# HiSCORE

## Hundred*i Square-km Cosmic Origin Explorer

### – accessing the accelerator-sky from 10 TeV to 100 PeV –


M. Tluczykont[1], D. Hampf[1], D. Horns[1], R. Eichler[1], R. Nachtigall[1], T. Kneiske[1], G. Rowell[2]

martin.tluczykont@physik.uni-hamburg.de (1) Universität Hamburg, Germany; (2) School of Chemistry and Physics, Adelaide, Australia


**HiSCORE – Hundred*i Square-km Cosmic ORigin Explorer**
**A new ground-based large-area wide-angle air Cherenkov detector for gamma-ray astronomy above 10 TeV and cosmic-ray astrophysics from 100 TeV to 1 EeV.**


**Abstract:**

We propose to explore the so far poorly measured cosmic ray and gamma-ray sky (accelerator-sky) in the energy regime from 10 TeV to 1 EeV with the new large-area (~100km²) wide-angle (~0.84sr) cosmic ray and gamma-ray detector **HiSCORE.**

HiSCORE is a non-imaging Cherenkov light-front sampling array with sensitive large-area (order of 1 square-m) detector modules, distributed over an array covering a total area of up to few 100 square-kilometers. The lateral intensity and arrival-time distributions will be sampled with high sensitivity up to large distances from the shower Core, providing a large lever-arm for shower reconstruction.

HiSCORE addresses fundamental physics questions of astroparticle and particle physics, including the origin of charged Galactic cosmic rays (gamma-ray observations), spectral and composition measurements of charged Galactic cosmic rays, diffuse gamma-ray emission (e.g. Galactic plane, local super-cluster), attenuation by Galactic interstellar radiaton fields and the cosmic microwave Background. Topics of particle are the study of possible effects on this attenuation by photon/axion conversion, hidden-sector photon oscillations or violation of Lorentz invariance, independent measurements of the proton-proton inelastic cross-section overlapping with and exceeding LHC energies, and the search for non-thermal dark matter (wimpzillas).


**Impact of physics motivations on basic detector design:**

**ultra-high energy key: area**

Source flux decreases towards higher energies ultra-high gamma ray (UHE gamma, E>10TeV) regime is **statistics-limited !**

**Large field of view**

Diffuse / extended fluxes
Simultaneous exposure of large part of the sky (~1 sr)

**UHE Gamma-ray Astronomy**

VHE spectra: where do they stop in the UHE / cutoff regime ?
Origin of cosmic rays: where are the Galactic pevatrons ?
Absorption by pair-production in Galactic interstellar radiation field
Absorption in CMB field – new estimation of object distance ?
Diffuse emission:
- Galactic plane / cosmic ray acceleration efficiency mapping
- Local supercluster
- Very extended objects – pevatrons ?

**Charged cosmic ray physics**

Composition & Spectrum 100TeV – 1EeV
extragalactic transition
Large scale Anisotropies
Sub-knee to pre-ankle

**Particle physics beyond LHC**

Axion / photon conversion
Hidden photon / photon oscillations
Lorentz invariance violation
pp inelastic cross-section
non-thermal dark matter / winpzillas

