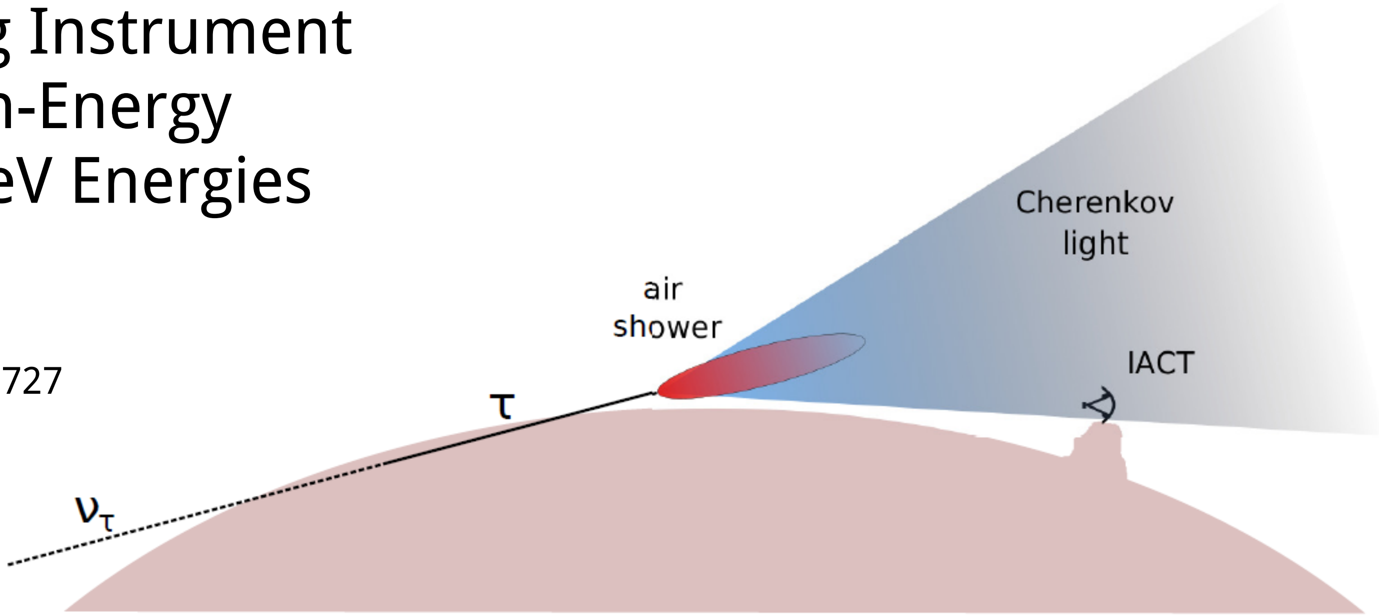
Trinity:

An Air-Shower Imaging Instrument to Detect Ultrahigh-Energy Neutrinos down to PeV Energies

Phys. Rev. D 99, 083012 (2019)
Astro2020 white paper arXiv:1907.08727
ICRC 2019 arXiv:1907.08732



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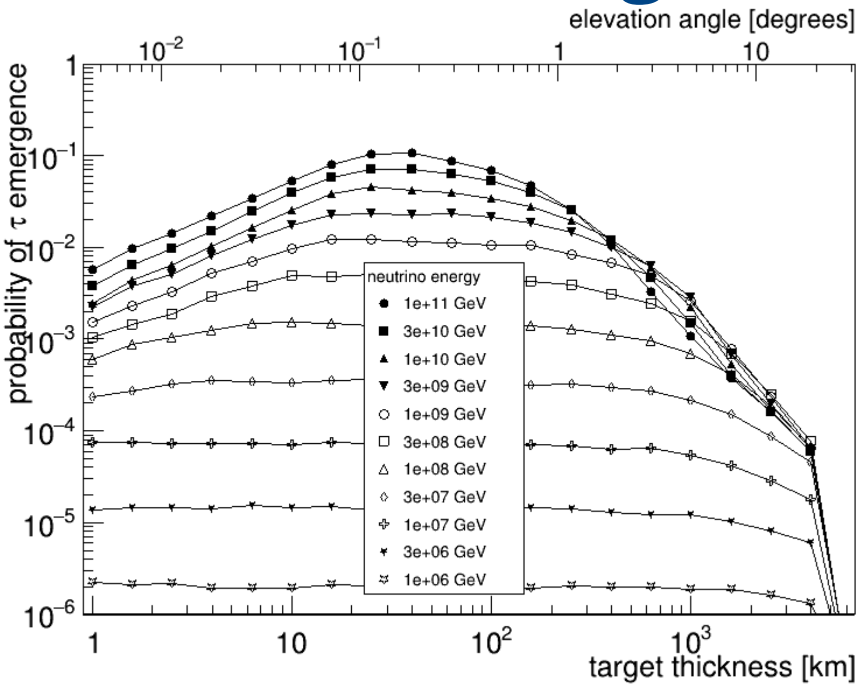


Probability if ν conversion and emergence of τ from ground

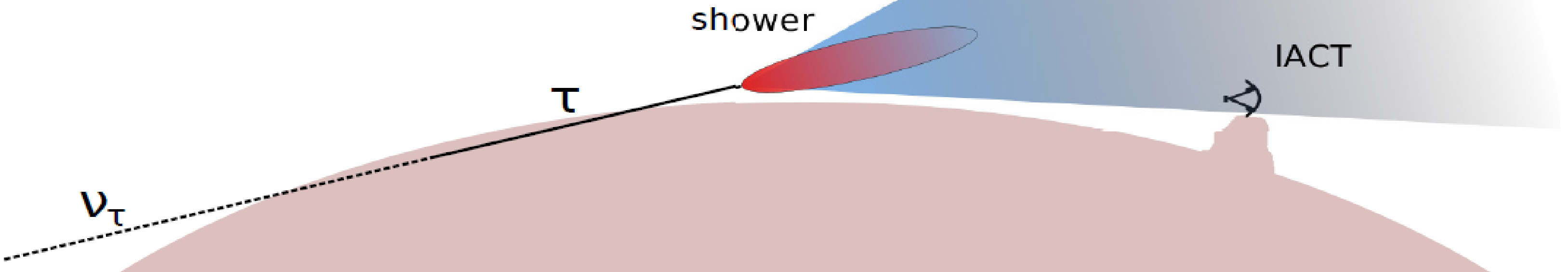
Limiting factors above 10^8 GeV:

- Target to thin: ν does not convert
- Target to thick: τ does not make it out

Limiting factors below 10^8 GeV:

τ decay length: $49\,km \times \frac{E_\tau}{10^9\,GeV}$ <1 km

Only works for tau neutrinos



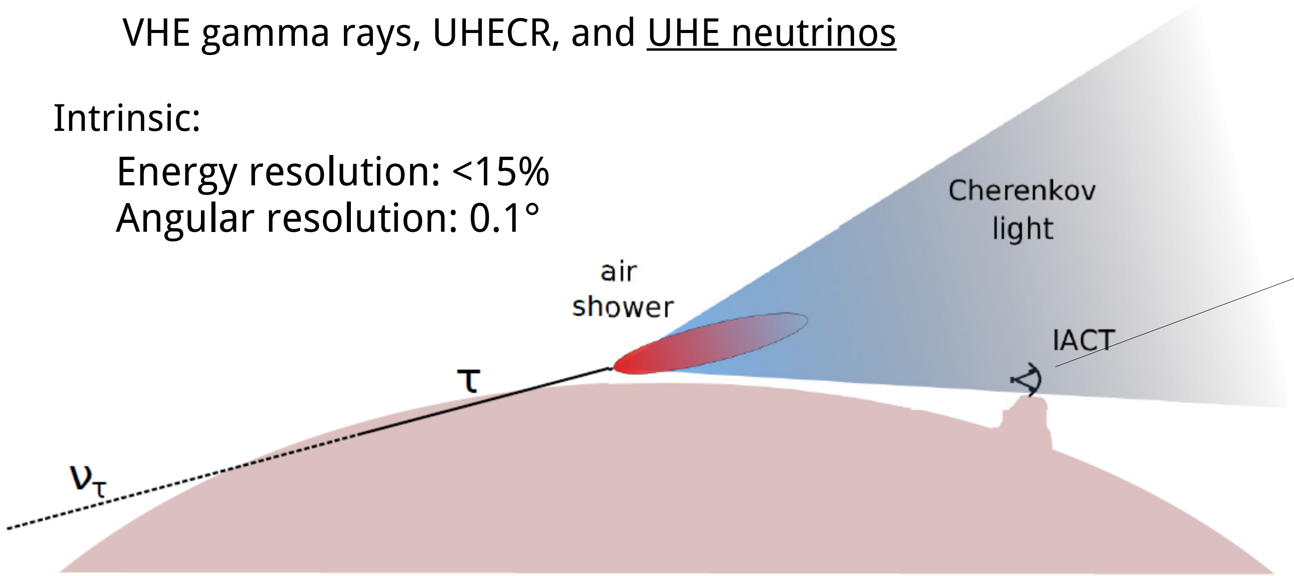
Air-Shower Imaging

A proven technique for

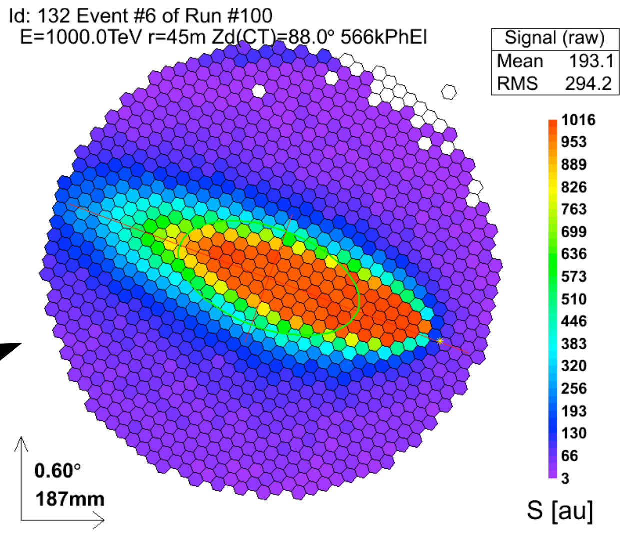
VHE gamma rays, UHECR, and UHE neutrinos

Intrinsic:

Energy resolution: <15%
Angular resolution: 0.1°



Simulated 1 PeV tau shower image



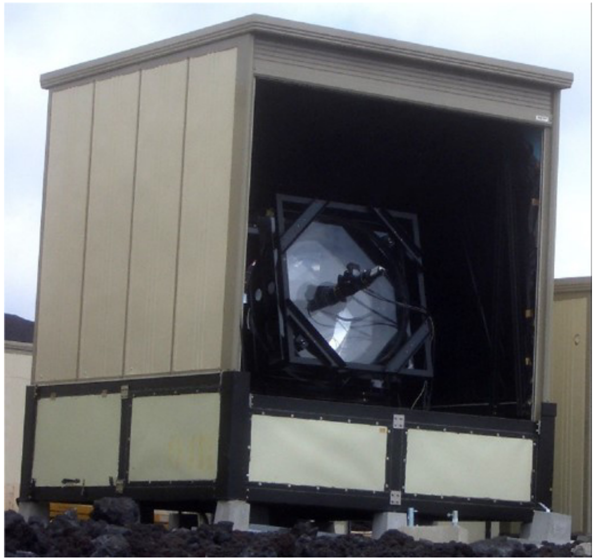
credit: MAGIC

Concept has been shown to work for UHE-neutrino observations:

e.g. MAGIC (2018), Astropart.Phys.102,77-88.

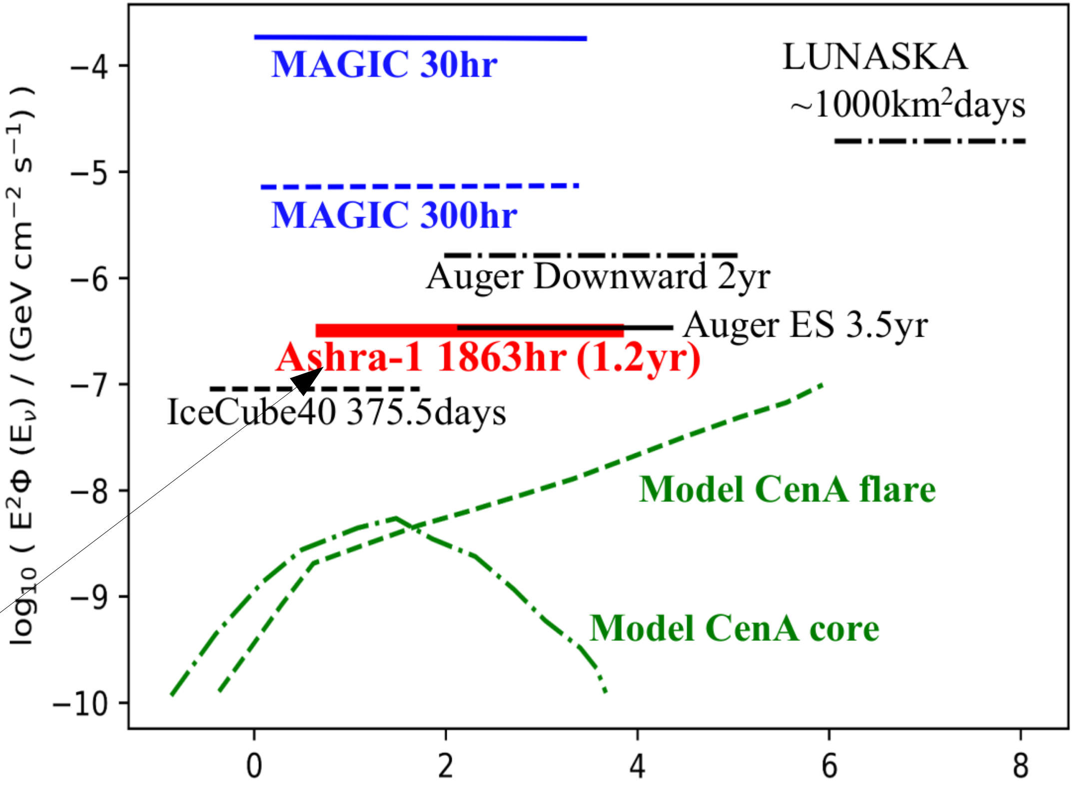
Ashra-1 PoS(ICRC2019)970

UHE Neutrino Searches with Ashra

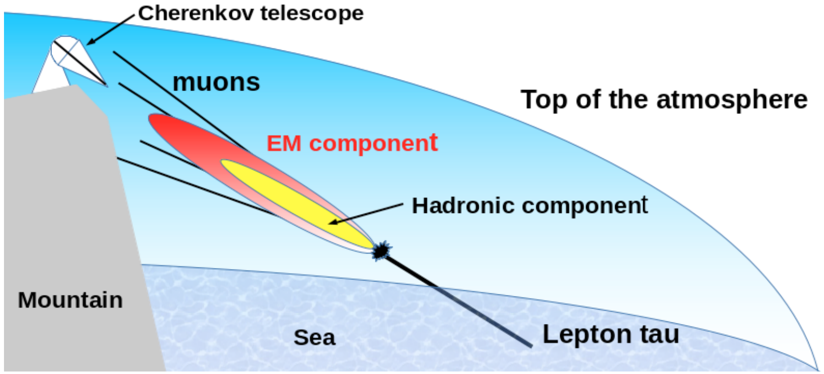


Ashra-1 PoS(ICRC2019)970

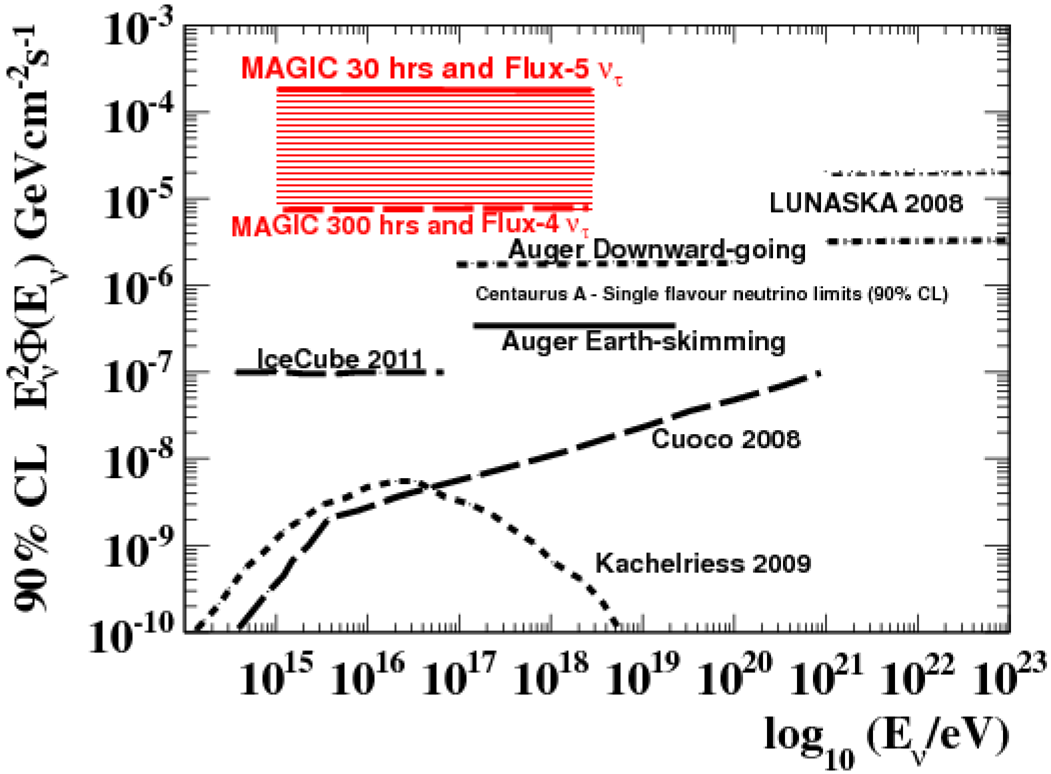
20% duty cycle



UHE-Neutrino Searches with MAGIC



MAGIC telescopes



MAGIC (2018), Astropart.Phys.102,77-88.

