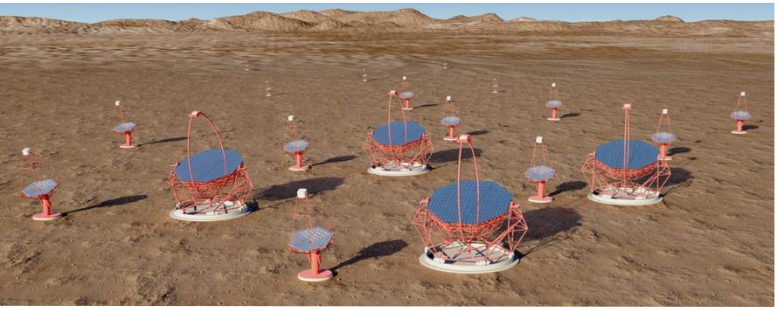
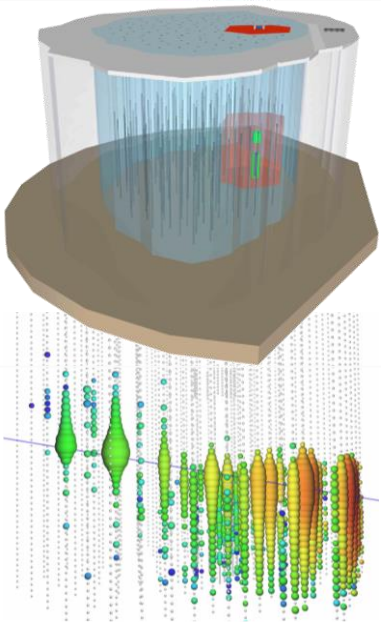
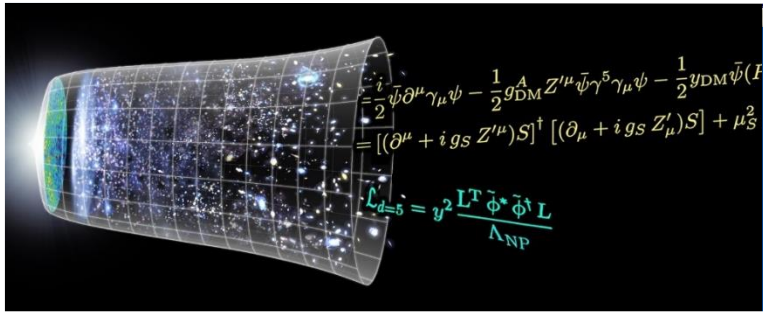
Matter and the Universe

Matter and Radiation from the Universe
KIT & DESY



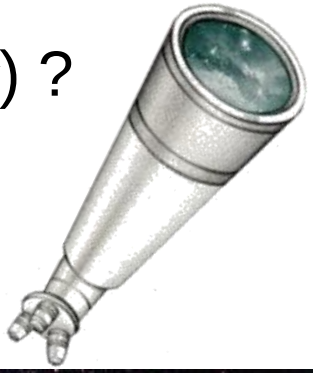


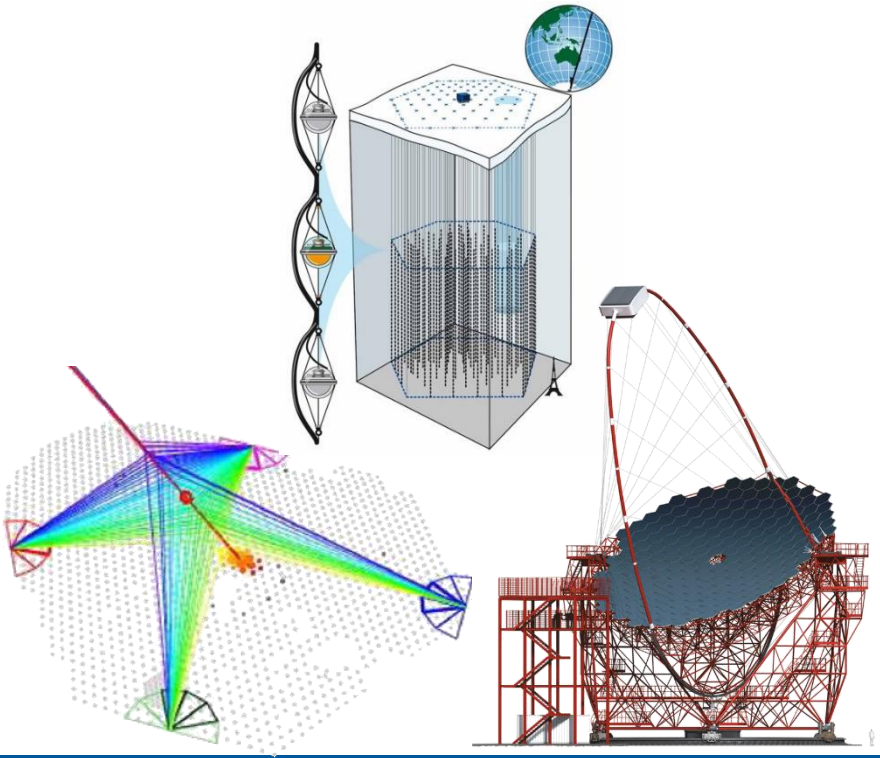
Guido Drexlin, KIT
MU Programmtag 2016, Helmholtz Institute Mainz, Dec. 12, 2016
with input kindly provided by Chr. Stegmann, R. Engel, A. Haungs, T. Schwetz, K. Eitel and others

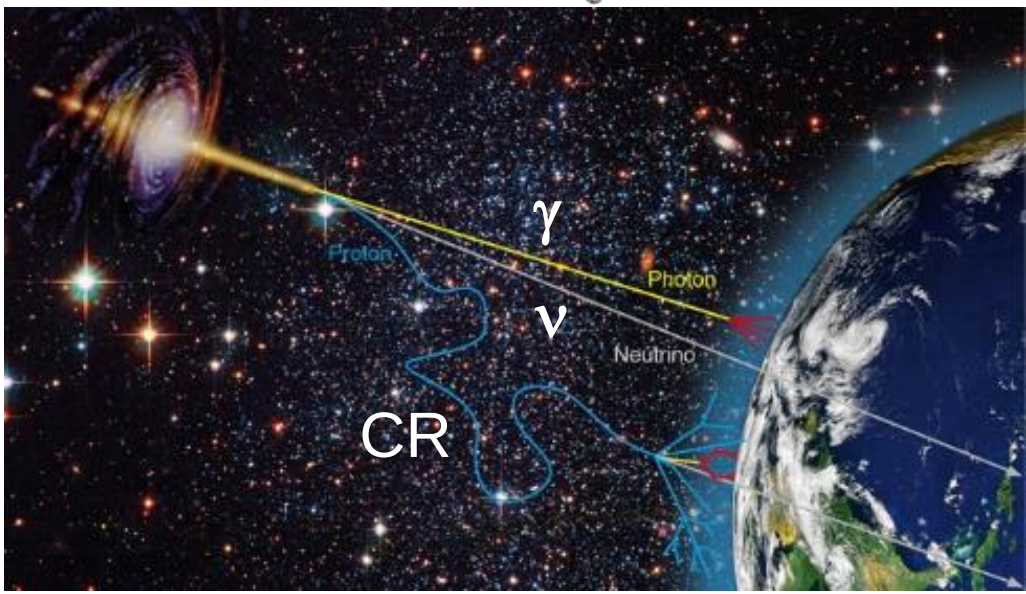
Subtopic: Non-thermal Universe

Science Mission:

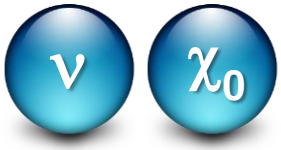
- nature & sources of cosmic radiation (CR, ν, γ) ?
- acceleration (& transport) mechanisms?
- multi-messenger studies of sources





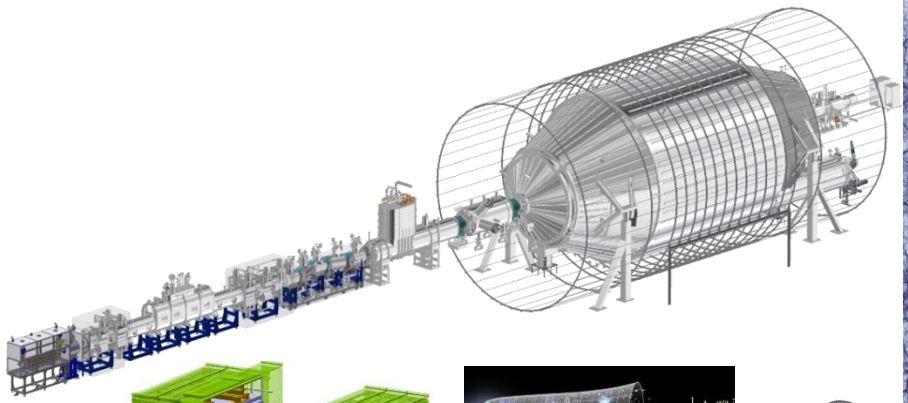


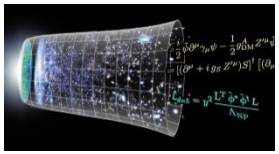
Subtopics: Neutrinos & Dark Matter

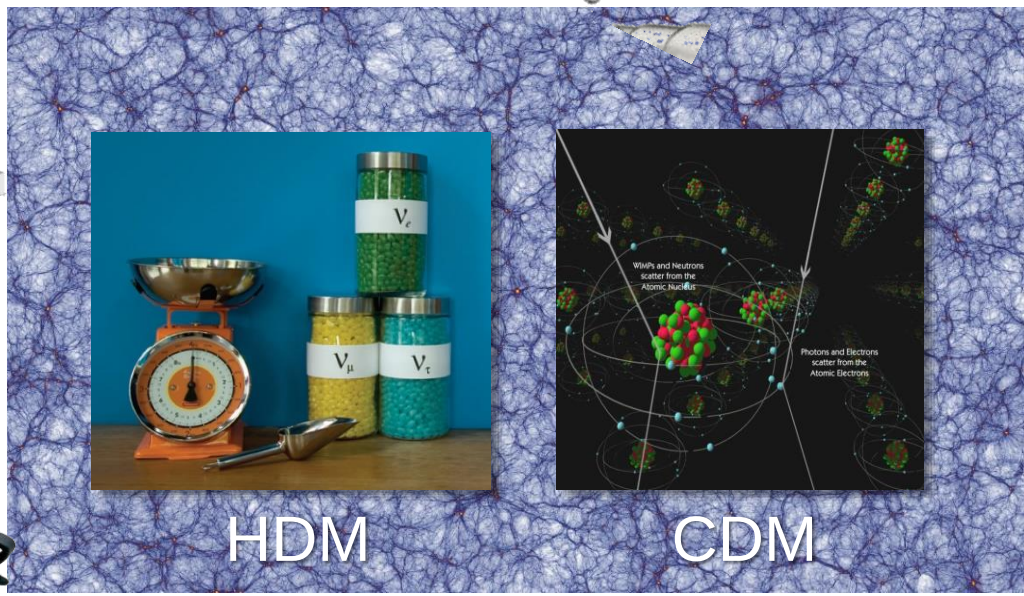


Science Mission:

- Neutrinos: absolute mass scale & mass hierarchy
- Dark Matter: direct detection experiments
- theoretical investigations: phenomenology, models







Scientific Instruments of Topic 3

cta
cherenkov telescope array

IceCube
SOUTH POLE NEUTRINO OBSERVATORY

H.E.S.S.

