The Auger contribution to AMON

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RWTH Aachen University

on behalf of

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Miguel Mostafa and Foteini Oikonomou,
Penn State University

Third AMON Workshop DESY / Zeuthen 11 Dec. 2014

Overview

- Auger detector overview
- Datasets of interest to AMON
  - Neutrons
  - Photons
  - Neutrinos
- Current status of Auger contribution to AMON
- Summary

Auger MOU

The Pierre Auger Observatory

Av. San Martin Norte 304, Malargüe - Mendoza (Argentina)
web-site: http://www.auger.org

Spokesperson:
Prof. Dr. Karl-Heinz Kampert
University Wuppertal (Germany)
Tel: +49 202 439 2856 (Secr: -2640)
Fax: +49 202 439 2662
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PIERRE AUGER OBSERVATORY

Participation in AMON 16.08.2013

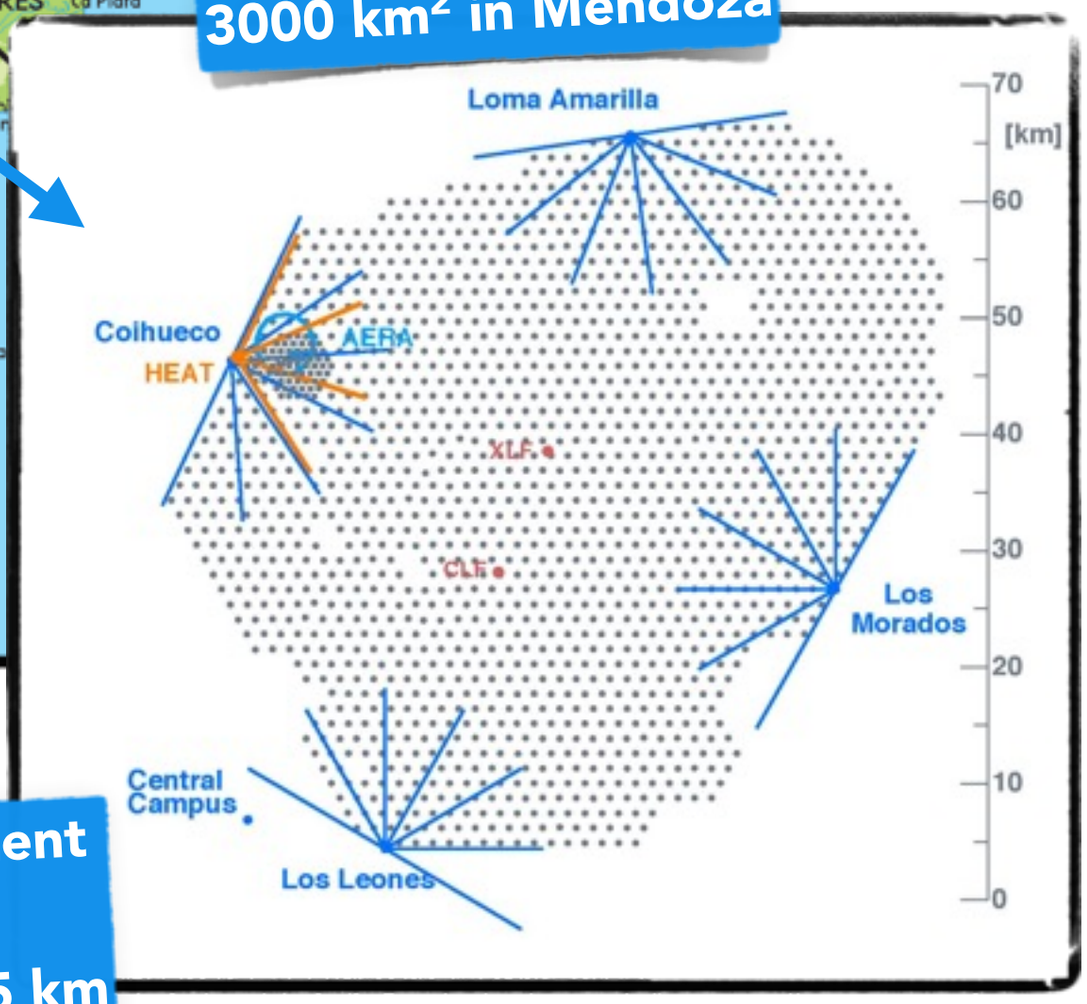
Dear Prof. Sommers,

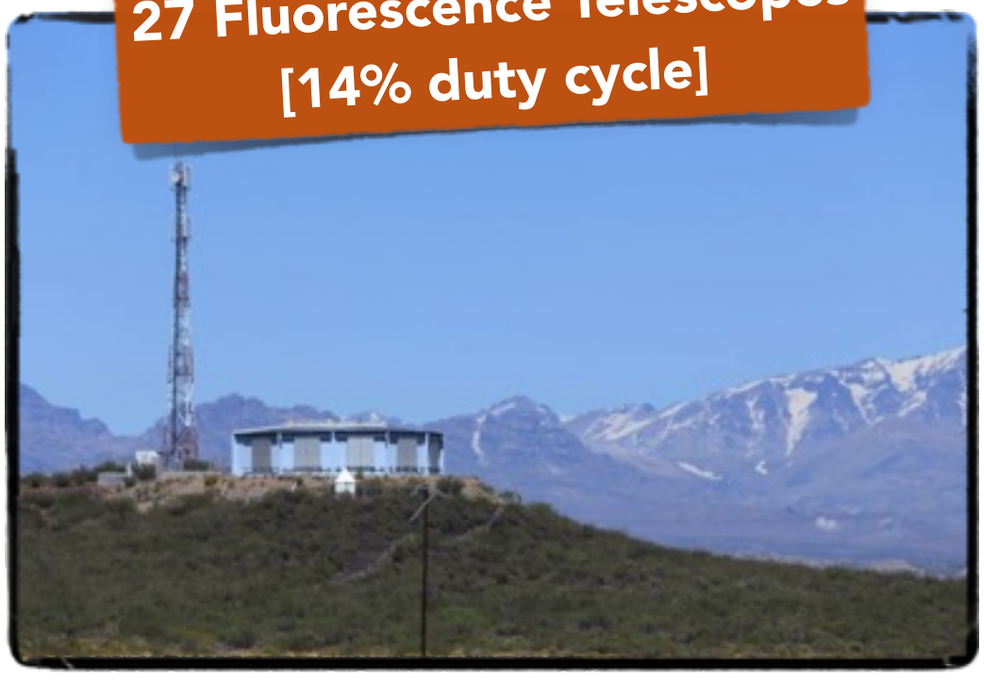
I am happy to inform you that the Collaboration Board of the Pierre Auger Collaboration has approved participation in AMON and has authorized me to sign the MoU. Please consider this letter as signature to the AMON MoU dated August 22, 2012 and attached to this document.

