NEUTEL 2013

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Pierre Auger Observatory

studying the universe's highest energy particles

Updated Results on Neutrinos with the Pierre Auger Observatory

Viviana Scherini* for the Pierre Auger Collaboration

*** Università del Salento and INFN Lecce, Italy**

Outline

- search for UHE neutrinos: motivations
- the Pierre Auger Observatory
- search for neutrinos in Extensive Atmospheric Showers:

  detection channels
  data selection
  exposure

- upper limits on neutrino fluxes
- directional limits

Motivations

The most extreme window for astronomy can be opened based on multi-messenger observation:
charged Cosmic Rays, γ, and in particular ν

UHE neutrinos can be produced

at the sources (astrophysical ν)
during propagation (cosmogenic ν)

Neutrinos are excellent messengers:

- point back to the sites of production
- not absorbed so they can probe cosmological distances

→ acceleration of nuclear primaries in astrophysical objects
→ tracers of the propagation effects (GZK, photodisintegration)
thus sensitive to primary CR composition at the highest energies
→ can test alternative models for the origin of UHECR

The Pierre Auger Observatory

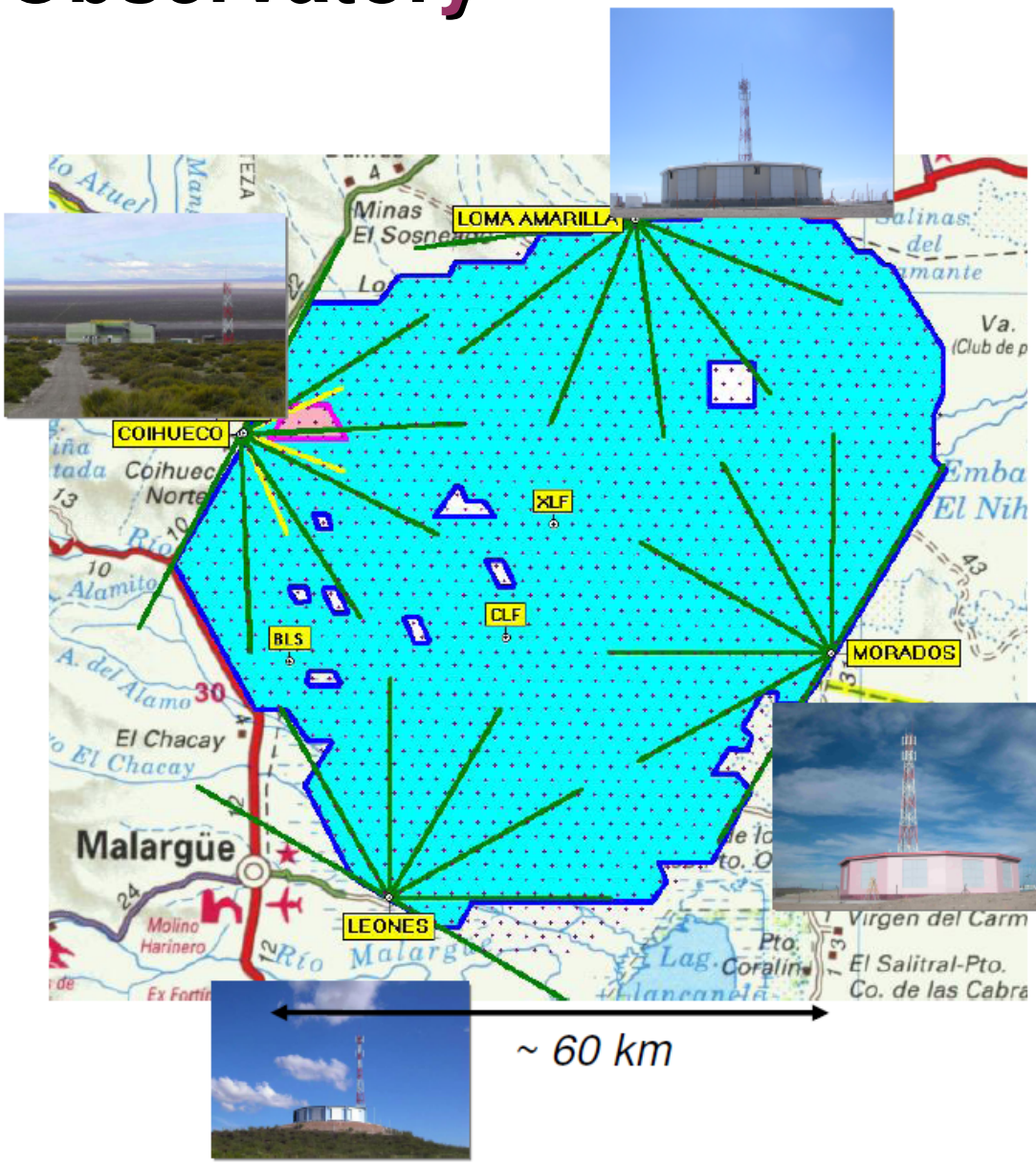
- **Surface detector**

an array of 1660 Cherenkov stations on a 1.5 km triangular grid (~ 3000 km^2)
particle lateral distribution
100% duty cycle