PIERRE AUGER OBSERVATORY

KATRIN
KARLSRUHE TRITIUM NEUTRINO EXPERIMENT

EDELWEISS
Expérience pour DEtecter Les WIMPs En Site Souterrain

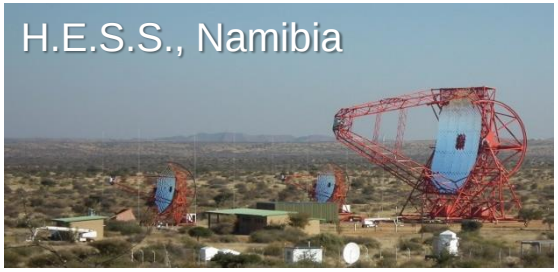
selected Milestones of topic 3 in 2016

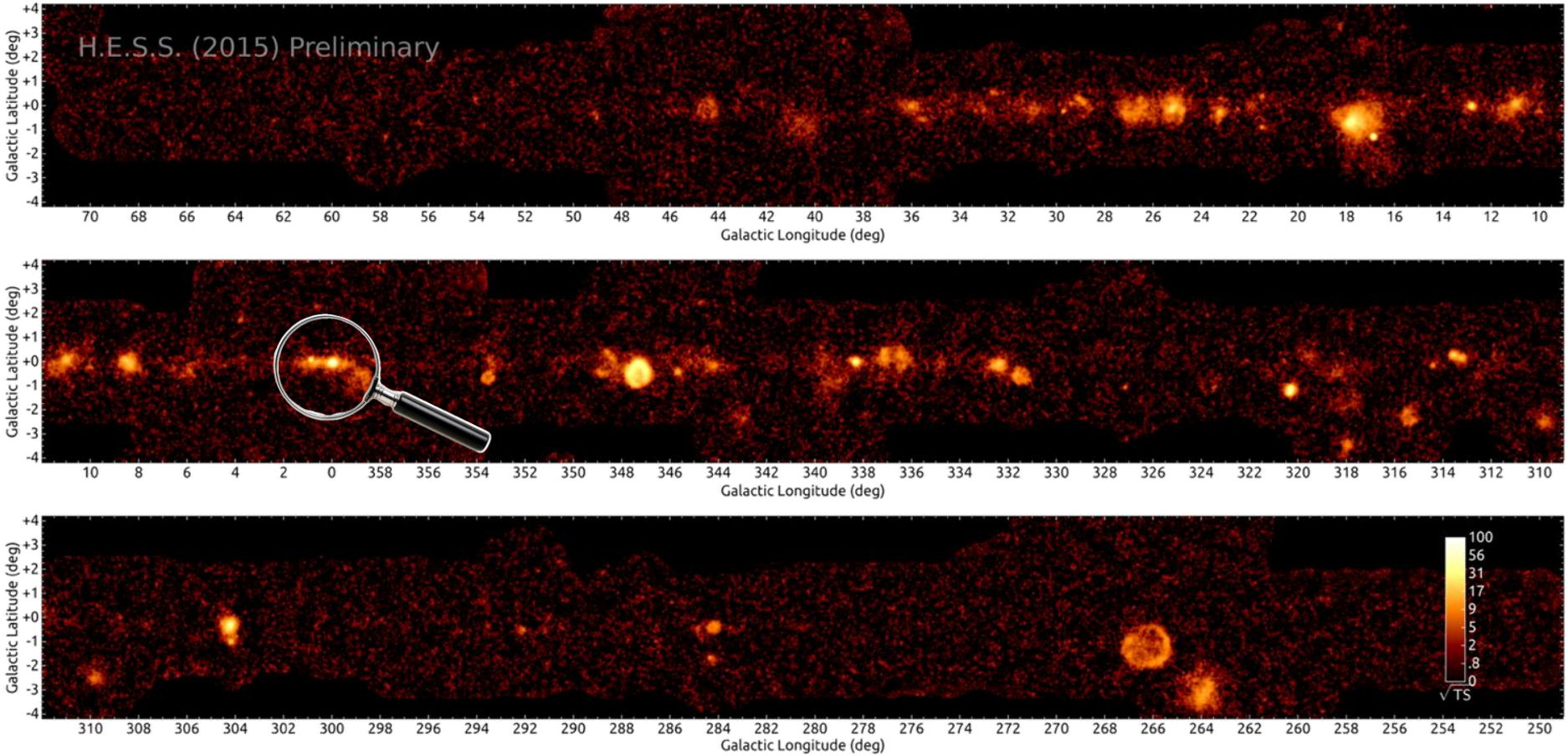
- March: HESS: publication „Acceleration of PeV protons in galactic centre“ (Nature)
- June: CTA: Science Data Management Centre to be locacted at DESY-Zeuthen
- Sept: AugerPrime: first SD station equipped with scintillator, KIT funding approved
- Oct: KATRIN: „First Light“, 70 m long beam line, excellent performance

  EDELWEISS: publication of improved EW-III low-mass WIMP results (EPJ C)
- Nov: IceCube: Gen2 Phase-I proposal submitted to NSF physics mid-scale instrumentation program

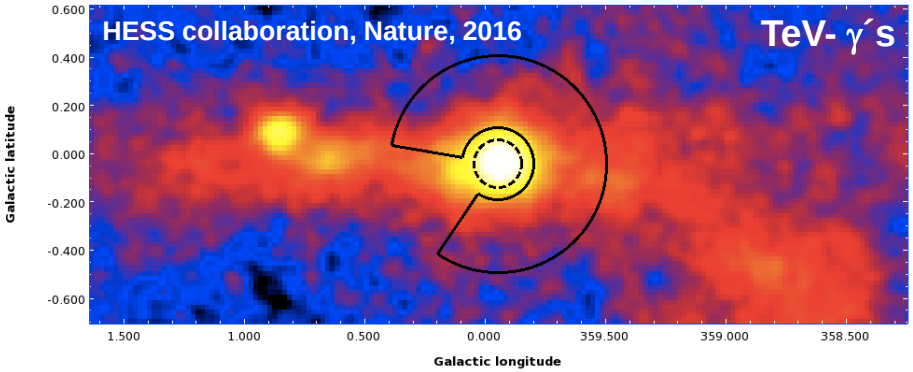
The Galactic Plane in Gamma-rays

- HESS: detection of many γ-ray sources galactic plane survey (2004-…), 2% Crab

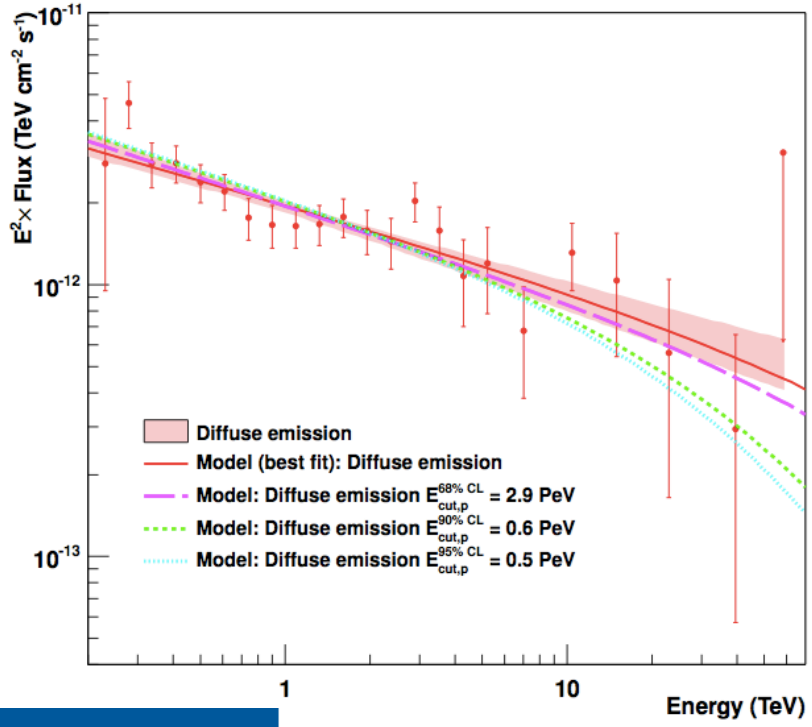




Galactic Centre – a PeVatron in space



- HESS detects γ-rays from Sgr A* & diffuse emission from ridge
- no γ-energy cut-off (power law)
- interpretation: Sgr A* acclerates CR up to PeV, CRs diffuse away & interact with diffuse gas



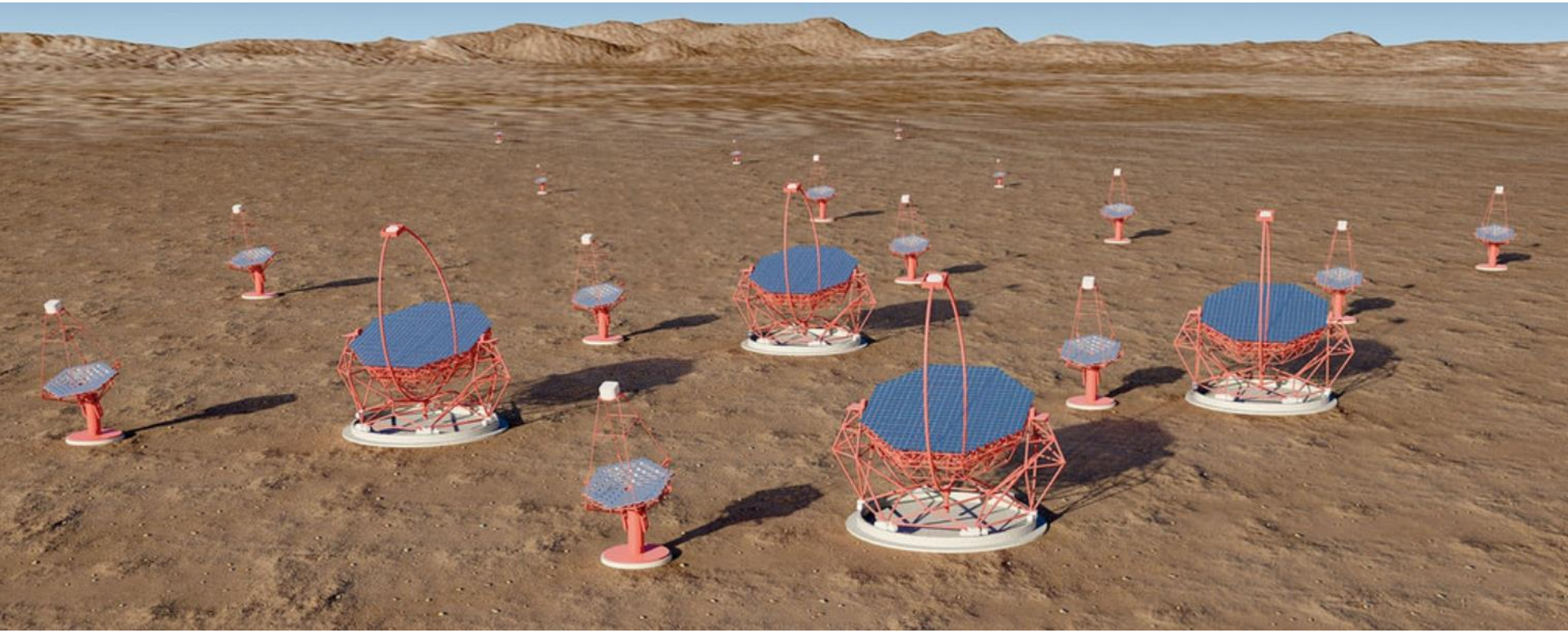
- H.E.S.S. upgrade (DESY-led): 4 new cameras installed in time

CTA Observatory – mCrab sensitivity

science mission:

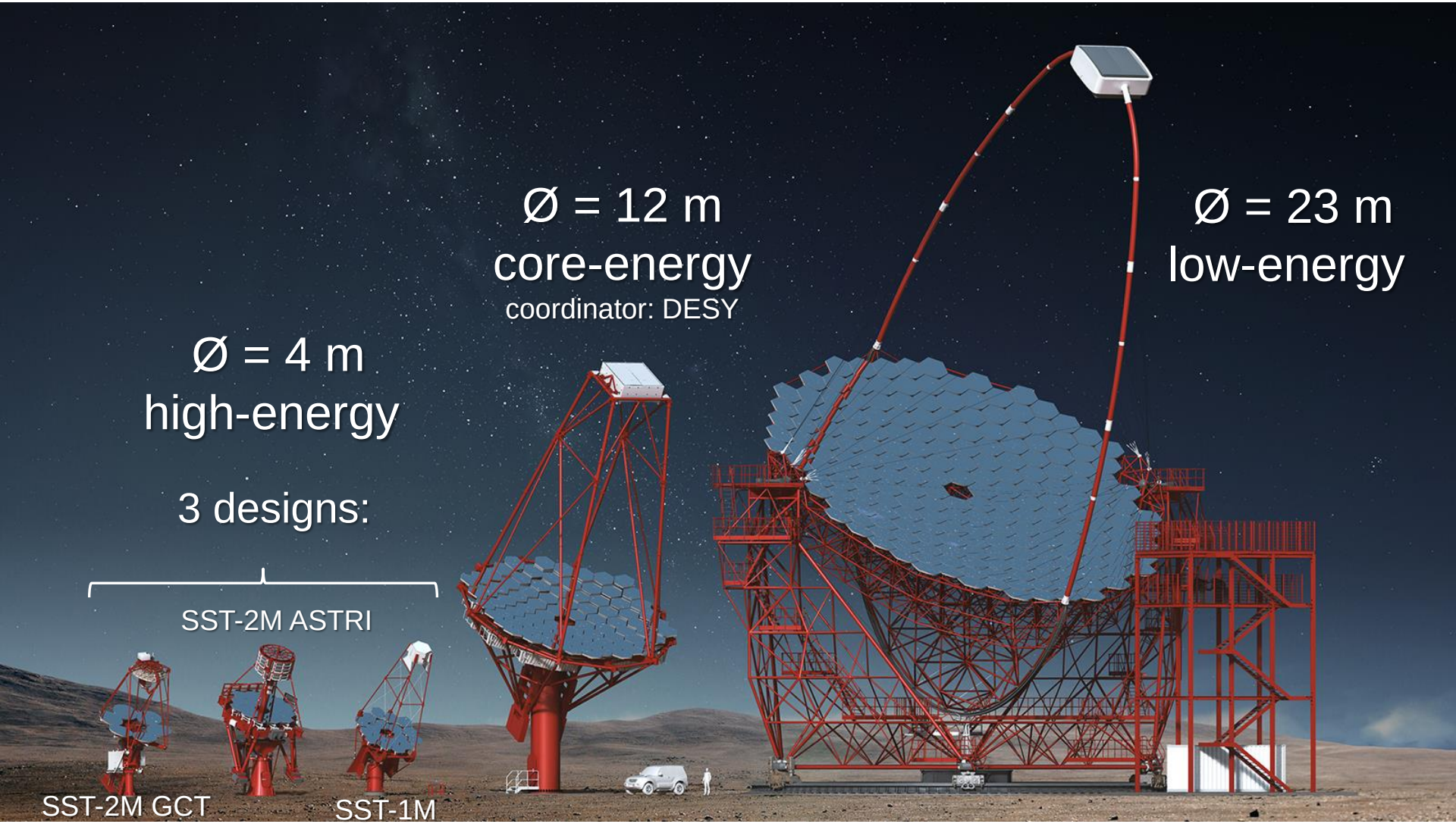
- cosmic particle acceleration
- probing extreme environments
- physics frontiers – beyond the SM

29 Countries
178 Institutes
1187 Members



see also talk by J. Hinton (MPIK): *„Status and perspectives of CTA",* today, 18:20-18:45

CTA: 3 Telescope classes (20 GeV- 300 TeV)