Looking forward to a fruitful cooperation and
with best regards,

(Karl-Heinz Kampert)

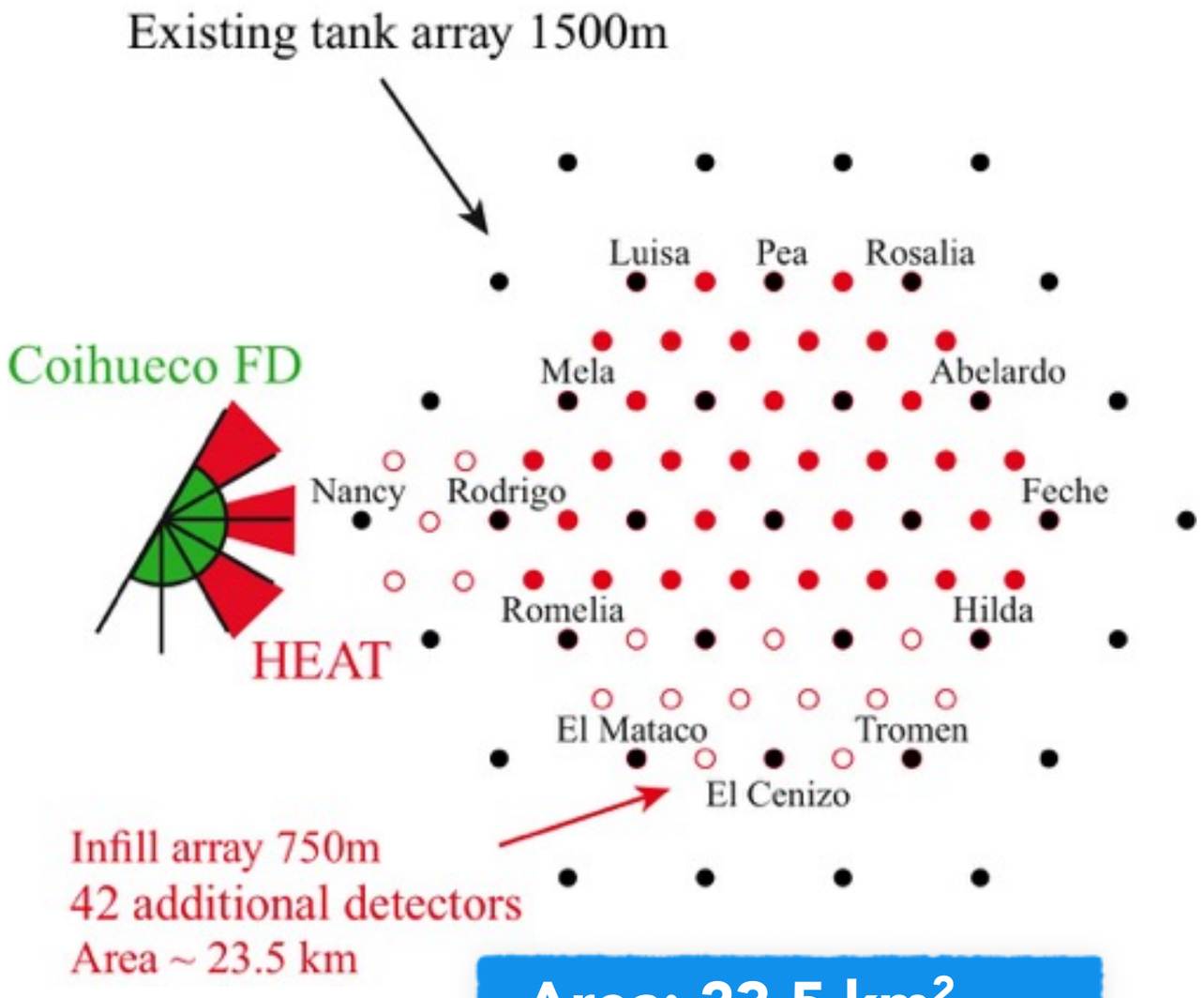
The Pierre Auger Observatory





Array fully efficient
E > 3 EeV
SD spacing ~ 1.5 km

The Infill Array



Area: 23.5 km²

Fully efficient at:

0.3 EeV (SD alone)

0.1 EeV (FD+SD)

HEAT (FD Extension)

AMIGA (SD + buried muon detectors)

Auger Status

- Auger measures (searches for) UHE charged hadrons plus UHE neutrons, photons, neutrinos, with E ≳ 0.1 EeV energy

- **Auger unique among current AMON members:** AMON discovery of transient = Discovery of UHECR source!!!

- Event rate ~ 500,000/yr

- Infill rate ~ 16000/day

Auger Datasets of interest to AMON

- [ ] UHE Hadrons
  [deflected by (poorly known) magnetic fields => delayed arrival]

- [x] UHE Galactic neutrons

- [x] UHE Photons

- [x] UHE Neutrinos

UHE Neutrons

- Existence implied by UHECR observations

- **But: Can they reach us?**

$$L_n \sim c \cdot \tau_n \cdot \gamma_n \sim 9 \left(\frac{E_n}{1\ \mathrm{EeV}} \right)\ \mathrm{kpc}$$

[c.f. MW radius ~ 8 kpc]

Yes!!