- **Fluorescence detector**

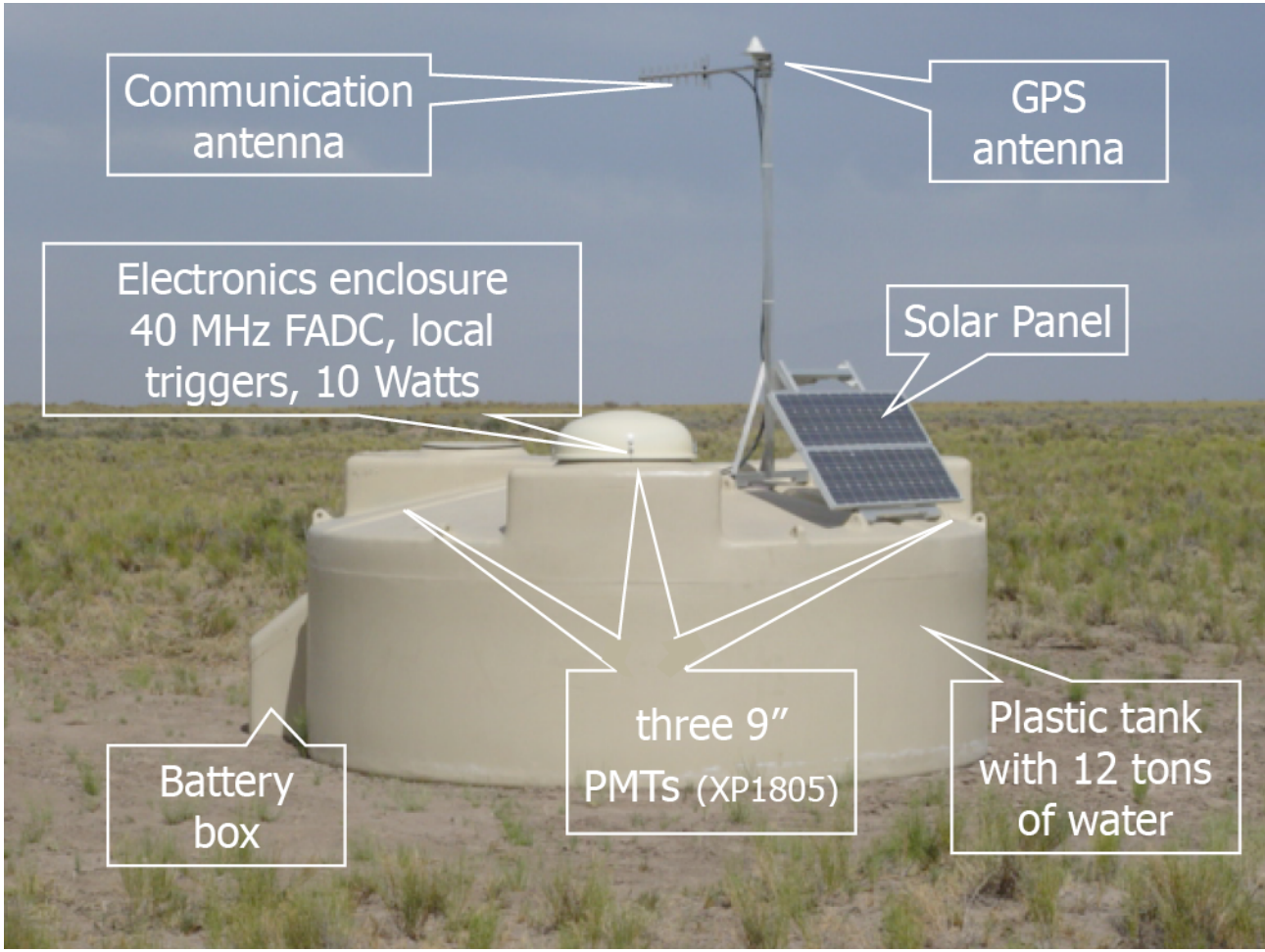
4+1 buildings overlooking the array (24+3 telescopes)
calorimetric energy measurement
15% duty cycle

Low energy extensions
AMIGA: dense array plus muon detectors
HEAT: three further high elevation FD telescopes



The surface detector

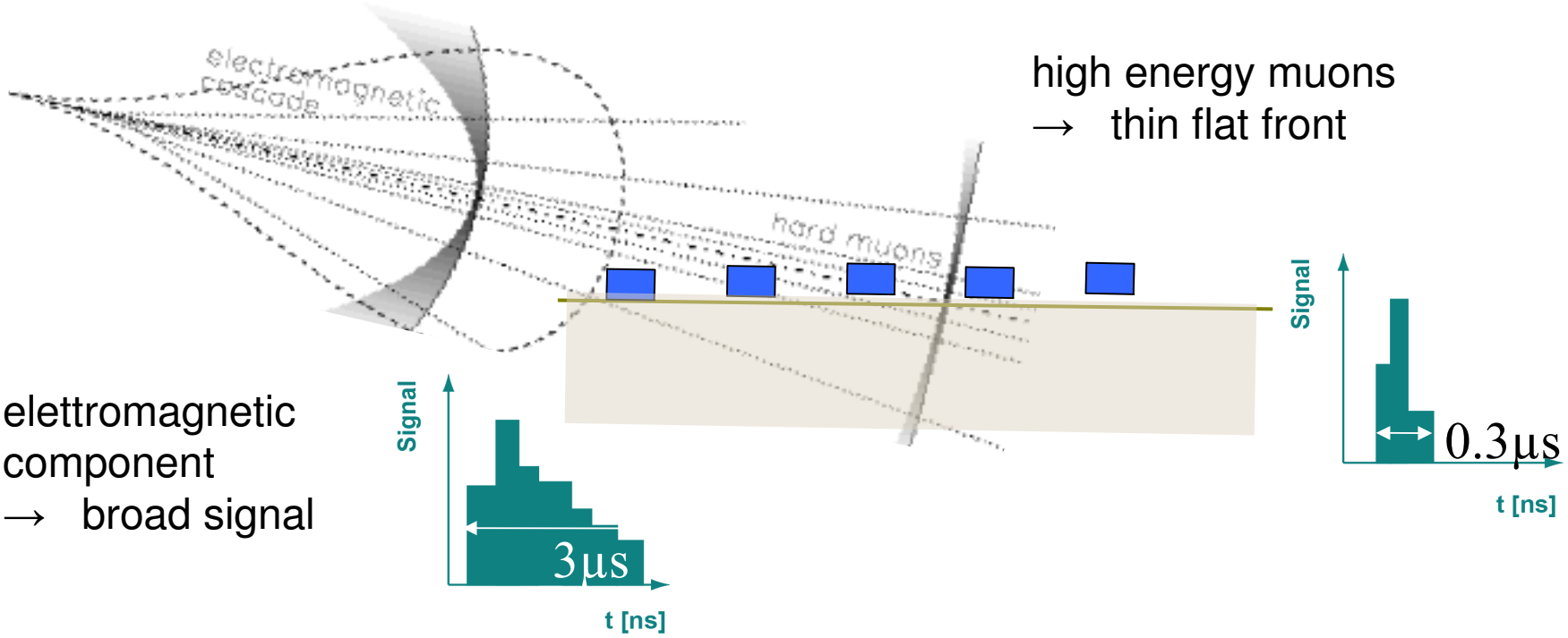
- Plastic Tank
- Ultra-reflective tyvek liner
- 12 m^3 purified water
- 3 PMTs (9 inches)
- Independent power supply (solar panels)
- GPS antenna
- Communication antenna



DAQ : 40 MHz FADC sampling (10 bit resolution)