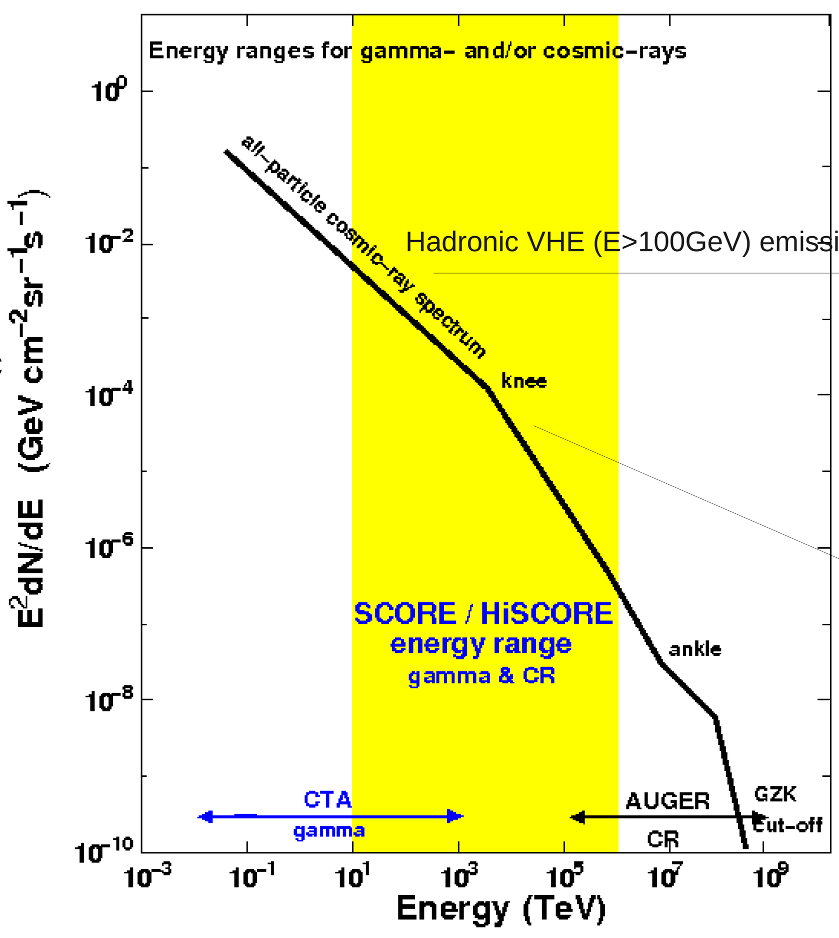
## Spectrum, composition and origin of cosmic rays

**Cosmic rays with HiSCORE**

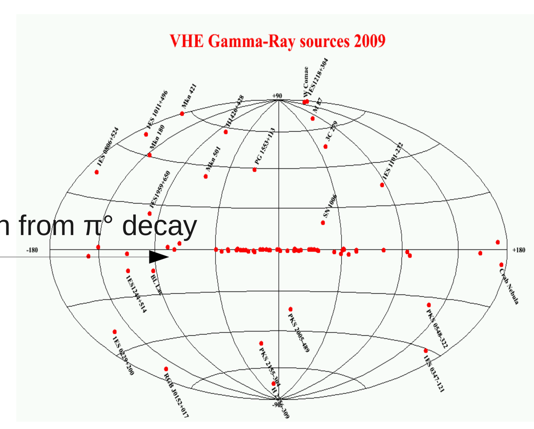
→ Spectral and chemical composition measurements from 100 TeV to 1 EeV, fully covering the energy range of a probable transition from a Galactic to an extragalactic origin of cosmic rays ($10^{15}$ – $10^{17}$eV).

→ measurements of cosmic ray anisotropies. E.g. TeV-anisotropy [Am06] over an unprecedented energy range.

→ origin of cosmic rays via gamma-ray observations in the UHE gamma-ray regime (E > 10 TeV)