Trinity: Baseline Configuration

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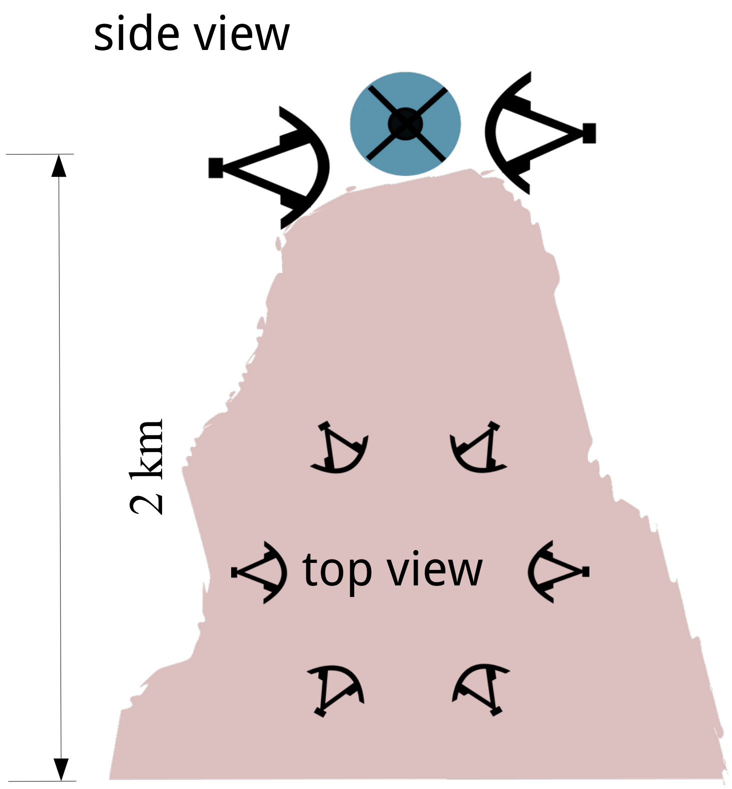


Compact Telescopes

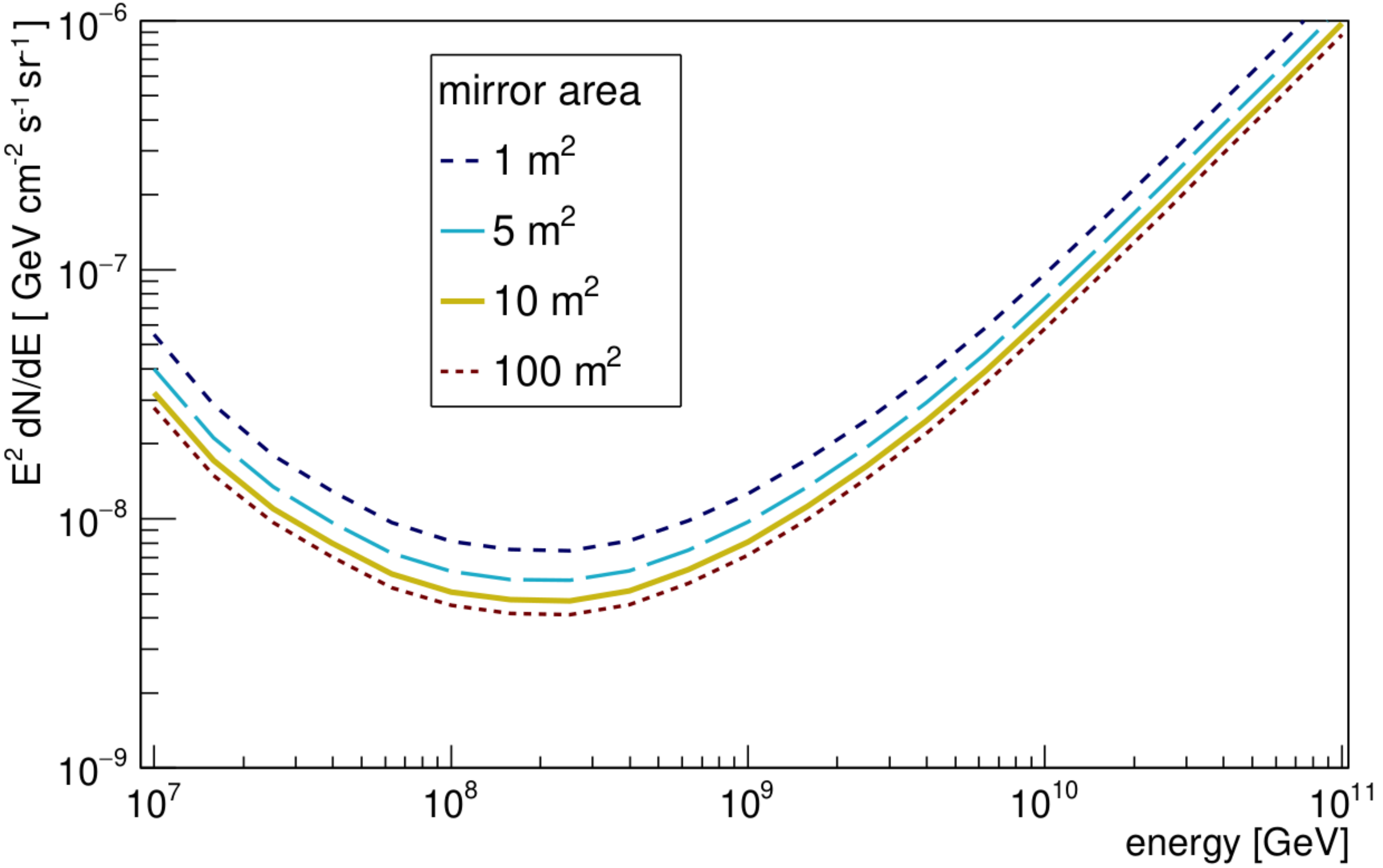
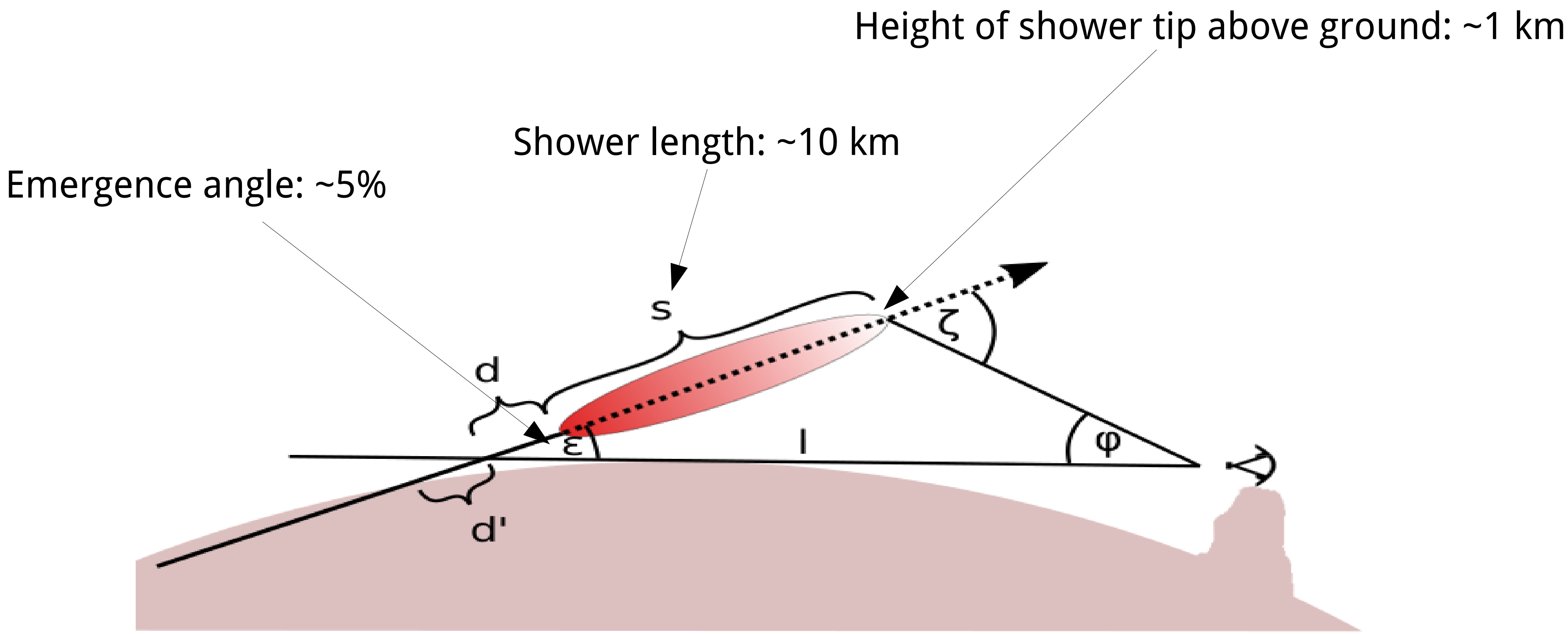
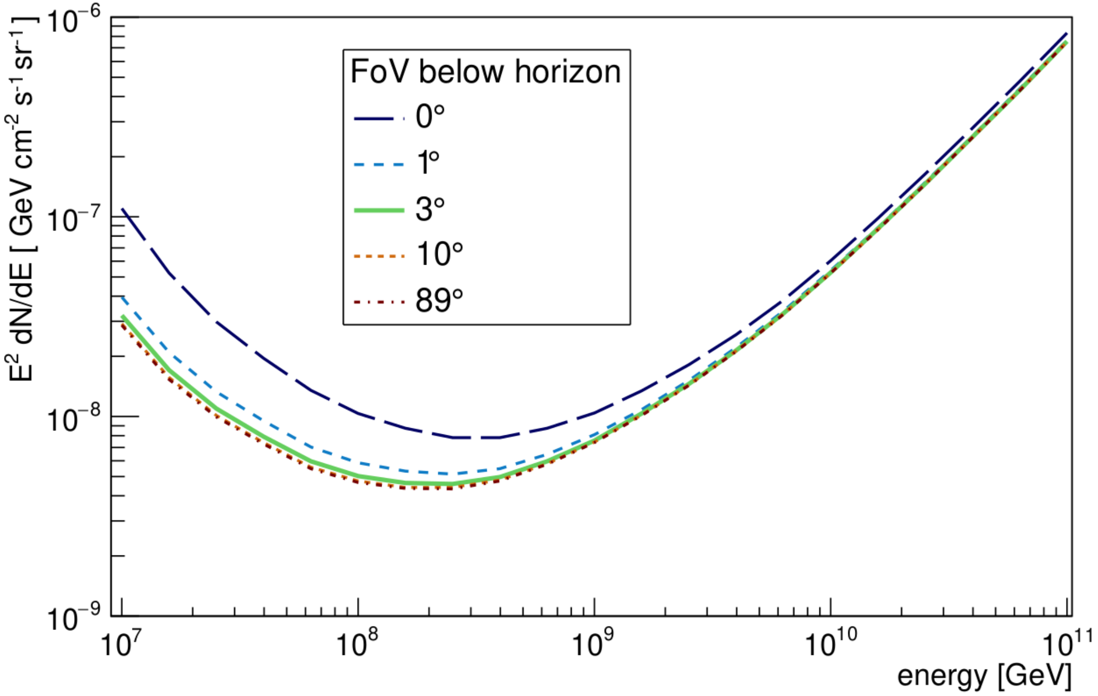
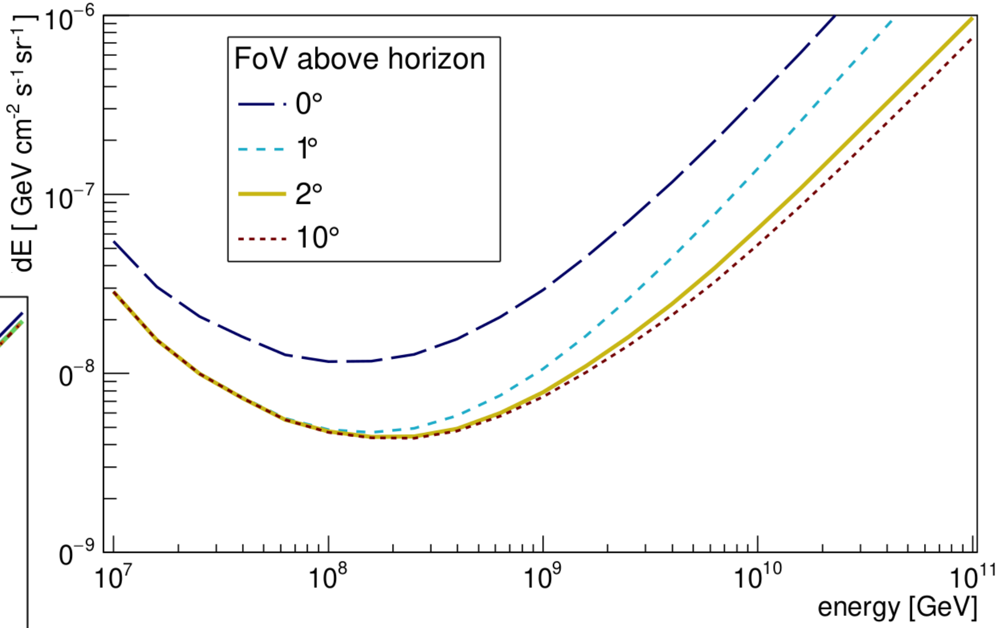