Detection of UHE neutrinos with EAS

neutrino signature:
young shower i.e. with large electromagnetic component
→ inclined event with slow rising and broad signal



UHE neutrinos detectable as almost horizontal young showers

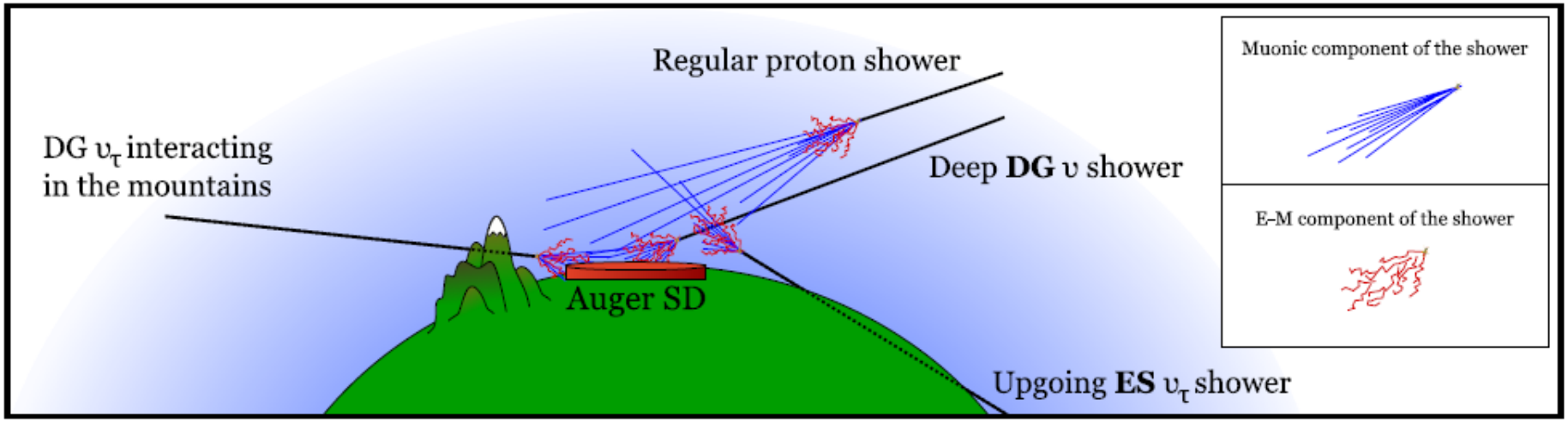
Neutrino detection channels @ Auger

Earth-skimming (ES):
upward going tau neutrinos
CC
zenith angle 90° ÷ 95°

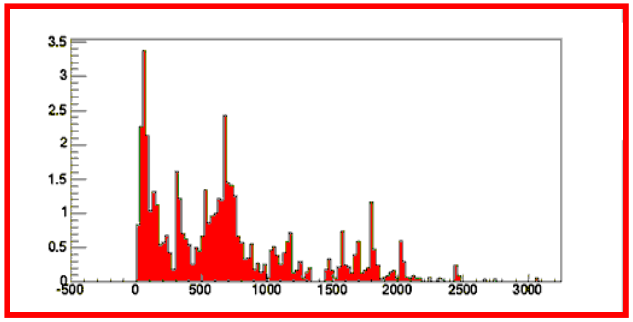
τ can emerge from the Earth crust and decay close to the detector

Downward Going (DG):
deeply interacting ν all flavours
CC & NC
zenith angle 75° ÷ 90°

Sensitivity to ALL ν flavours and ALL interaction channels



Identification of neutrino candidates



"Slow & broad signal"

select the inclined events with significant electromagnetic component:

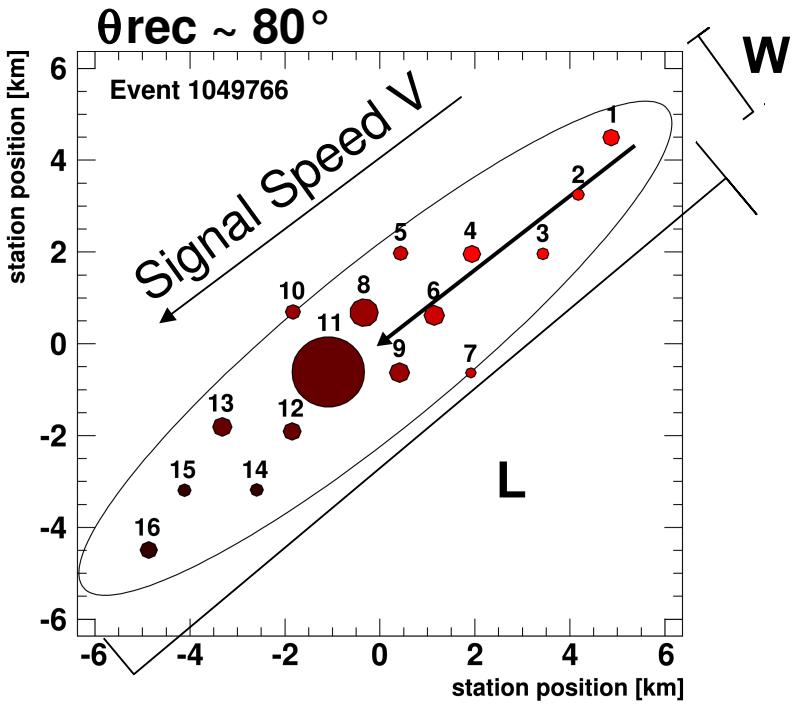
min 60% stations with **local ToT trigger**

