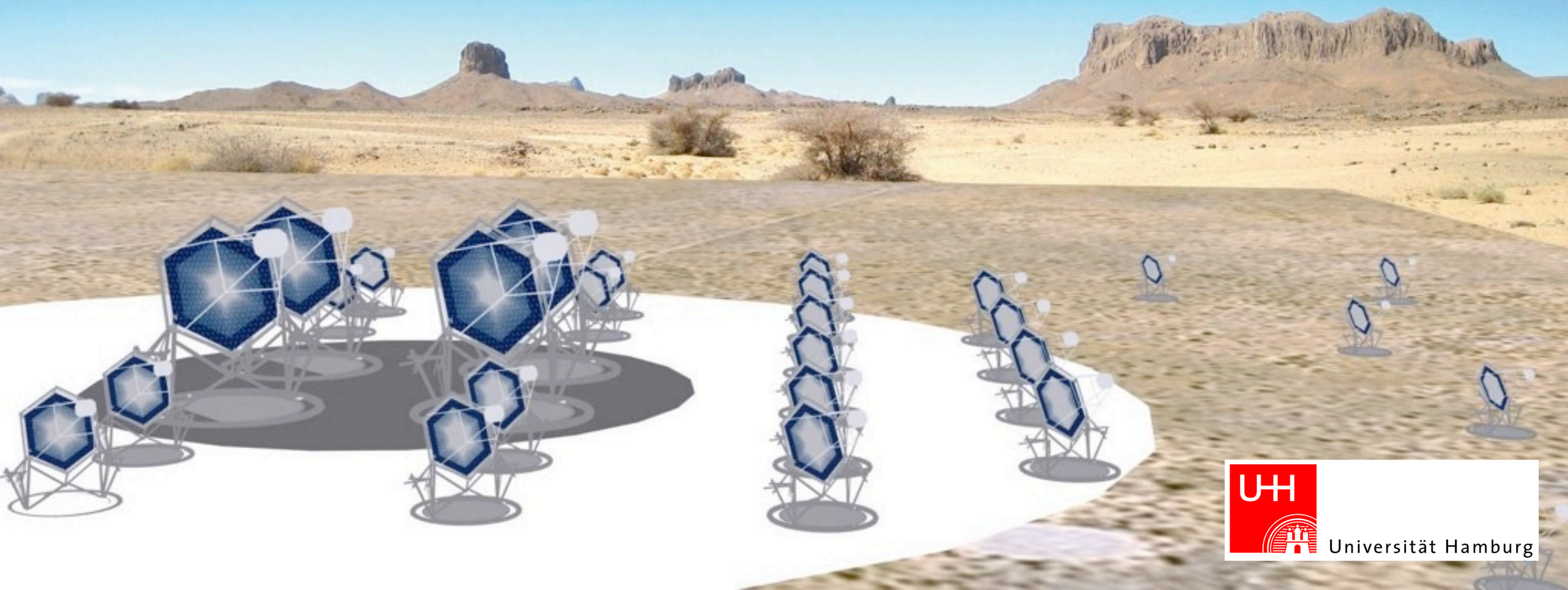
Fundamental physics and cosmology with the next generation Cherenkov telescope systems

Martin Raue

Fundamental Physics Laws: Gravity, Lorentz Symmetry and Quantum Gravity
2 & 3 June 2010 - Paris, France