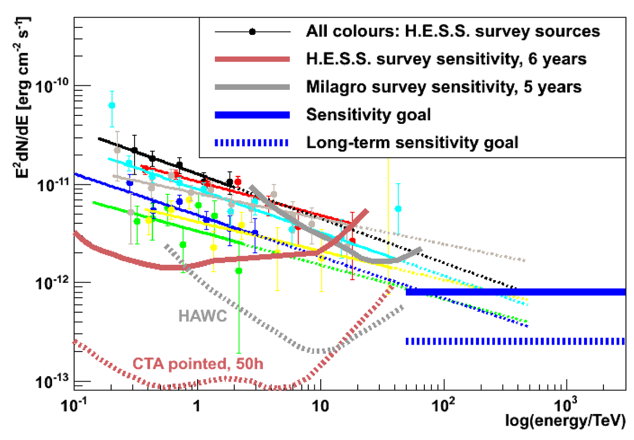



**Where are the Galactic cosmic-ray pevatrons ?**




*Ambiguous VHE regime:*

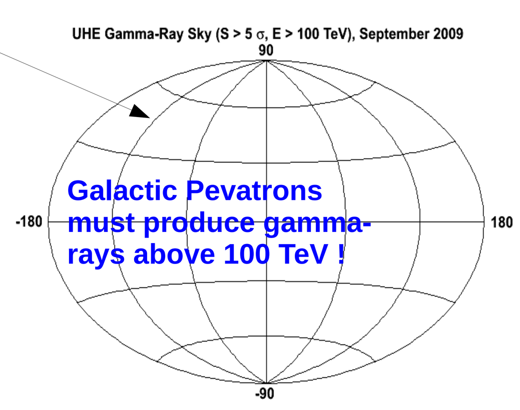
Also leptonic VHE (E>100 GeV) gamma-ray signals from accelerated electrons (inverse Compton effect)




*Hard Galactic sources:*

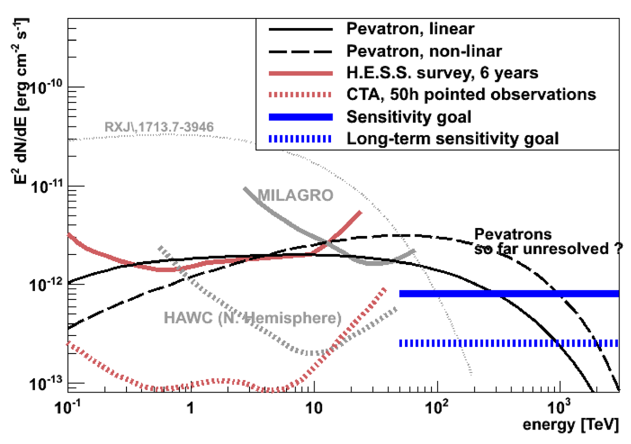
Where do the spectra of Galactic VHE sources stop ?

Could they be Galactic pevatrons ?