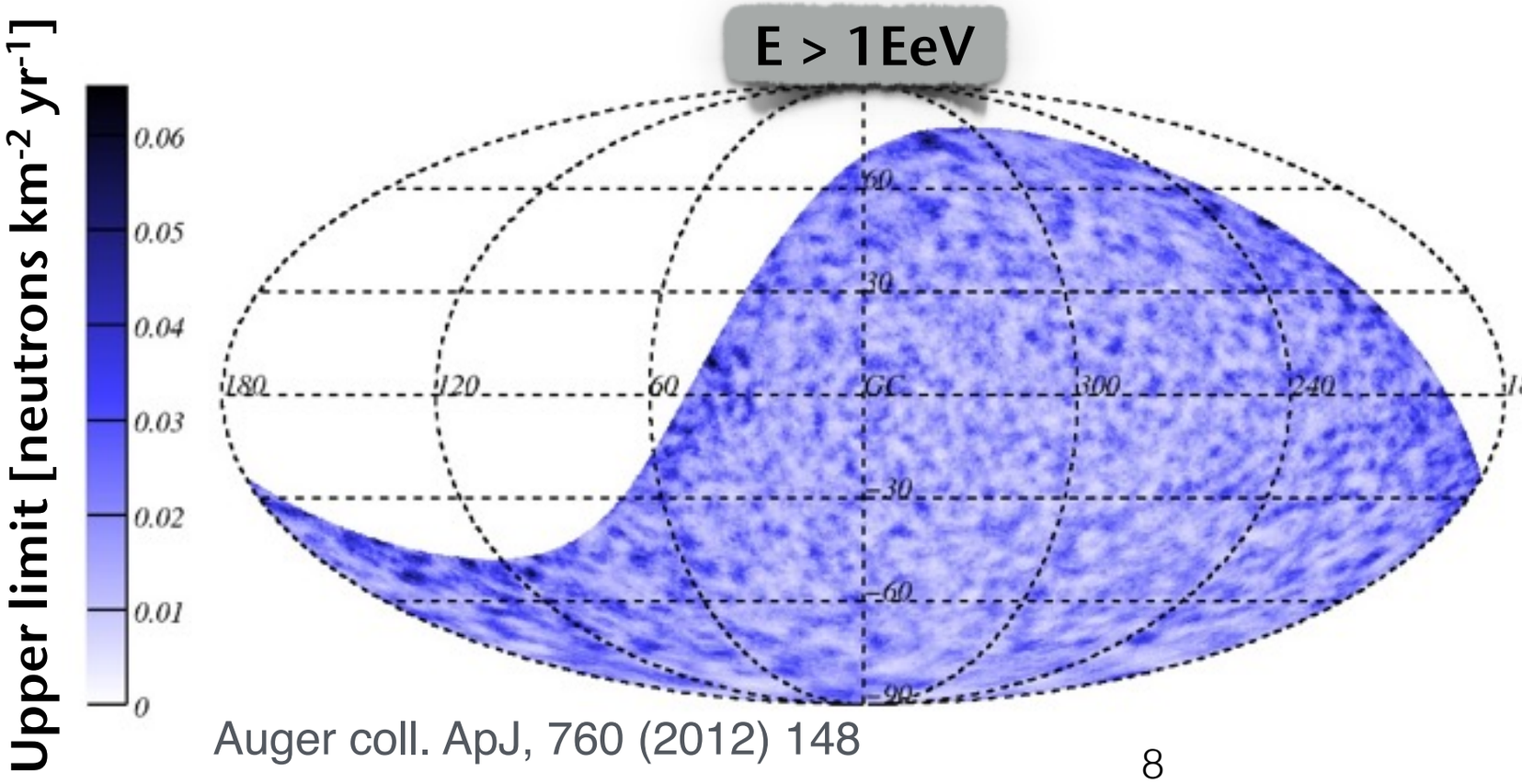
Galactic

E < 1 EeV neutrons

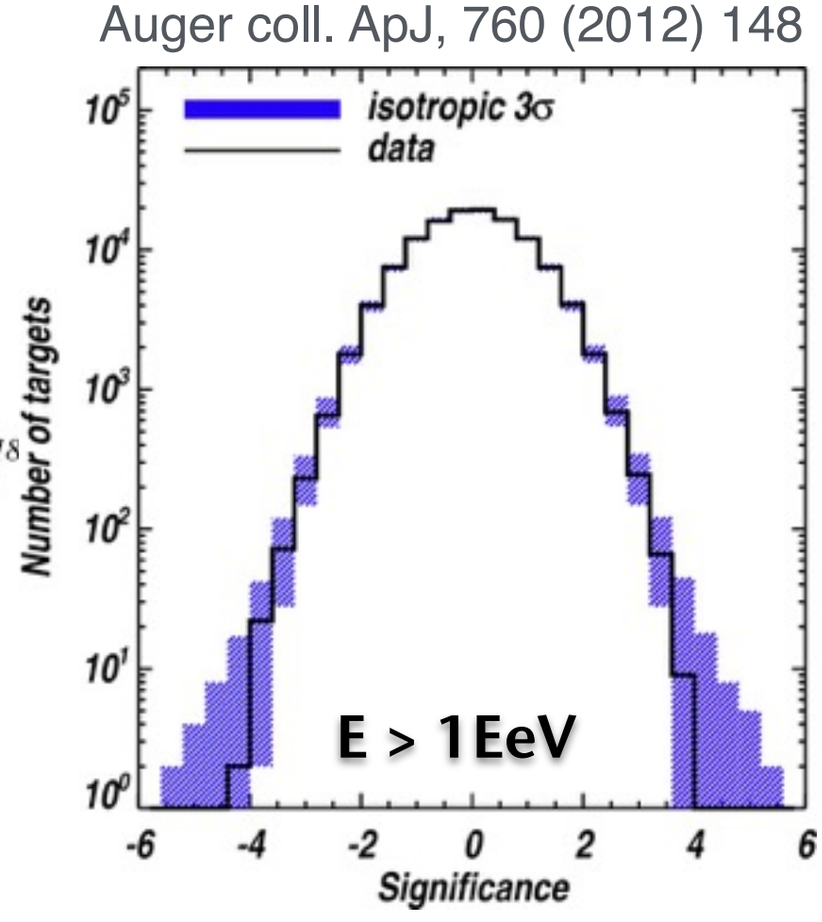
- AMON Science opportunity:
  - ☑ Local SNe
  - ☑ Cataclysmic variables
  - ☑ Magnetar flares
  - ☑ Pulsar Quakes

UHE Neutron searches in Auger

- Neutron showers indistinguishable from proton showers
- Look for correlations/excesses at E > 1EeV to identify
- Blind/targeted/stacked Auger searches have placed strong limits on UHE neutron flux from Galactic sources/GC



Auger coll. ApJ, 760 (2012) 148



Auger coll. ApJ, 760 (2012) 148

Auger trigger stream to AMON

Messenger	Neutron
Status	Real time reconstruction running
	Test alert system running
Latency	~30 minutes
Field of view	~3π sr
Arrival direction uncertainty	~1°
Signal rate	unknown
Background rate	500,000/yr
Doublet background rate	20/yr

- Singles & doublets trigger AMON
- Send alerts to AMON for all $E > 1$ EeV, $|b| < 5°$ Auger events
- Small data load (arrival direction, energy, time)
- Expected 3-fold coincidence rate with other AMON observatories ~0.06/yr

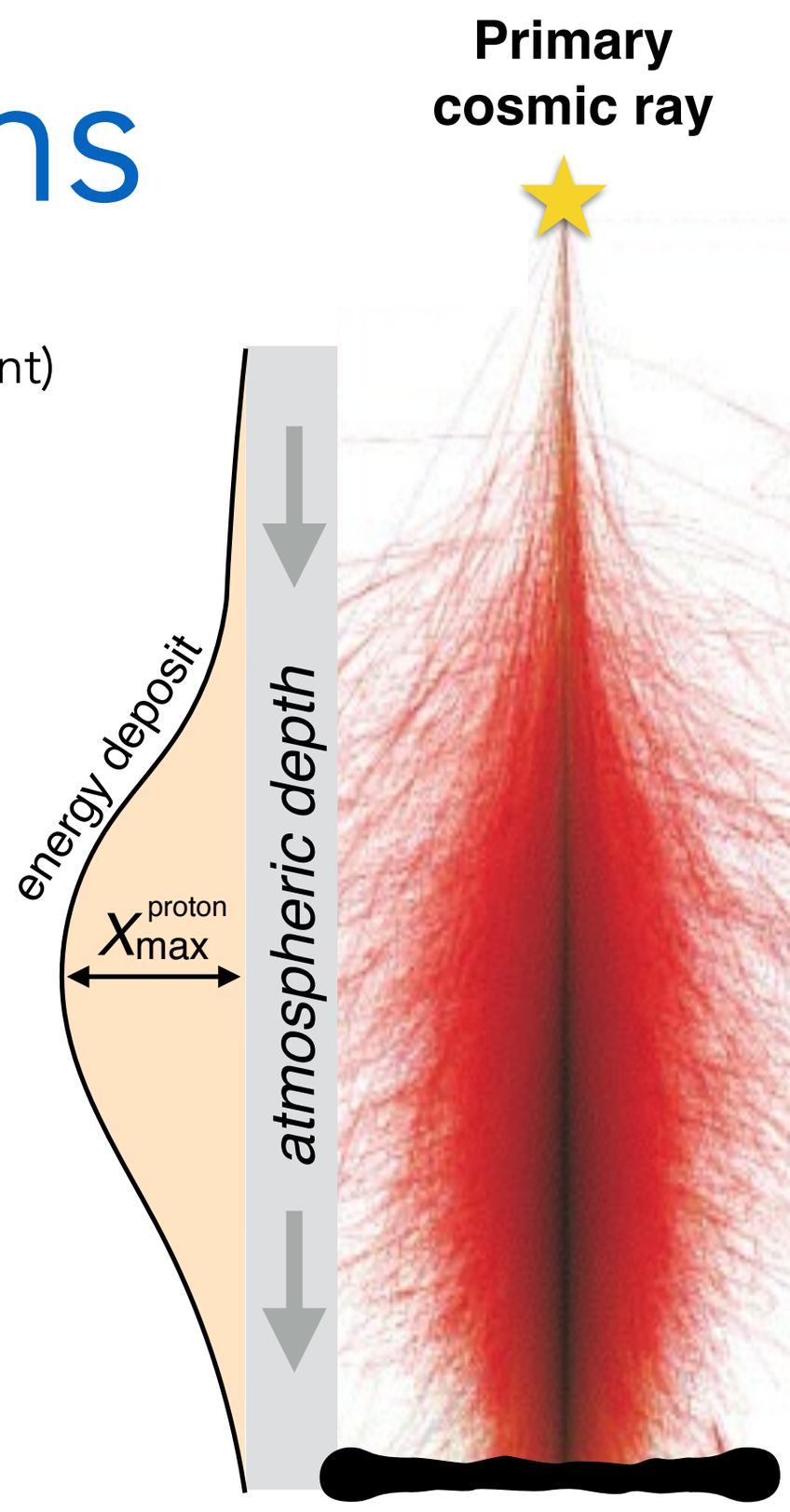
UHE Photons

- UHE photons distinguishable from hadronic showers
  (SD: Universality/shower radius of curvature/risetime/muon content)
- Loss length (1-100 EeV photons) up to ~30 Mpc
- AMON Science opportunity:

☑ Nearby AGN flares

☑ Nearby sources of UHECRs
(e.g. tidal disruptions, pulsars)