Image Containment



Compact Field-of-View



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+031.69168° / -110.88498° 8436ft 13:15:52
MAIL
POSITION - ALTITUDE - TIME
MAP
LOG
1° veto region
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ANGLE
5° signal region
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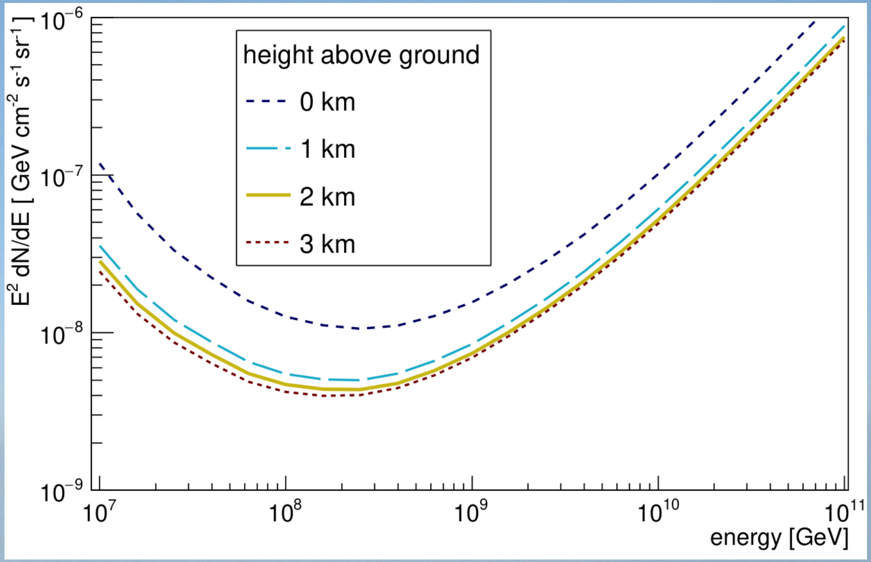
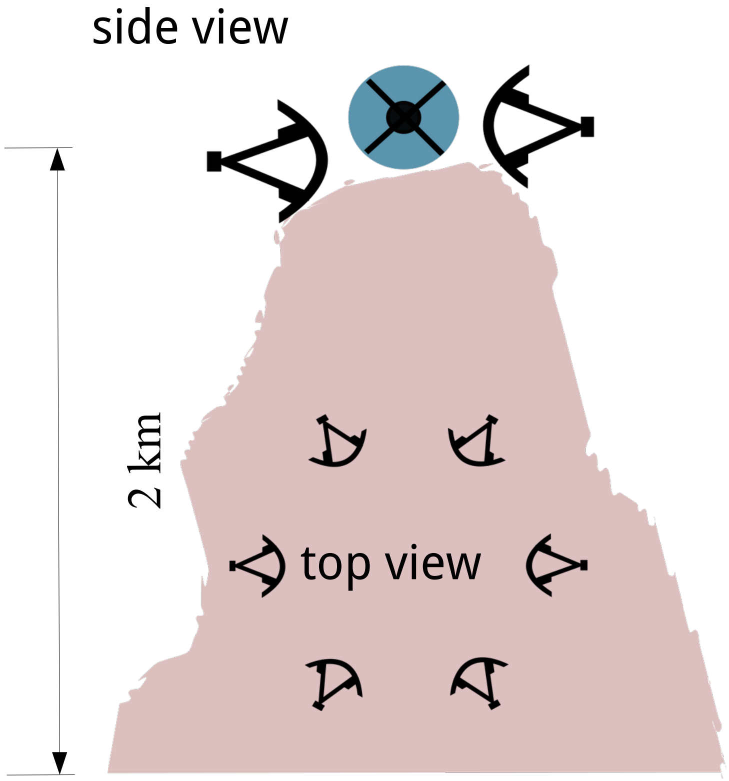
Keeping out of the Haze



