

SCORE: Physics and Concept



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- What is SCORE ?
- Why SCORE ?
- How SCORE ?
- First simulation results !

What is SCORE ?

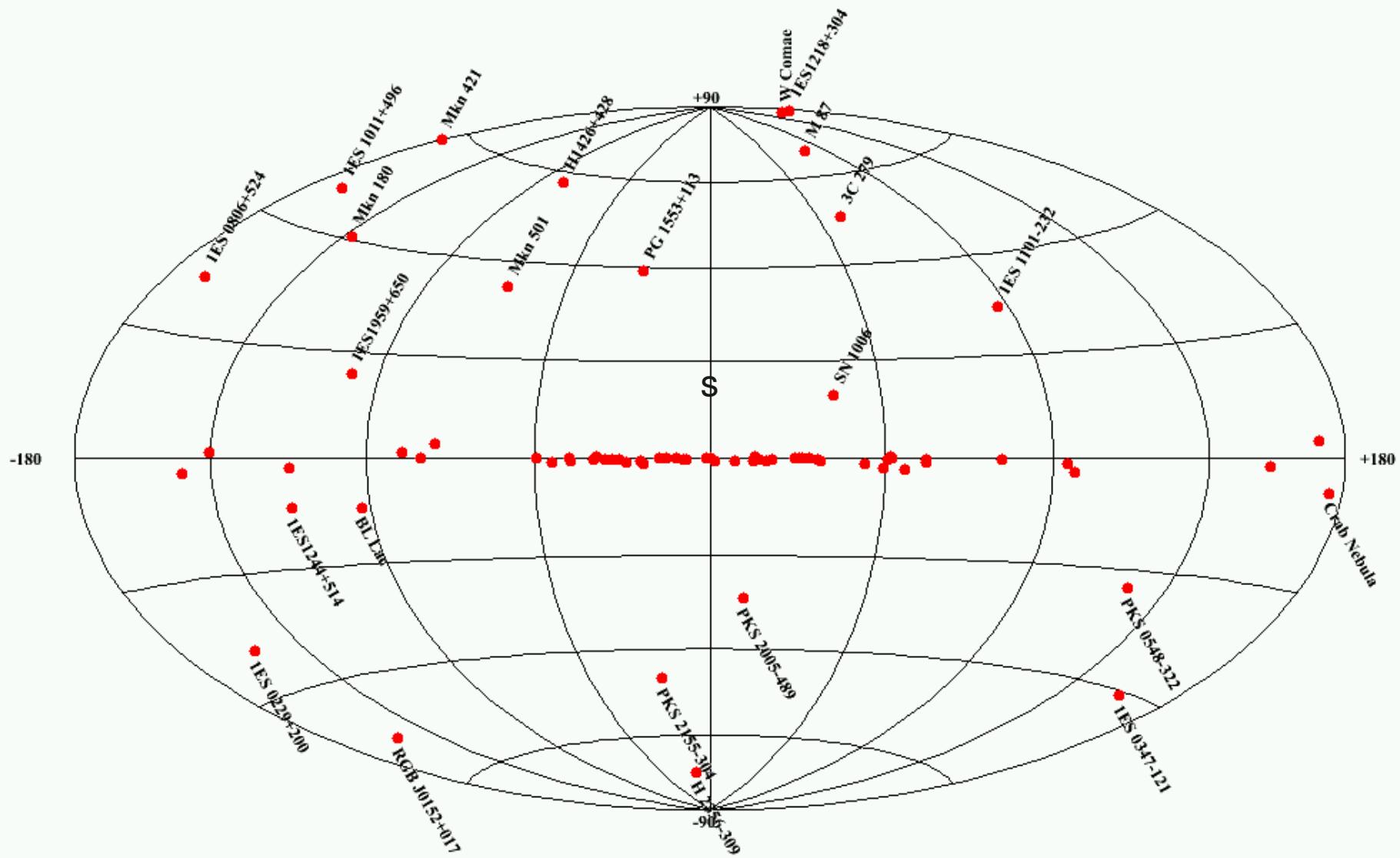
- Study for a Cosmic ORigin Explorer
- Aim at Very High Energy / Ultra High Energy regime
 - Gamma-rays: $E > 10 \text{ TeV}$
 - Cosmic-rays: $100 \text{ TeV} < E < 1 \text{ EeV}$
- Non-imaging Cherenkov detector $10 \text{ km}^2 / 1 \text{ sr}$
- Recommendation of Astroparticle physics Roadmap:
ground-based wide-angle gamma-ray detectors

Why SCORE?

- **Gamma-ray Astronomy**
- **Cosmic-ray physics**
- **Particle physics beyond the LHC scale**