☑ Galactic sources/GC



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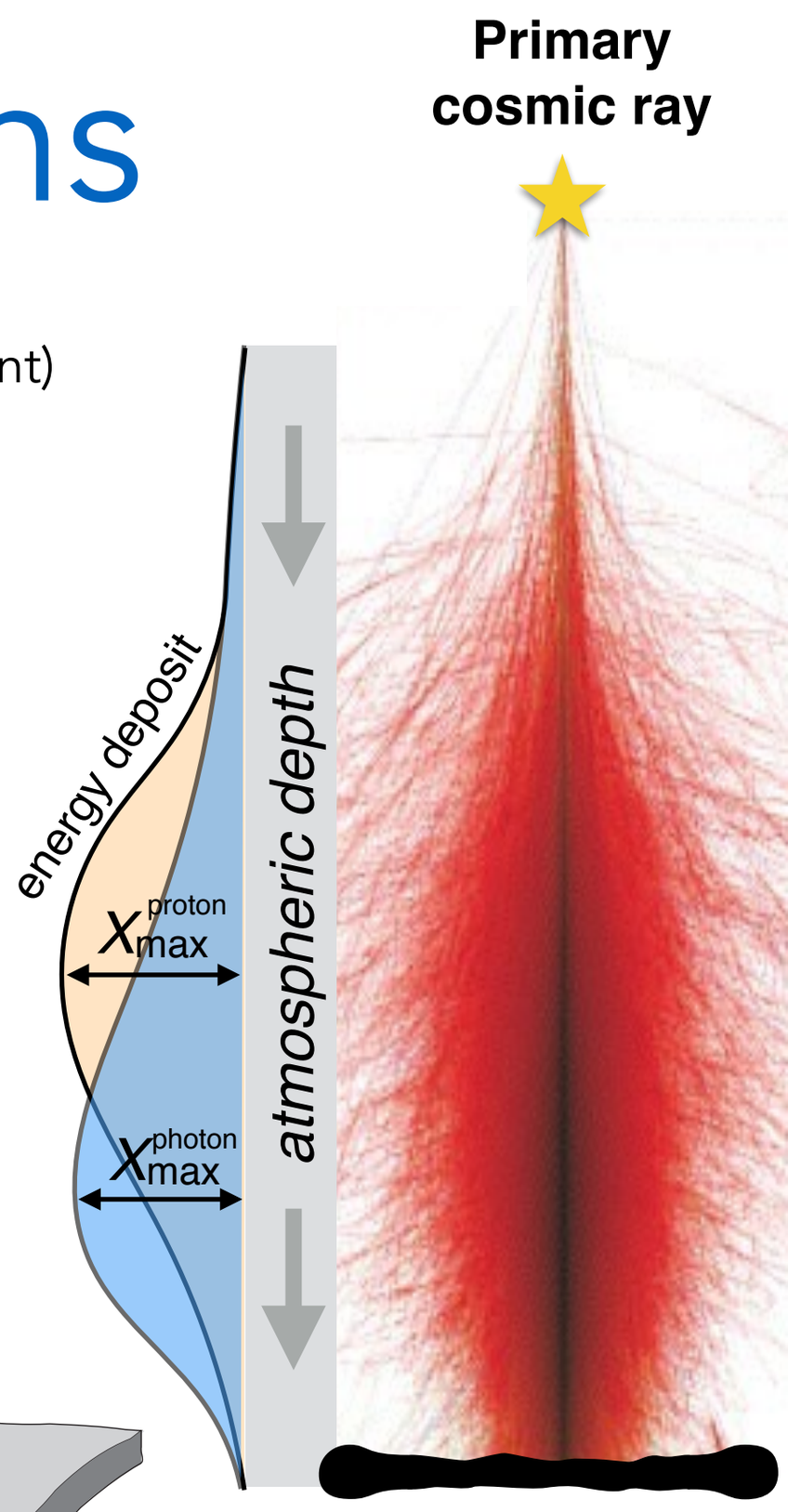
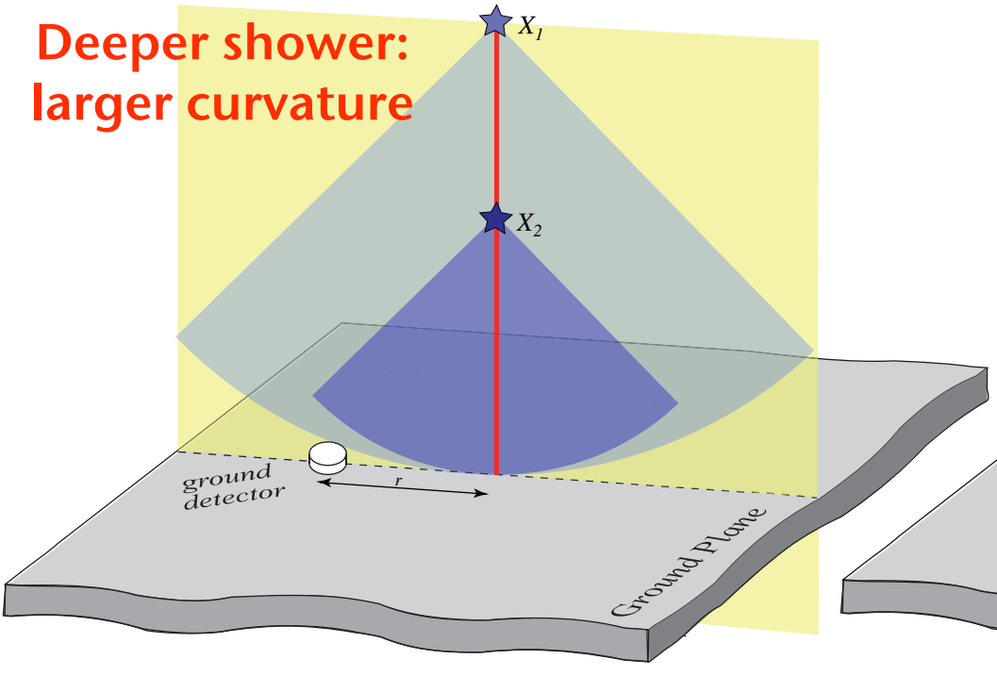
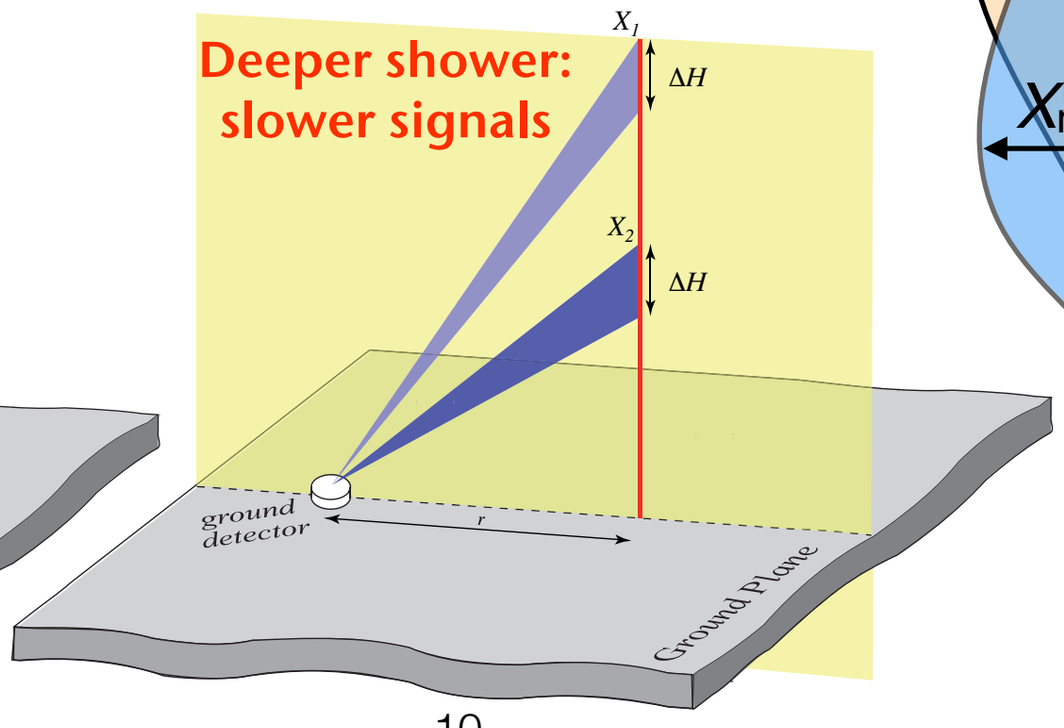