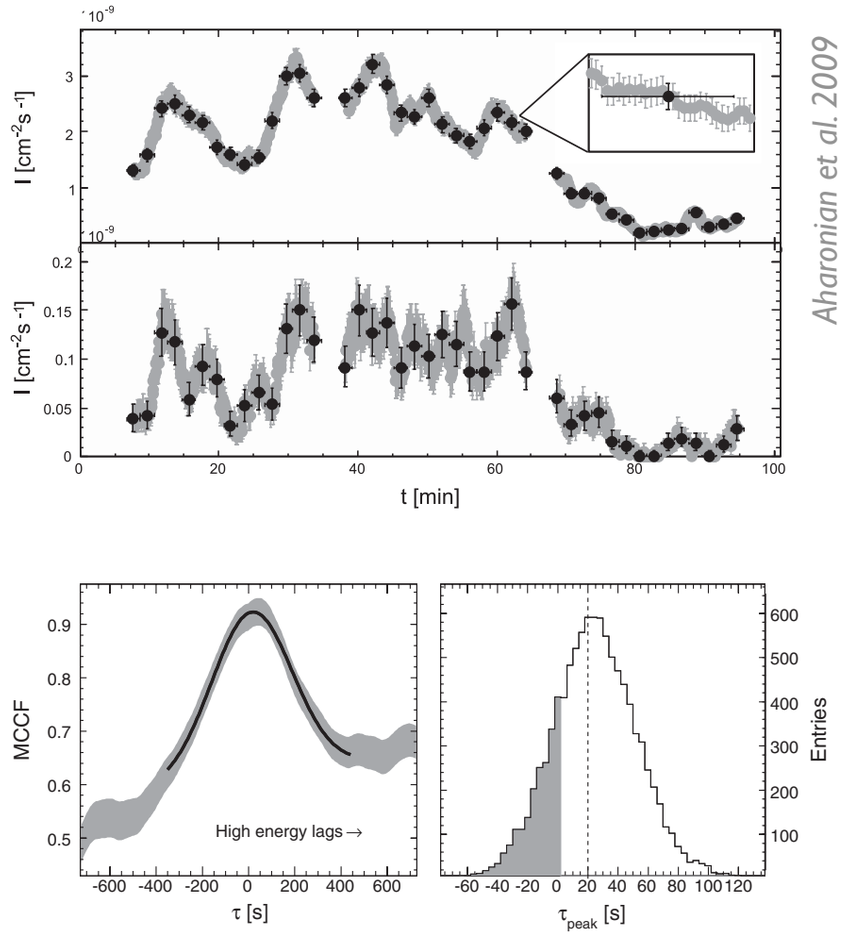
Universität Hamburg

Outline

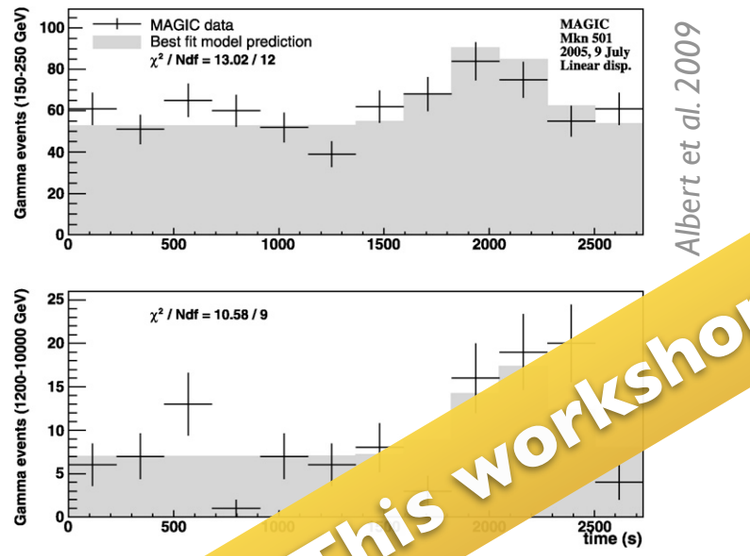
- Fundamental physics & cosmology with ground based VHE instruments
- Current generation: status & results
- Future experiments

Quantum gravity

- Some QG models allow/ demand LI violation
- c energy dependent
- Time of flight measurements can provide measurements/constrains on the QG models
- Blazar outburst (GRBs)



Aharonian et al. 2009



Albert et al. 2009

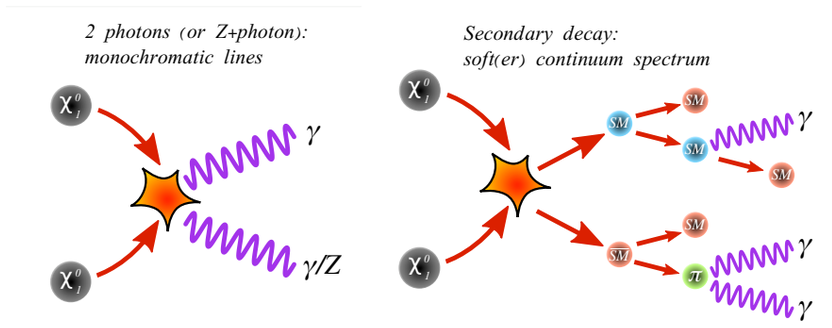
This workshop!

Dark matter

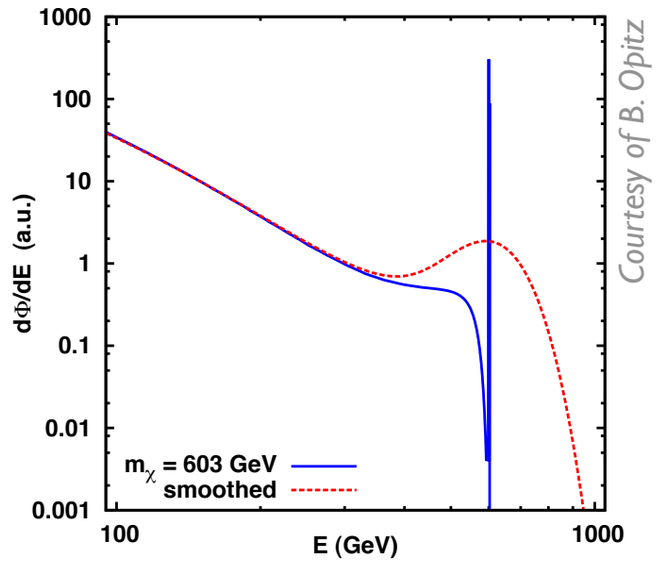
» Popular models for DM predict a stable, self-annihilating particle (WIMP) in the ~1 GeV to 10 TeV range

» γ-rays from DM annihilation can give smoking gun signature

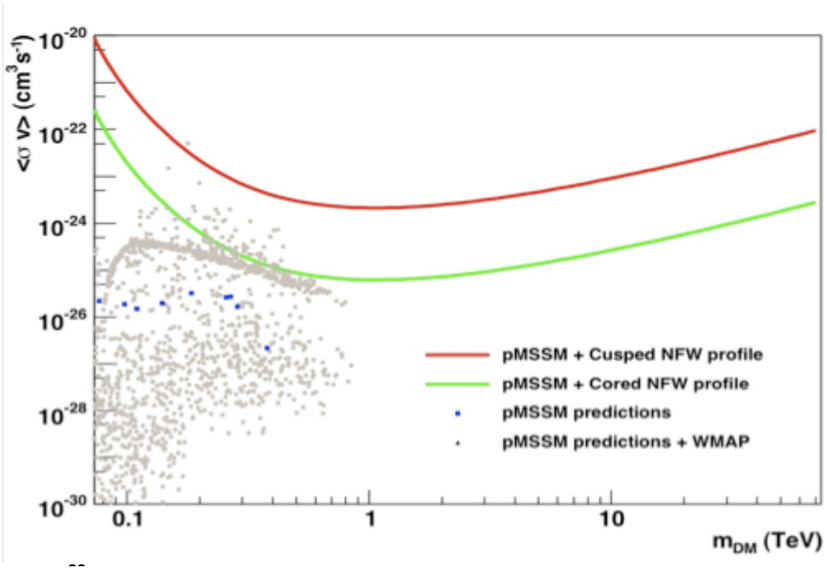
» Non-detection leads to limits on the model parameter space