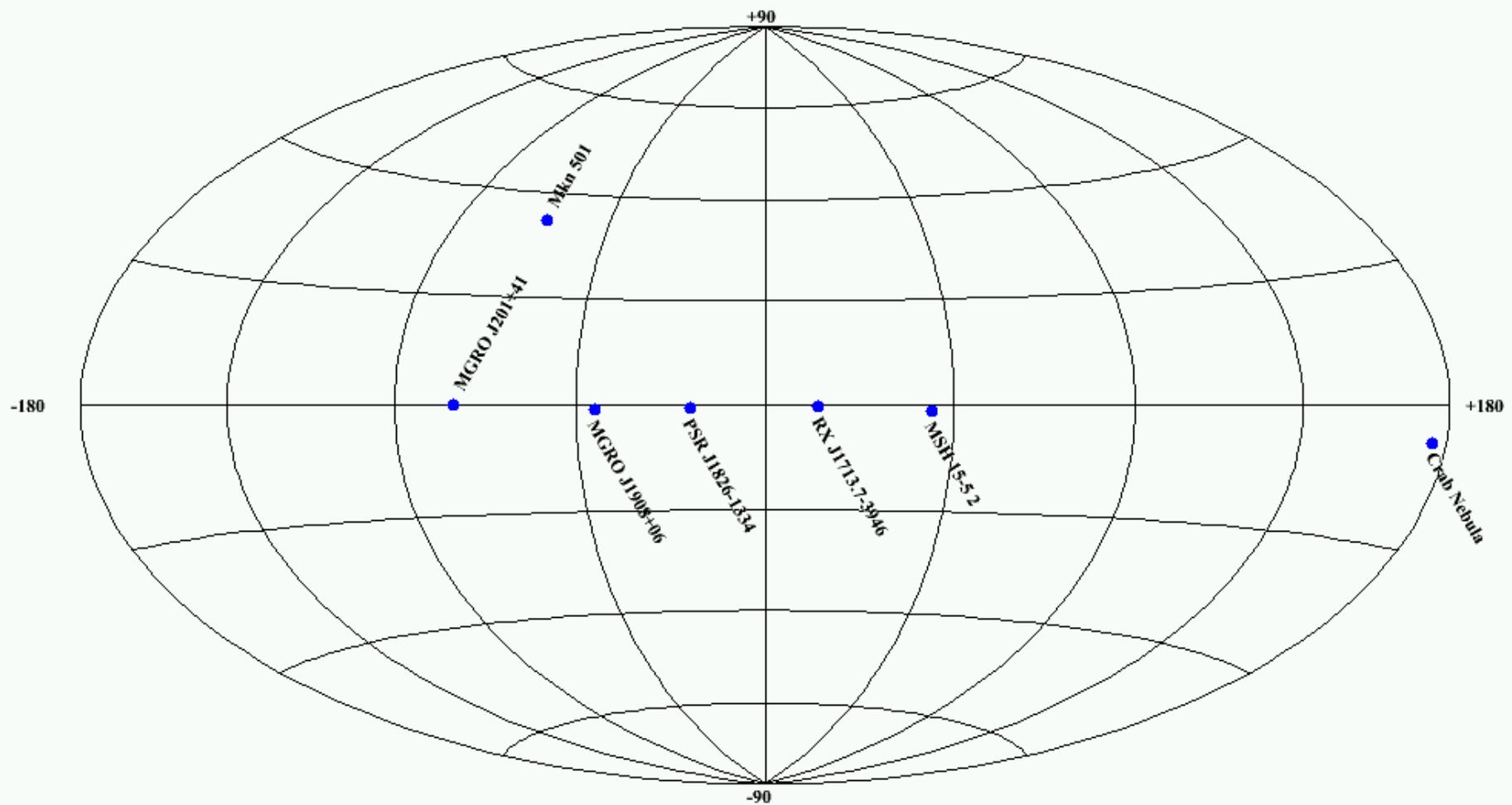
Gamma-Ray Astronomy

VHE Gamma-Ray sources 2009



$E > 10$ TeV Gamma-Ray Astronomy

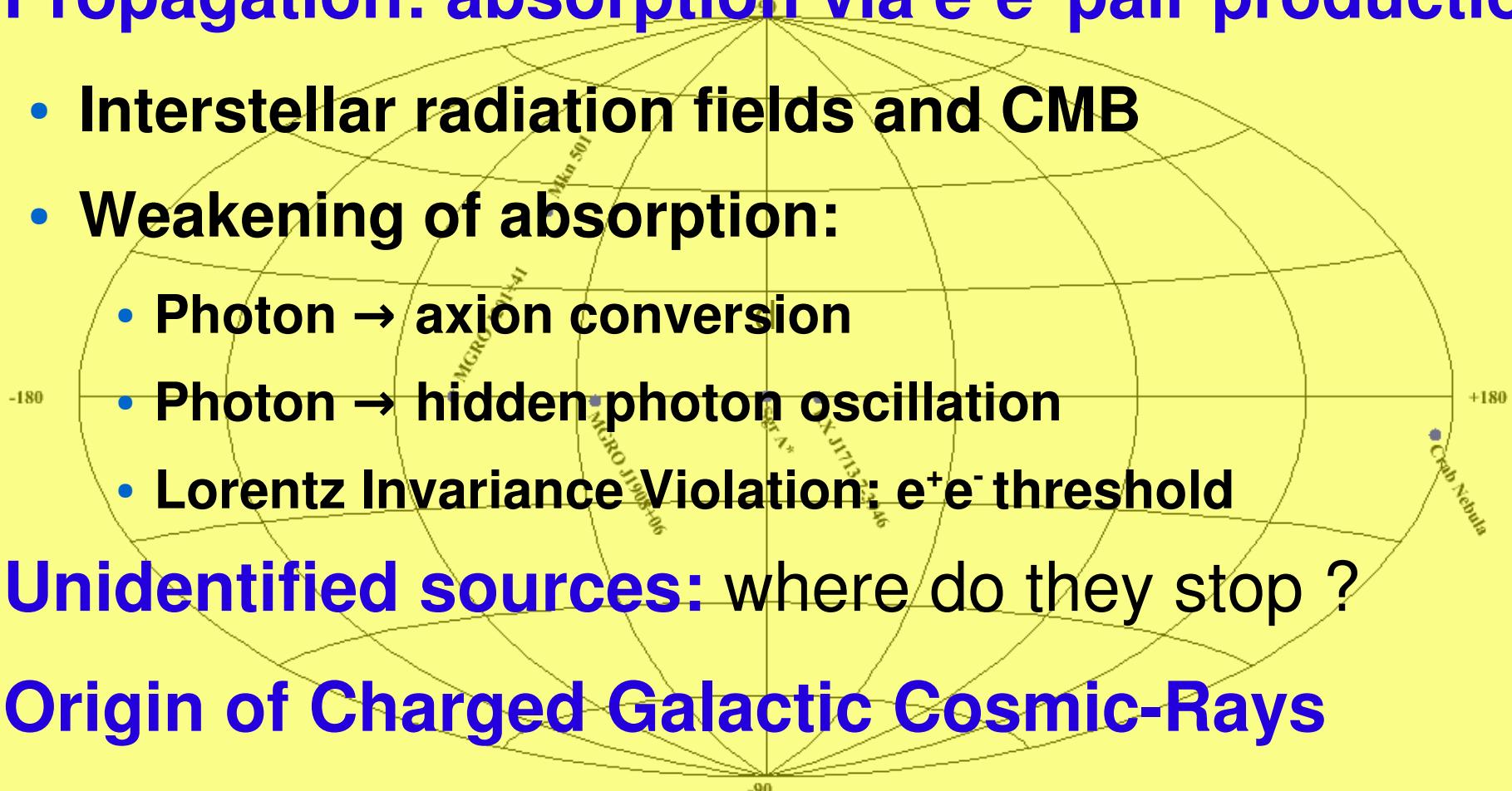
VHE Gamma-Ray sources 2009
 $E > 10$ TeV / $S > 5\sigma$



$E > 10$ TeV Gamma-Ray Astronomy

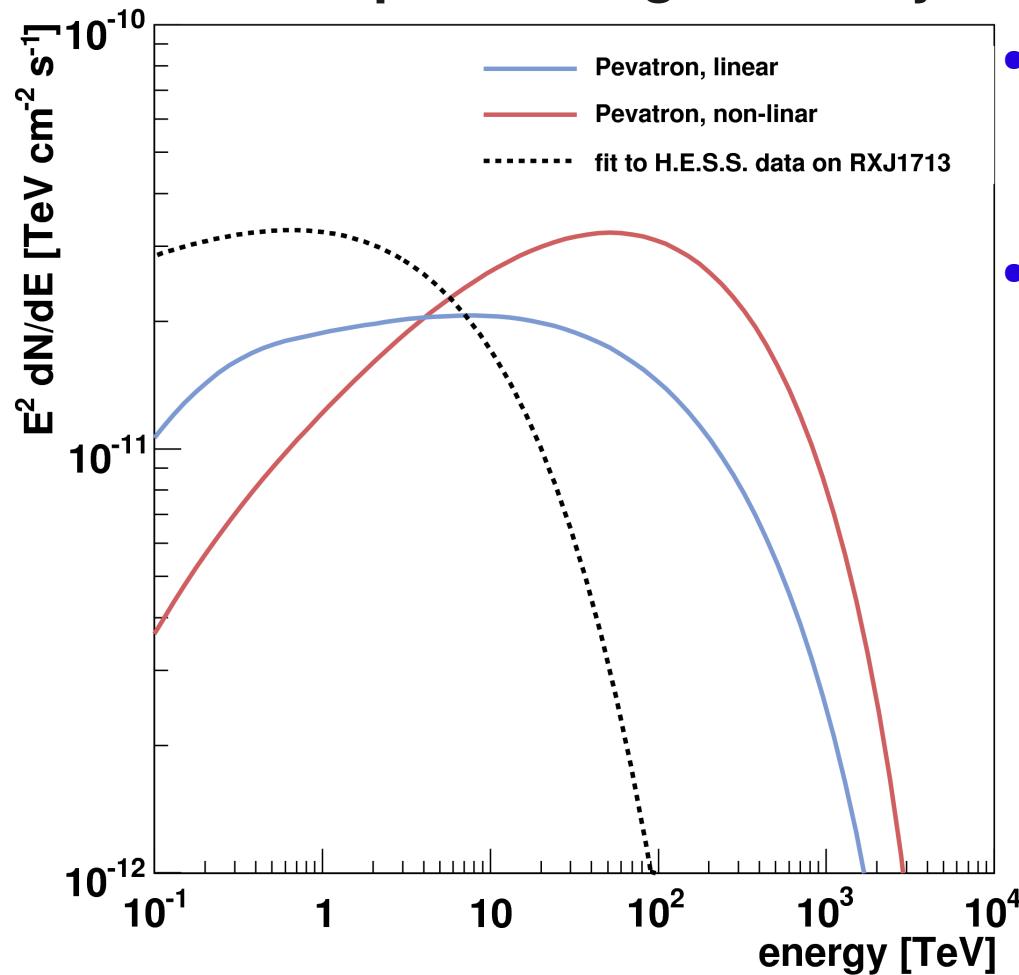
Last observation window of gamma-ray astronomy

- Propagation: absorption via e^+e^- pair production
 - Interstellar radiation fields and CMB
 - Weakening of absorption:
 - Photon → axion conversion
 - Photon → hidden photon oscillation
 - Lorentz Invariance Violation: e^+e^- threshold
- Unidentified sources: where do they stop ?
- Origin of Charged Galactic Cosmic-Rays



Origin of Galactic Cosmic-Rays

Cosmic pevatron: gamma-rays



- **Pevatron:** Current instruments not optimized for pevatrons !
- **Find Cosmic accelerators:**
 - Hard spectra beyond 10 TeV
 - No ambiguity: Inv. Compton spectra are soft !
(Klein-Nishina regime)

Possibly extended structures →

Diffuse Emission

- **Extended γ -ray emission**
 - Superbubbles as Pevatrons?
 - MILAGRO sources
- **Galactic plane**
- **Local Supercluster (T. Kneiske, this conference)**
- **Charged CRs with SCORE:**
 - Composition (shower depth)
 - Energy range from balloons to AUGER !
 - pp-cross section beyond LHC scale (first interaction)

How SCORE ?