*Unambiguous UHE regime:*

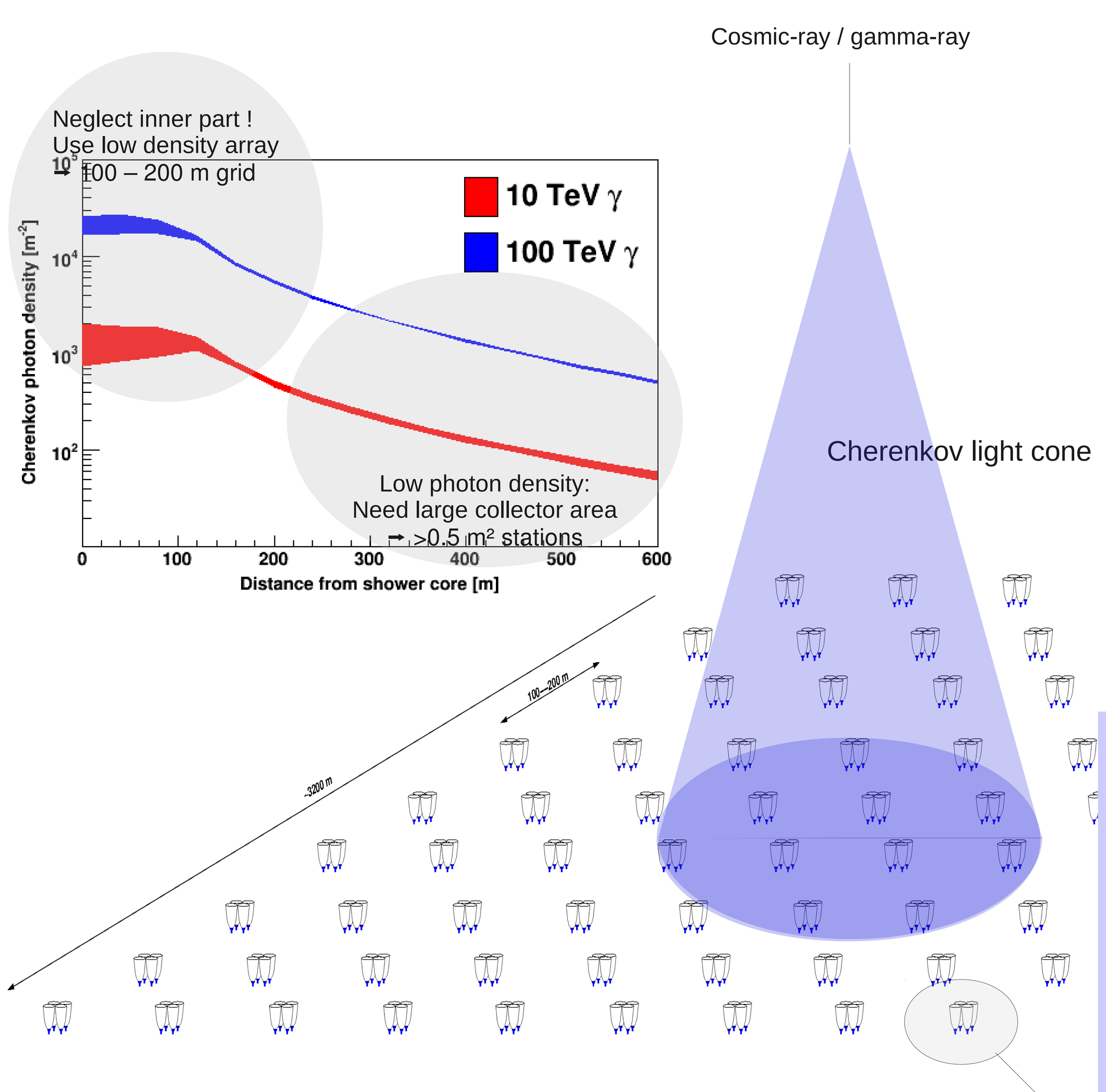
Inverse Compton in deep Klein-Nishina regime
→ Soft leptonic spectrum
→ Hard gamma-ray spectra around 100TeV are an unambiguous signature of hadronic acceleration !