Trinity: An Optimized PeV Threshold UHE-Neutrino Detector



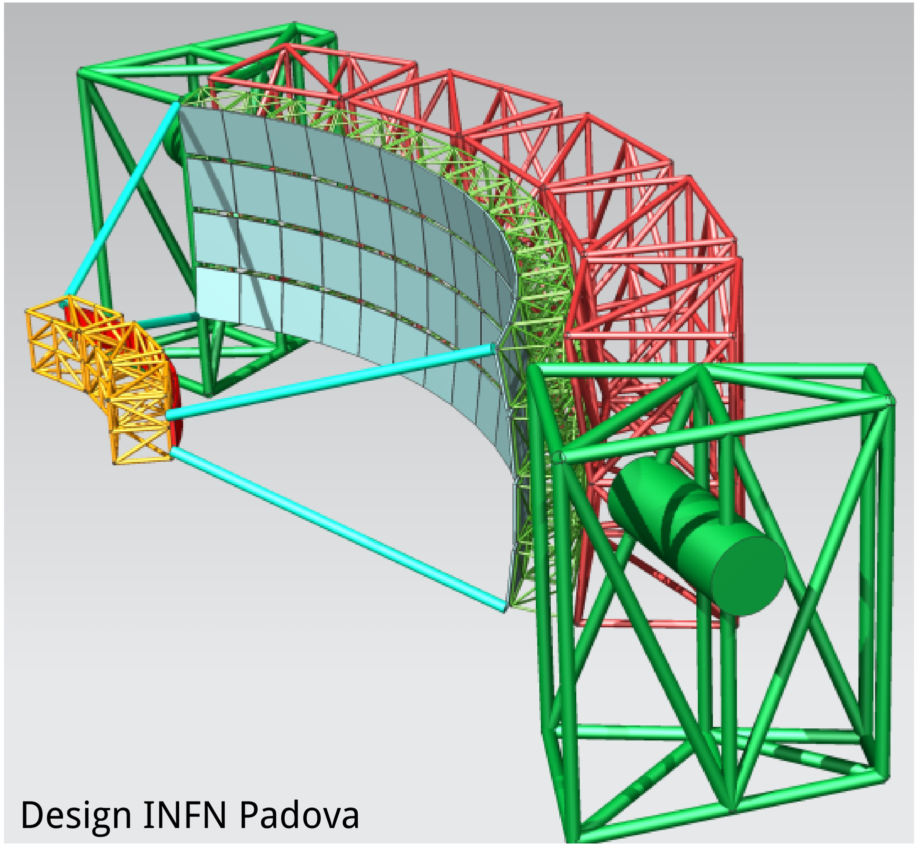
- 2 km above ground
- 360° azimuthal acceptance (six 60° FoV telescopes)
- Three sites (18 telescopes)
- 10 m^2 effective mirror area
- 3° FoV above horizon, 2° FoV below horizon
- 0.3° angular resolution
- Silicon photomultipliers instead of bialkali photomultipliers
- $15 M (telescopes + infrastructure)

Suitable sites for Trinity with existing infrastructure:
Frisco Peak, UT; Hawaii; Canary Islands La Palma and Tenerife

Optics

Based on J. Cortina et al., Astrop. Physics 72 (2016) 46

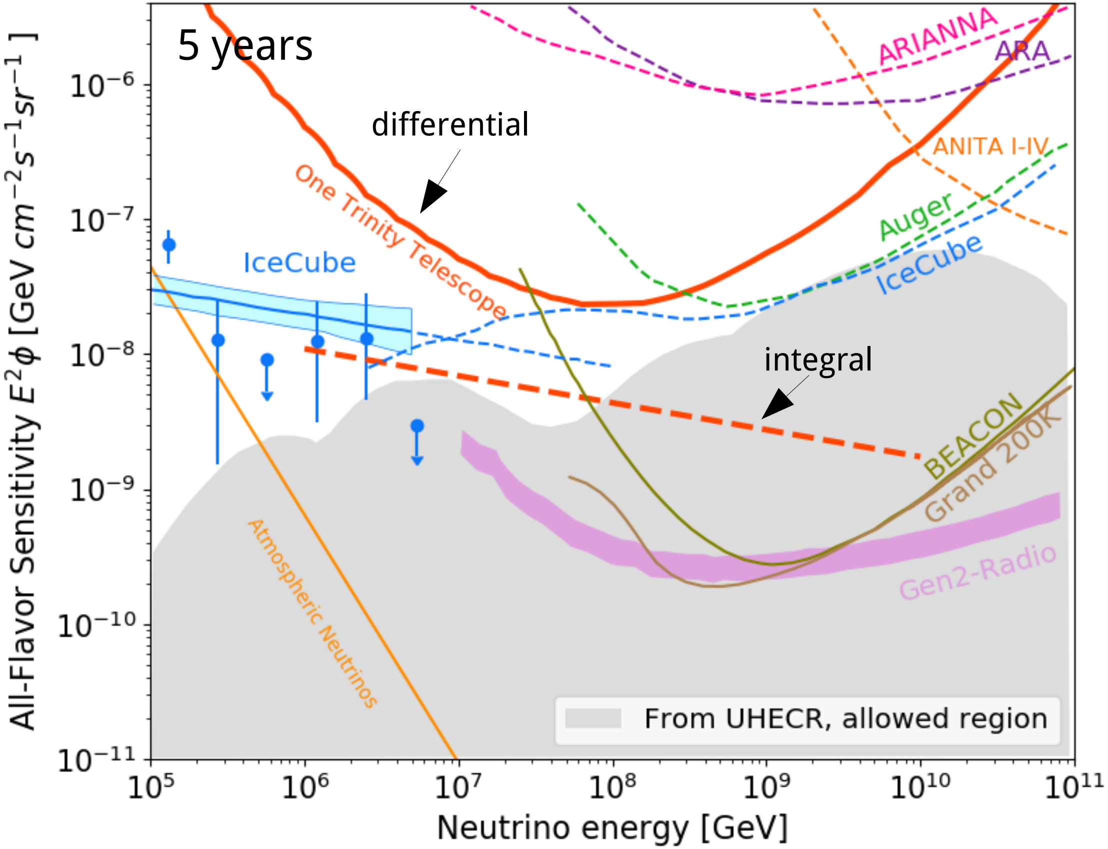
- **FoV 5° X 60°.**
- 5.6 m focal length.
- 68 m^2 mirror area → **16 m^2** in any direction.
- 0.3° optical PSF.
- 3,300 pixel camera.
- 20 mm Winston cones coupled to **9 mm SiPMs**.
- Thin-glass replica mirror technology ~$2k/$m^2$.
- Implementation based on MAGIC structure.
- Rotates in elevation.
- $170k for one telescope.
- $330k for one camera.