Challenges

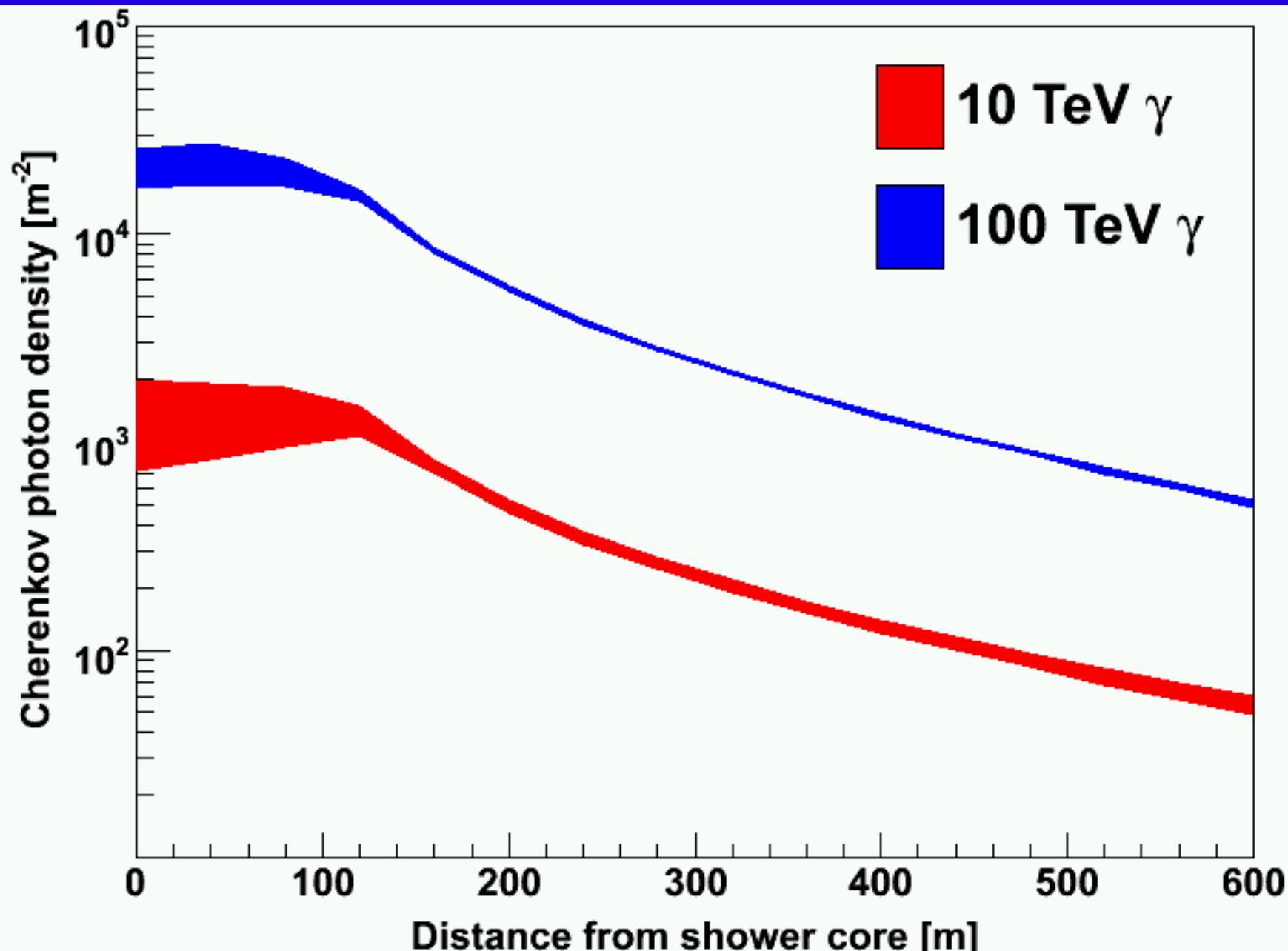
Non-imaging Cherenkov technique

- Gamma-hadron separation
 - Night-Sky-Background suppression
-

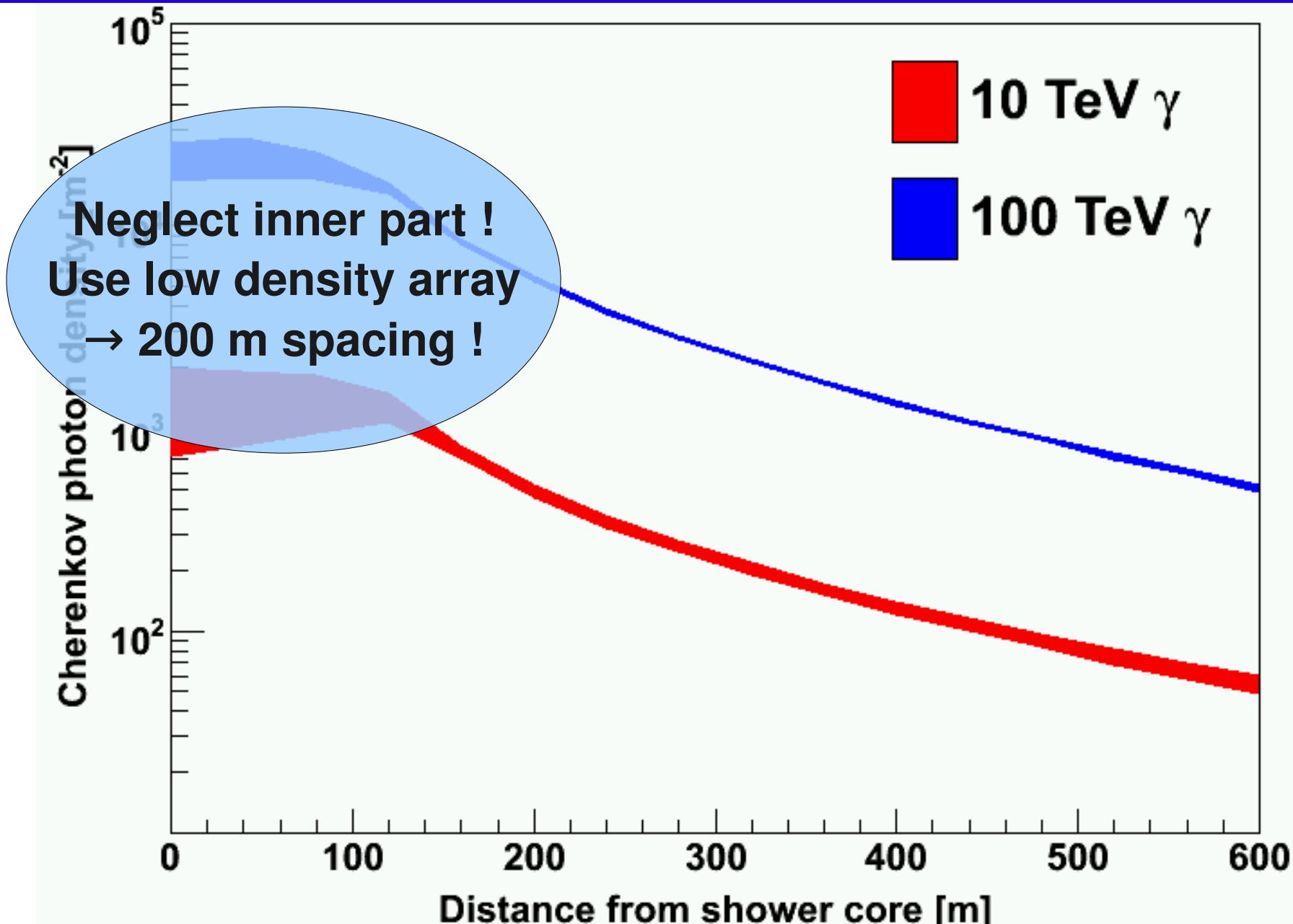
Benefits

- High photon statistics per shower
- Channel-per-km² factor
 - Imaging technique: ~25000
 - SCORE: < 150 !
- **Lateral photon density distribution ...**