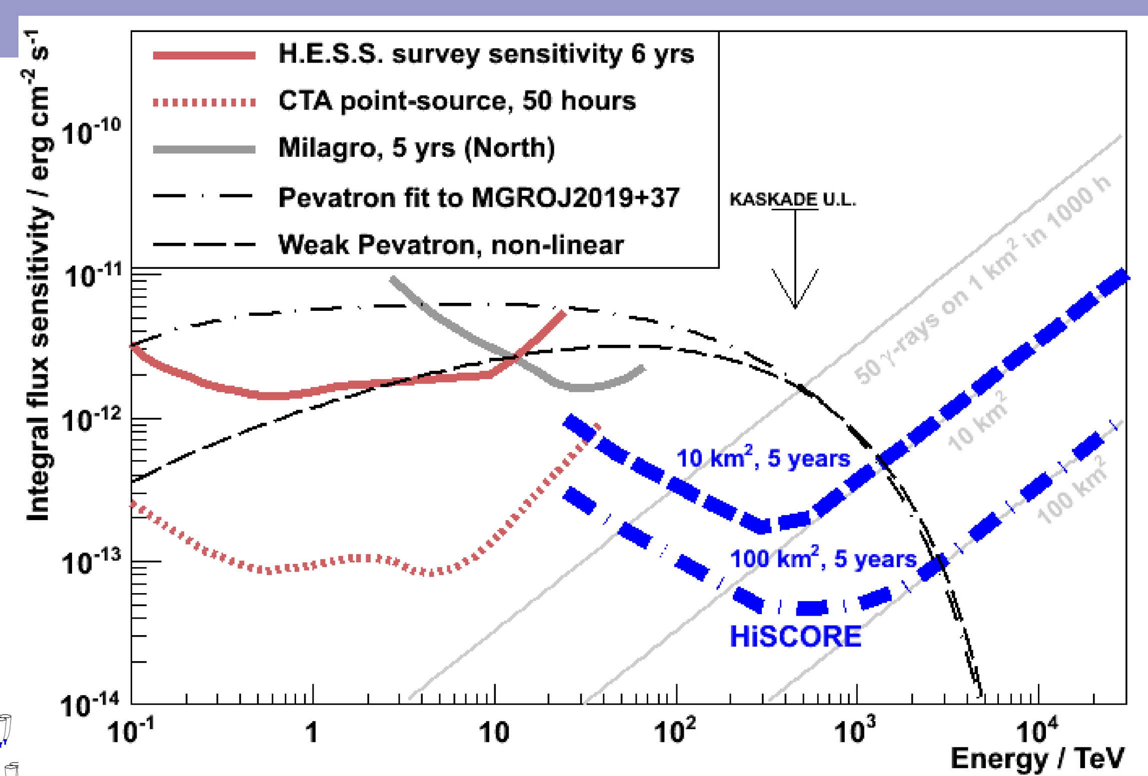



*Pevatron search:*

Existing and planned experiments don't cover the cutoff energy regime of Galactic Pevatrons. HiSCORE will open up this most crucial energy regime !

## The HiSCORE detector



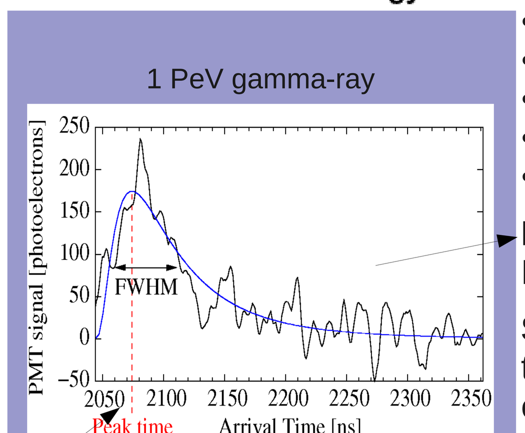




**Pevatron search with HiSCORE:**
- Assuming MGROJ2019 is a pevatron *template:* dash-dotted line
- CTA will not be able to resolve the cutoff regime of this or similar sources
- HiSCORE will fully resolve the pevatron cut-off regime!

**Cosmic ray astrophysics with HiSCORE:**
- $E_{thr}$ >100 Tev (protons): ~20Hz cosmic ray trigger rate
- The 10 km² stage: > $10^{10}$ cosmic rays per year above (E>100 TeV) and ~10 per year above the ankle.

**HiSCORE array layout**

- **Large instrumented area**, 10 km² – 100 km²: compensate decreasing statistics (high energies)
- **Large individual detector station area**, 0.5m²: sensitivity far off shower-core, allowing wide station spacing / large total area.
- **Wide station spacing** (also see previous point): good lever-arm for reconstruction
- **Fast, modern electronics**: resolving the Cherenkov photon arrival time




### Simulation and detector sensitivity

**Air-shower simulation CORSIKA 6735 [Hec98]:**
- using the hadronic interaction model Gheisha [Fe85]
- including the iact Cherenkov photon package by [Be08]

**Full detector simulation – sim_score [Tl09]:**
- using iact package I/O routines, provided by [Be08].
- Winston cone acceptance included by ray-tracing simulation
- PMT quantum efficiency included (Electron Tubes 8inch PMT data)
- PMT signal pulse-shaping based on pulse-shape parameterization [Hen94].
- Next neighbour trigger simulation – 1μs coincidence window
- Night-sky background simulated (including pulse shaping), added to signals

**Reconstruction (see Poster by Hampf et al., this conference)**
Based on the amplitude and timing of the Cherenkov photons.

**Sensitivity:** Effective areas for gamma-rays, p, He, N and Fe are folded with the polygonato model for the spectrum of individual elements. 200 hours of exposure per year were used (based on full southern site-simulation).