Deeper shower: larger curvature



Deeper shower: slower signals

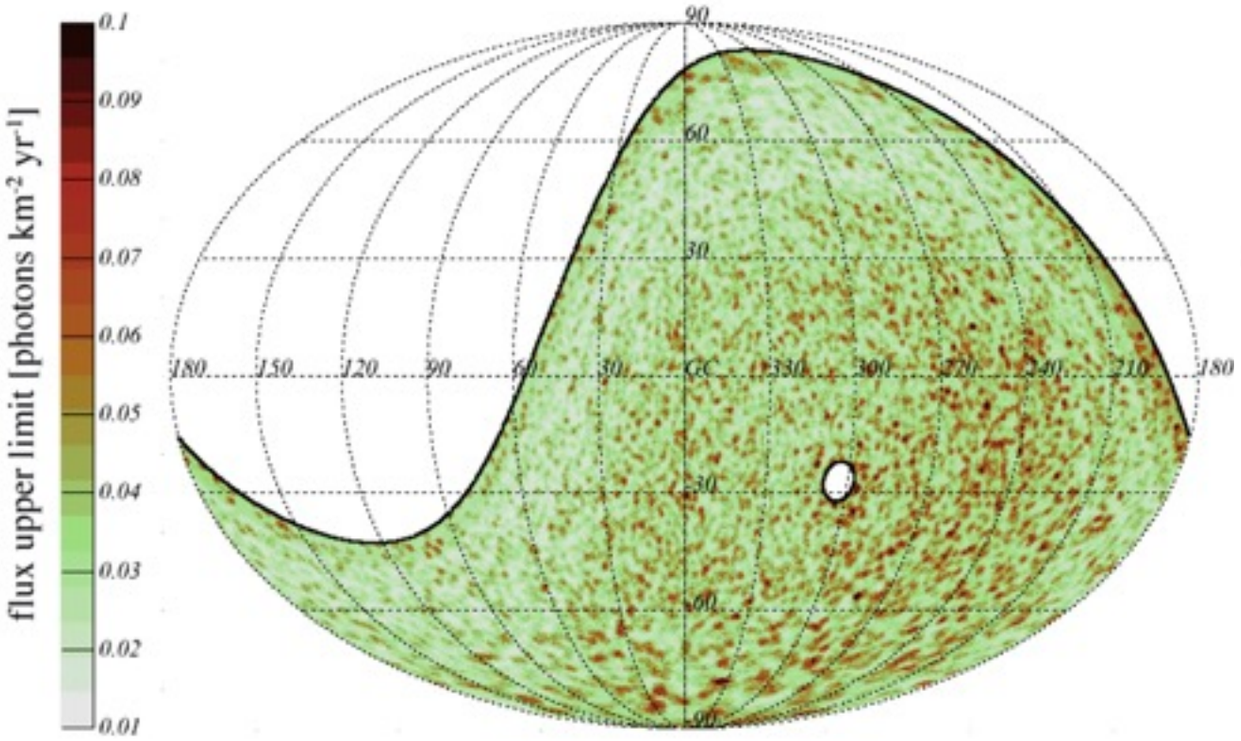


UHE Photon searches in Auger

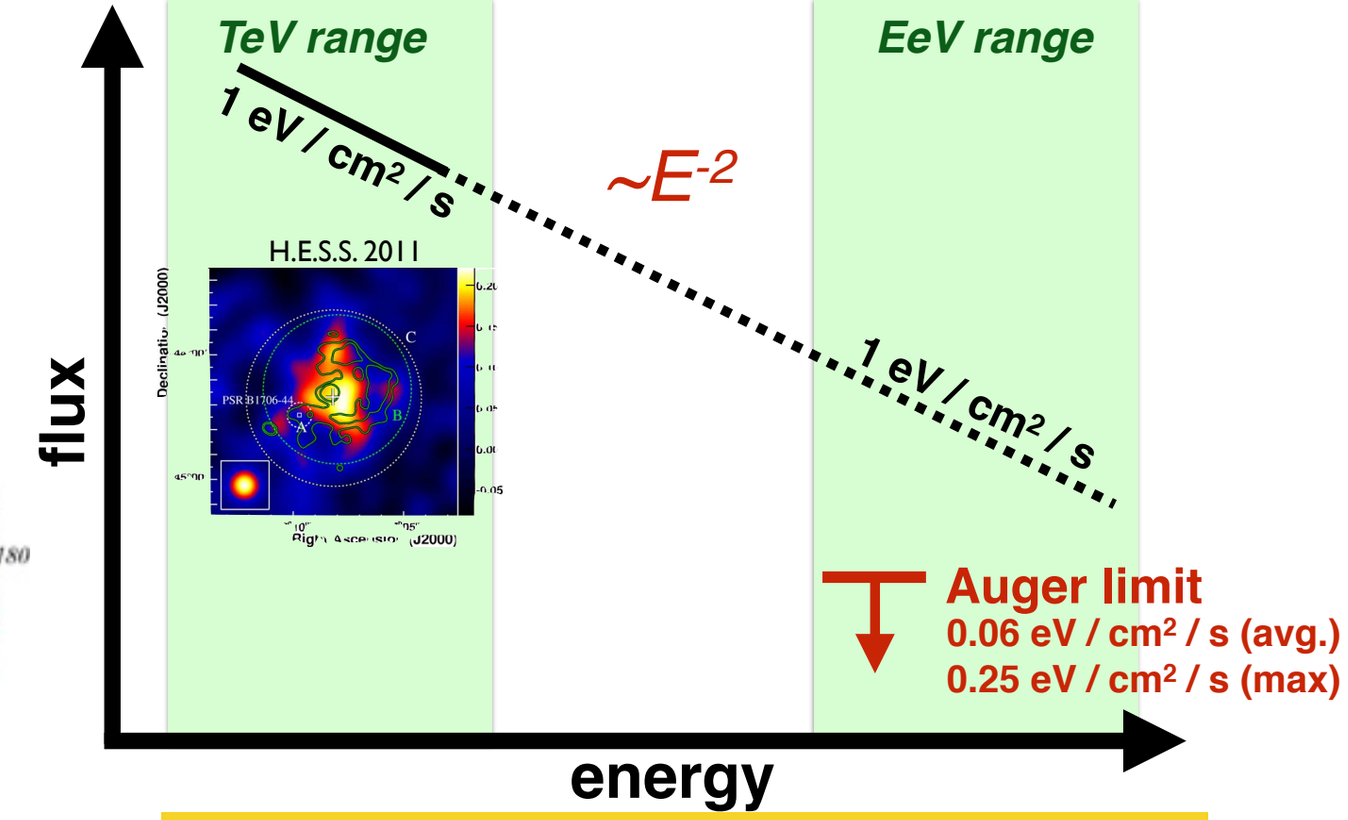
- Auger has placed strong limits on photon flux at > EeV energies
- Diffuse upper limits strongly constrain exotic models
- Directional searches for point sources with photon-like candidates have returned null results (strong limits on Galactic sources)