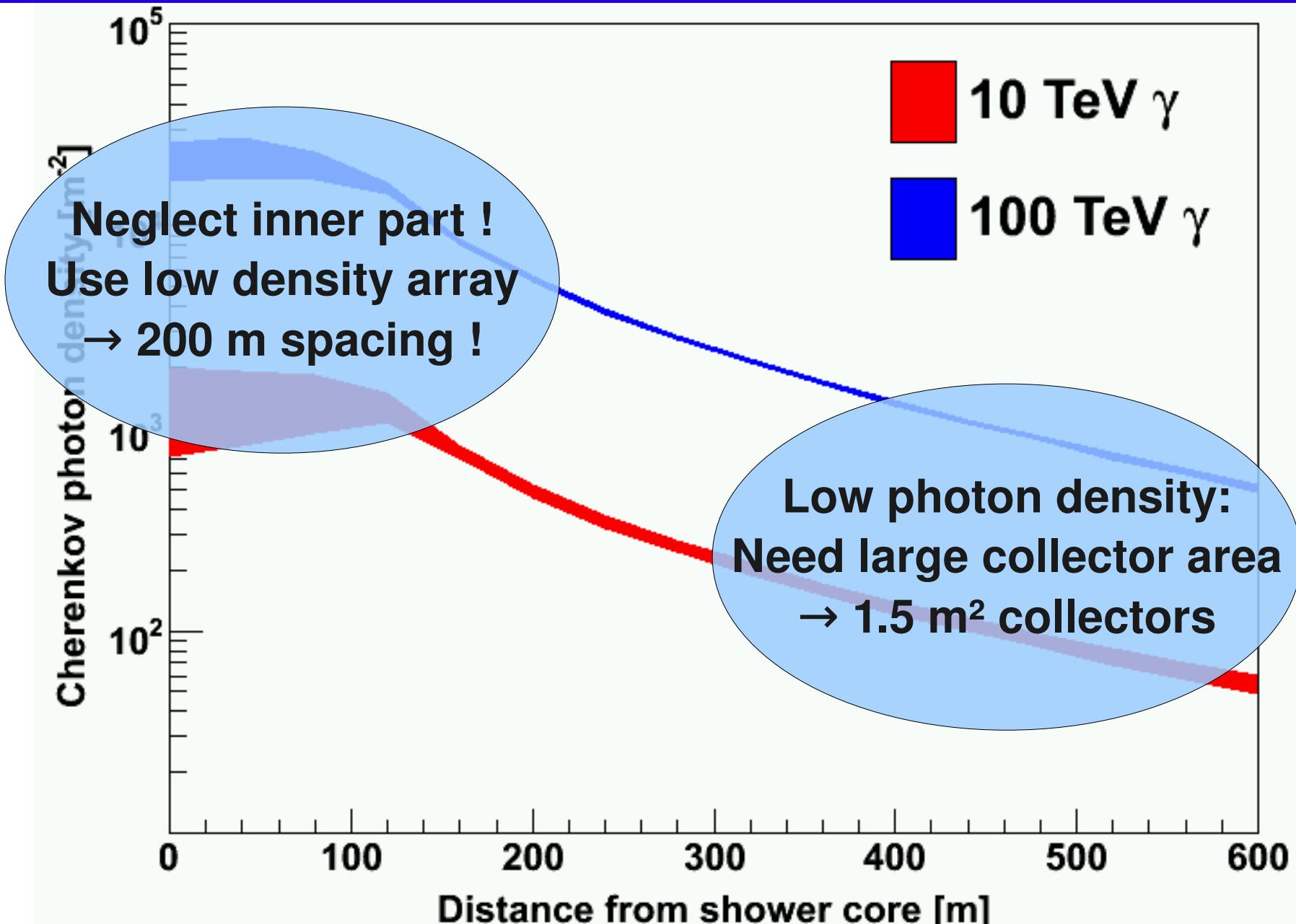
Lateral Cherenkov Photon Distribution



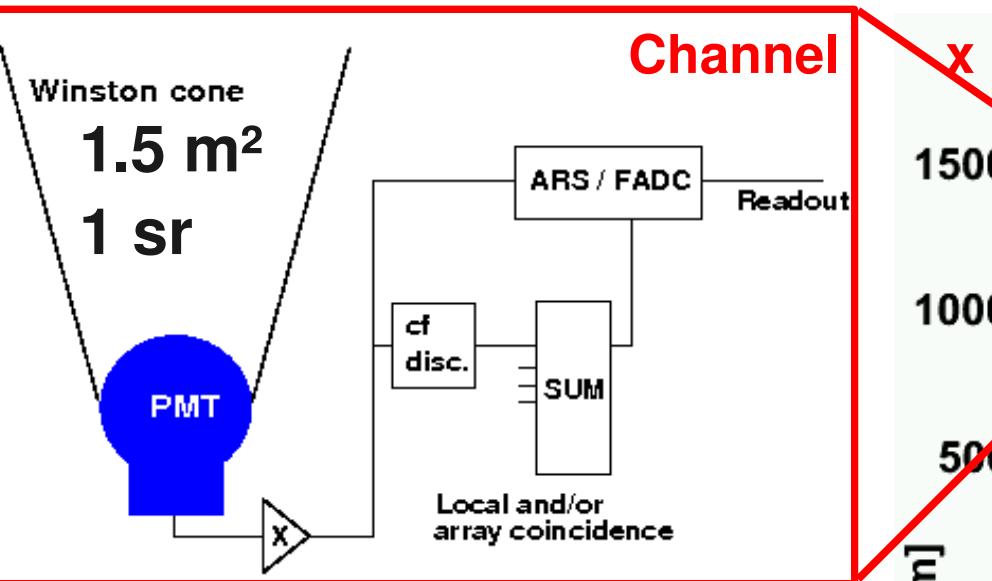
Lateral Cherenkov Photon Density



Lateral Cherenkov Photon Density



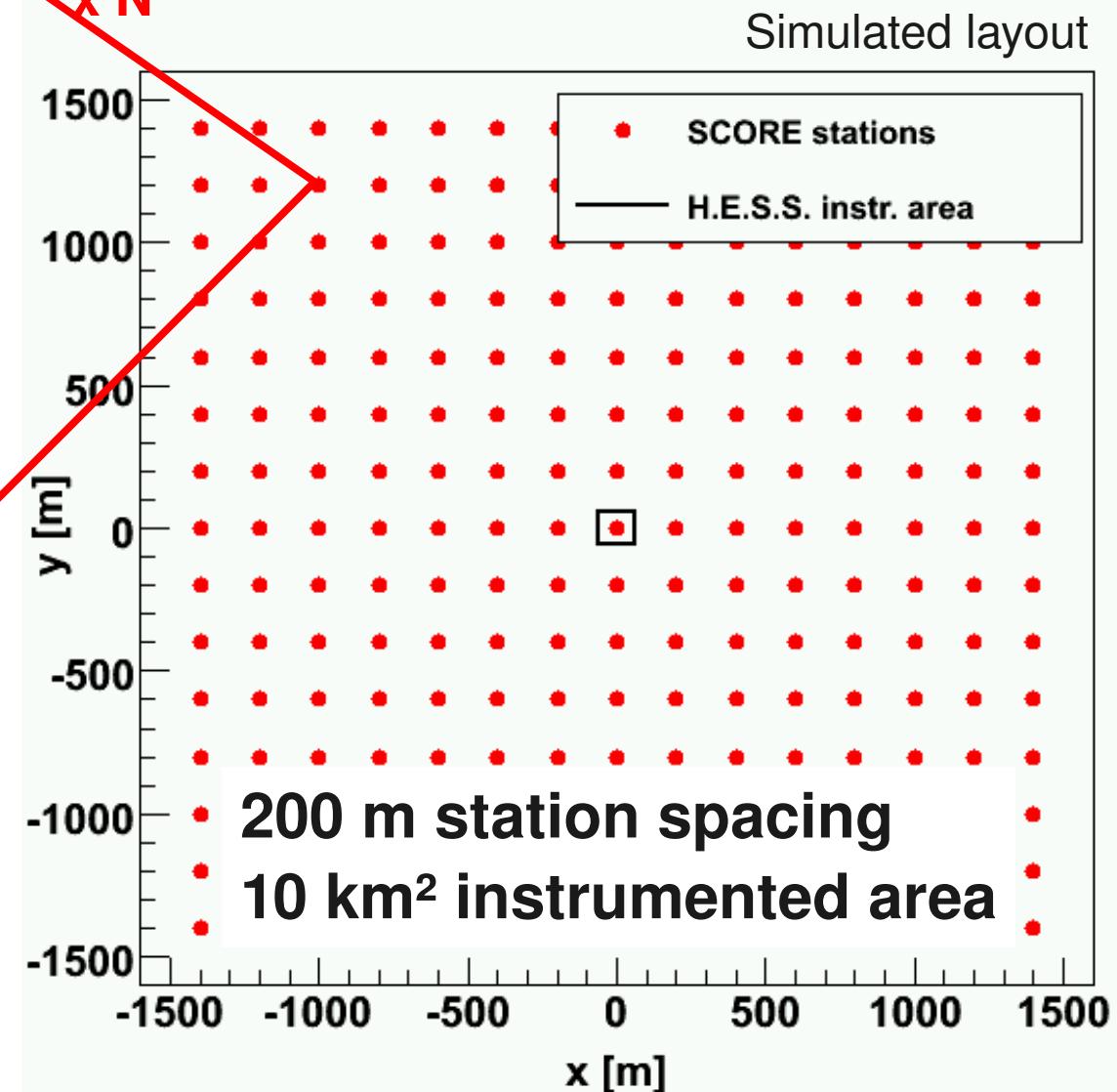