Stolen from P. Scott



Courtesy of B. Opitz



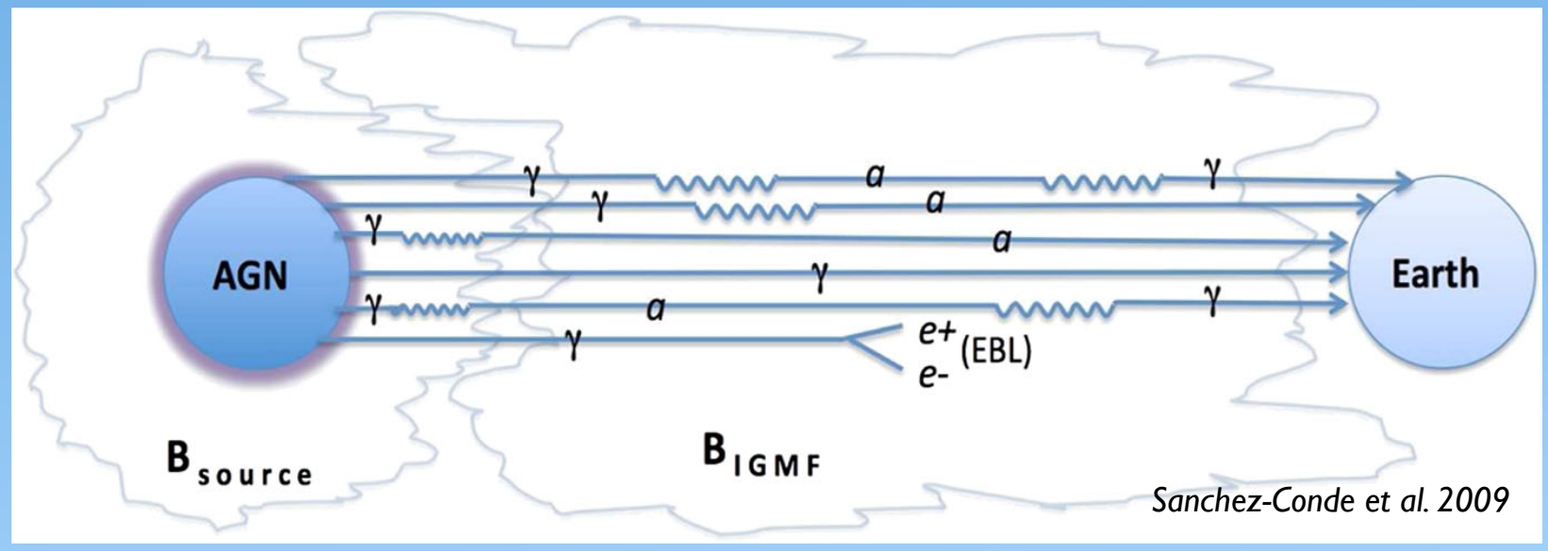
Cosmic background radiation

- Extragalactic background light (optical/IR)
  - EBL density keeps information about the cosmic radiation history (star formation rates, ...)
  - VHE γ-ray from distant sources as probes of the meta-galactic radiation fields ($\gamma_{VHE}\gamma_{IR} \rightarrow e^+e^-$)
  - Limits on cosmological parameters
    if EBL density and source physics well understood
- γ-ray background
  - Signature from DM annihilation (constrains)

Axions, hidden photons, ..

- Axions
  - U(1) symmetry extension of the SM to reconcile CP violation, DM candidate
  - Photon-Axion oscillation in B-field (~B^2)
    Hidden photons: no B required

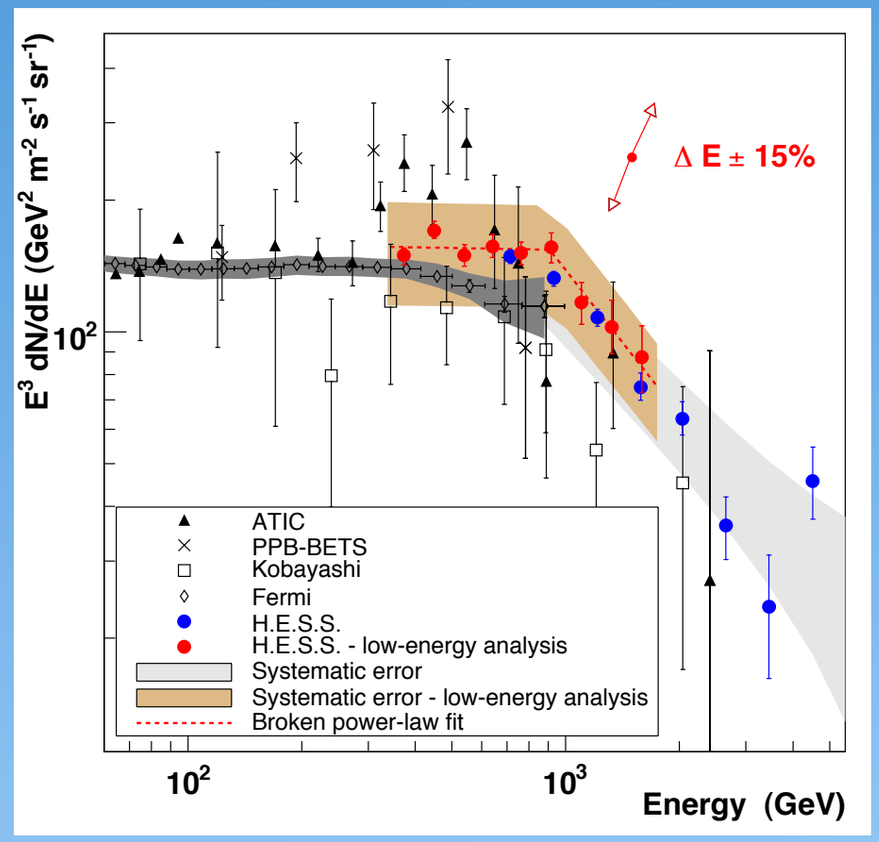
- Photon propagation affected
  - EBL
  - Escape effects



Sanchez-Conde et al. 2009

More ...