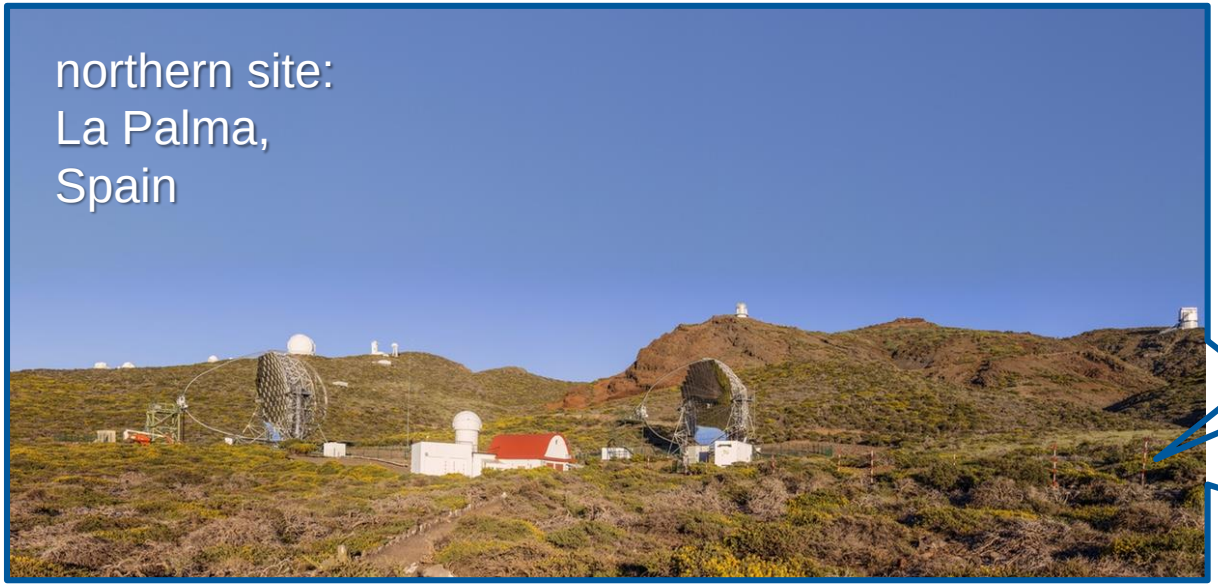


70 SST 40 MST 8 LST

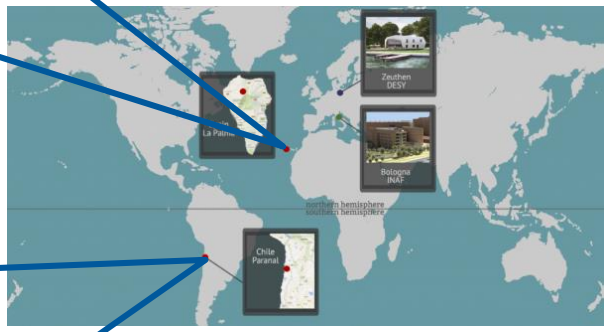
CTA Observatory: Sites

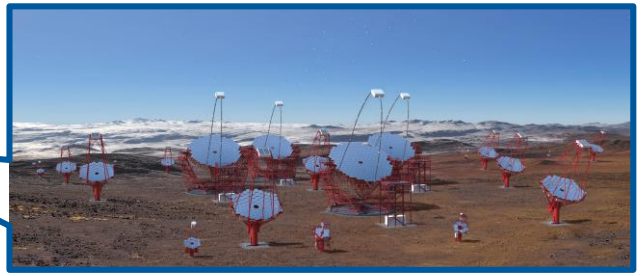
- two observation sites, plus: headquarters & science center

CTA Observatory: Sites



4 LSTs / 15 MSTs





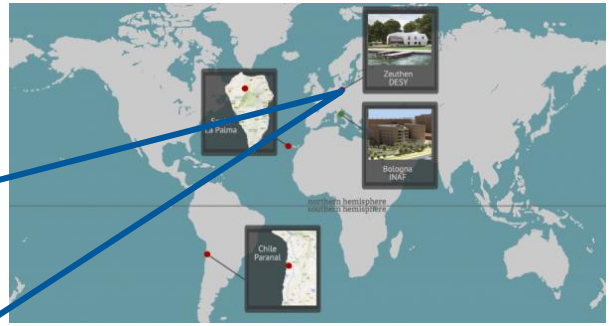
4 LSTs / 25 MSTs

CTA Observatory: Science Management

6/2016: DESY Zeuthen to host Science Data Management Centre

- seat of CTA Director of Science Operations
- new building to host more than 20 new staff members & guest scientists

Model of the CTA Science Management Centre
Image: Dahm Architekten & Ingenieure



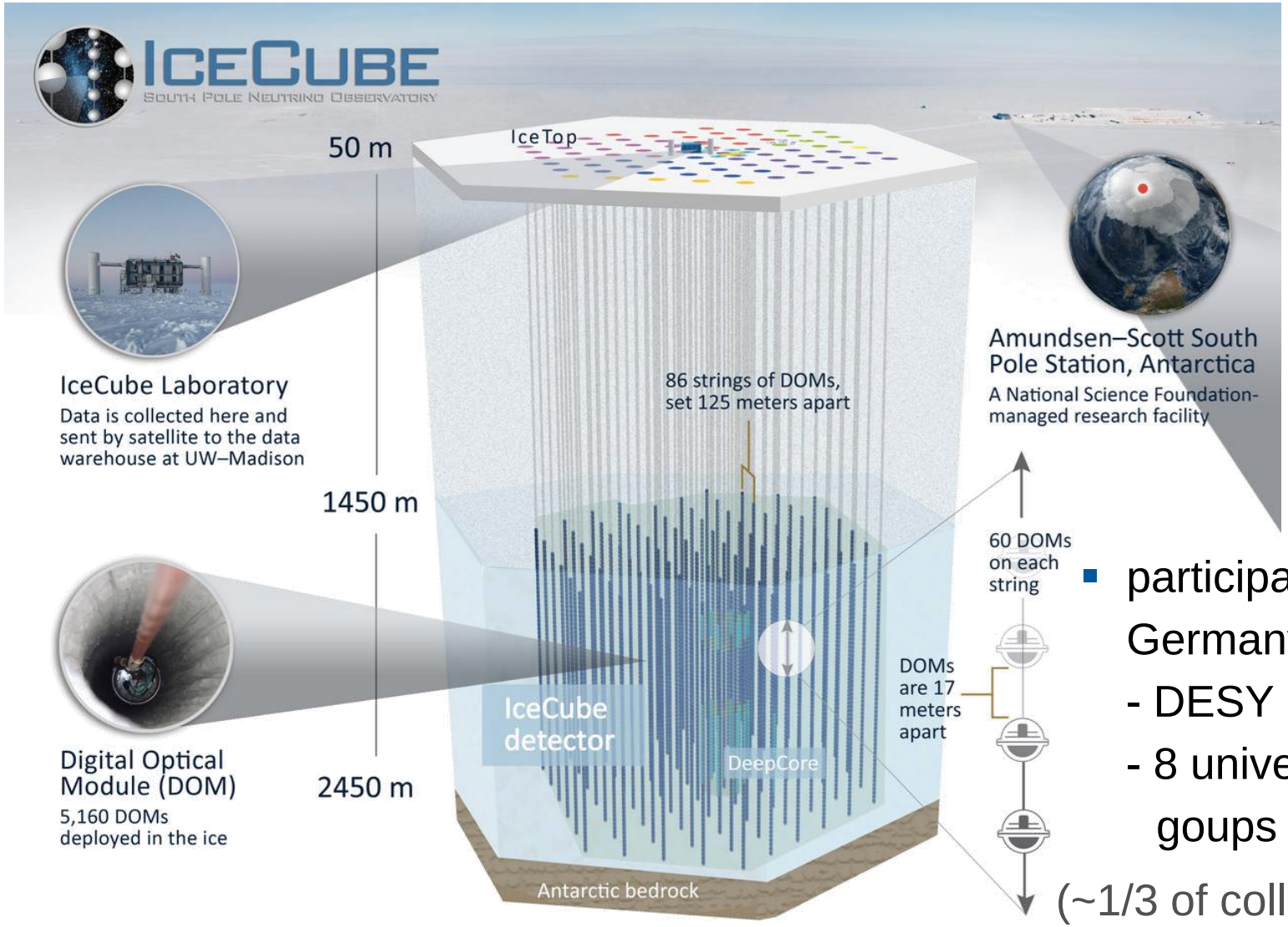
DESY

CTA Observatory: site agreements

- **site hosting agreements**:
  - nothern site at La Palma: signed in Sept.
  - southern site in Chile: to be signed in Dec.
- **CTA Founding Agreement:**
  - in preparation
- 2017:
  start of construction
- 2020/21:
  start of science operation

Neutrino astronomy: IceCube

science mission: cosmic ν-fluxes, point sources, atmospheric-ν



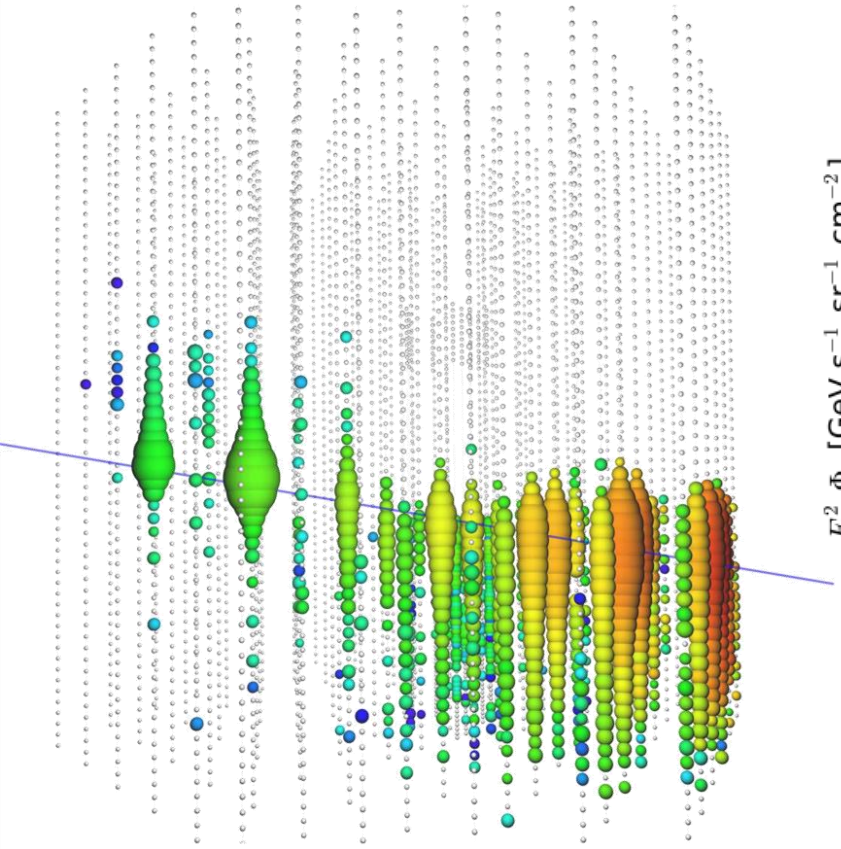
- participation from Germany:
  - DESY
  - 8 university goups

(~1/3 of collaboration authors)

see also poster by T. Huber (DESY/KIT): IceCube-Gen2: IceScint

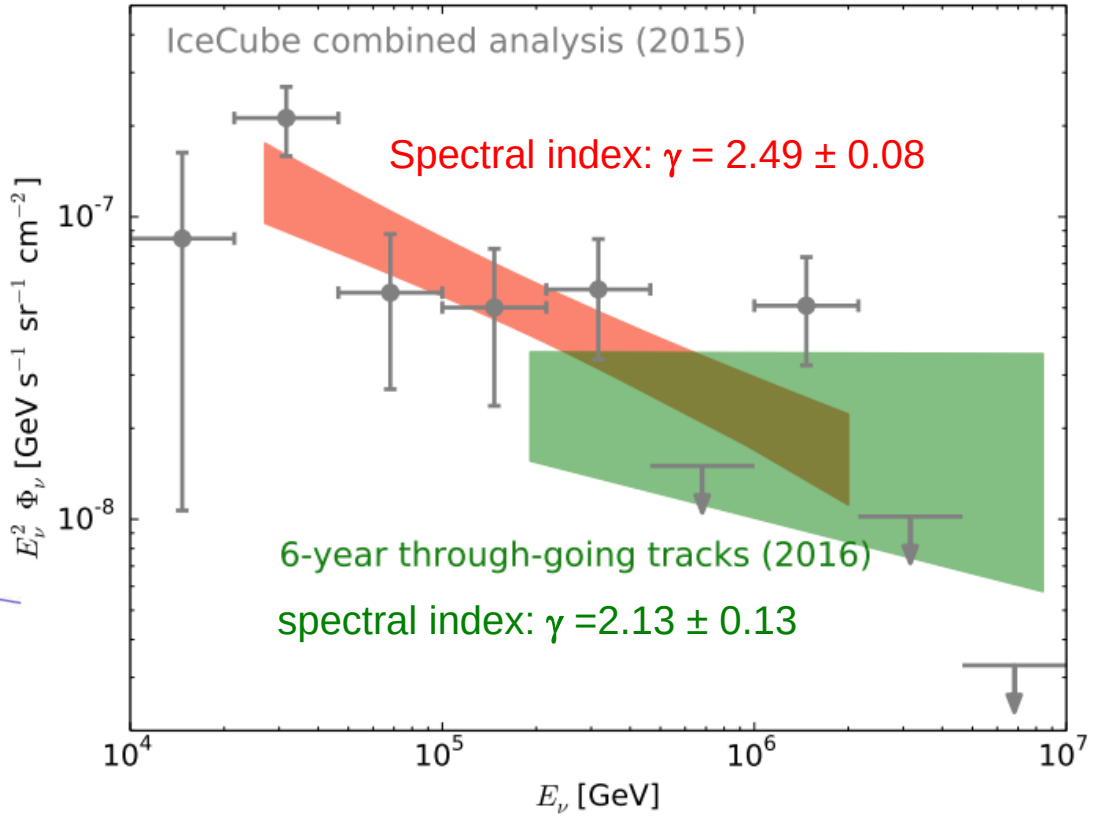
IceCube: astrophysical ν-flux measurements