### HiSCORE station concept

**Station:** 4 channels inside a box, including all local electronics

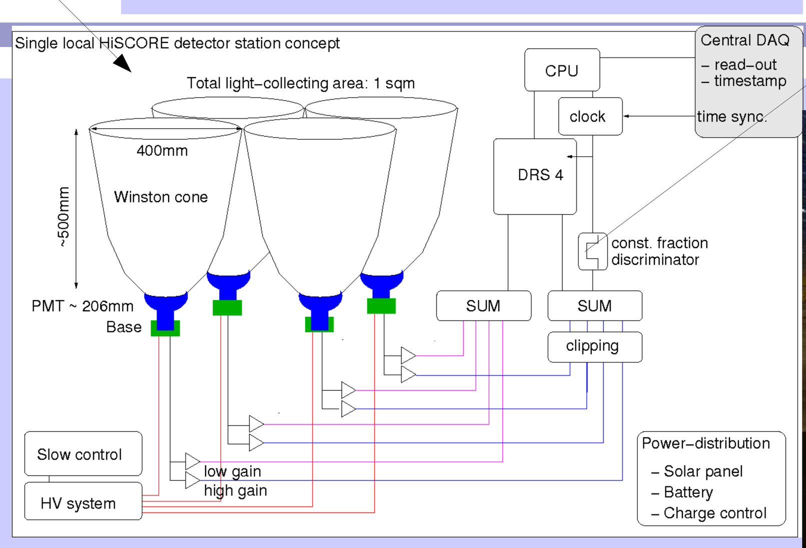
**Channel:** PMT with Winston cone oriented towards zenith.

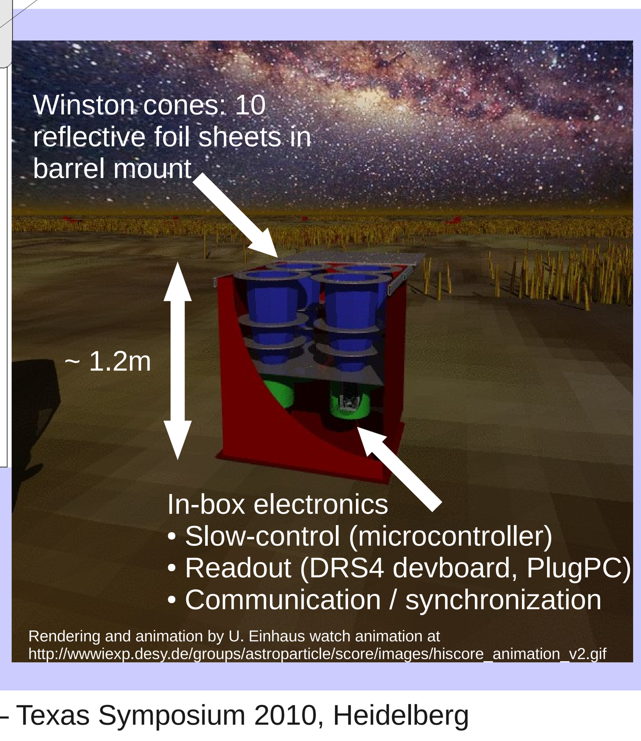
**Maximum automation:** solar/battery powered; self-calibration of position. A time-synchronization of the order of 1 ns is aimed at.

**Local station trigger:** 4-channel coincidence (ns window)
Sum of 4 channels has to pass discriminator threshold.

Night-sky background rate = ~10 Hz – 1 kHz (150 – 100 p.e. thresh.)
Hadron-shower rate = ~20 Hz (100 p.e. Discriminator threshold)

4-channel coincidence condition: significant reduction of accidental night- sky background triggers; larger total light-collecting area (0.5 m², crucial for sensitivity to outer parts of Cherenkov light pool); reduction of after-pulses.




**Status and future plans**
- A full prototype station is under construction
- Cooperation with the Tunka cosmic-ray experiment is planned for prototype field testing.
- Simulation of a hybrid detector array, combining the
- HiSCORE concept with imaging atmospheric Cherenkov telescope arrays such as CTA.
- Studies of combination with other experiments (e.g. AUGER)
- Optimization of reconstruction in progress
- Journal paper in preparation.

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