- Cosmic rays
  - Electron/Positron spectrum
  - Iron spectrum
- UHE neutrinos
  - Moon shadow ...
- ...



Current generation instruments

Current generation: performance

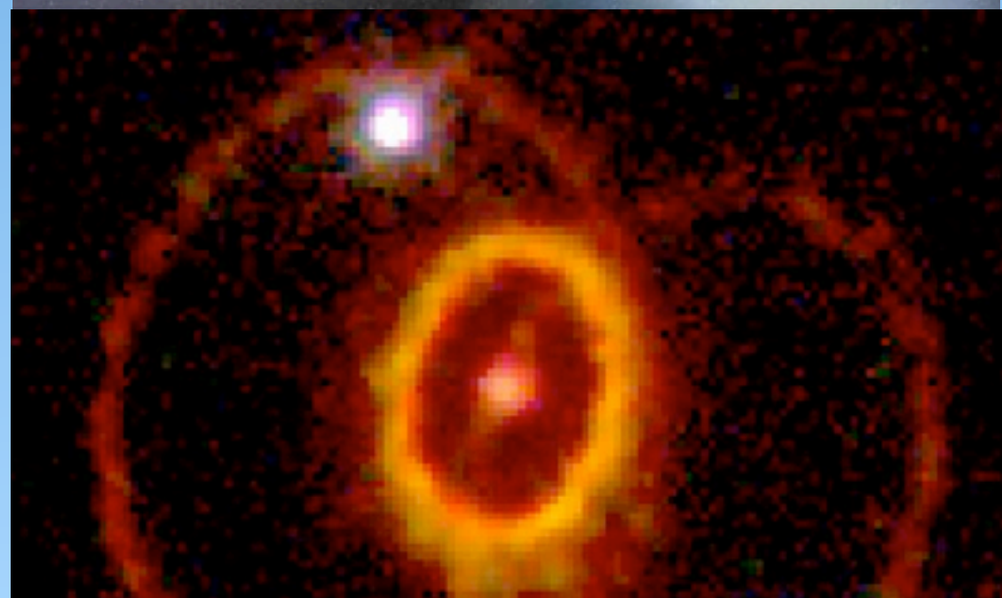
- 100 GeV - 10 TeV core energy range
  - MAGIC: down to ~30 GeV, HESS: up to 100 TeV
- ~15 % energy resolution
  - lower energies worse!
- 0.1 deg angular resolution per event
  - Astrometric precision down to 6”

Current generation: results

- Quantum gravity
  - Limit on the QG energy scale from flares observed from AGNs (Julien's presentation)
- Dark matter
  - No detection (yet ☺)
  - Constrains on the parameter space from observations of the galactic center, dwarf galaxies, ...
- EBL
  - Strong constrains on the EBL density (z=0)

Open questions / limitations

- Source physics does matter!
  - Are source standard candles?
  - Results on fundamental physics are only as good as the understanding of the source physics
- Sources are often complex & unique, <100 VHE source
- Source physics has to be understood in great detail



Open questions / limitations

- Dark matter
  - No detection, no strong constrains
  - High sensitivity 10-100 GeV required
  - Complementary to LHC, Fermi
- Quantum gravity
  - see Julien's presentation
- EBL
  - Evolution of the EBL density
  - Precision EBL physics (SFR, reionization, exotics ..)

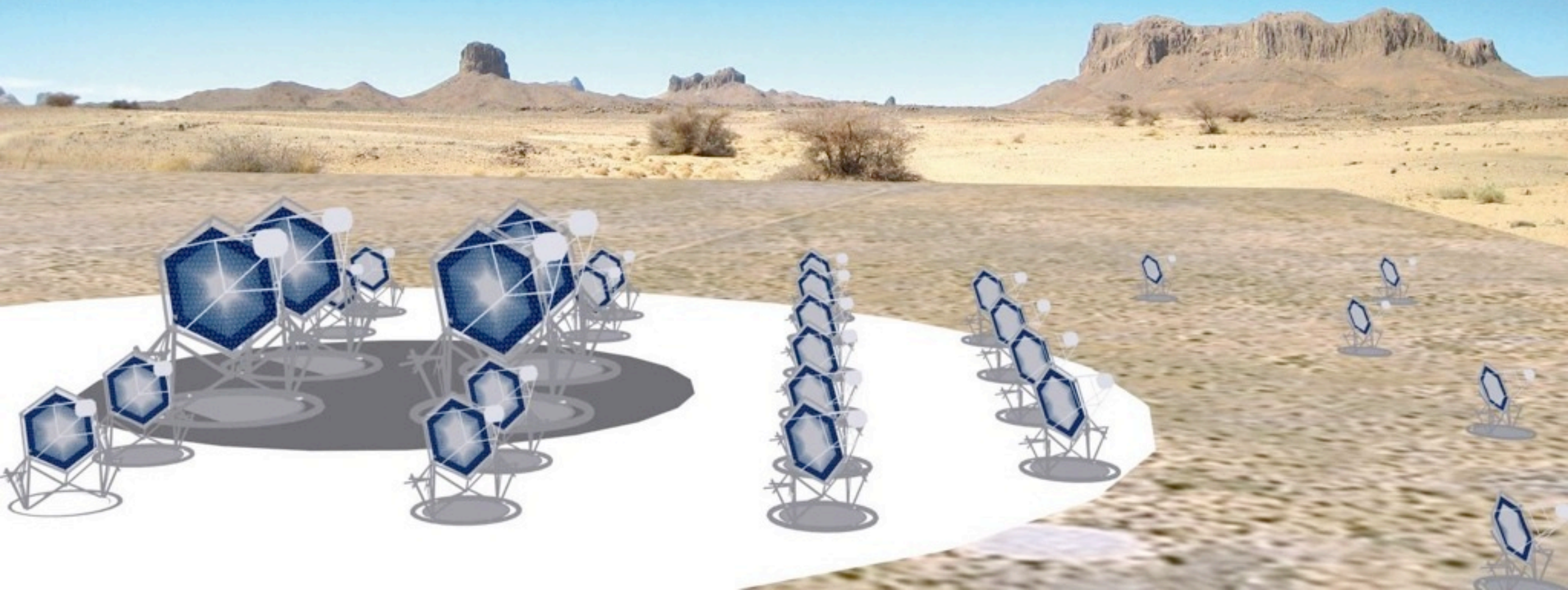
The next steps: MAGIC-II/HESS II

- MAGIC-II
  - 2nd MAGIC telescope (clone) to enable stereoscopic observations
  - In operation since 2009