- a muon with > 2.6 PeV



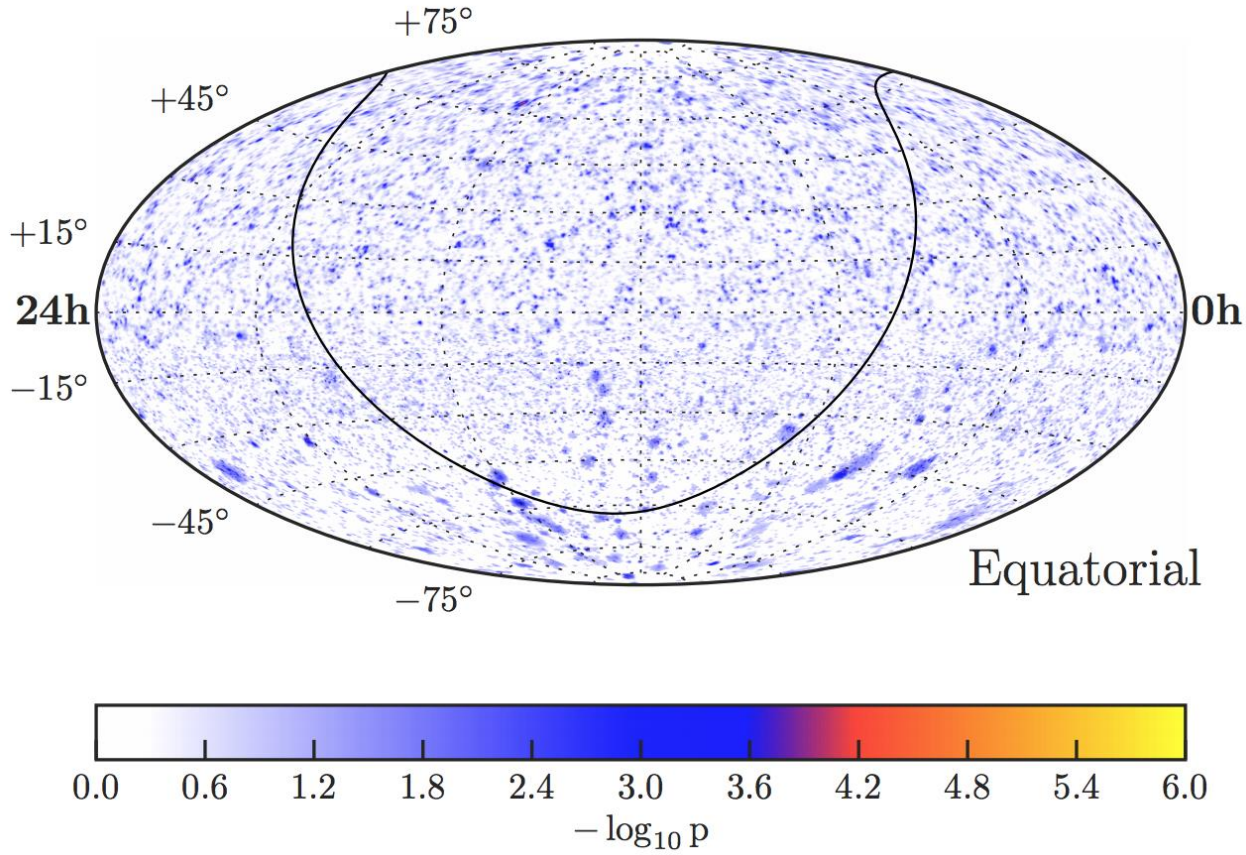
Astrophysical Journal 833, 18 (2016)

- indication of spectral hardening at few hundred TeV ?



Astrophysical Journal 809, 98 (2015)
L. Mohrmann, ICRC, The Hague (2015)
Astrophysical Journal 833, 18 (2016)

Origin of astrophysical neutrinos



- **no point sources**
- no signal from galactic plane
- allows to constrain contributions of source classes with low population density

Blazars $\lesssim 25\%$

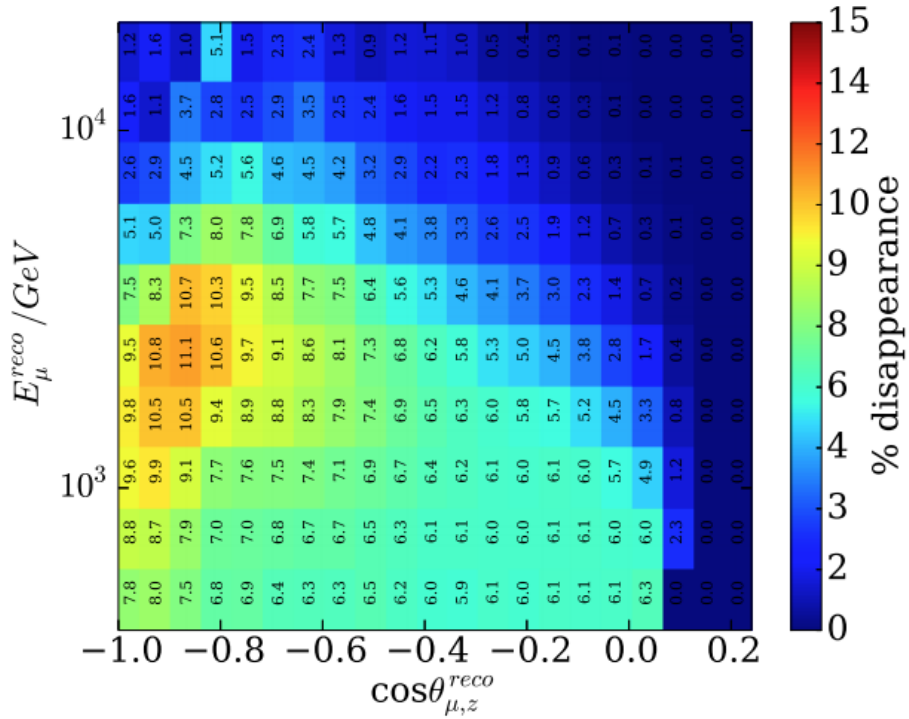
GRBs $\lesssim 1\%$

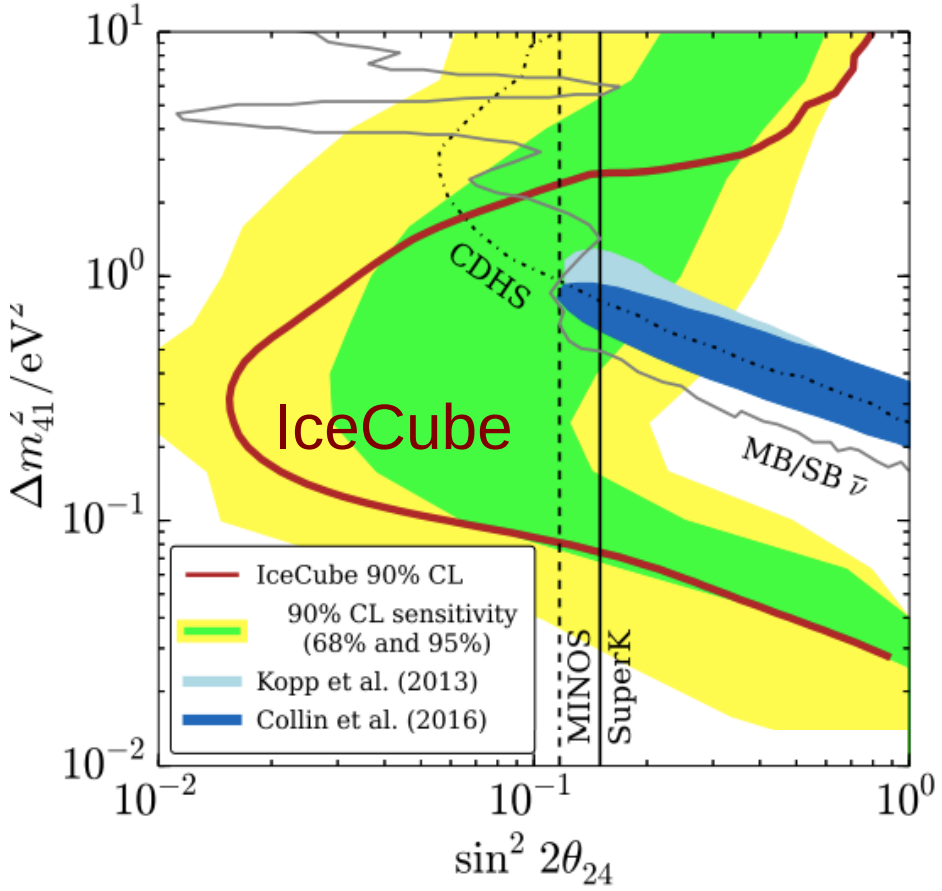
contribution to cosmic ν-flux

astro-ph/1609.04981 (2016)
astro-ph/1611.03874 (2016)
Astrophysical Journal 824, 115 (2016)

IceCube - sterile neutrino constraints

- O(eV) sterile ν´s can be probed with TeV-scale atmospheric ν´s world-leading constraints from 1 y IceCube data

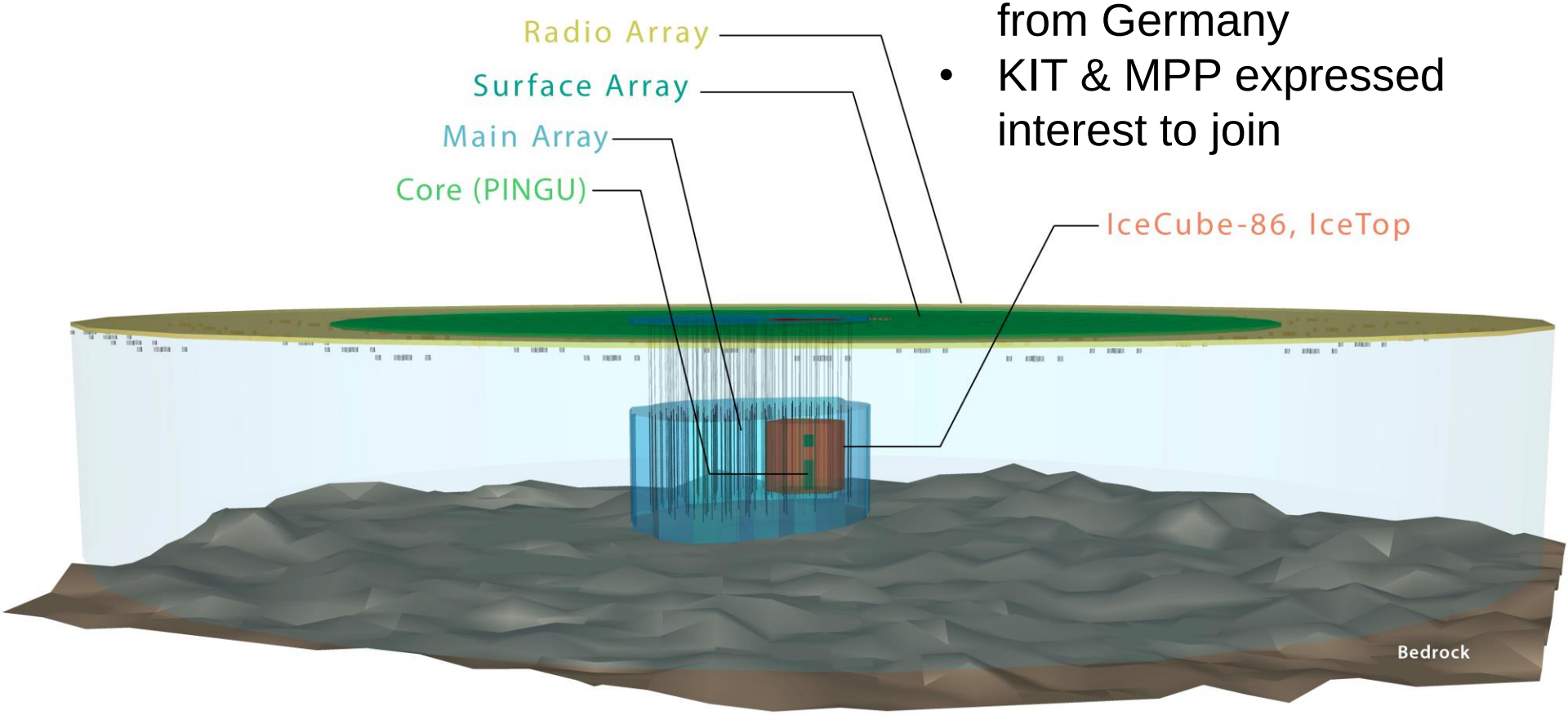




PRL 117, 071801 (2016)