ToT= time bins over threshold

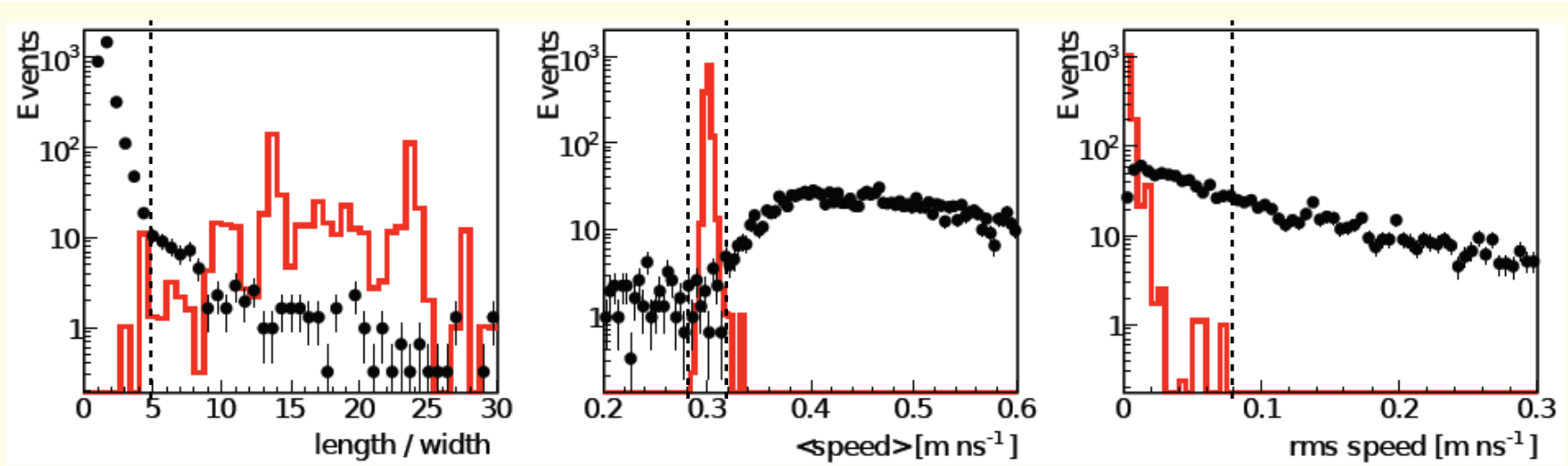
Quality cuts for ν identification:

- Shape (Elongated Footprint): large L/W
  ES: L/W >5
- speed along footprint close to speed of light:
  ES: 0.29 m ns-1 ÷ 0.31 m ns-1
- small RMS[*speed*]:
  ES: 0.08 m ns-1

→ similar selection criteria for DG



Selection and MC expectations: ES



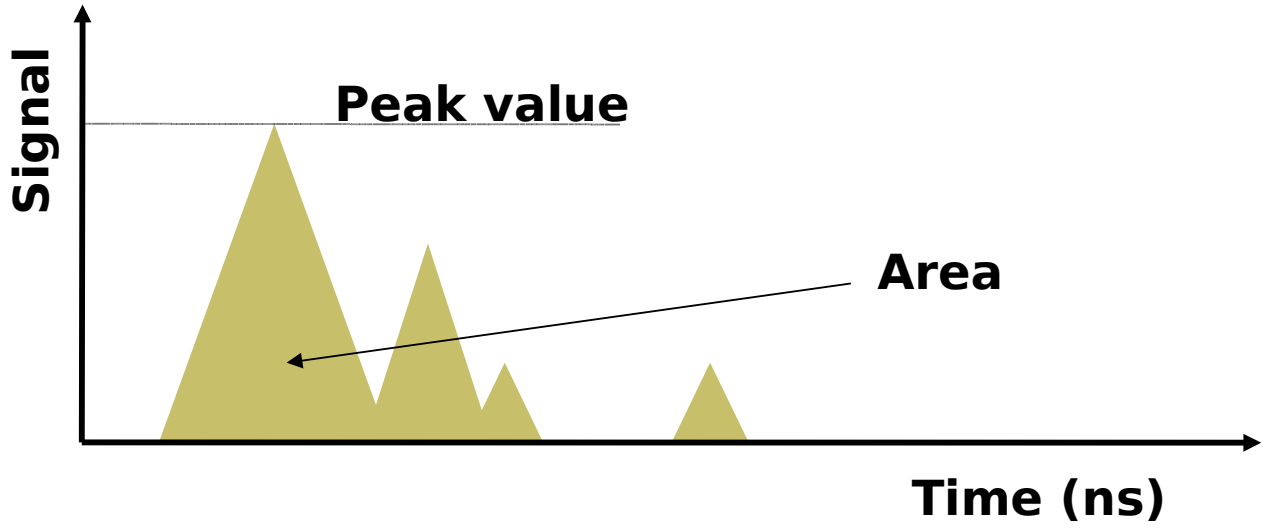
— MC inclined showers (E^{-2} ν_τ flux)

• training data (~ 1%)