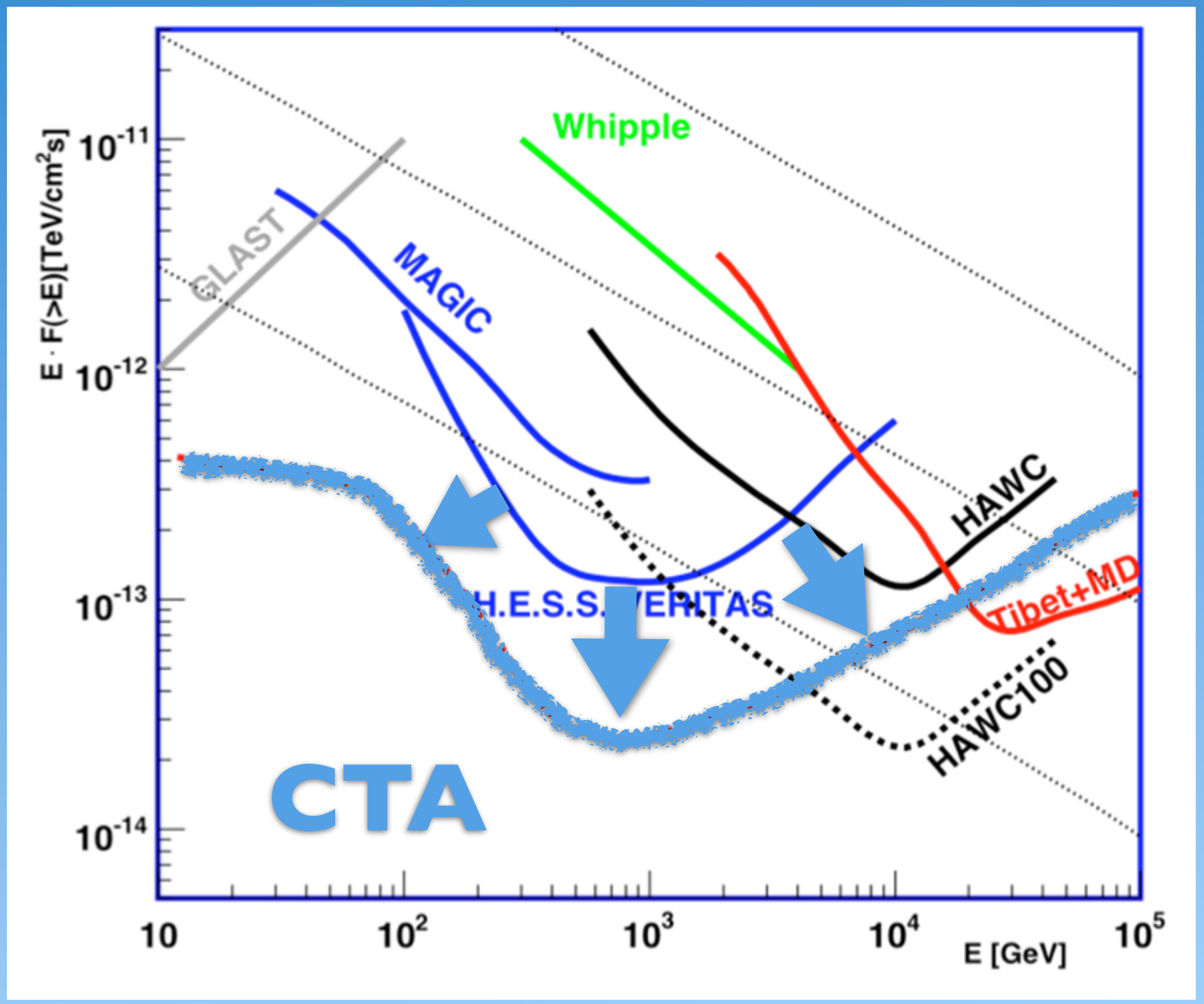
- H.E.S.S. II
  - One extremely large telescope (mirror diameter 30m) extending the H.E.S.S. I array
  - Mono and stereoscopic observations
  - Science operations in 2012