IceCube – Gen2

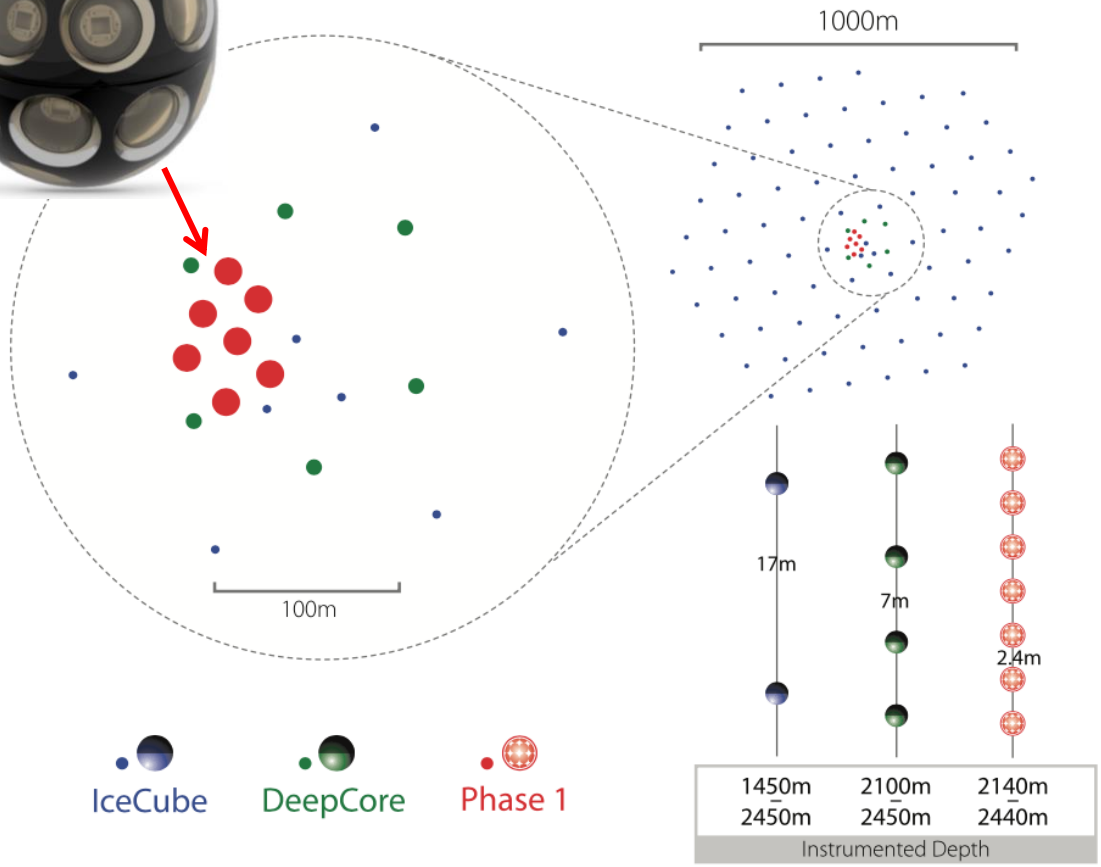
- Total project cost: ~$400M
- aim for ~25% contribution from Germany
- KIT & MPP expressed interest to join



possible timeline:

IceCube – Gen2 Phase I proposal

mDOM sensors developed at
DESY, Erlangen, Münster



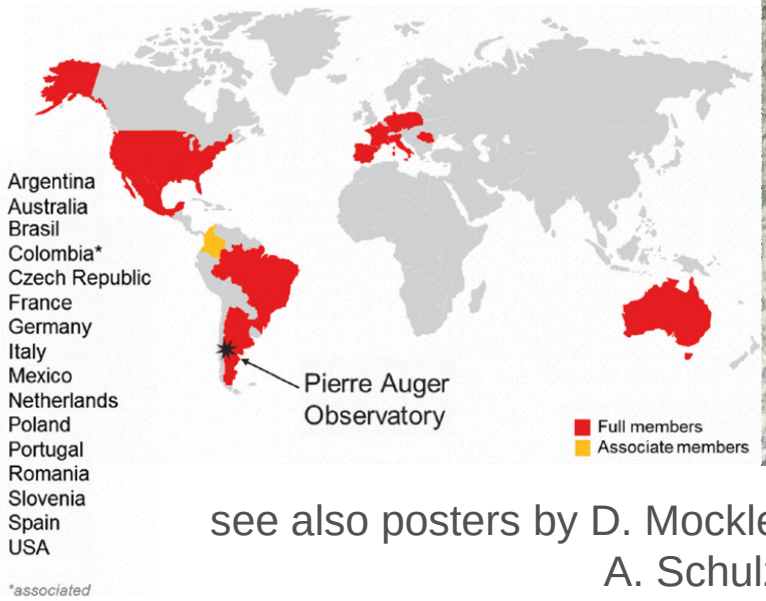
- 7 strings with sensors & calibration devices
- $23M asked from NSF
- $13M from foreign contributions, includes 2M€ from DESY
- Scientific focus: identification of ν_τ

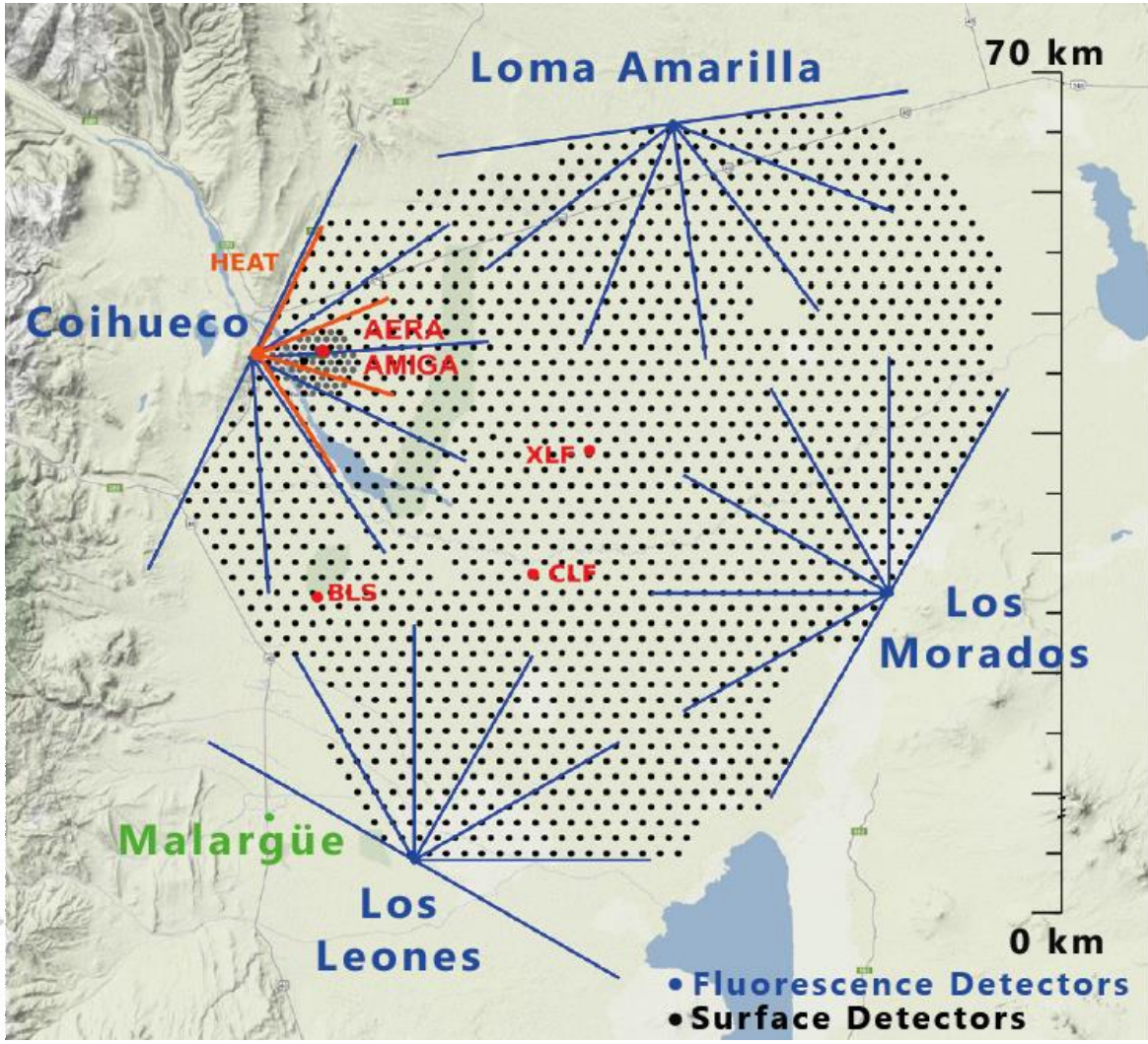
- submitted in Nov 2016 to NSF physics mid-scale instrumentation program

Pierre Auger Observatory

strong German contributions

- KIT (largest group) &
  U Aachen
  U Hamburg
  U Siegen
  U Wuppertal

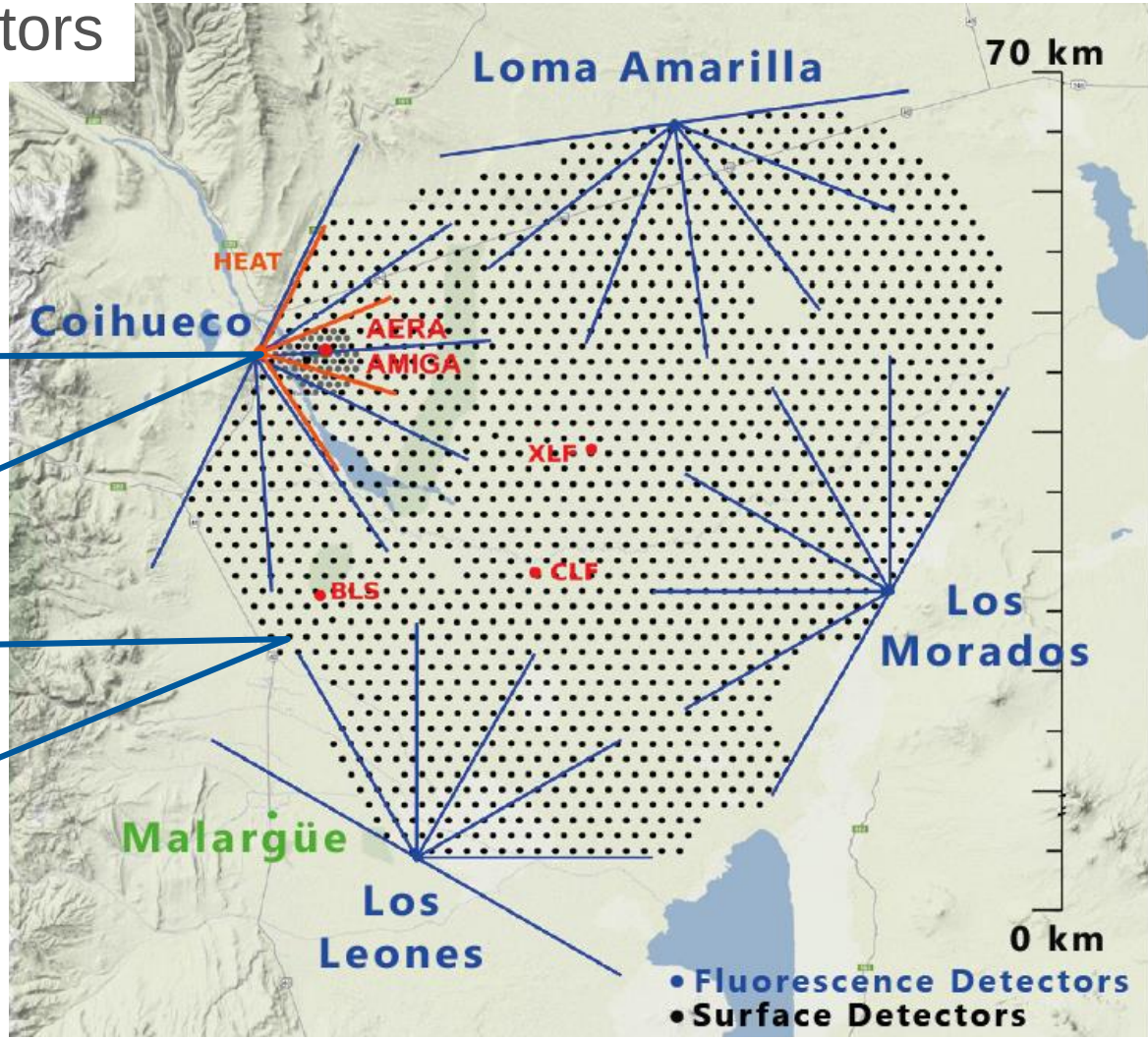




see also posters by D. Mockler (KIT): latest results from Auger
A. Schulz (KIT): AugerPrime