The SCORE Detector



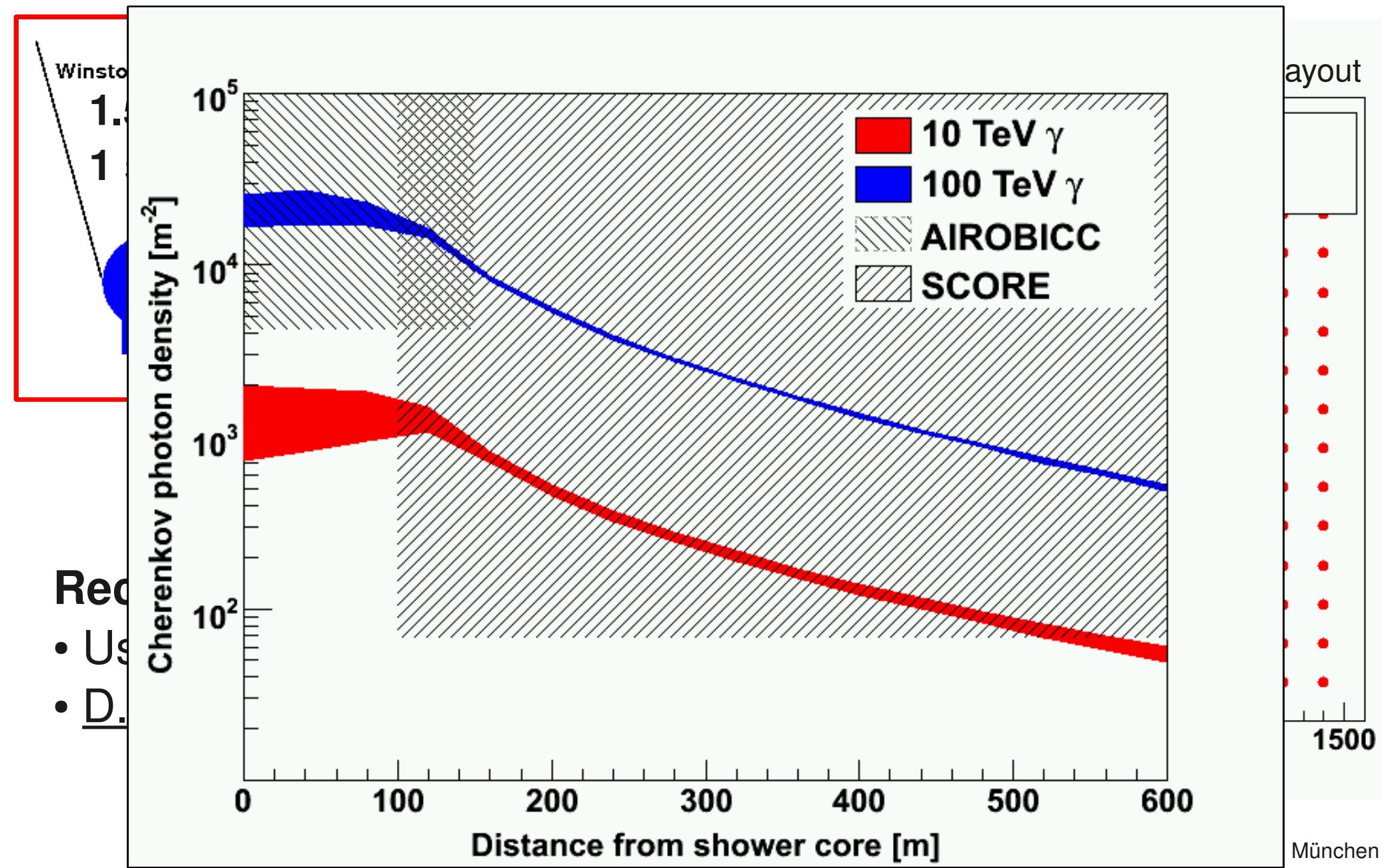
Each station: x 1 – 4 channels

Reconstruction:

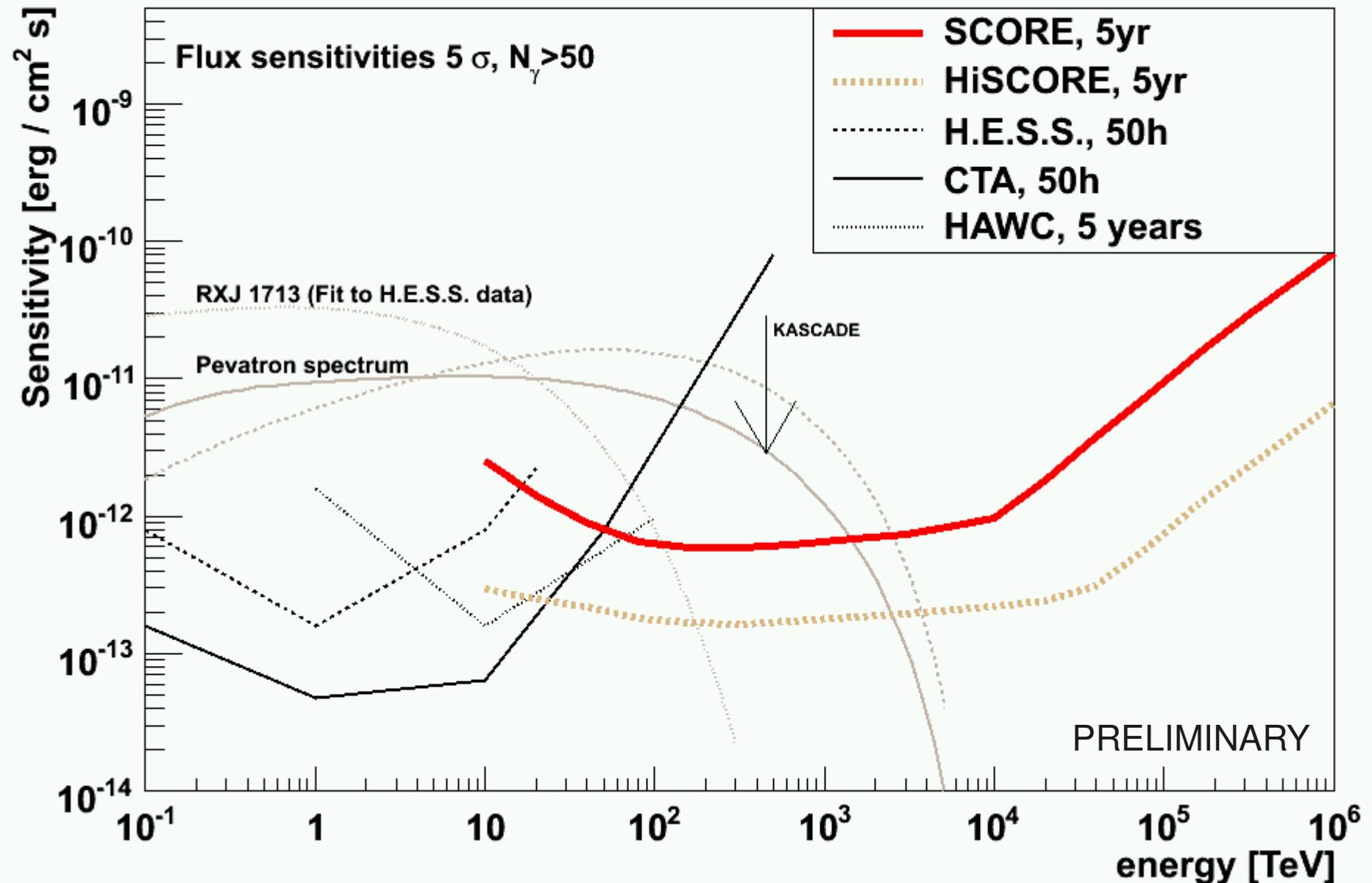
- Use intensity and timing
- D. Hampf, next talk!