Cherenkov Telescope Array

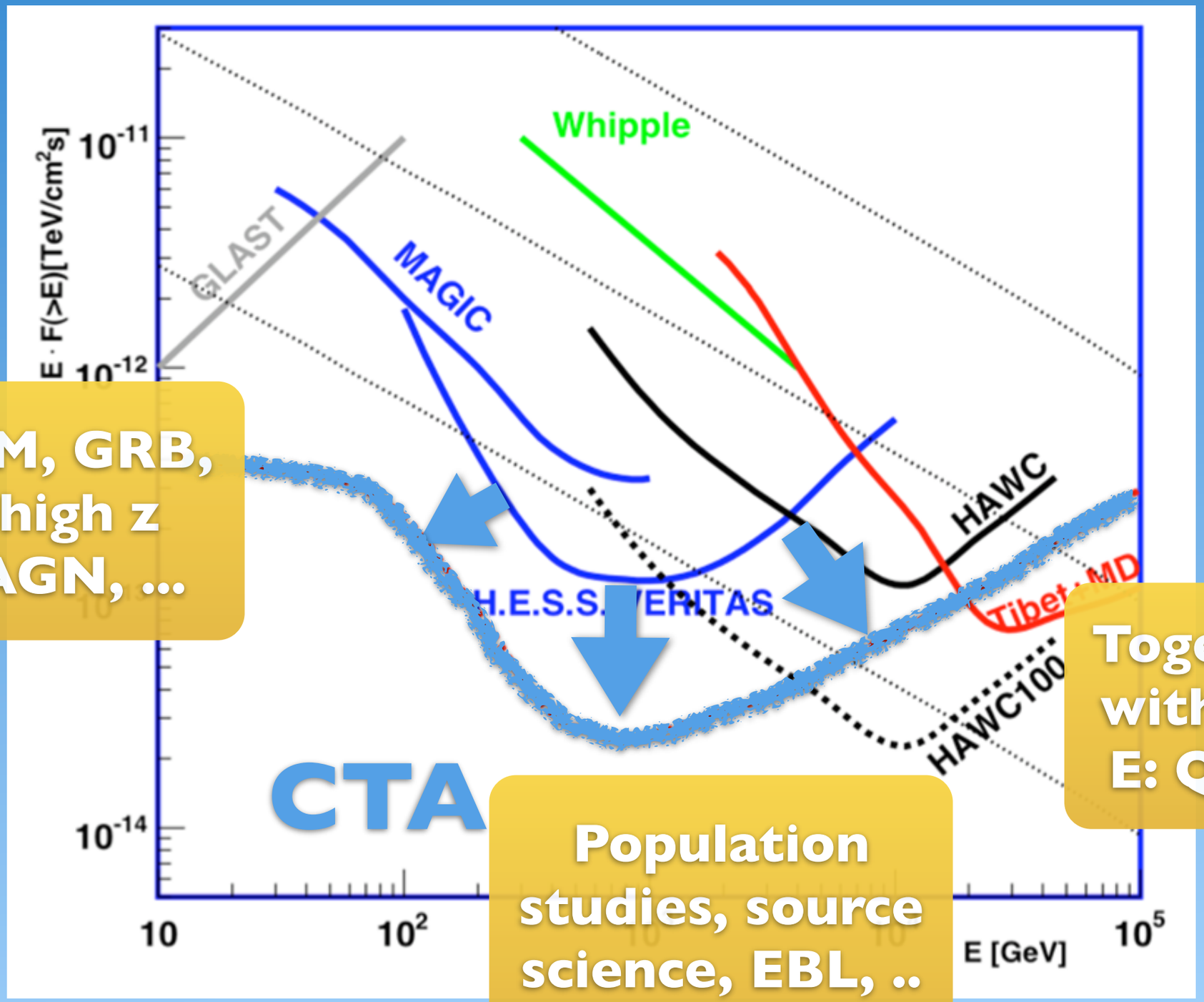
- Next generation instrument for ground based VHE γ-ray astronomy
- Joint global effort



CTA target sensitivity



CTA target sensitivity



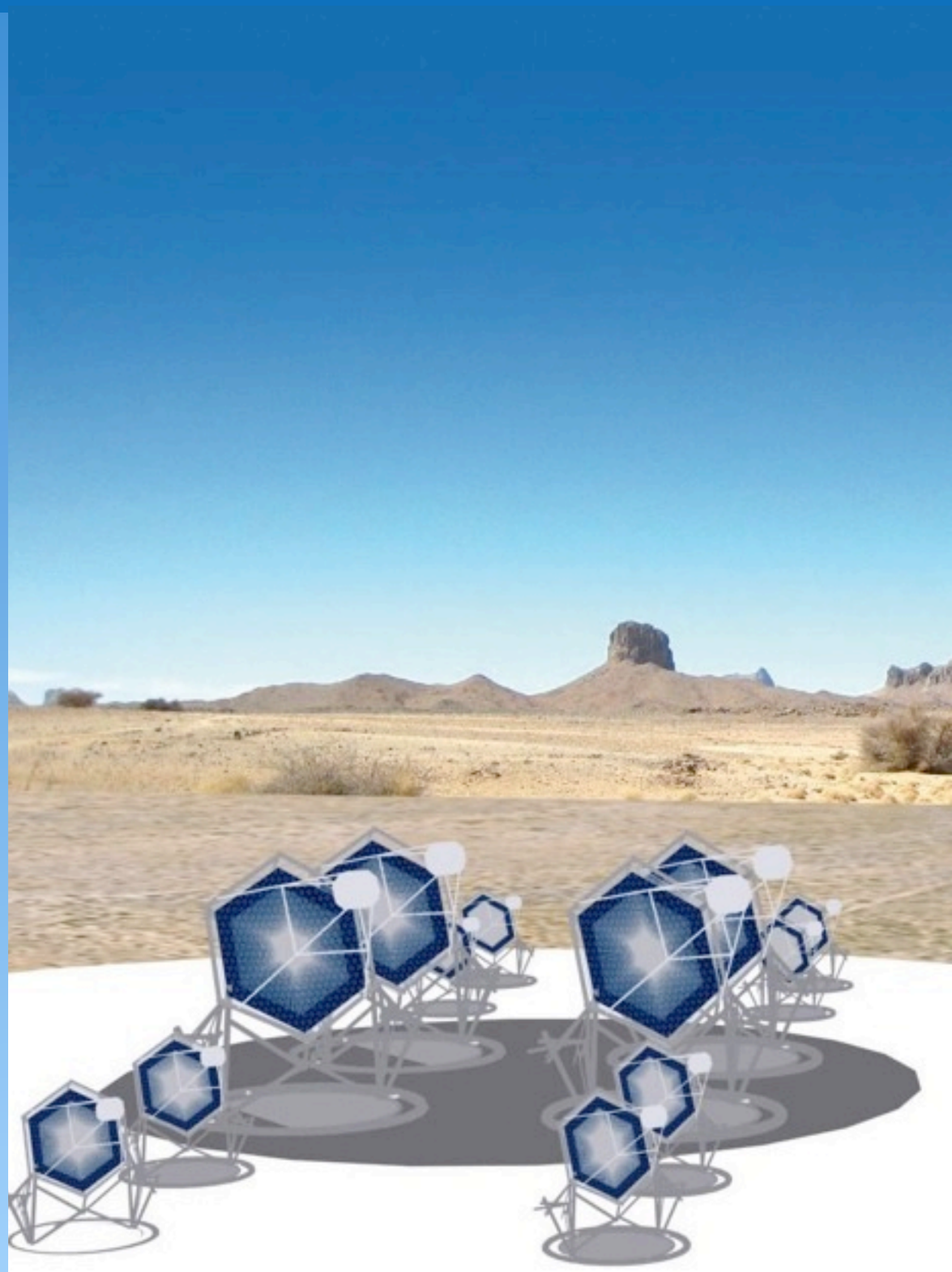
DM, GRB, high z AGN, ...

