: DAQ Station



(prelimin. design, still under development)

WR TimeStamping: Monitoring needed

- Two dedicated, redundant monitoring systems under consideration

- FO-based calibration system
  - Send “calibration events” trigger signals over spare fibers from DAQ-center to all stations
  - FO-Converter: need 1ns intrinsic stability. commercial ? Custom-made ?
  - Problem: how stable is the FO-calibration; correlated with WR ?
    - Slow drifts – no problems (temperature,…)
    - jumps should be un-correlated with WR-clocks

- Radio-Beacon
  - LOPES/KIT idea: use central radio transmitter to synchronize local phases o(nsec)
  - E.g. 50MHz → 20nsec fine time scale: realistic and affordable.

WR @ DESY / HiSCORE: Plans

- Laboratory Setups (4-6/2012)
  - SPEC(Mast) ←→ SPEC(Slave) with FMC-DIO5CH
    - Time stamping with 8nsec (SPEC)
    - Fine time stamping: 1nsec with external TDC (DRS4)
    - Basic verification of time-base with single station (event_i – event_i+1)
  - WR-Switch → SPEC-1
    → SPEC-2 , SPEC_3, …
    - Multi-Station Clock stability test (!)
- Field-Tests (>7/2012)
  - WR-Switch Configuration over real 1km fibers (!)
  - WR-SWitch +2-3 stations for long-term operation from 9/2012
  - Monitoring: FO channels (+ radio) start in 2012 …
- HiSCORE-EA installation (summer 2013)
  - 20-40 stations
  - With FO & Radio monitoring included

Summary

- Tunka-HiSCORE is a new Gamma/CR-Detector: in final design phase
- WhiteRabbit is top-candidate for Tunka-HiSCORE timestamping

- Baseline WR-application in HiSCORE is relatively simple
  - DAQ station w/ 1 WR-SPEC slave; Deeper integration of WR into DAQ is possible

- Plans: 2012 - focus on proof of principle & performance
  - Proof-of-principle by summer 2012 (Lab + Field) → Final decision to accept WR
  - Longterm test: 2-4 stations from 9/2012
- Plans: 2013 - HiSCORE-Engineering Array
  - 20-40 stations by fall 2013
  - 10km2-Array in >2014: *o(200-400)* stations
  - Final aim: 100km^2 aray (Southern location) with ~2-4000 stations

Summary (2)

- WhiteRabbit - a candiate “standard” for time-synchronization in large scale experiments ?
  - CTA, AUGERNext, LHAASO, km3net, …

- Our points:
- Is schedule realistic : Summer 2012 – a stable mini-system ?
- Is design realistic: SPEC + TDC for nsec-time stamping ?
- Did we overlook any “show stoppers“ for a running timing system in 2013 ?

> Thanks.

Backup:
A side remark. WR as a backbone for distributed DAQ?

> TimeSynchronization of distributed DAQ-Systems on nsec-scale

is a standard challenge for many astroparticle physics experiments

- Important - for physics data quality
- Difficult - need of verification, calibration, monitoring (long-term)
- So far: always custom-made solutions solutions.
  Cost-effective (?), but always start from scratch; verification (longtime characterization, precision)…
- Having myself been busy in a few such experiments

  AMANDA/Baikal (IceCube)-NeutrinoTelescopes, Tunka-CosmicRay Experiment, now CTA around corner
- Thus, a natural question / suggestion :

  WR could become a standard “off-the-box” solution for time-calibration in experiments !