Pierre Auger Observatory: SD & FD

FD: 4 fluorescence detectors

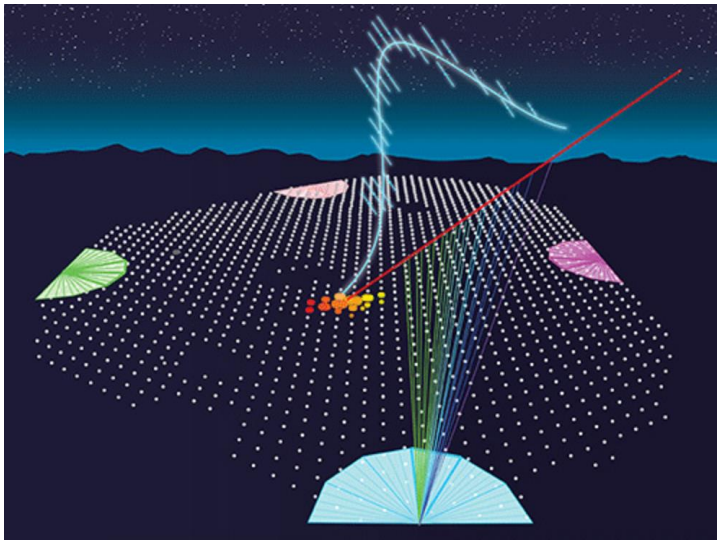


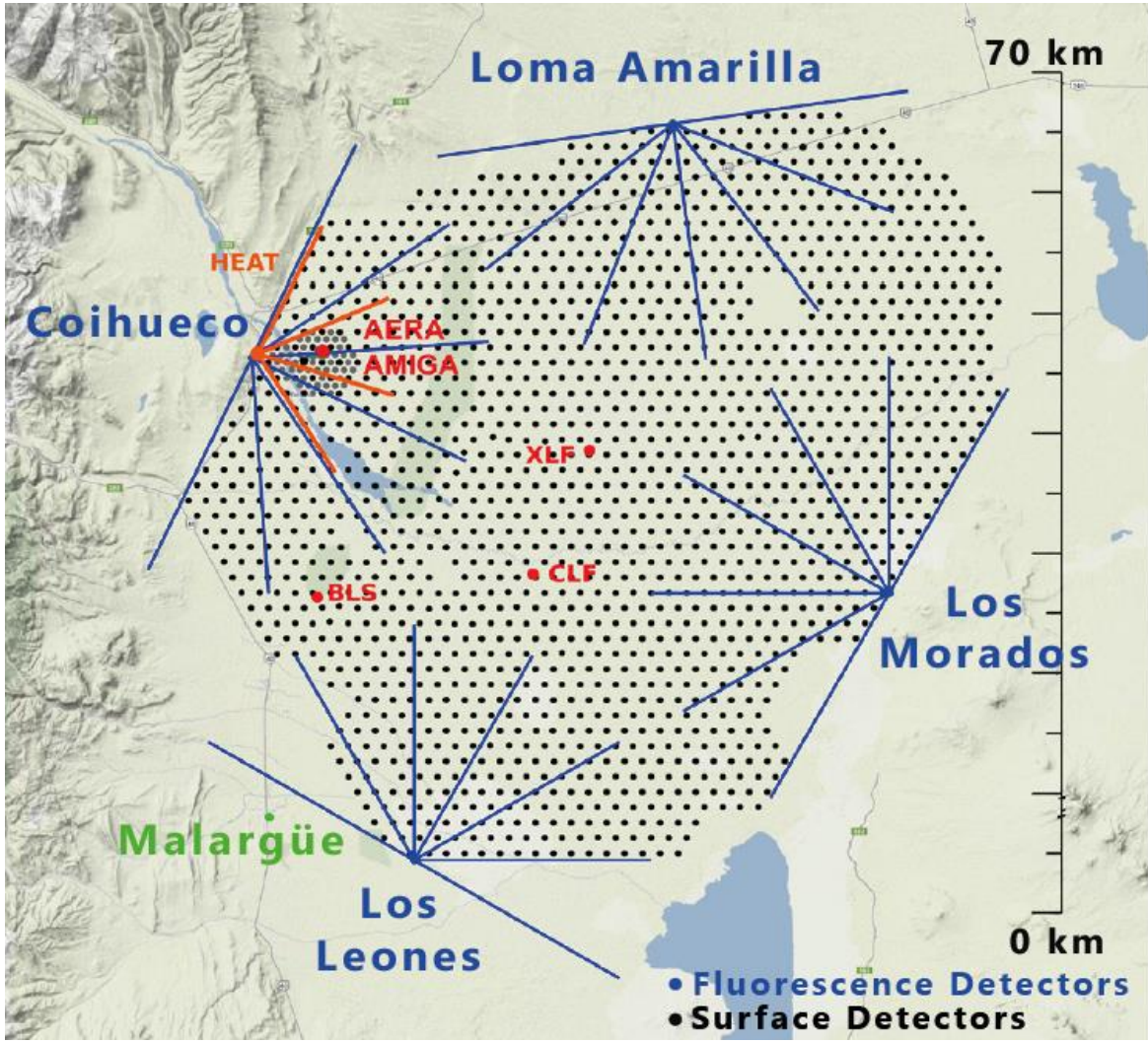
SD: surface detectors (1665) + radio antennas, infill array, LIDAR

Pierre Auger Observatory: SD & FD

science mission:

- energy spectrum and mass composition of UHECRs
- point sources?
- ν_τ-interactions



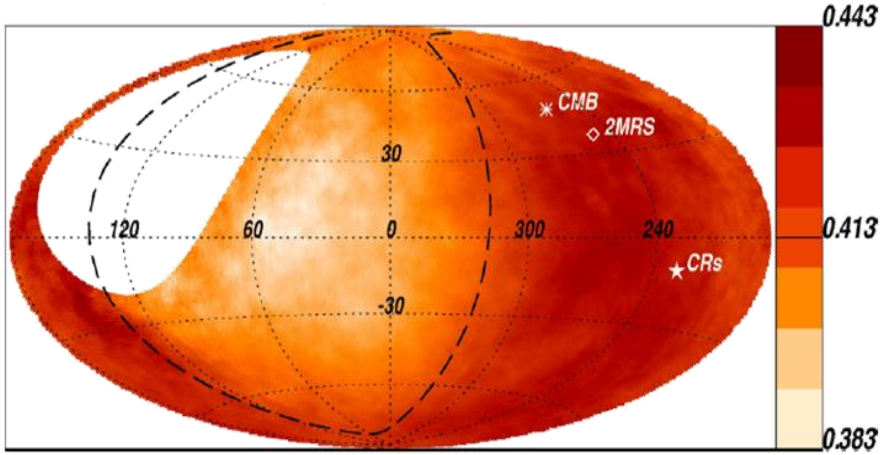


SD&FD: hybrid detection

Auger – science results: anisotropies

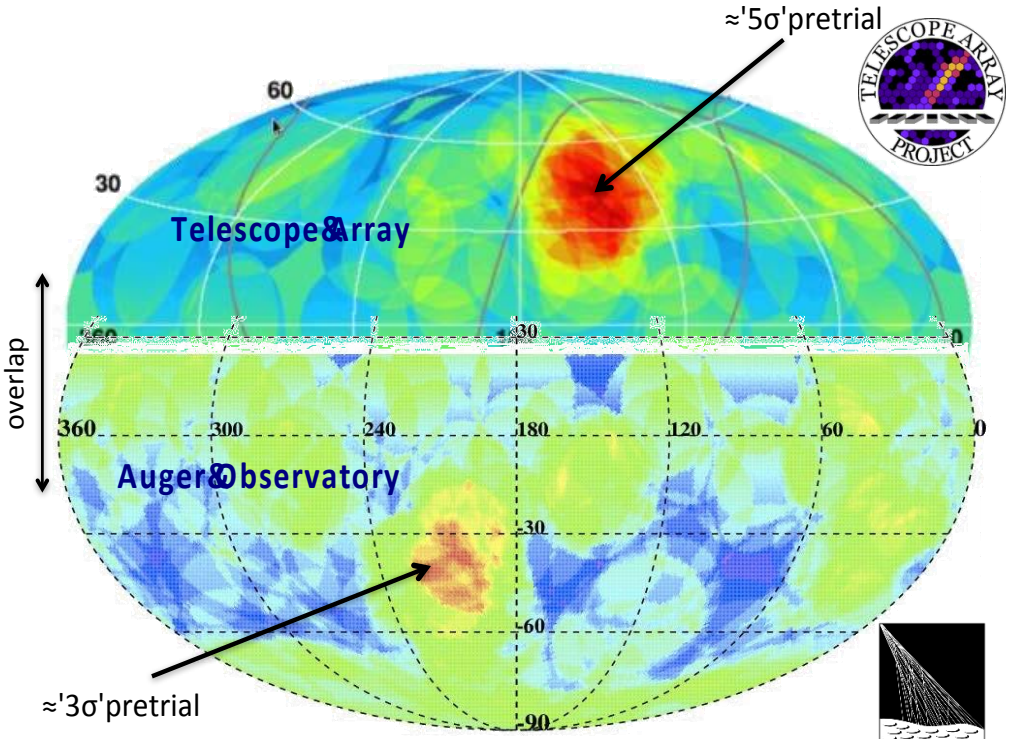
$E > 8 \times 10^{18}$ eV

dipole anisotropy
amplitude ~ 7%,
>5 σ significance
direction: (233°, -13°)



$E > 5.7 \times 10^{19}$ eV

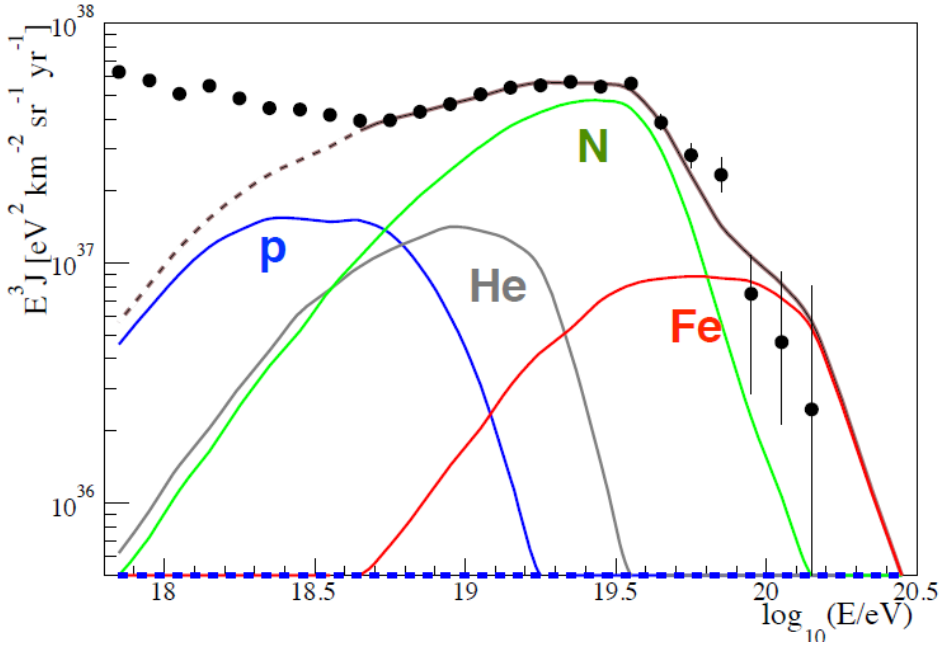
"warm" spot in direction of Cen-A,
(~20° size, need more data)



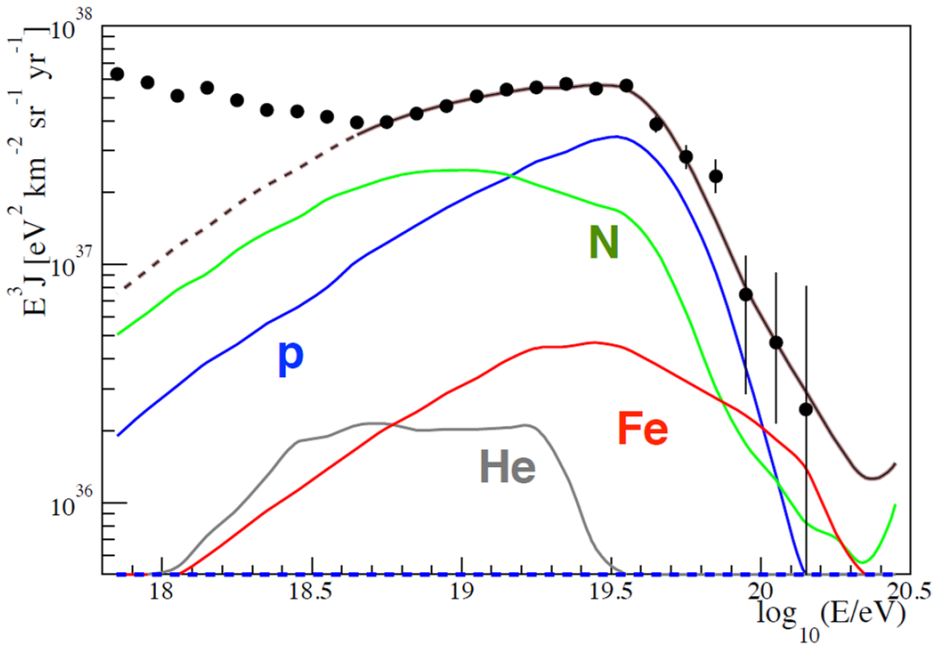
Qualitatively expected for
sources following extragalactic
mass distribution & B-field deflection

Auger – composition at highest energies

- clear evidence for cut-off in spectrum, model *without* GZK cutoff preferred, but many alternative scenarios