Population studies, source science, EBL, ..

Together with low E: QG, ..

CTA

- Array of 70-100 telescopes of different sizes
  - Few large, fast slewing for AGN, GRBs, PSRs ..
  - Many medium/small with large FOV for galactic science, ...
- Two sites
  - Southern site with full array (large FOV) for galactic science
  - Northern site for extragalactic science optimized for low energies



CTA collaboration

- Joint global effort (start: Europe + x)
- Recently: AEGIS will join CTA
- Members from all current generation VHE instruments (HESS, MAGIC, VERITAS, ..)
- Note: CTA will be an observatory
  - Science strongly driven by external proposal
  - Implications for organization etc.

CTA status

- CTA activities started in 2006 (Berlin)
  - Collaboration is constantly growing
  - Regular collaboration meetings (twice/yr)
- Organizational structure in place
  - Collaboration board (SP: W. Hofmann, M. Martinez)
  - Work packages with regular meetings
- Strong european support
  Aspera, Astronet, ESFRI

- 2010: design phase ➠ prepatory phase

ESFRI Roadmap 2008

- ESFRI = European Strategy Forum on Research Infrastructures
- Physical Sciences and Engineering:

	Construction cost	Operations cost	Time scale
CTA	150	10	2013
E-ELT	950	30	2018
ELI	400	50	2015
FAIR	1187	120	2016
KM3NeT	200	5	2016
PRINS	1400	300	2009-2015
SKA (GLOBAL)	1500	100-150	2016
SPIRAL2	196	6.6	2014

green = construction started,
funding (almost) approved

slide borrowed from W. Hofmann

CTA challenges

- Building organizations
  - Current generation instruments are run by small, closed collaboration, which have to be integrated in CTA
    - CTA will be a large observatory with users
- Cutting costs
  - Previous VHE experiments where constructed in the labs and institutes workshops
  - CTA has to be mass produced by the industry (time & money)

CTA physics studies

- Fundamental physics & cosmology is a strong driver of CTA science
- Physics potential of CTA is intensively studied inside CTA (PHY WP)
  - Extensive and detailed MC studies on going
  - Most studies not yet public
  - Expect that to change in the coming months