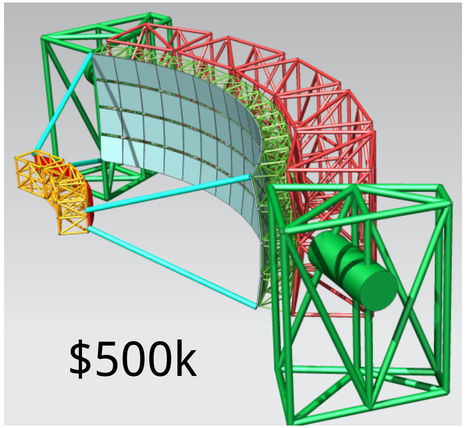


Design INFN Padova

Astro 2020 APC White Paper arXiv:1907.08727

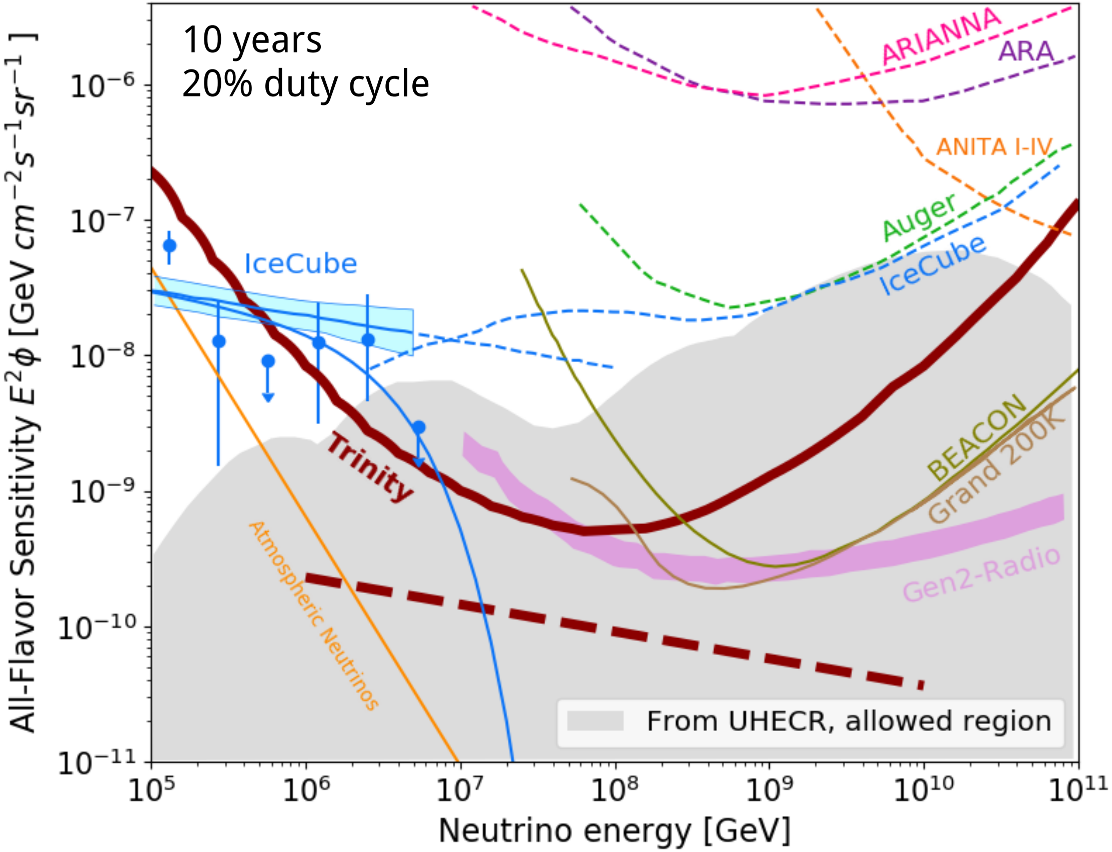
Trinity: Single-Telescope Sensitivity





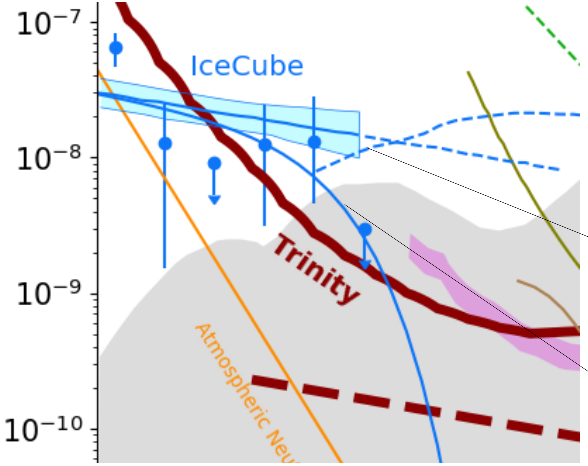
A single telescope will detect astrophysical neutrinos provided the spectrum does not cut off.

Trinity's Sensitivity to Diffuse Neutrino Fluxes



- 18 telescopes on three sites
- $15M invest
- Useful sensitivity from $5x10^5$ GeV to 10^{10} GeV
- Sensitive to 1% of the astrophysical-neutrino flux

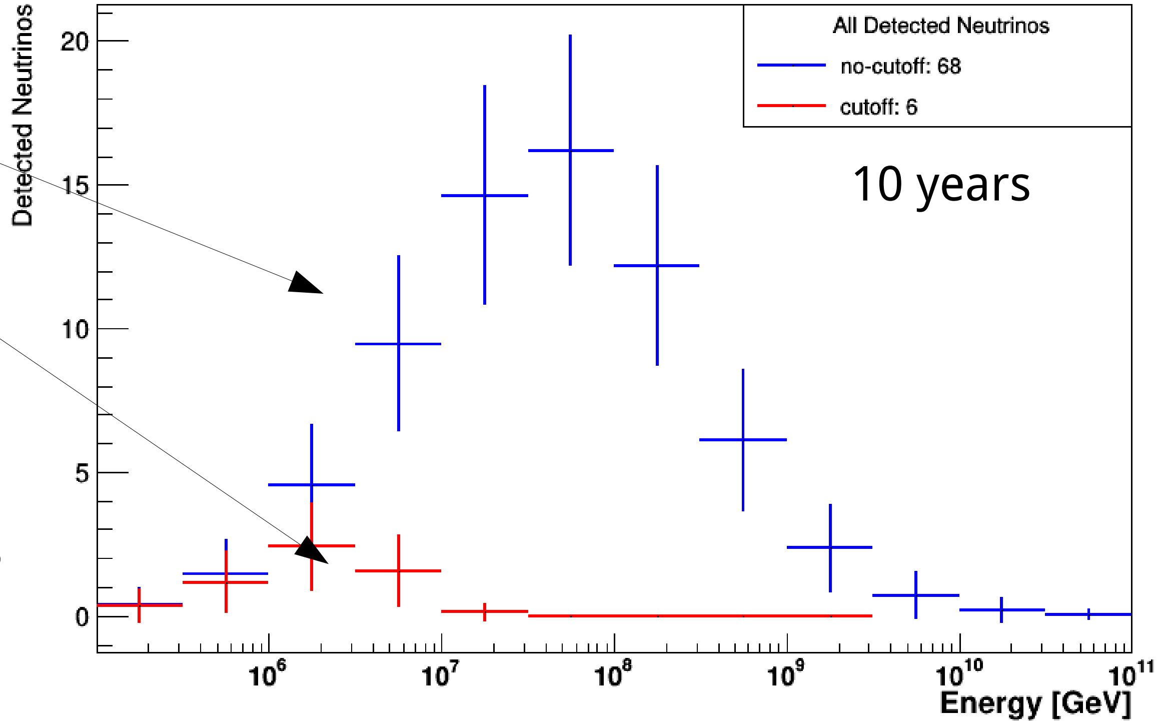
Astrophysical-Neutrinos with Trinity



Pure tau-neutrino sample

Sources must turn off but where?

→ Need a low energy threshold



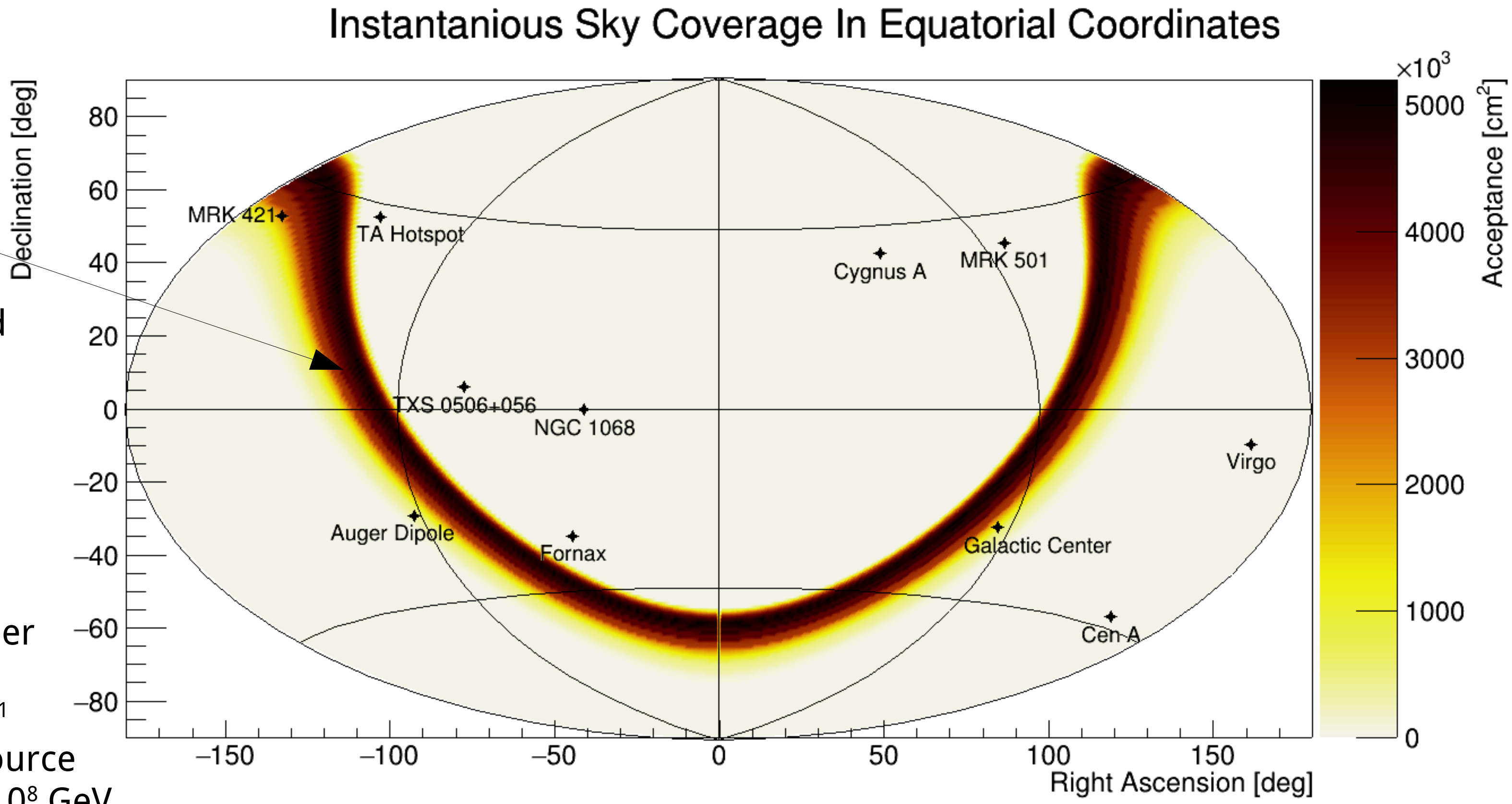
Instantaneous Sky Coverage (One Site)