Flux upper limit of photon point sources in EeV range

Auger coll. ApJ, 789 (2014) 160



Exclude extrapolation of TeV sources



An energy flux of 1 eV / cm^2 / s would have been detected with > 5 sigma

Photon trigger stream

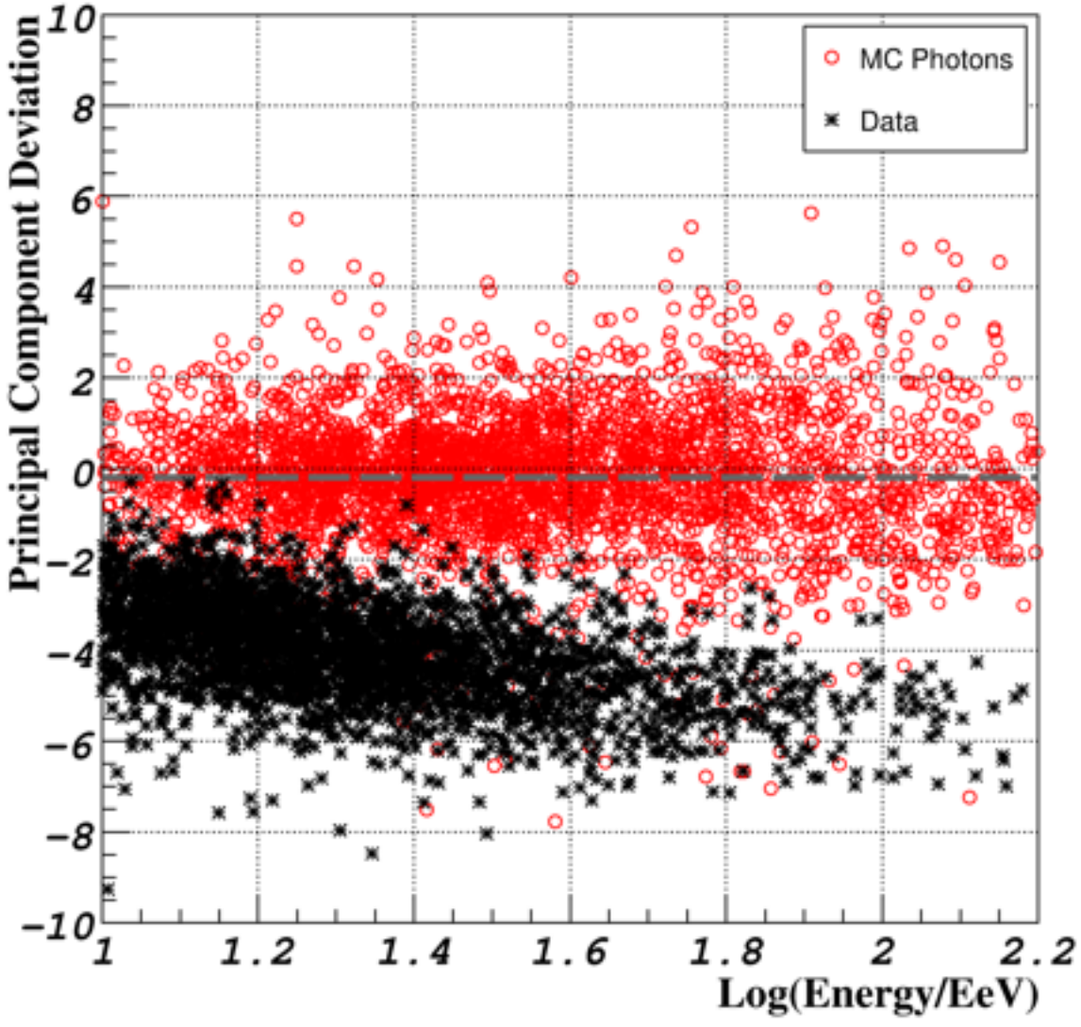
- Real-time "tagging" of photon like showers under development at Penn State

- Use SD for high statistics

- Lower E threshold than neutrons (use infill) → increase statistics!

- AMON alerts with "photon"-like showers with relaxed threshold compared to standard Auger searches

Auger coll. Astropart. Phys. 29 (2008) 243–256



Auger upgrade

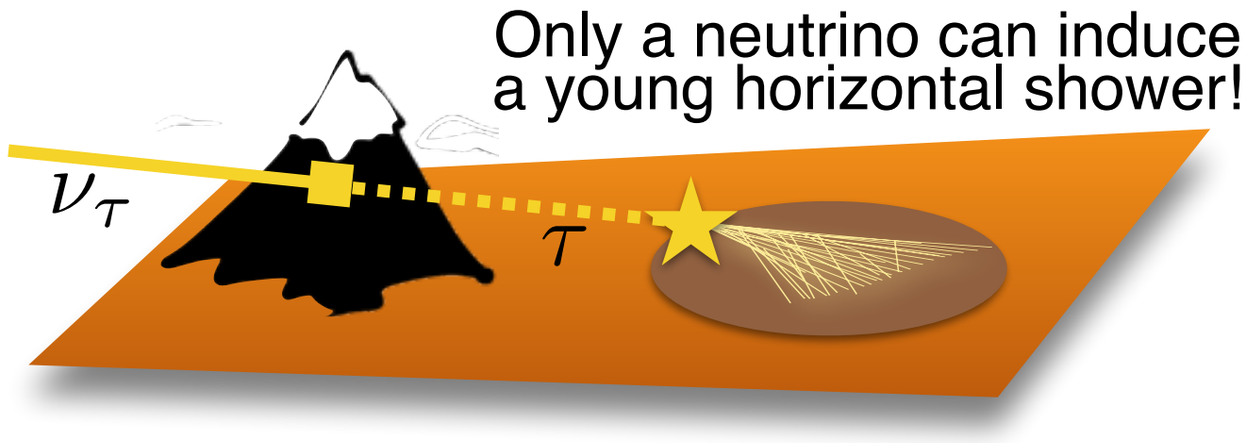
Scintillator on top
(ASCII)

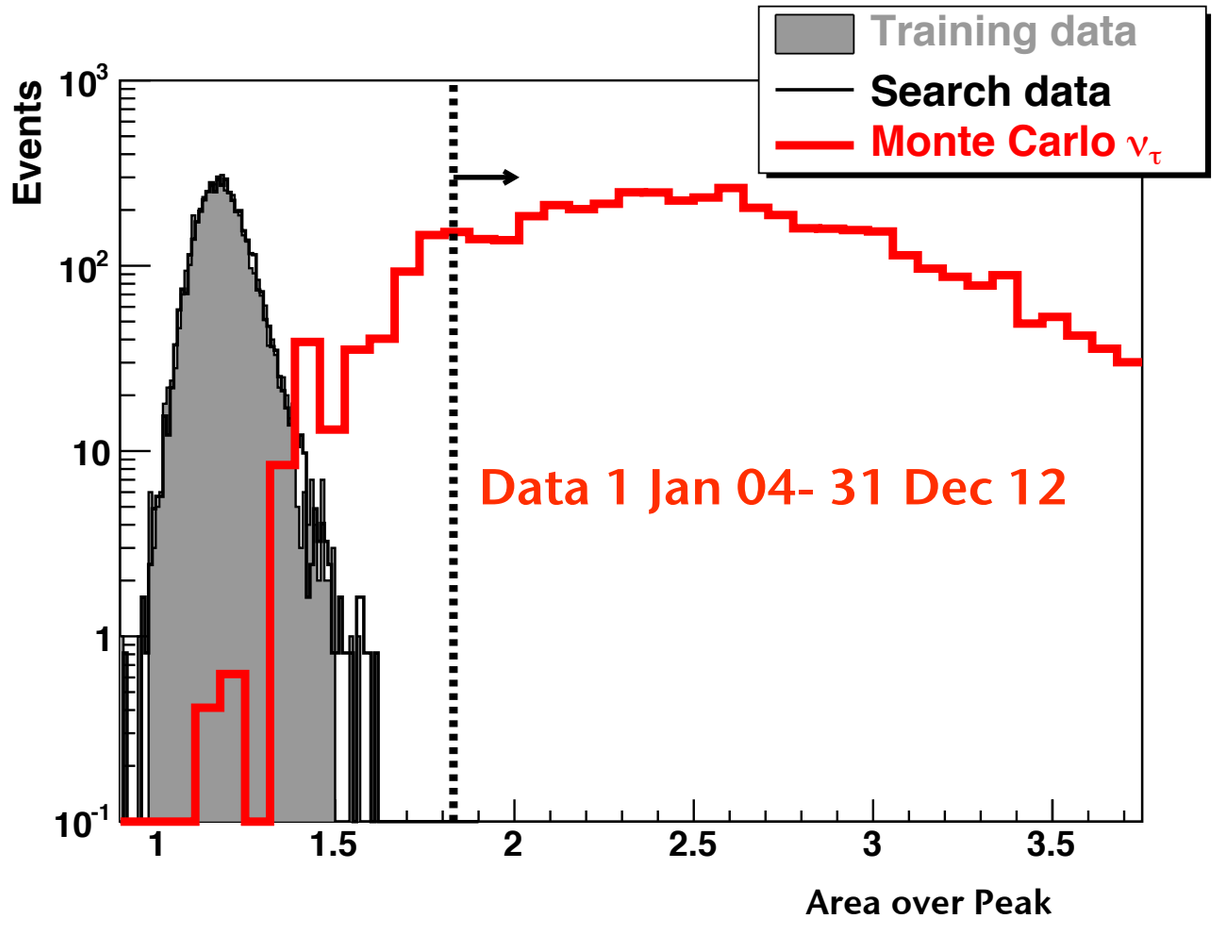
+ Improved new electronics upgrade to facilitate readout