The SCORE Detector



SCORE First Simulation Results



Summary

- **Many physics cases beyond 10 TeV primary energy**
 - Gamma-ray astronomy
 - Cosmic-ray physics
 - Particle physics
- **SCORE**
 - Opens the last remaining Gamma-ray observation window
 - CRs: Bridge E-range from direct detectors to AUGER !
- **We invite for collaboration !**

Outlook

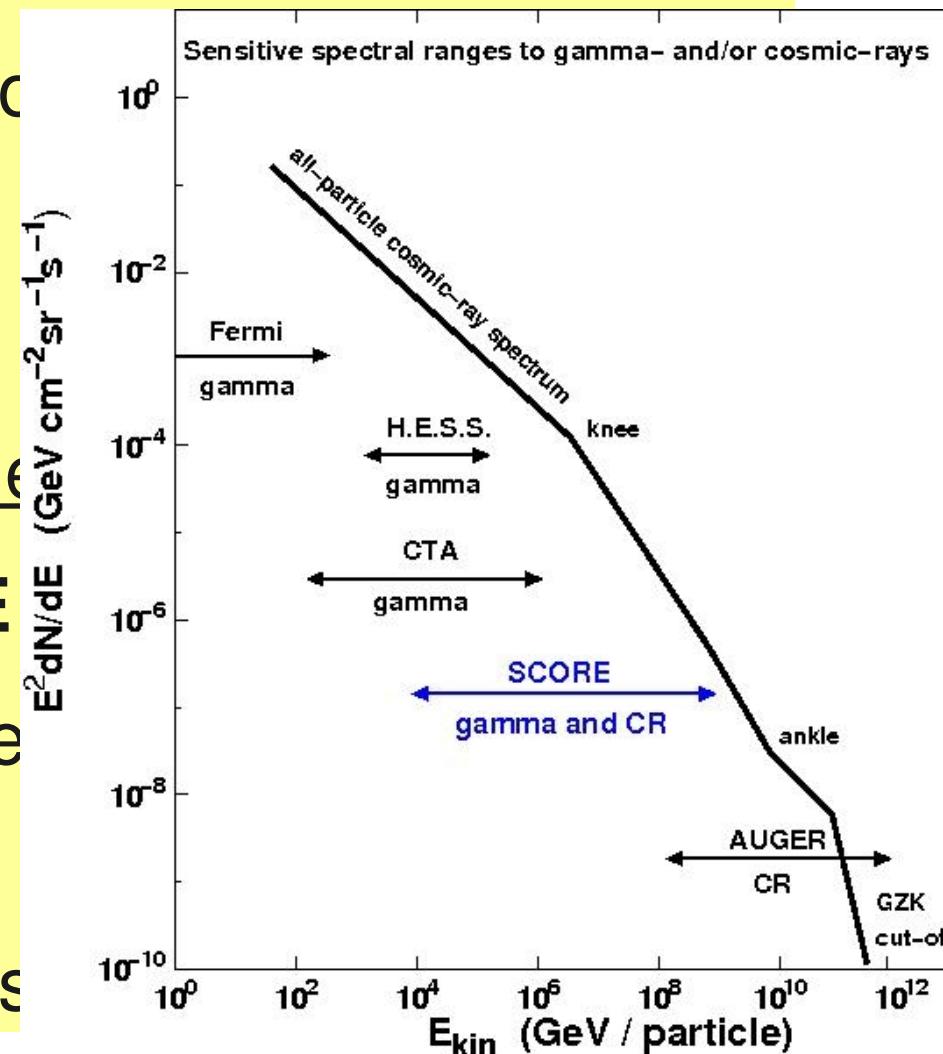
- **H_iSCORE**
Hundred Square-km Cosmic ORigin Explorer
- **Extension / Synergies** with other techniques
 - Radio (LOFAR)
 - Szintillation counters (hybrid array)
 - Possible combination with imaging Cherenkov technique

Status

- Full detector simulation ready
- Studies of first Hardware components in progress
- Funding of first prototype (8 stations) in 2009
- Funding for first SCORE stage pending
- Collaboration from other institutes is welcome !

Diffuse Emission

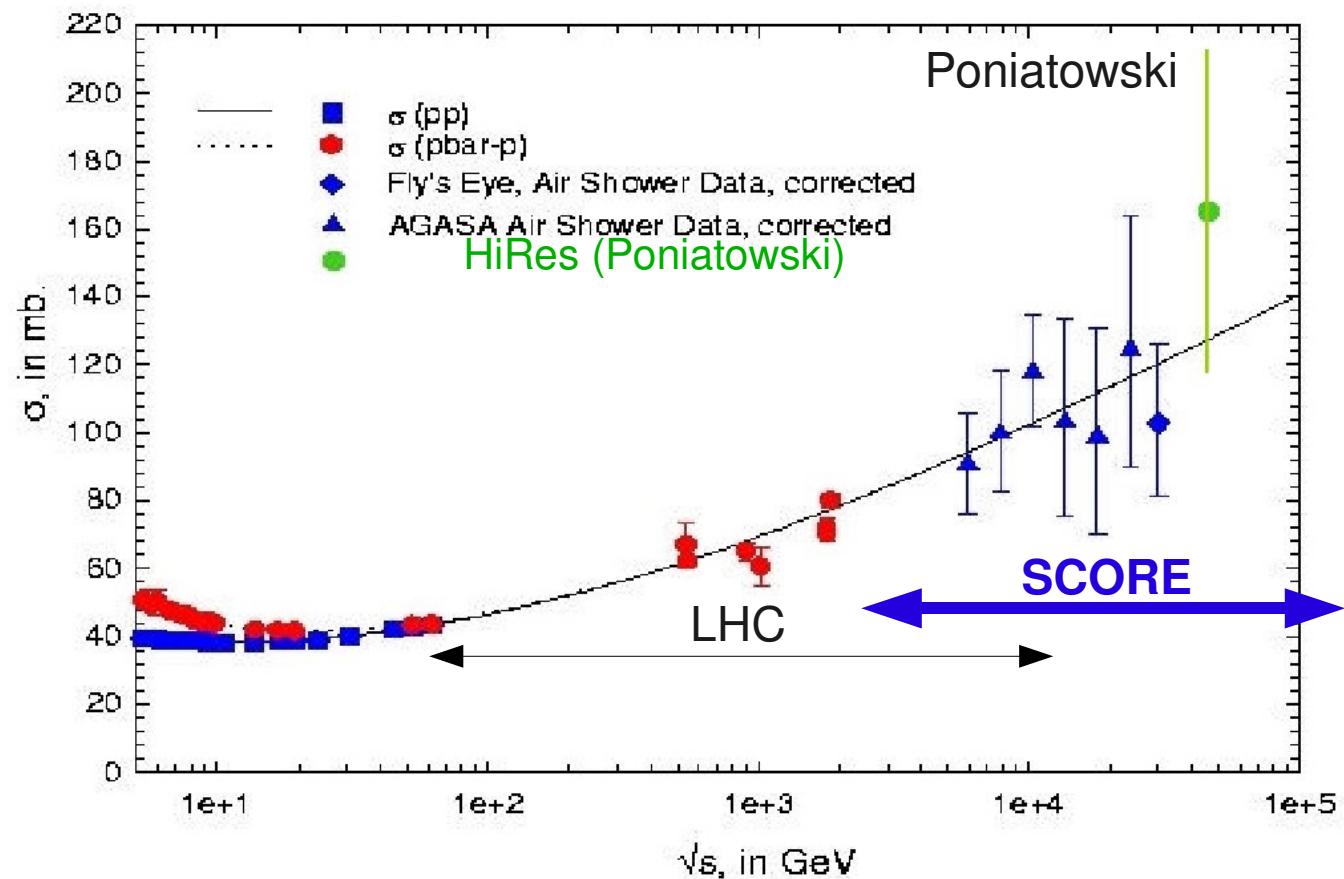
- Extended γ -ray emission
 - Superbubbles as Pevatrons
 - MILAGRO sources
- Galactic plane
- Local Supercluster (T. Kneiske)
- Charged Crs with SCORE
 - composition / anisotropies
 - Sub-knee to pre-ankle !
 - pp-cross section from first



p-p cross-section

- Correlation shower depth / first interaction
→ measure interaction length in air $\sigma(p\text{-}p)$
- SCORE: $1 < E_{\text{CM}} < 150 \text{ TeV}$