15° wide band → 13% of sky

~50% of the sky observed every night

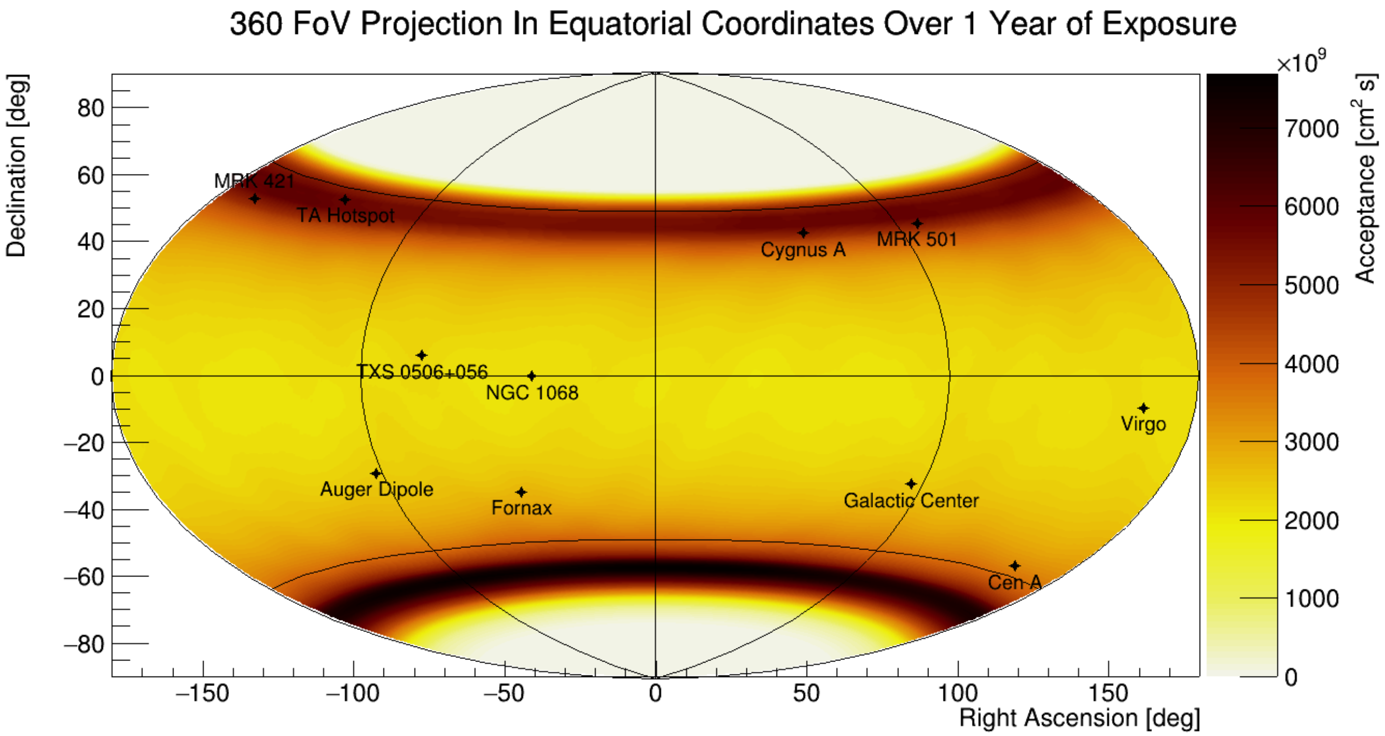
Expect 10 GRBs/year go off in FoV

typical observing time per source: 1-2 hours
→ 2 ... $5 \cdot 10^{-3}$ GeV cm^{-2} s^{-1} differential flux point source detection sensitivity @ 10^8 GeV per night :(



Sky Coverage (One Year, One Site)

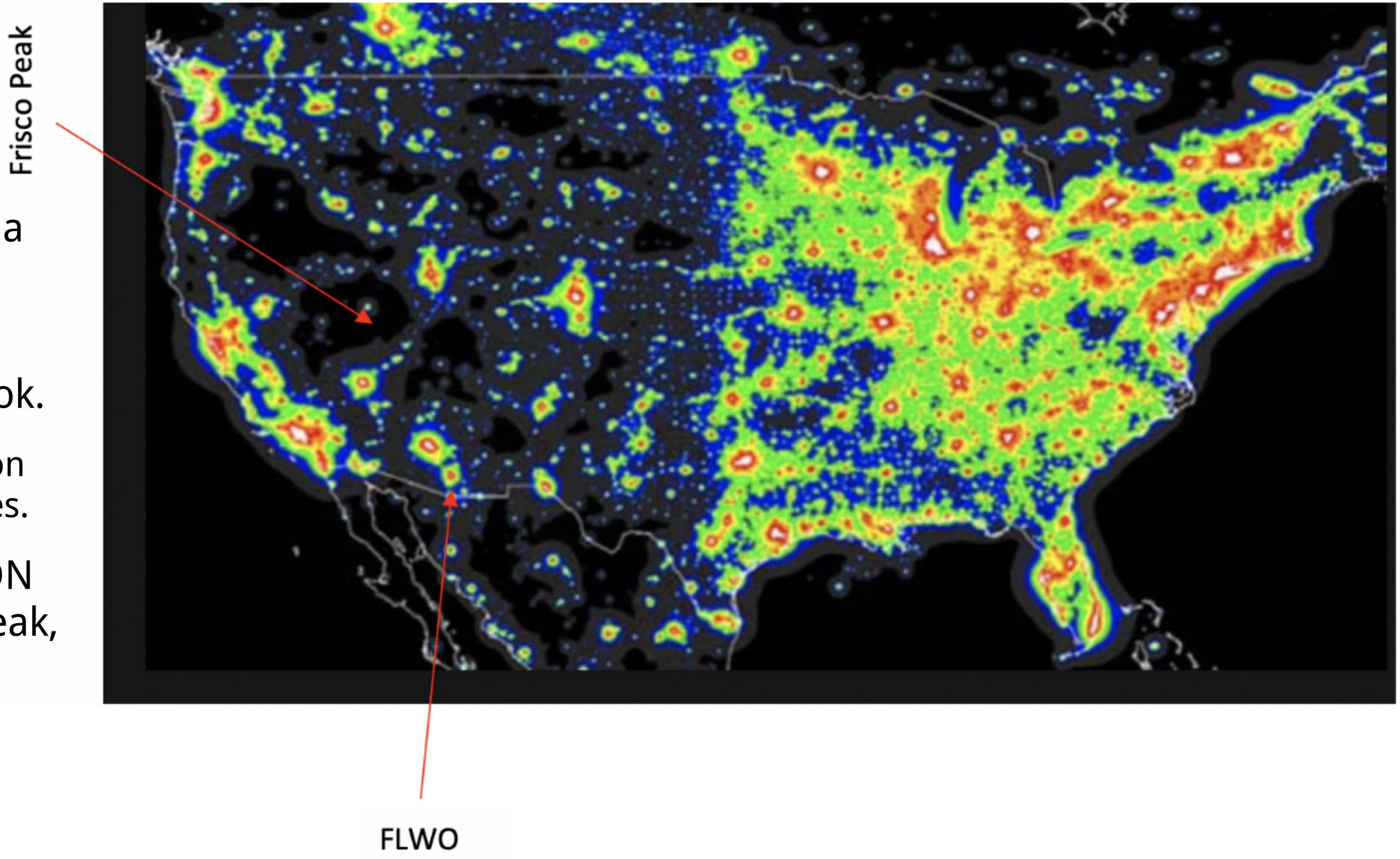
Annual point source sensitivity:
1…5 $\cdot 10^{-5}$ GeV cm^{-2} s^{-1} @ 10^8 GeV



- Trinity has much of the same sky coverage as all major EM and GW multi-messenger instruments.
- Trinity observes 50% of the sky every night.