Expect boost in photon / hadron separation

UHE Neutrinos

- Auger SD sensitive to cosmogenic neutrino showers (peak sensitivity ~ 1 EeV)
- Auger first observatory to place limit below Waxman-Bahcall bound
- Neutrinos easy to identify (search exposure limited)
- Real-time neutrino candidate analysis can be incorporated in AMON alert stream ⟶triggering/follow-up





Current Status

☑ Real-time sub-threshold photon shower analysis under development

☑ Scrambled test stream with AMON established

☐ Next priorities:

☐ Real-time stream from Argentina

☐ Real-time neutrino candidate triggering+follow-up

Summary

- Auger unique among current AMON members: Transient discovery = discovery of UHECR source!

- Test alert stream established, working towards real-time alert stream

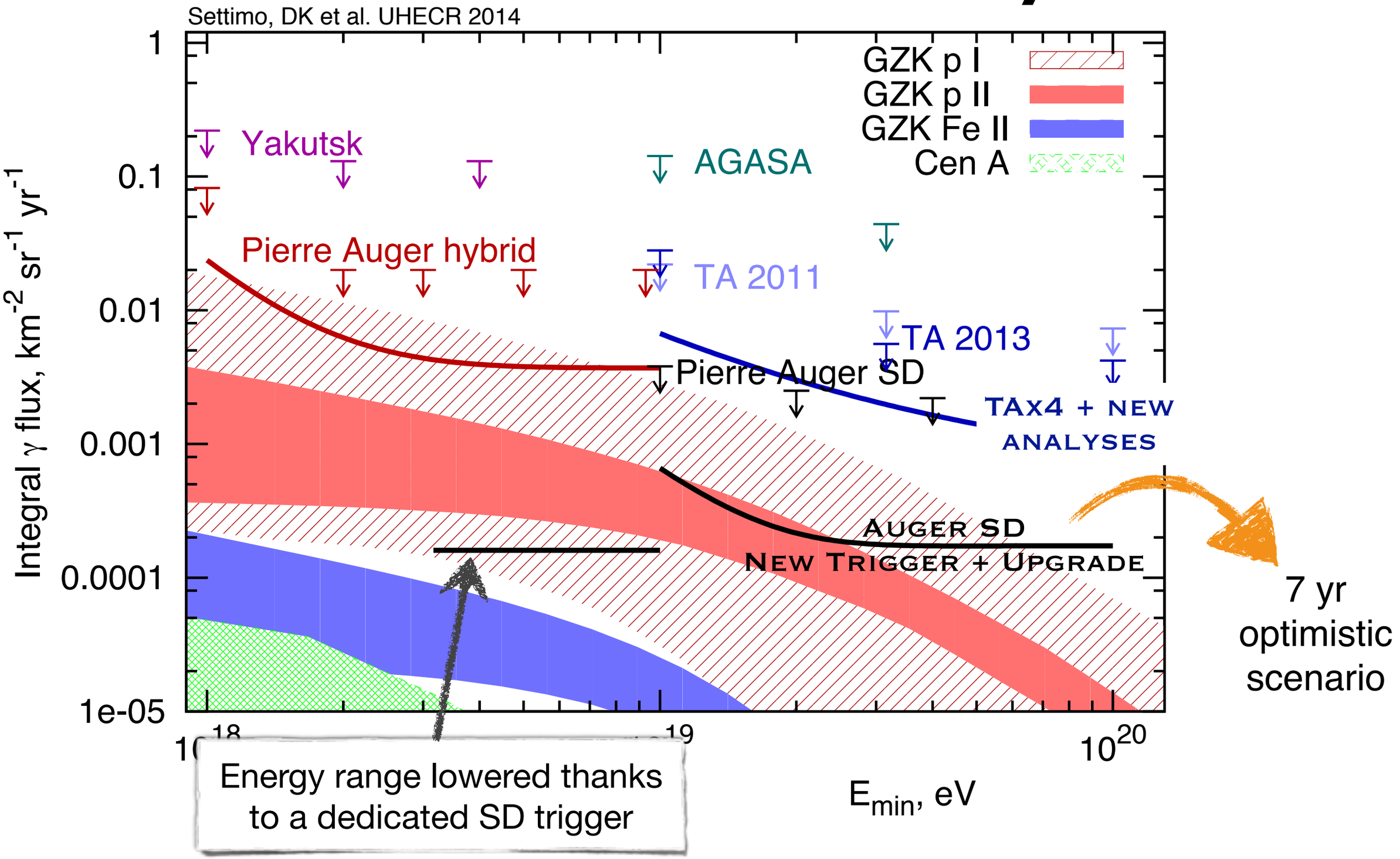
- Auger ready to provide Galactic neutron alerts