- Overlap: LHC,
CR experiments

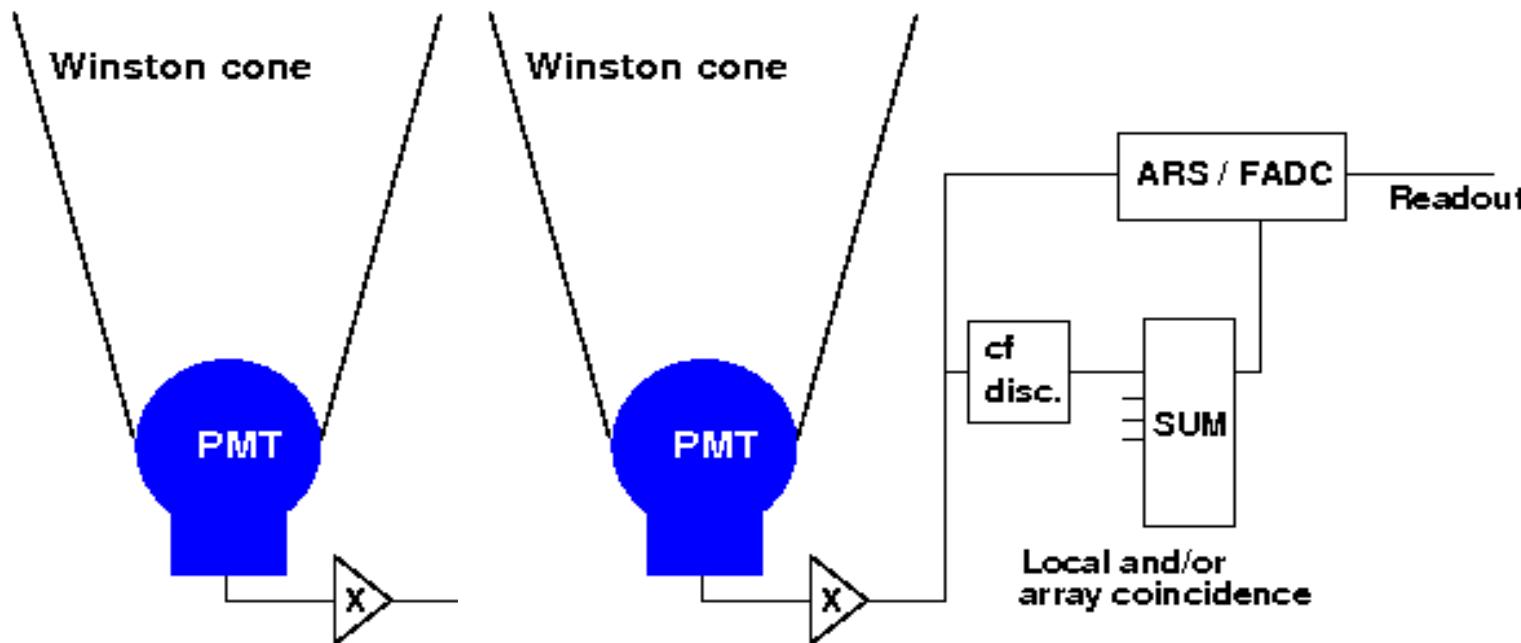


Alternatives / Extensions

- Daytime-measurements with scintillator material in lid: 100% duty cycle
- Combination with imaging technique:
 - provide core-reconstruction for low-density telescope grid (even monoscopic ?)
 - Instrumentation of larger area for highest energies
- Combination with radio detection technique ?
- ...

Trigger levels

- Local station trigger:
 - multi-PMT station, e.g. 4 channels
 - 4-fold local coincidence ($\Delta t = 1\text{ns}$)

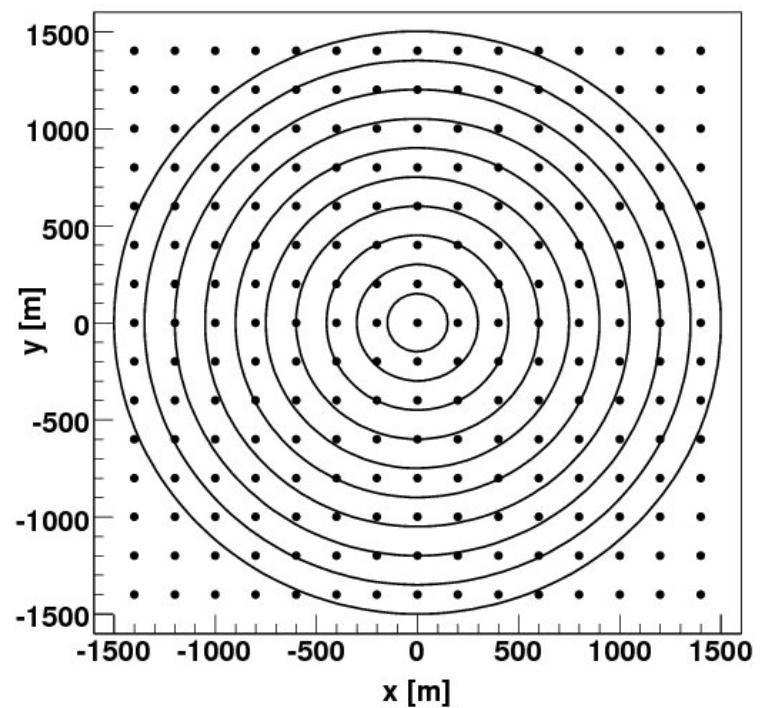
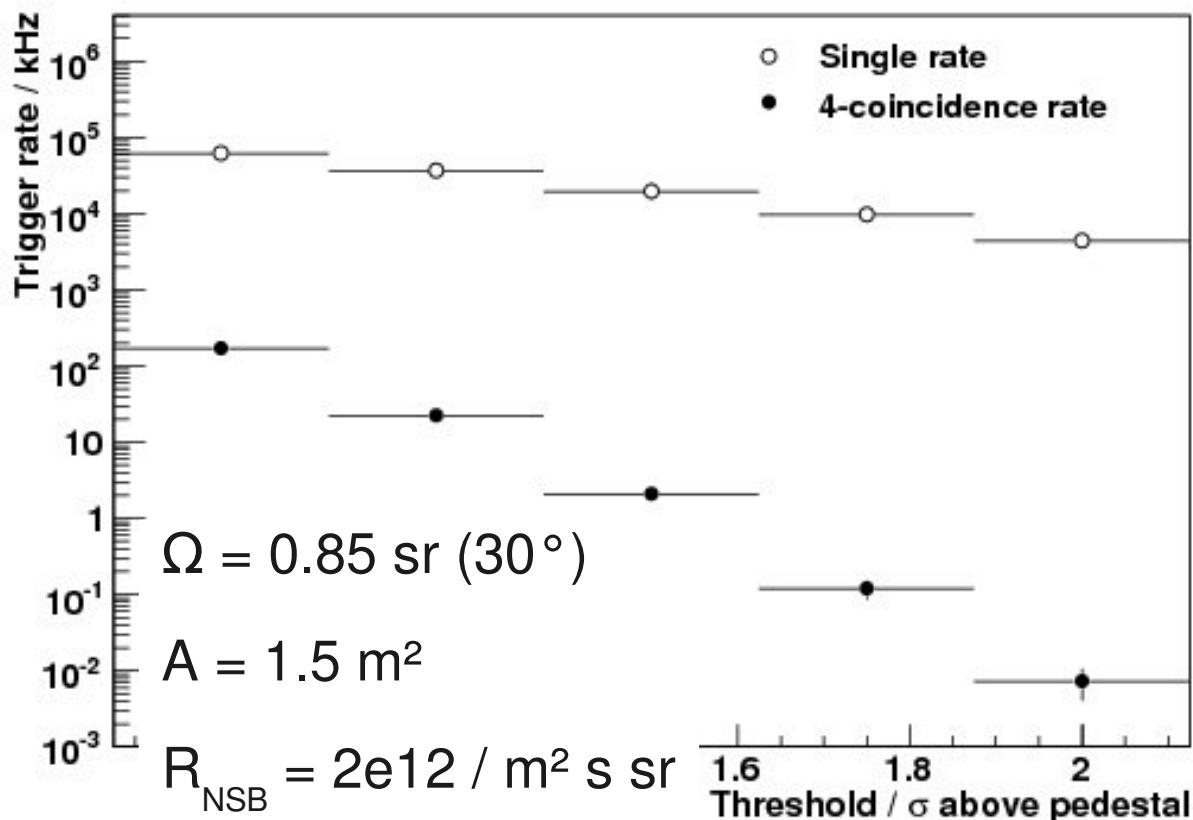