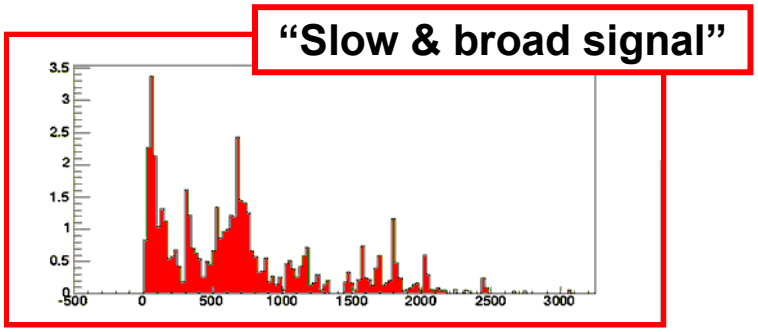
- - neutrino candidate cuts

Pierre Auger Coll., PRL 100 (2008) 211101; PRD 79 (2009) 102001

Further discriminating observables



AoP = Signal integral over Peak value



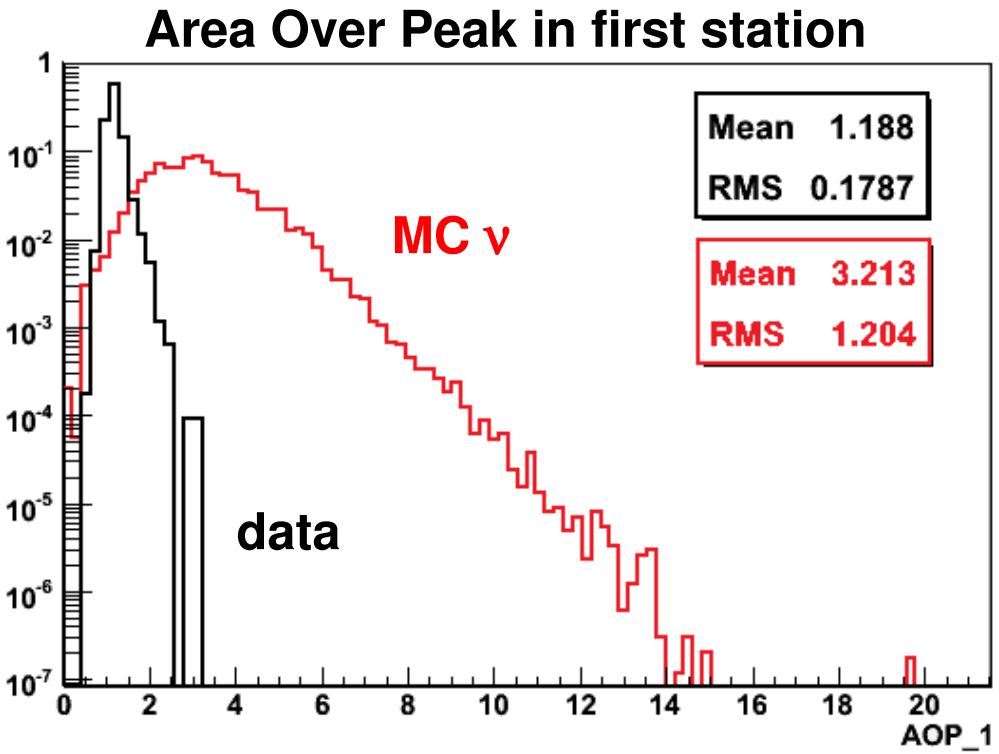
Large AoP (> 3)

Small AoP (~ 1)

Search for Down-Going candidates

analysis strategy

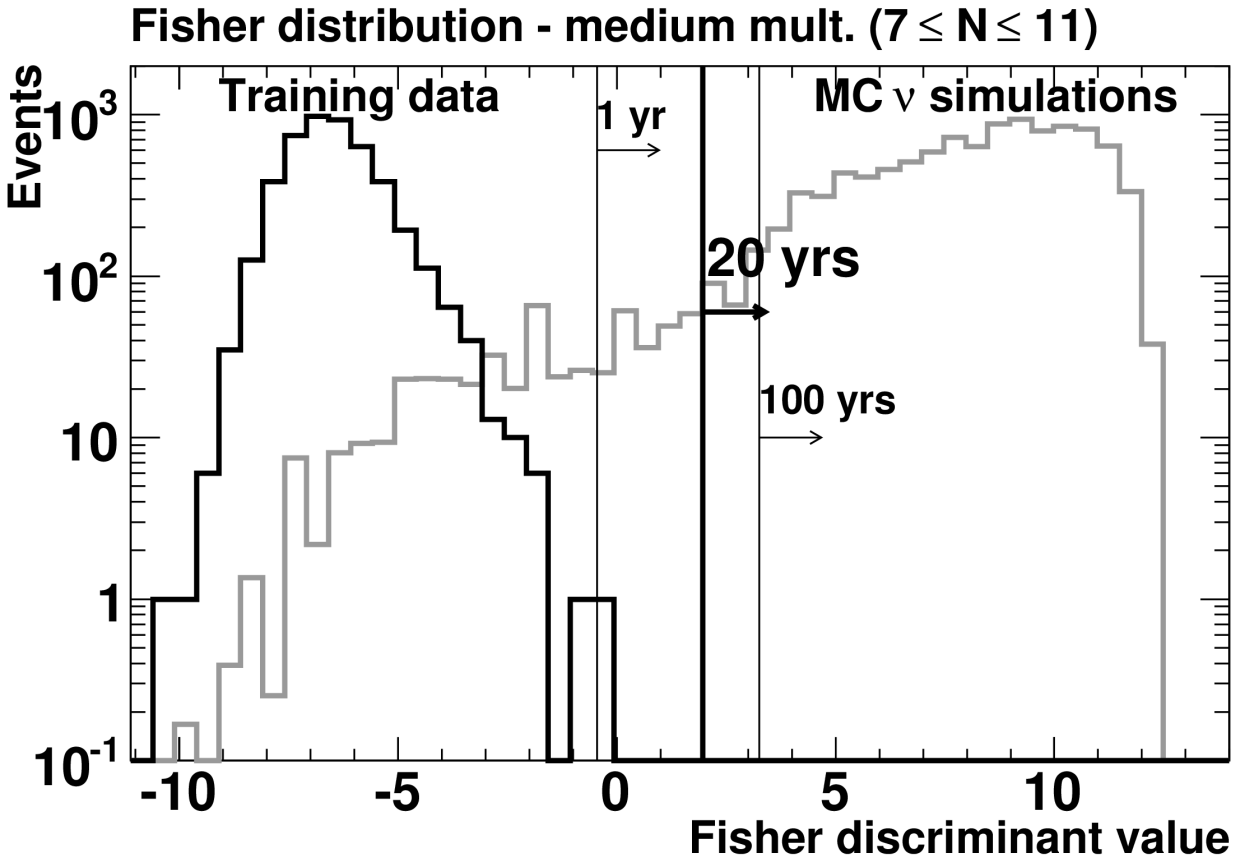
- training data set (1.4 yr)
- 10 variables
- Fisher linear discriminant
- disjoint data sets (based on station multiplicity)



Fisher variables:

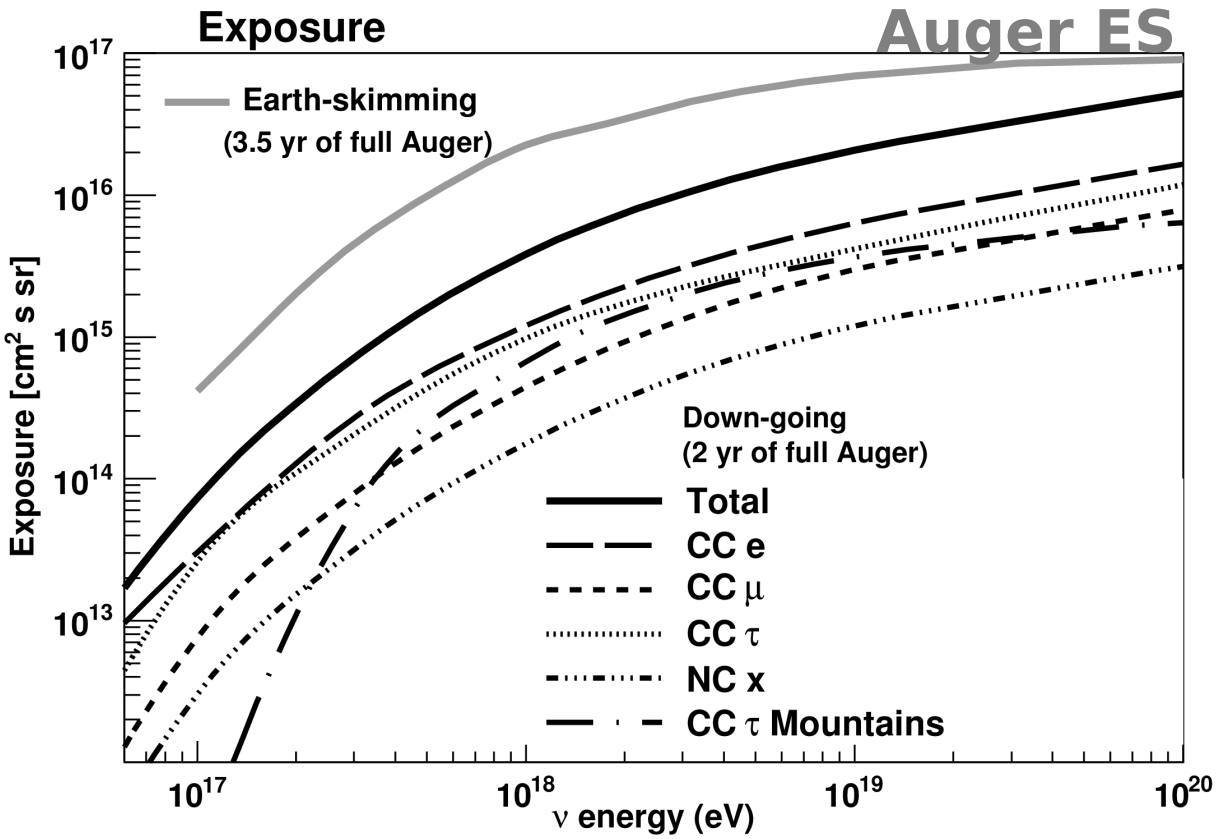
- First 4 AOPs
- First 4 $(AOPs)^2$
- Product of the first 4 AOPs
- An asymmetry parameter : Mean[*early AOP*] - Mean[*late AOP*]

Fisher discriminant analysis



→ set cut at <1 background event in 20 yr

Exposure to neutrinos for ES and DG



Pierre Auger Coll., HEP in press

→ larger ES exposure due to longer integration time and higher density target (Earth)

NO Candidates found

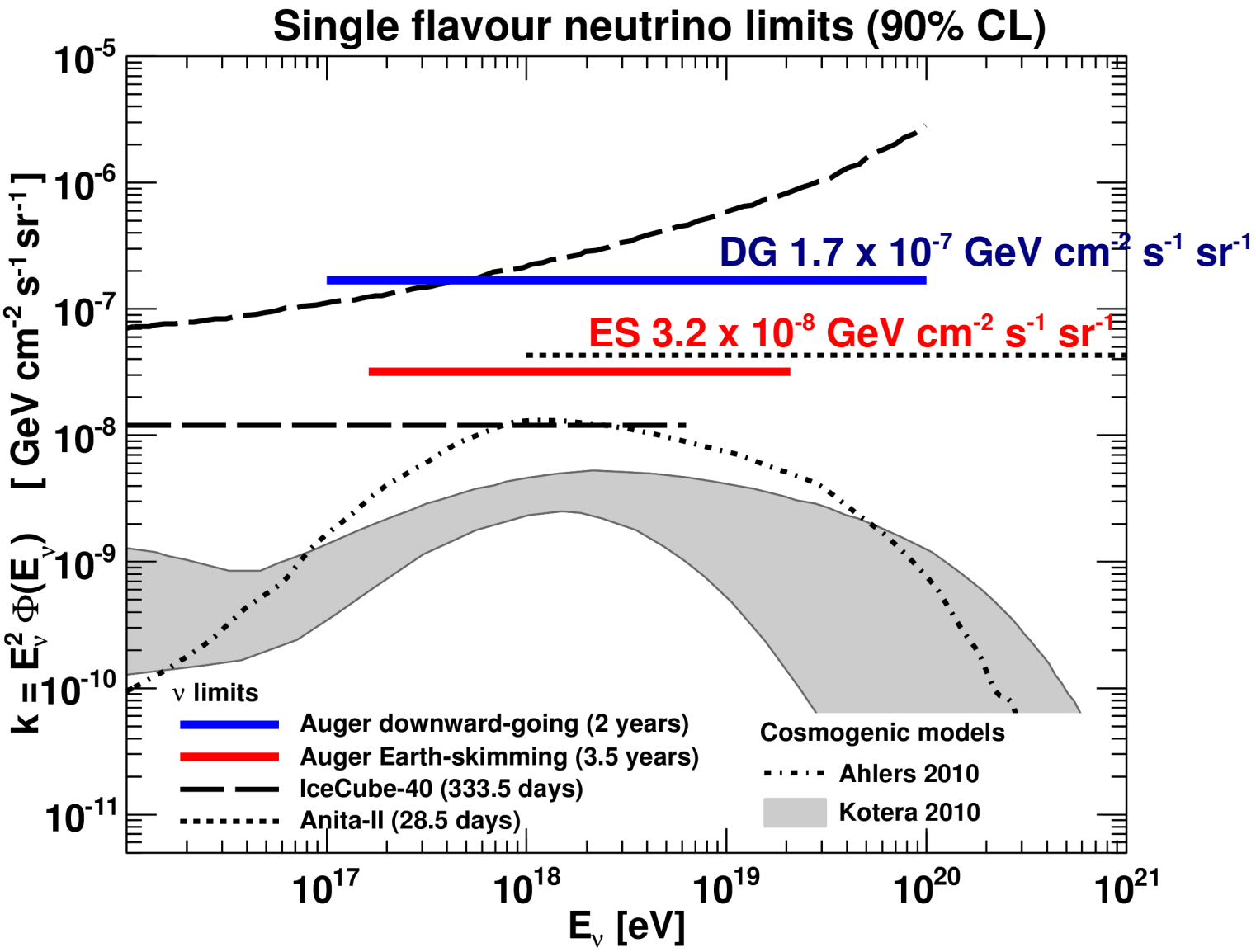
1 Jan 2004 - 31 May 2010 ~ 3.5 yr (ES)

Pierre Auger Coll., ApJ 755 L4 (2012)