AGN

Stars and **Dust**
in Galaxies

HE/VHE ϒ-
Rays

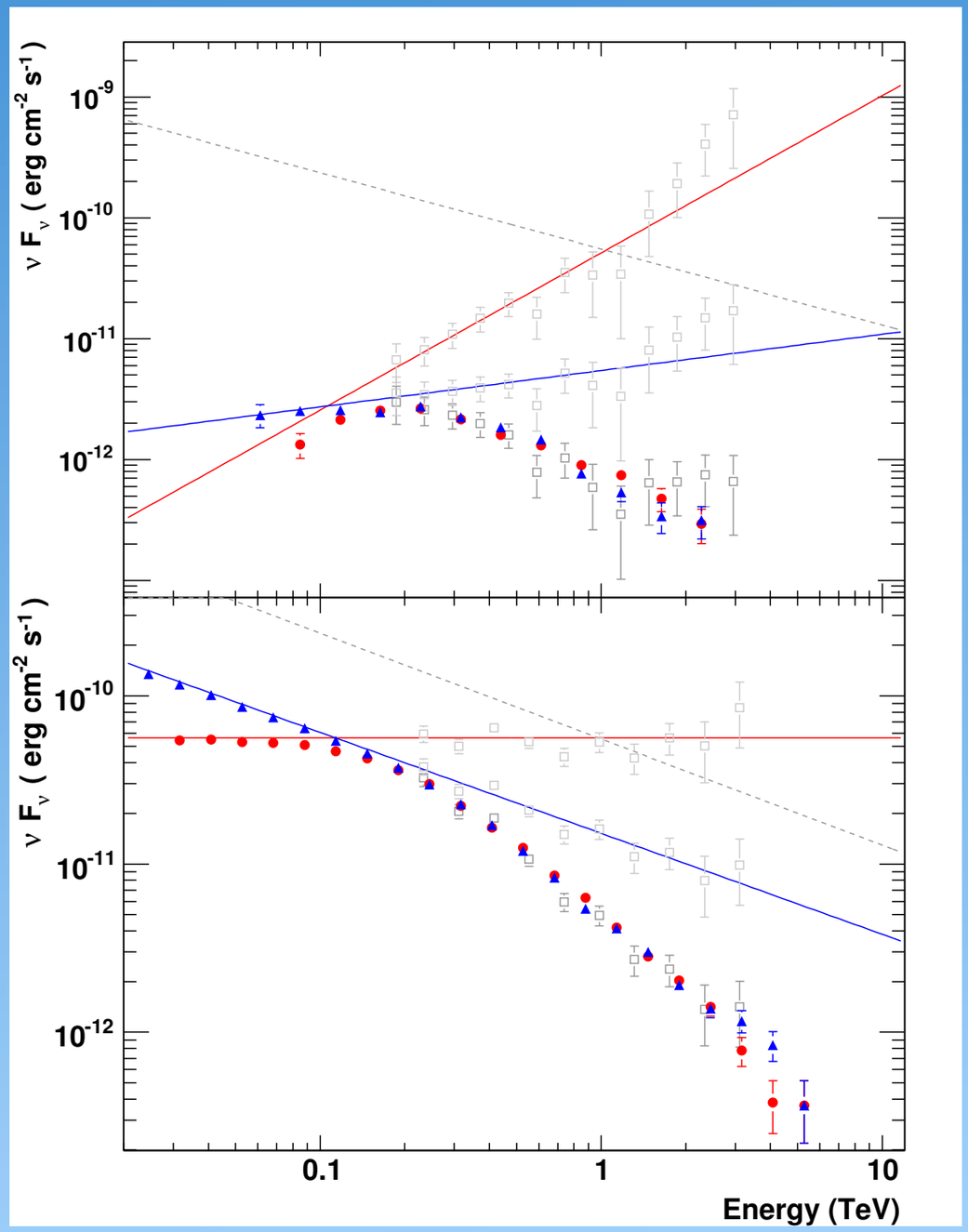
UV/O/IR
Photons

e+ e-

Nikishov (1962), Jelley (1966), Gould & Schreder (1966)

Example: CTA vs EBL I

- Simulate CTA spectra for known AGN
- Test new methods to limit EBL on simulated spectra

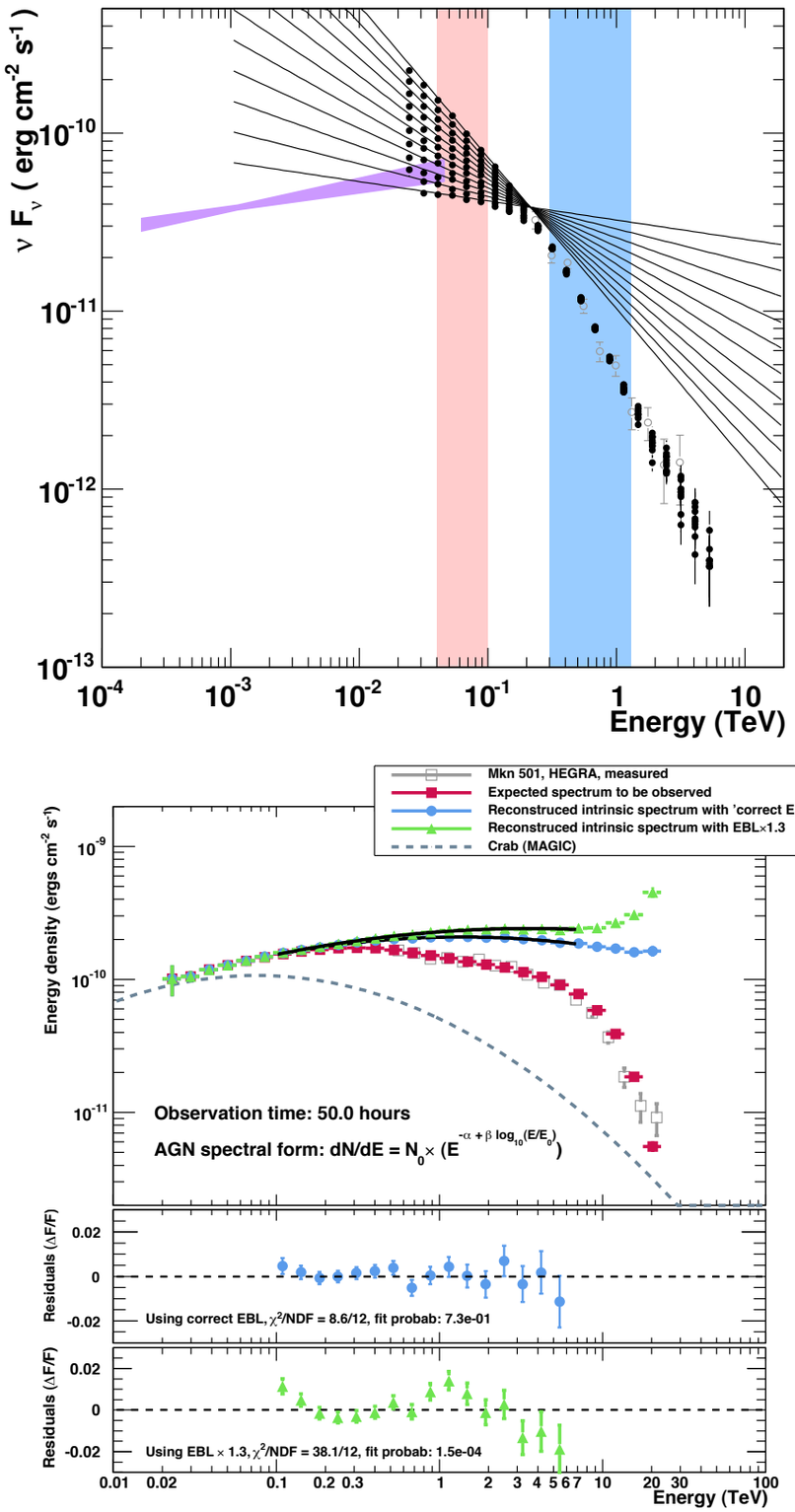


Raue & Mazin 2010, submitted

Example: CTA vs EBL II

- Two methods investigated
  - Utilize the unabsorbed part of the spectrum at low energies
  - Use EBL attenuation signature at mid energies
- Quantified possible constrains
  - New methods to constrain EBL will be available with CTA

Raue & Mazin 2010, submitted



Summary & conclusions I

- CTA is the next generation instrument for VHE science
  - Order of magnitude improvement in sensitivity over current generation instruments
  - Extended energy range
- CTA will be an observatory
- CTA collaboration has started the work
  - Joint project including members from HESS, MAGIC, VERITAS

Summary & conclusions II

- Fundamental physics and cosmology are strong science drivers for CTA
  - Extended energy range & high sensitivity
- Understanding the source physics is essential!
- Expect more publications on CTA physics topics in the coming months!