- Array trigger: next-neighbour station trigger ($\Delta t = 1\mu\text{s}$)

Coincidence: benefits

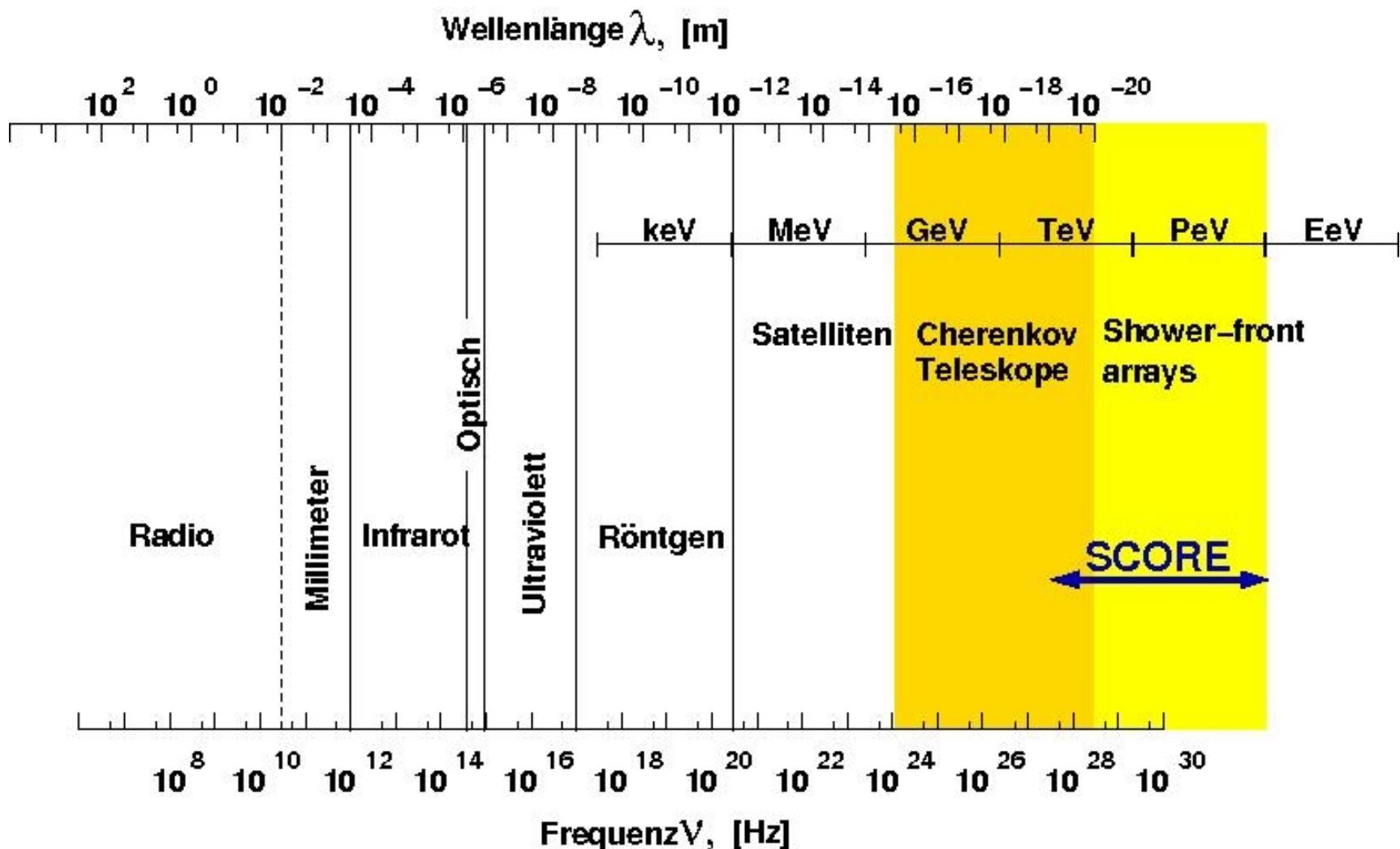
SUPPRESS NSB → Channel threshold as low as possible:

- Trigger threshold energy
- Station stacking: sum weak signals in concentric circles around core



→ Reconstruction: D. Hampf, this conf.

The last Observation Window



SCORE = Study for a Cosmic ORigin Explorer

Aim at: $10 \text{ TeV} < E < 1 \text{ EeV}$

(Some) Physics Cases for SCORE

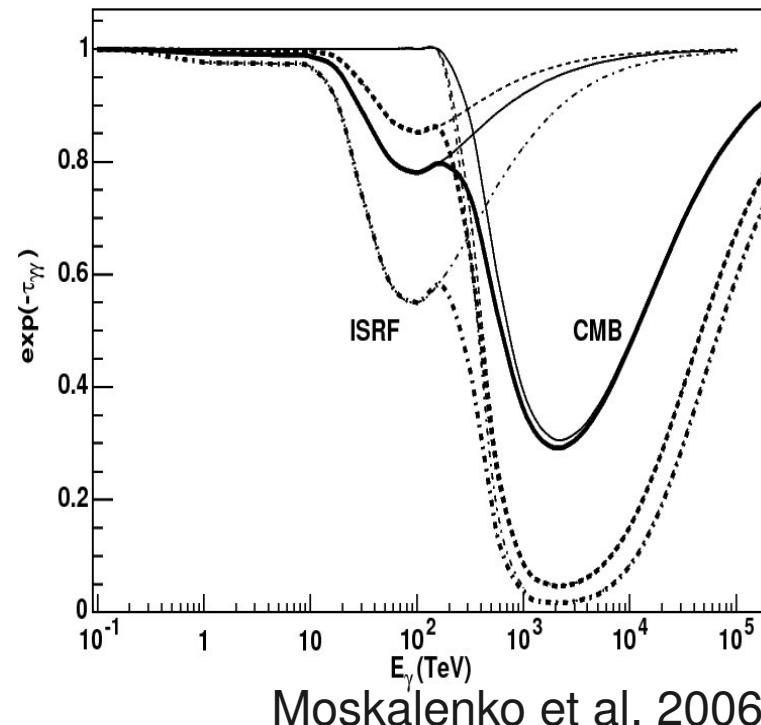
Gamma-rays: $E > 10 \text{ TeV}$

Cosmic-Rays: $100 \text{ TeV} < E < 1 \text{ EeV}$

- **Astroparticle physics**
 - Origin of Cosmic-Rays
 - Unidentified sources: where do they stop?
 - Local Supercluster
 - Absorption in Galactic radiation fields and CMB
- **Particle physics**
 - Axion / hidden photon search (propagation)
 - Lorentz Invariance violation (propagation)
 - Measurement of p-p cross-section

Propagation: Galactic Absorption & CMB

- e^+e^- pair production: Interstellar radiation field (ISRF) and CMB
- **estimate ISRF density**
- CMB well known: **distance estimate?**
- Weakening of absorption by:
 - **Photon / axion conversion** in Galactic Magnetic field
 - **Photon / hidden photon oscillation**
 - **Lorentz invariance violation** (modification of e^+e^- threshold)



Shower-front sampling arrays

	SCORE	HiSCORE	TUNKA	BLANCA	AIROBICC
instrumented area [km ²]	10	100	1	0.2	0.04
detector station area [m ²]	1.5	1.5	0.2	0.1	0.13
field of view [sterad]	0.84	0.84	1.8	0.12	1
station spacing [m]	200	200	85	35	30
# of modules	256	2601	133	144	49

Station Stacking

- NSB suppression w coincidence
- Low PMT thresholds
- Large core distances:
 - Weak signals
 - Many Stations
 - **Sum weak signals: improve S/N**