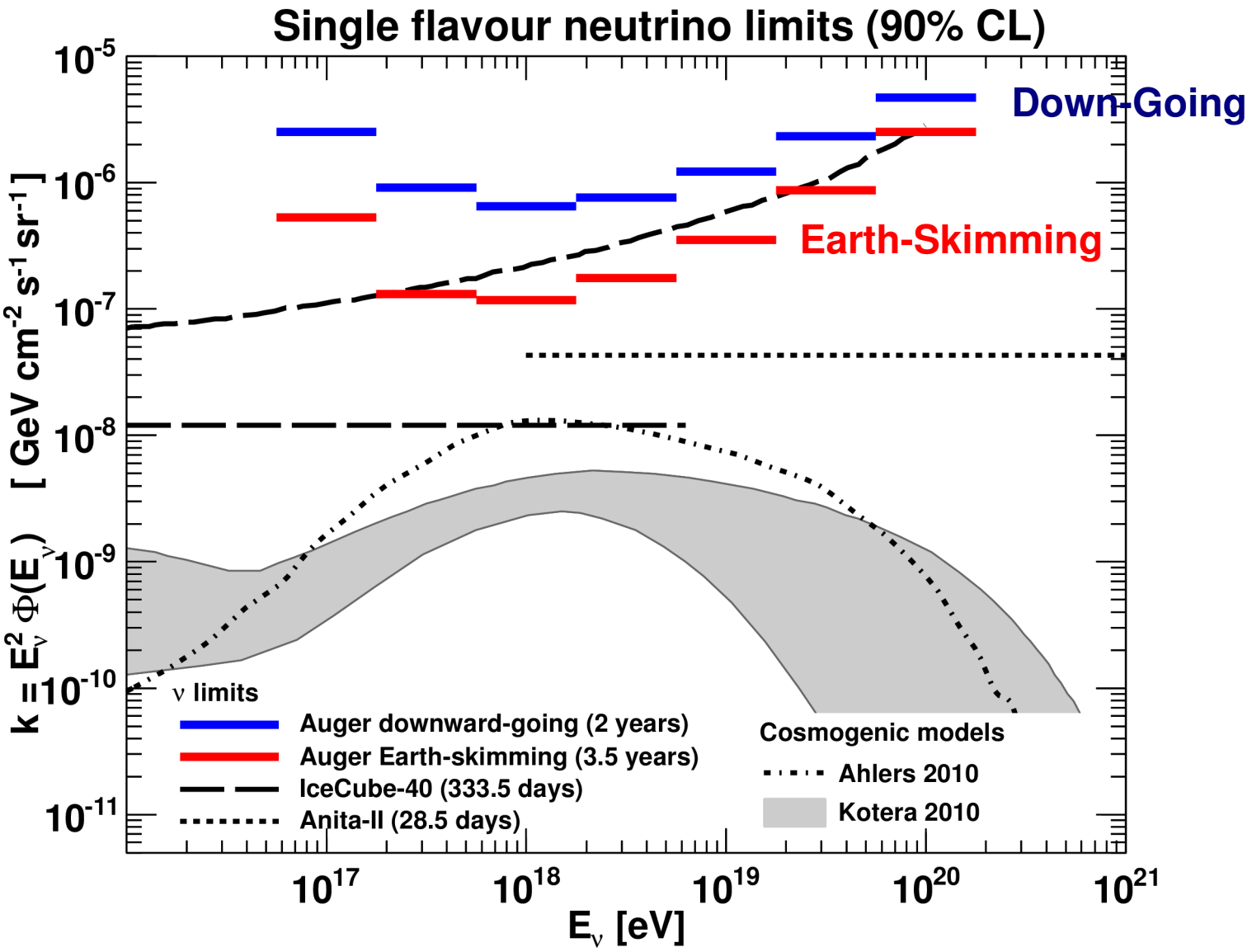
1 Nov 2007 - 31 May 2010 ~ 2 yr (DG)

Pierre Auger Coll., PRD 84 122005 (2011)