- Photon alert pipeline under development

- Next step: cosmogenic neutrino candidate alerts

Backup

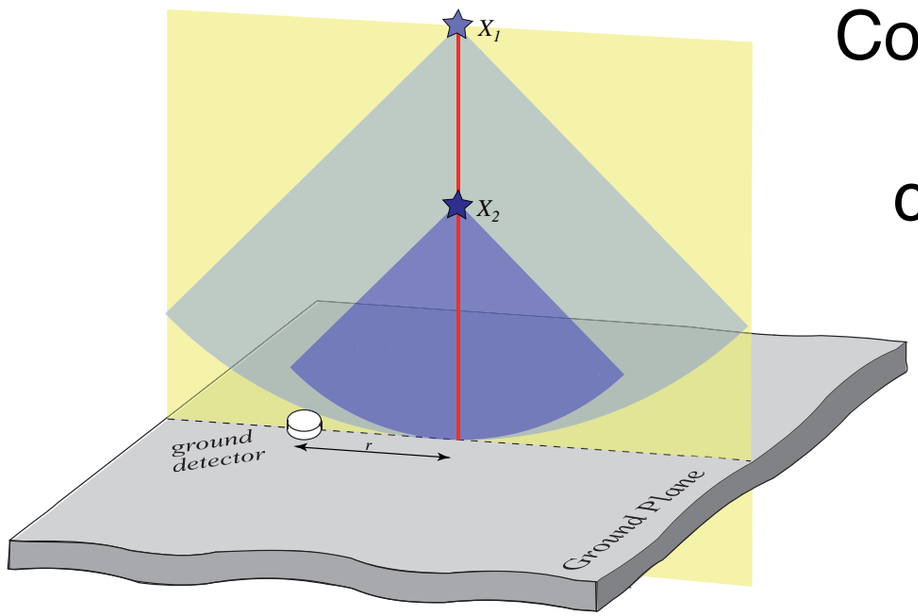
Photon sensitivity



▶ Optimistic **GZK-predictions in reach**

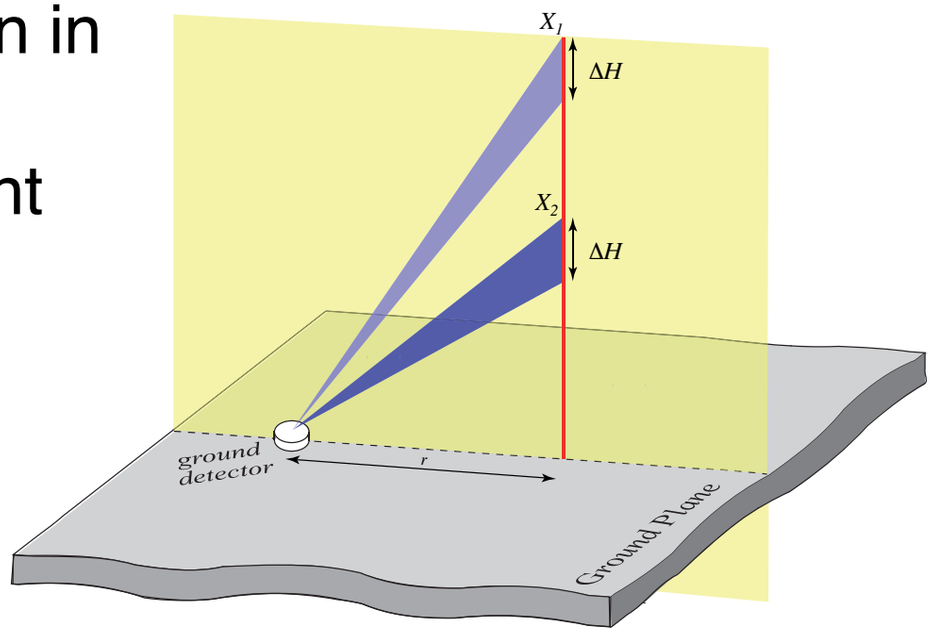
Diffuse photon search

Radius of curvature

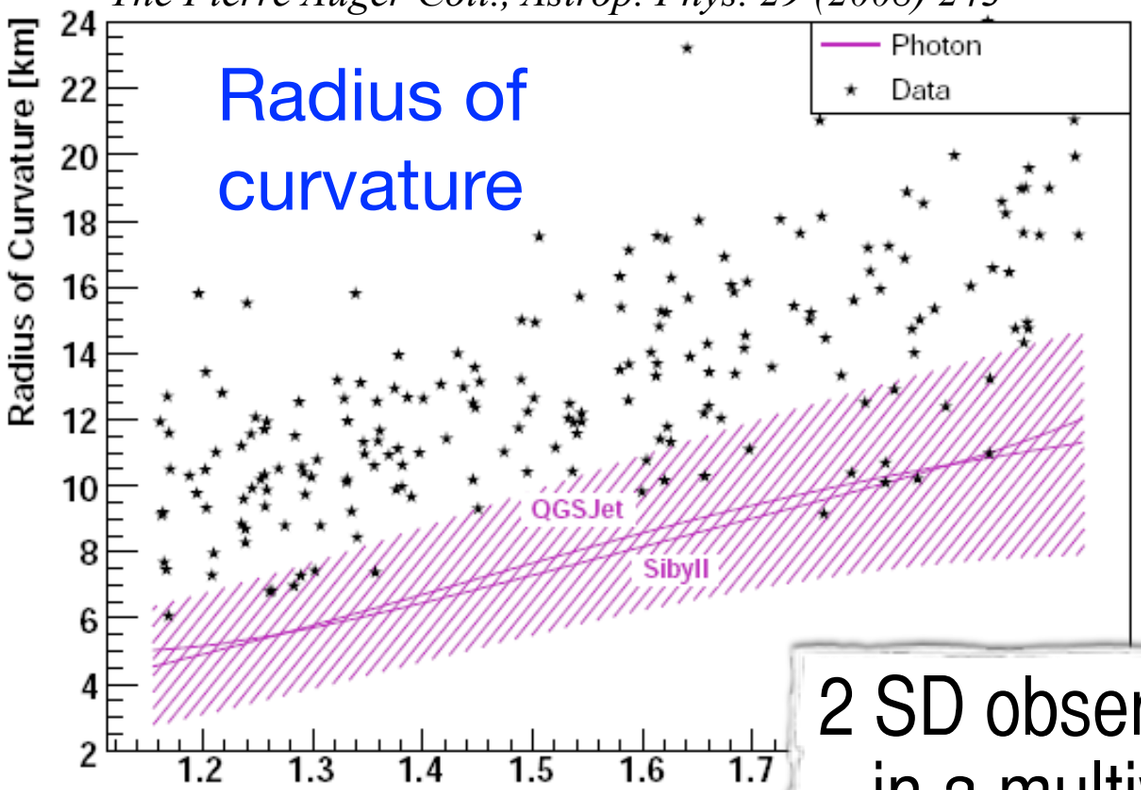


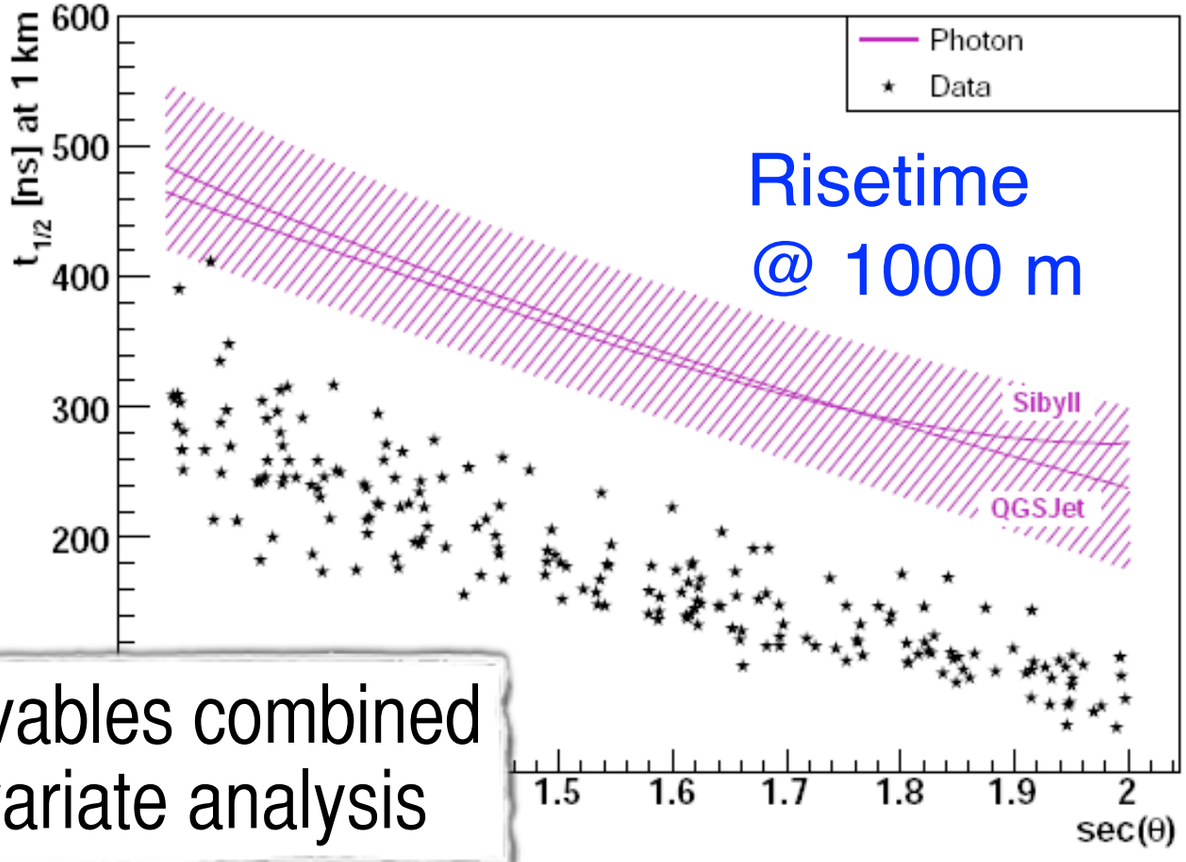
Combination in principal component analysis

Risetime



The Pierre Auger Coll., Astrop. Phys. 29 (2008) 243





2 SD observables combined in a multivariate analysis