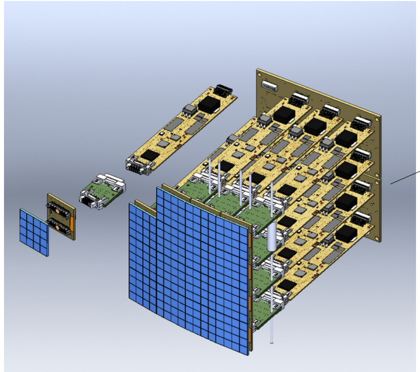
Site

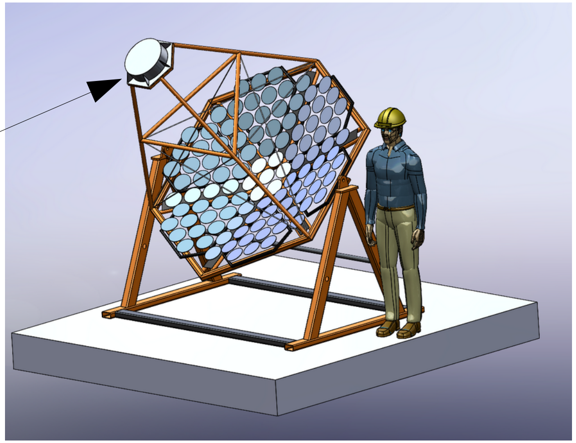
- Needs to oversee a remote area.
- Modest light contamination is ok.
  - Images happen on <100ns timescales.
- Ashra Site; BEACON Test site; Frisco Peak, UT, La Palma, ...



Trinity Demonstrator @ Frisco Peak

- Validate Trinity's telescope configuration
- Long-term stability of technologies
- Study background sources

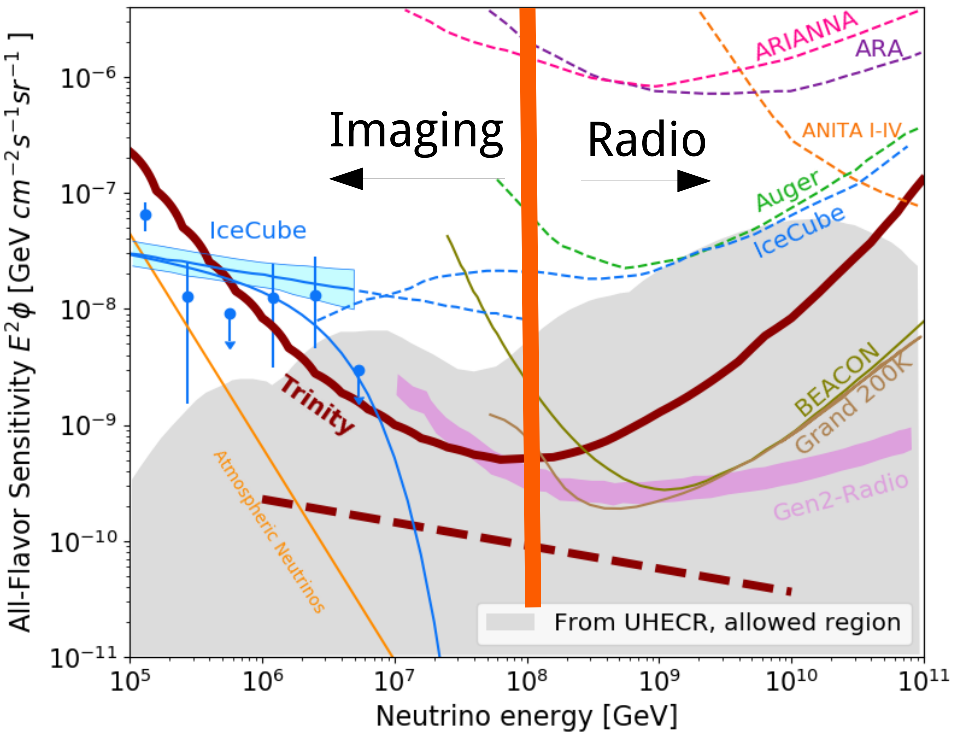




1 m^2 prototype

Take-Away Points and Remarks

- Trinity is the lowest threshold UHE-instrument in the market.
- The technique is thoroughly tried and tested → WYSISWYG.
- Overlap with astrophysical-neutrino flux → guaranteed signal.
- Highest sensitivity where peak of cosmogenic-neutrino flux is expected
- Pure tau-neutrino sample from 5×10^5 GeV to 10^{10} GeV → fundamental physics.
- The source density in the non-thermal universe decreases rapidly with energy → a low energy threshold yields more science.



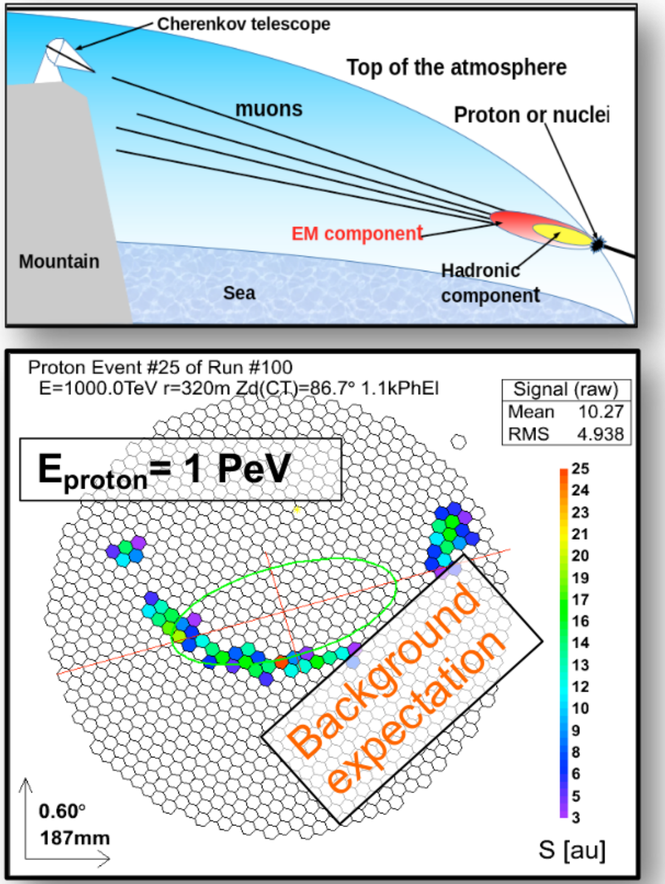
Remarks

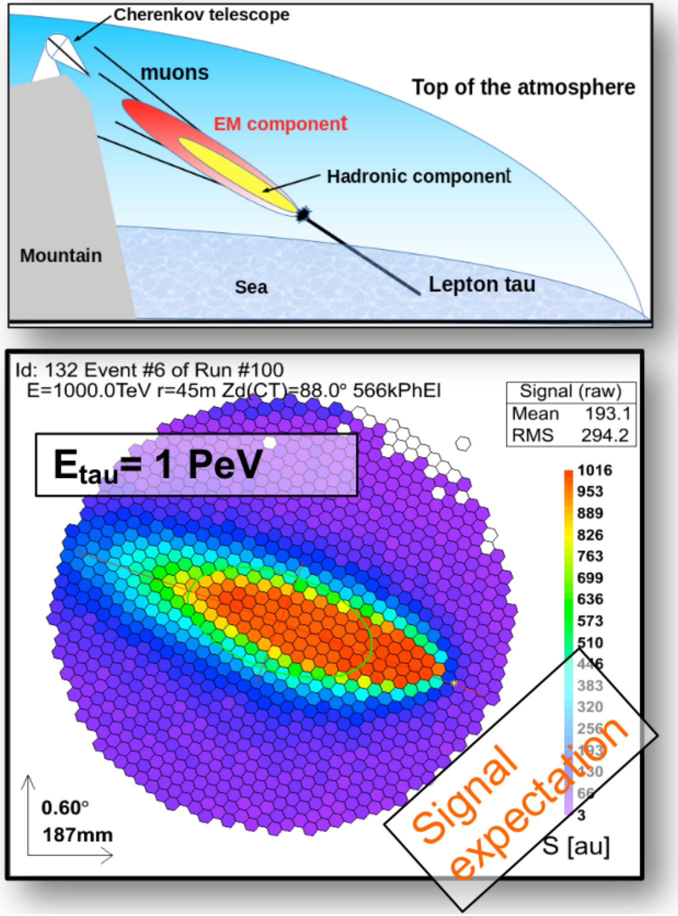
- Trinity and radio UHE-detectors complement each other.
- Exploration of the UHE-neutrino band requires a multi-pronged approach.

Backup

Proton injected at the top of the atmosphere
(~800 km to the detector for 87°)

Deep tau-induced shower
(~50 km to the detector)





Slide from Dariusz Gora (MAGIC)


MAGIC 200m² class telescopes
FACT 10m² class telescope