Updated limits: integral plot



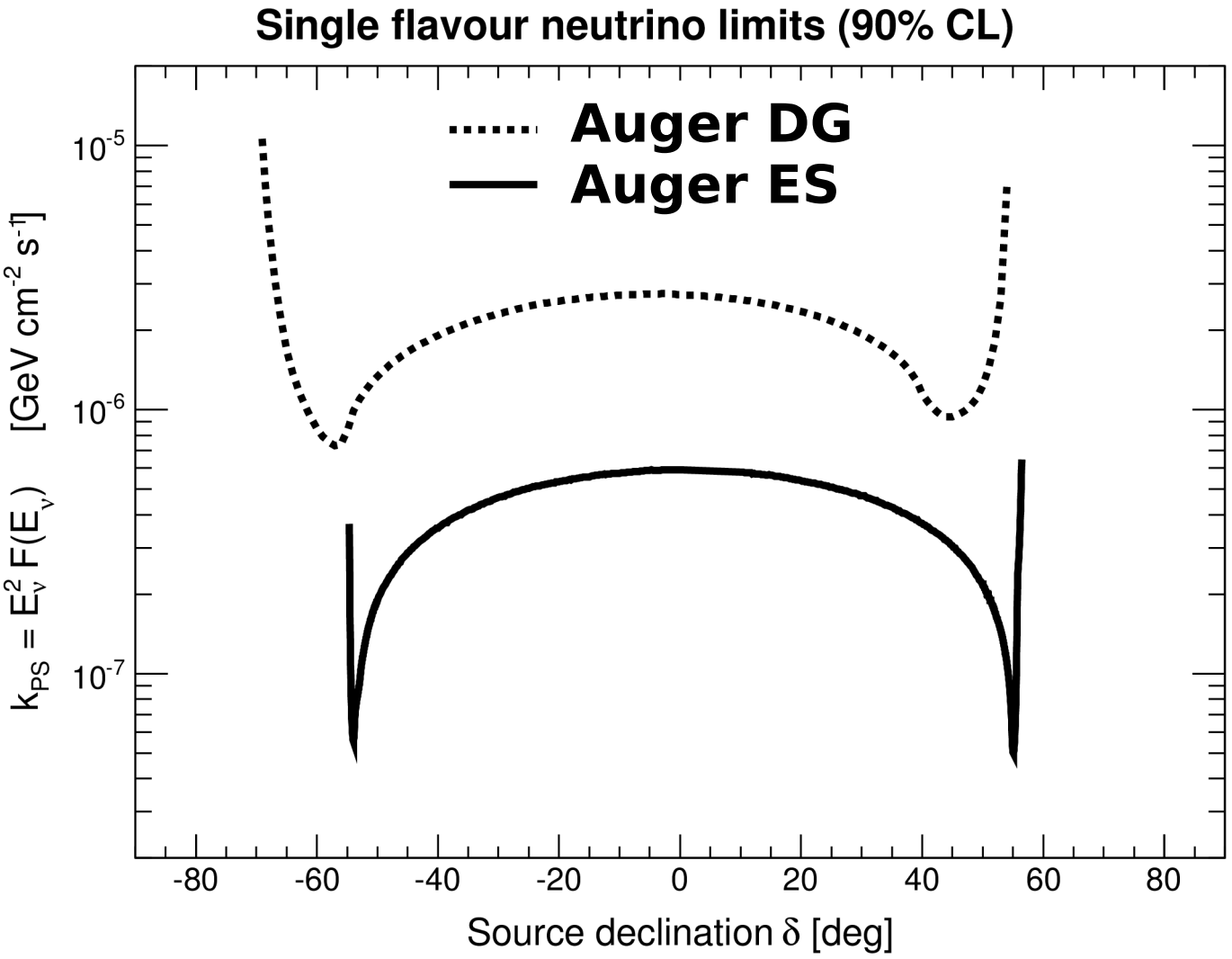
Updated limits: differential plot



Systematic uncertainties

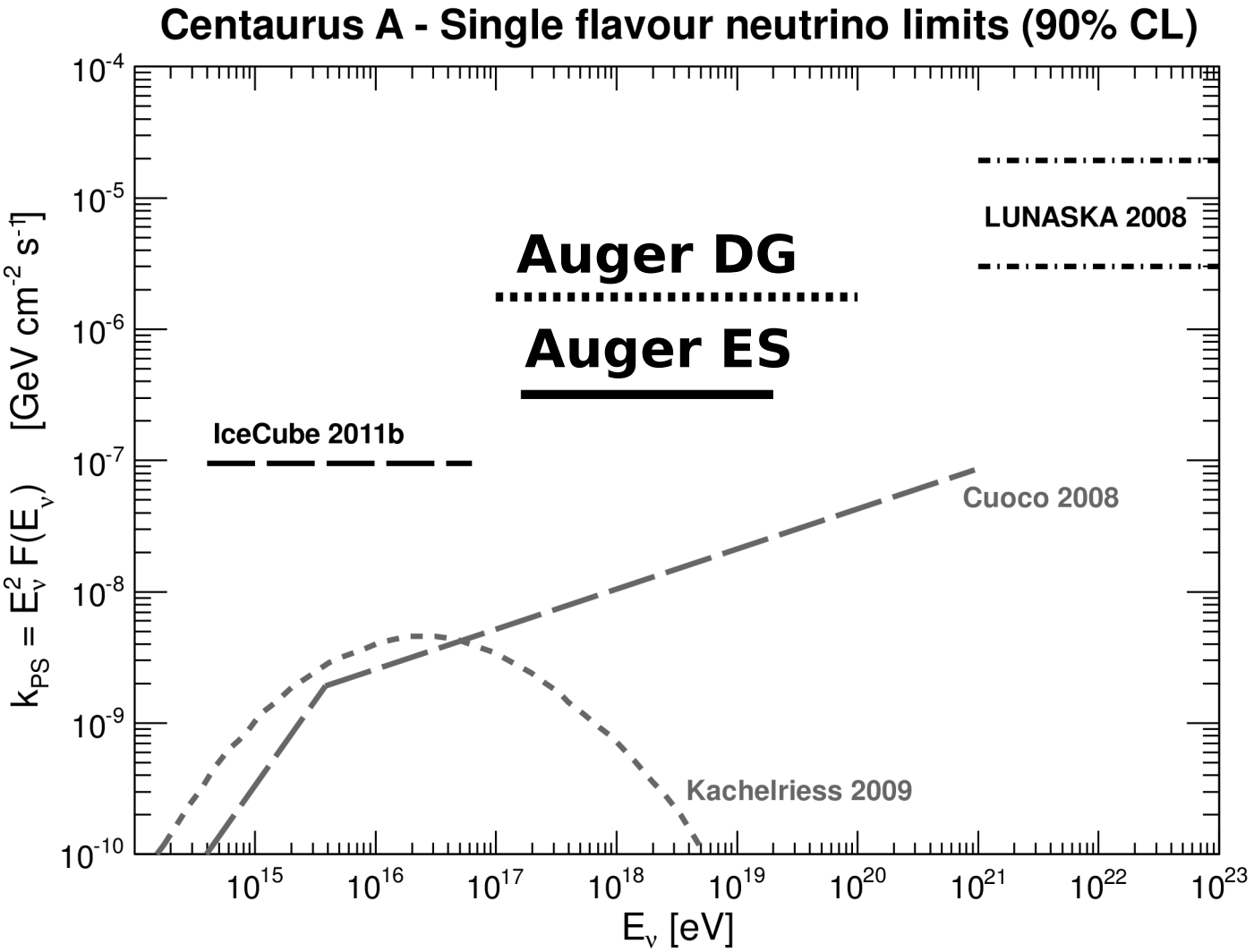
	Auger ES most/least fav. scenarios	Auger DG maximum deviation
Monte Carlo ν simulations	+20% -5%	+9% -33%
ν-nucleon cross section	+7% -7%	+7% -7%
τ energy loss	-10% + 25%	+6% -6%
topography	+18%	–
Pierre Auger Coll.,	**PRD79 (2009)102001**	**PRD84 (2011)122005**

Directional limits



Pierre Auger Coll., ApJ Lett 755 L4 (2012)

Candidate sources: Centaurus A



Pierre Auger Coll., ApJ Lett 755 L4 (2012)

Conclusions

The Pierre Auger Observatory is sensitive to **UHE neutrinos** in two different channels: **Earth-skimming** tau ν & **Down-going** ν

No ν candidates found so far in the Auger data set
→ limit on **diffuse flux** competitive at and above the EeV region

Cosmogenic ν flux predictions (protons) in reach
indirect hint on primary CR mass composition

Search for point-like sources of UHE neutrinos over a broad declination range (-65° ÷ +55°) and between 10^{17} and 10^{20} eV
→ current best limits for CenA in the EeV region

PLANNED: extension of DG zenith angle range 60° ÷ 90°
Combination of limits and unblinding of new data (until 2012)