Scenario 1: maximum rigidity model
almost no protons



Scenario 2: photo-disintegration
large proton fraction

AugerPrime – Science mission

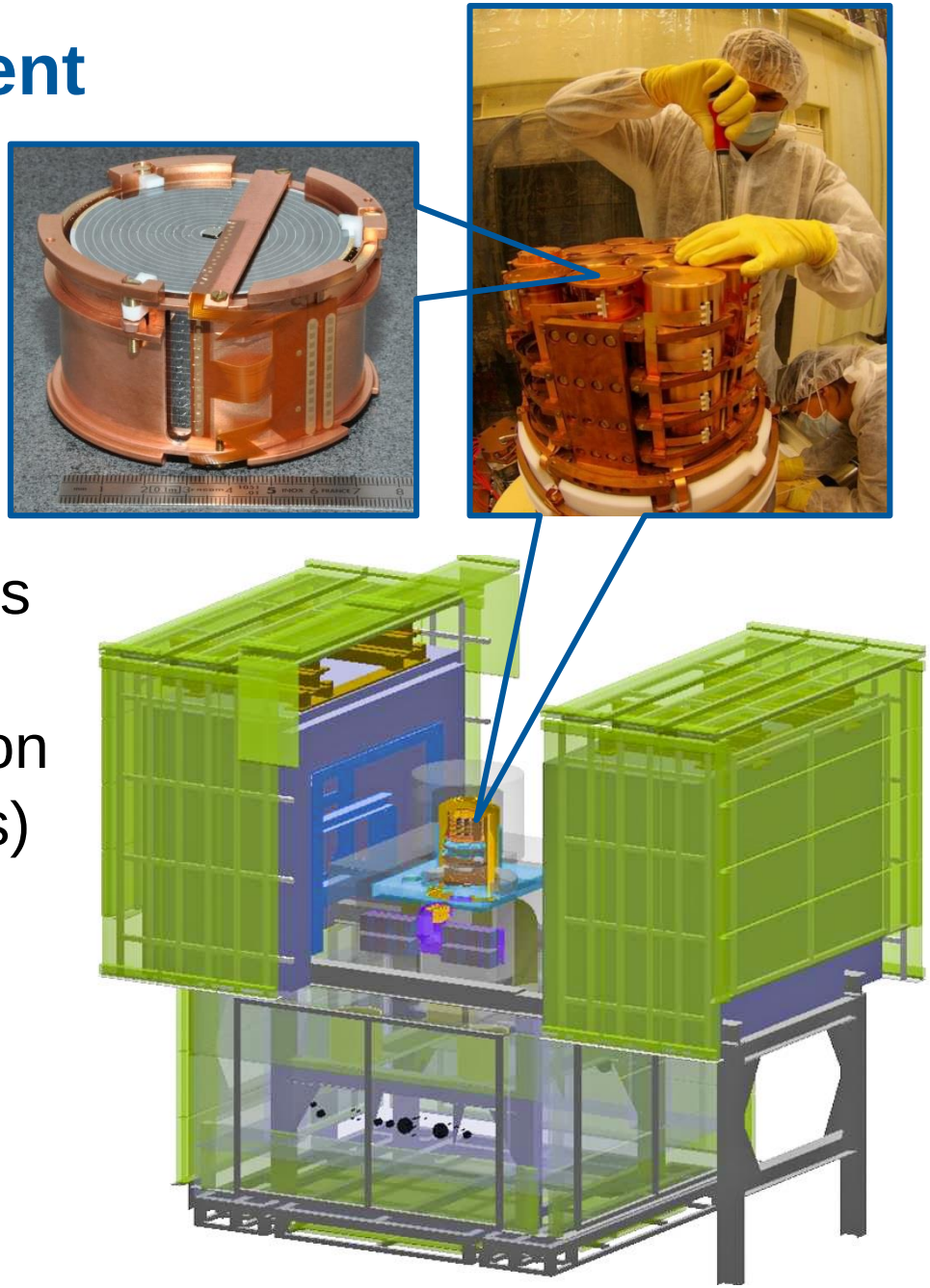
- discrimination of scenarios: detect 10% proton fraction!
- particle astronomy at highest energies ($E > 6 \times 10^{19}$ eV)? element (mass) information for individual showers
- new particle physics beyond LHC energy scale? (N_μ)
- Sept. 2016: KIT funding (2.8 M€) for upgrade approved

First AugerPrime Detector:
Sept 15, 2016

EDELWEISS-III experiment

science mission:

- search for WIMPS @ Modane Lab (LSM)
- Ge-bolometers @ 18 mK:
  - 24 FID800 HPGe detectors
  - heat (NTD thermistors)
  - ionisation (charge collection at top & bottom electrodes)
- focus now on low-mass WIMPS on few GeV-scale
  → low threshold (~1 keV) !



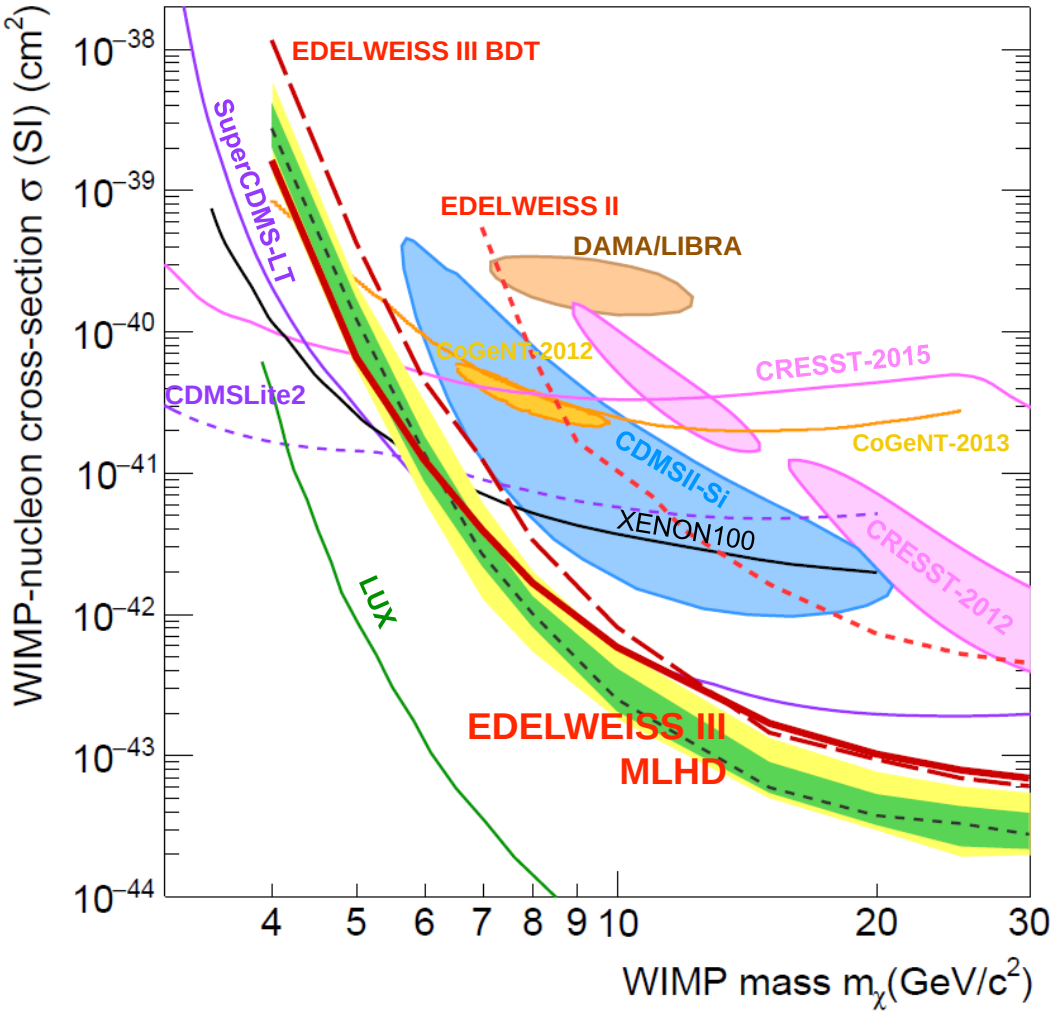
See also poster by B. Siebenborn (KIT):
The EDELWEISS Dark Matter search

EDELWEISS-III: results

WIMP search

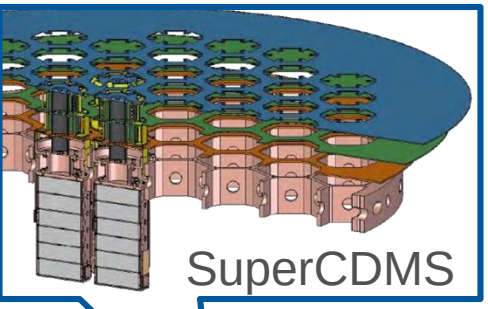
- 7/2014-4/2015 (160.7 d)
  8 detectors: 496 kg × d
- blinded ROI & maximum likelihood analysis (KIT)
- 40-120 × improvement
  wrt EDELWEISS II
  new exclusion limit
- future goals: extend search to few GeV range
  - amplify heat signal
  - optimized sensors

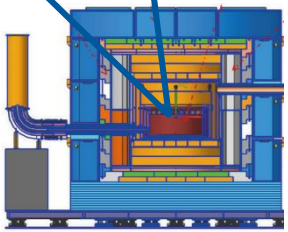
L. Hehn et al, EPJ C (2016) 76:548

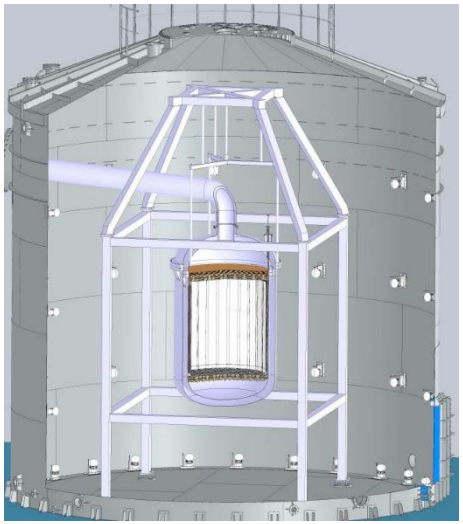


Dark Matter - strategy

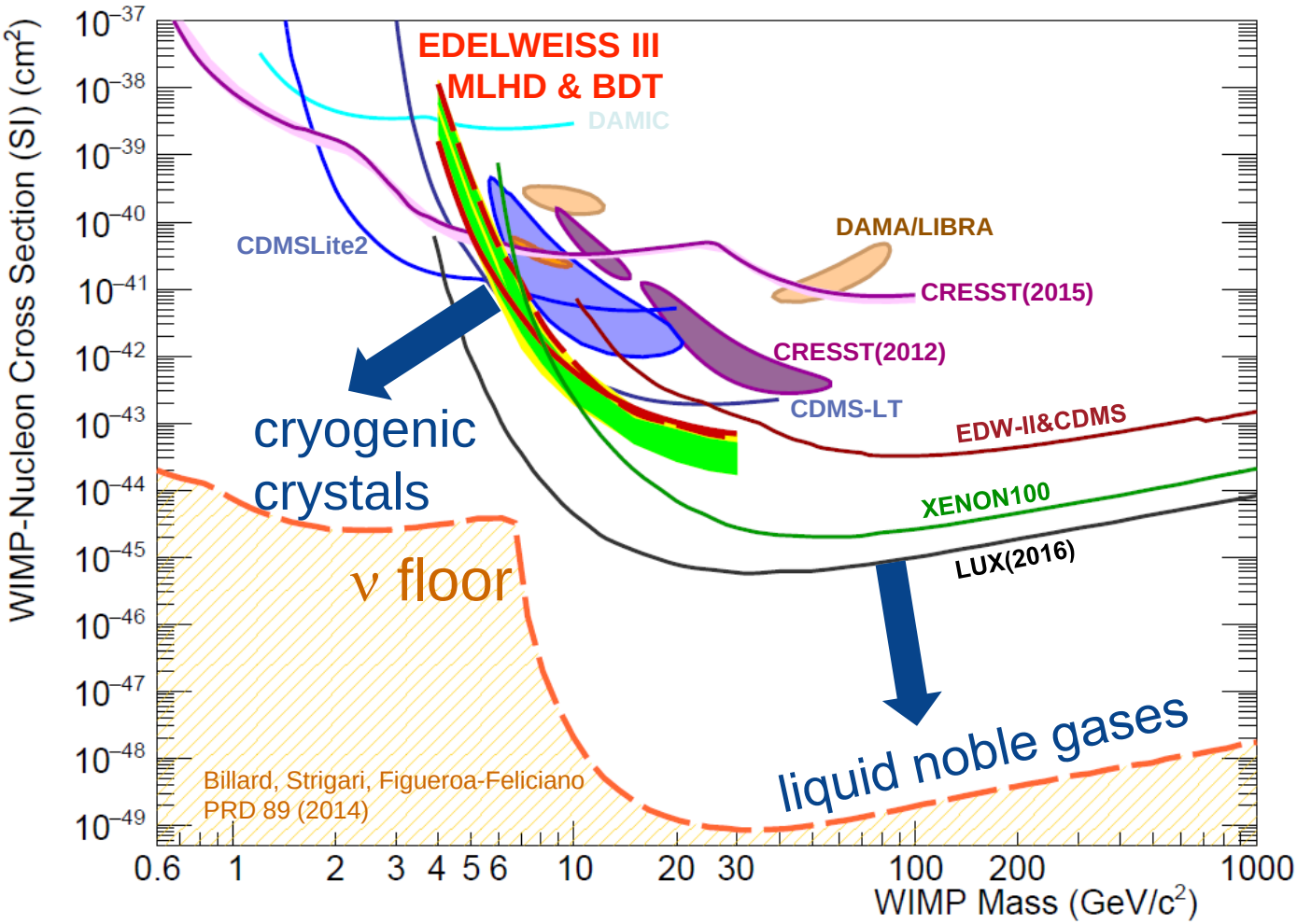
WIMP search: low mass via Ge, high mass via liquid Xe







DARWIN

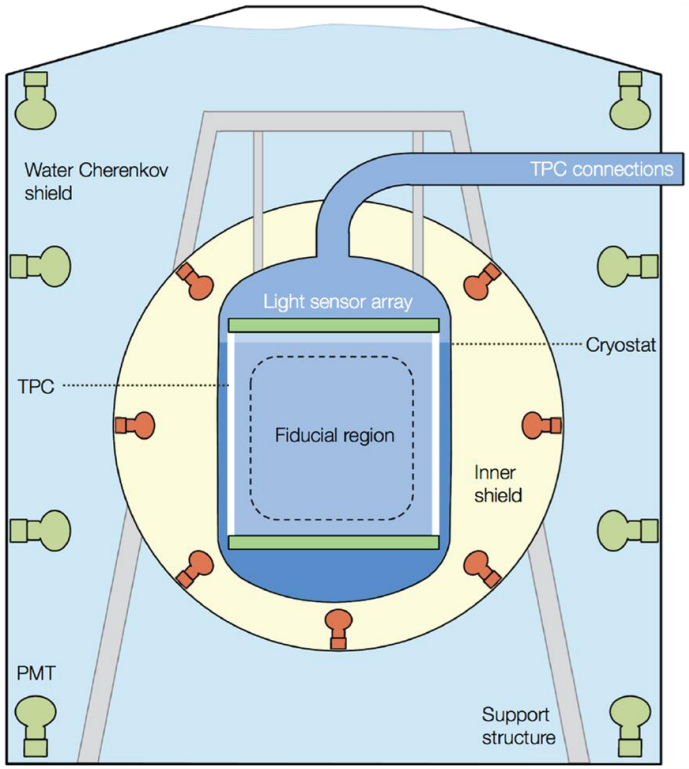


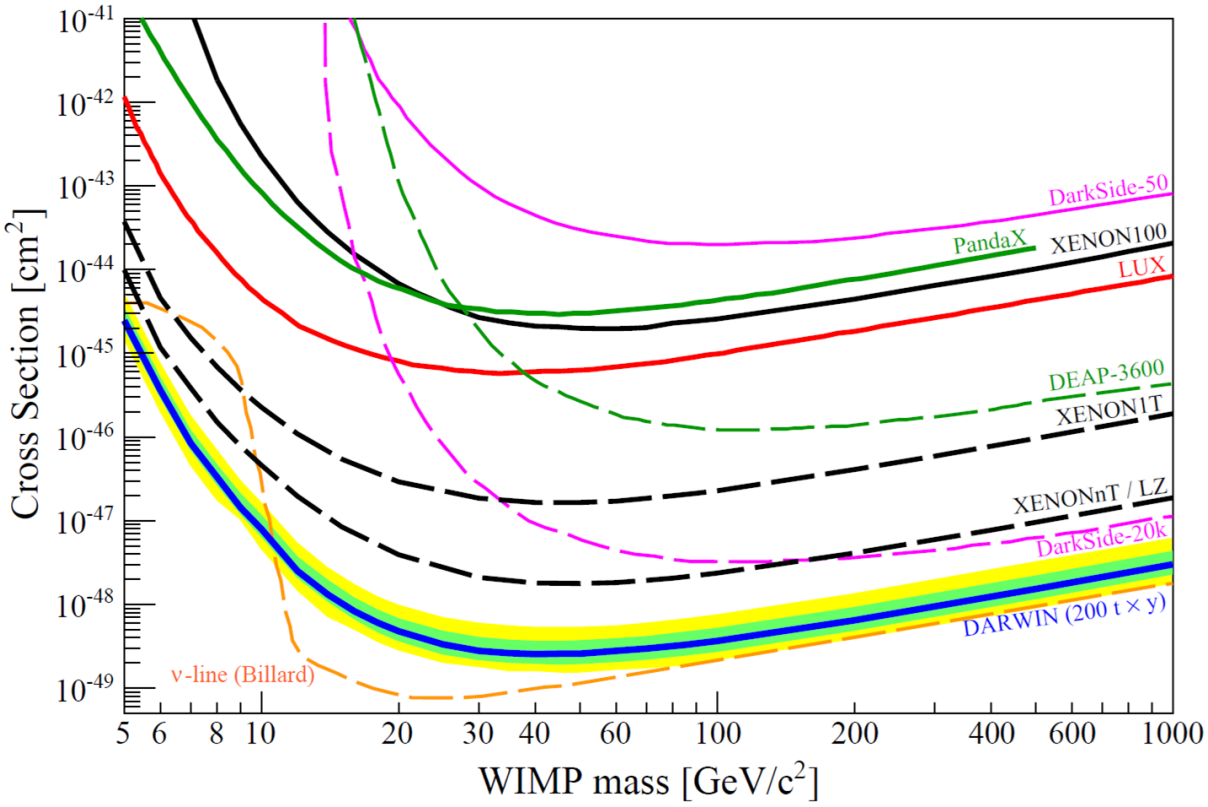
Dark Matter – long-term strategy (PoF-5..)

DARWIN (DARk matter WImp search with liquid xenoN)

KIT

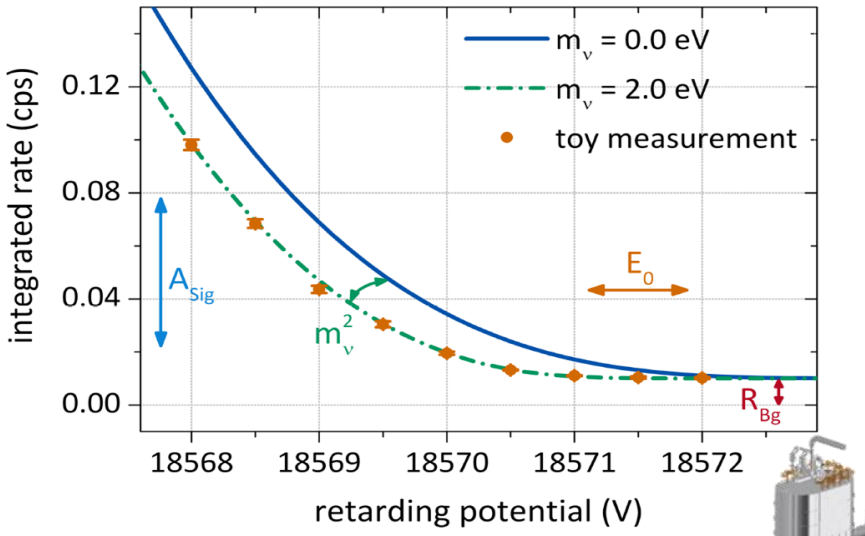
- a 50 t LXe dual-phase TPC: low threshold, ultra-low bg-levels
- **science mission**: explore WIMP region down to ν-floor, ν-physics





KATRIN experiment

science mission: absolute ν-mass scale (0.2 eV @90% CL), sterile neutrinos (eV…keV), BSM



see talk M. Steidl (KIT) “Testing ν-properties with KATRIN – status update”

see posters C. Röttele (KIT) “Cryogenic pumping section of KATRIN”

F. Heizmann (KIT) “Results of the First Light of KATRIN”

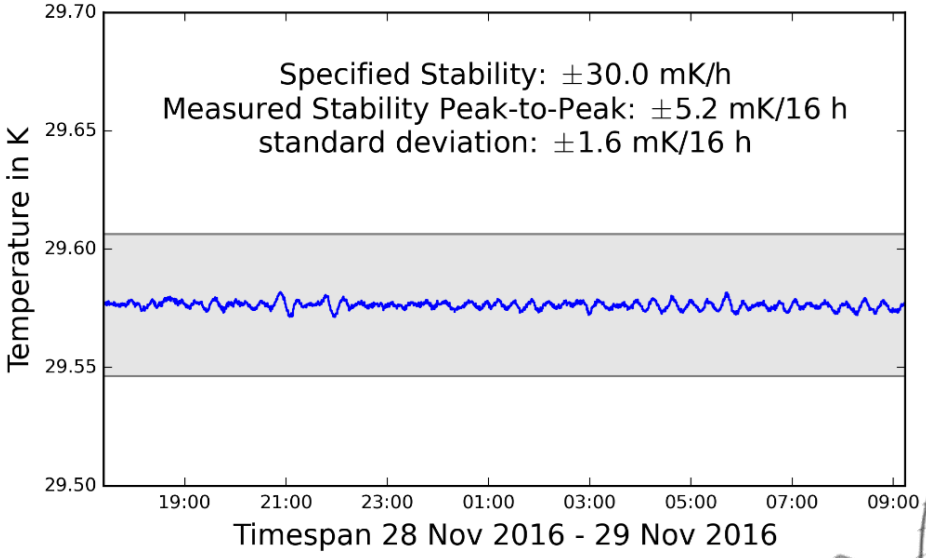
H. Seitz (KIT) – “The thermal behaviour of the WGTS“

KATRIN – recent milestones

cryo trap: 3K

spectrometer:
HV on ppm
UHV: < 10^{-10} mbar

KATRIN – technical milestone: WGTS stability



2-phase neon BT cooling system

KATRIN – First Light

DPG

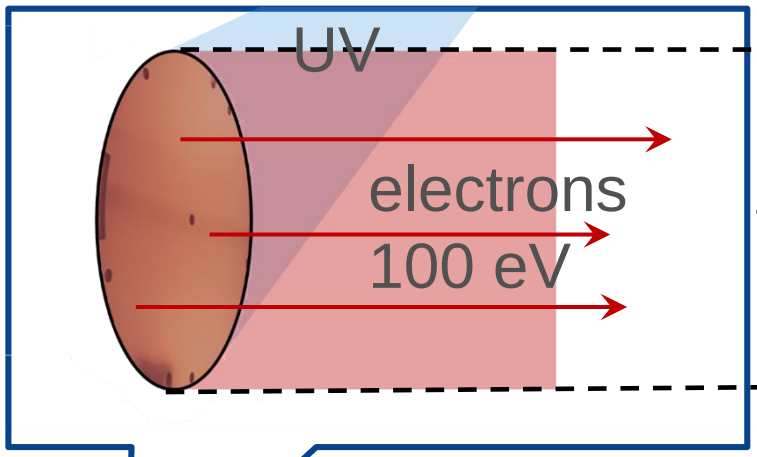
Neutrinos auf der Waage

Am 14. Oktober durchflogen erstmals Elektronen das Experiment KATRIN am Karlsruher Institut für Technologie

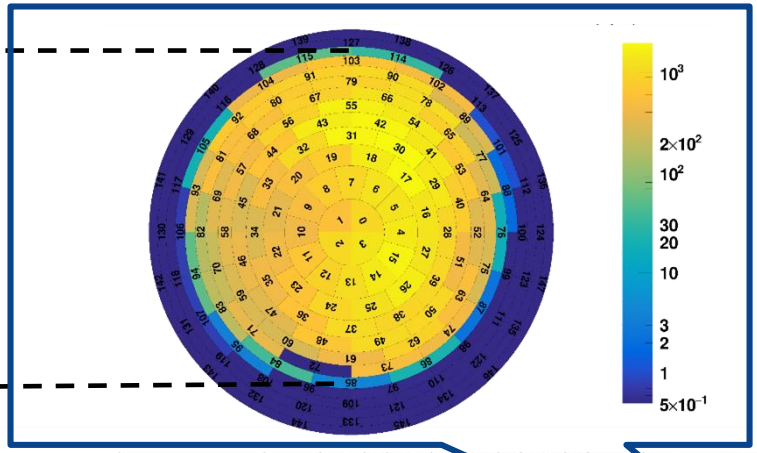
Neutrinos durchdringen uns jede Sekunde milliardenfach, ohne dass wir das Geringste davon bemerken würden. Lange Zeit galten die mysteriösen Teilchen daher als masselos. Seit dem Nachweis von Neutrino-Oszillationen, der im vergangenen Jahr mit dem Physik-Nobelpreis ausgezeichnet wurde, ist aber klar, dass Neutrinos eine geringe Masse besitzen müssen, wie groß sie genau ist, weiß nicht. Diese Frage soll

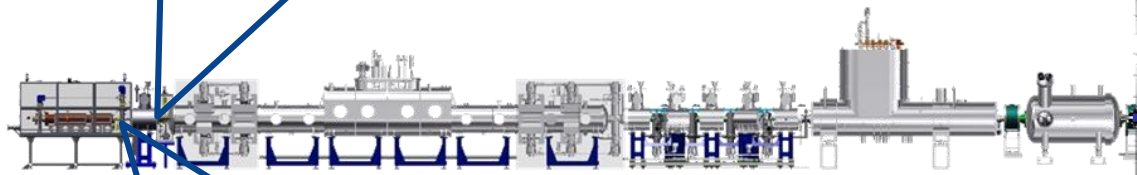
- technical inauguration of KATRIN Oct. 14, 2016

KATRIN – First Light

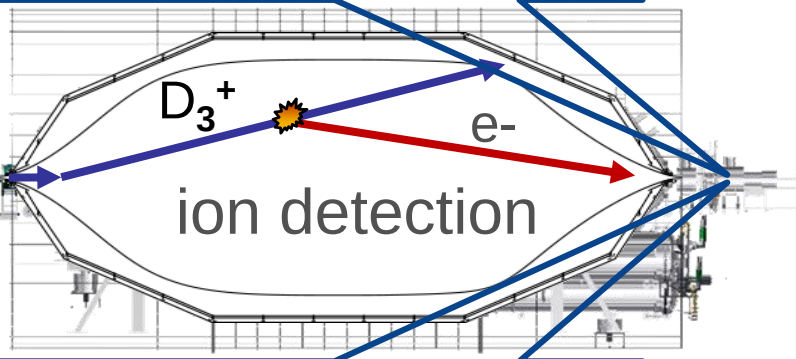


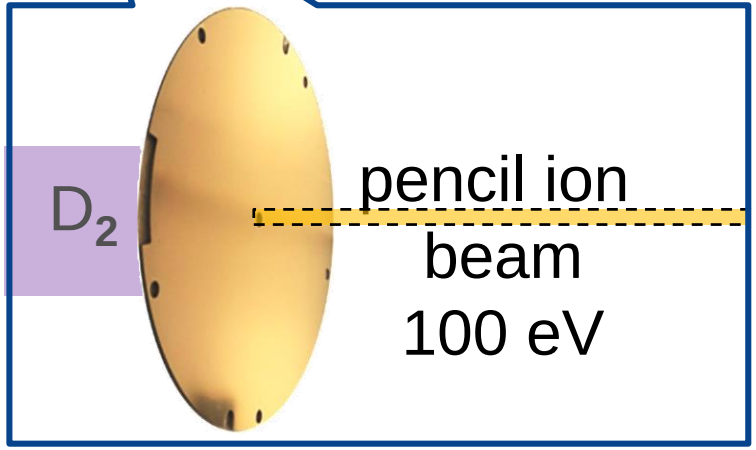
191 T cm²



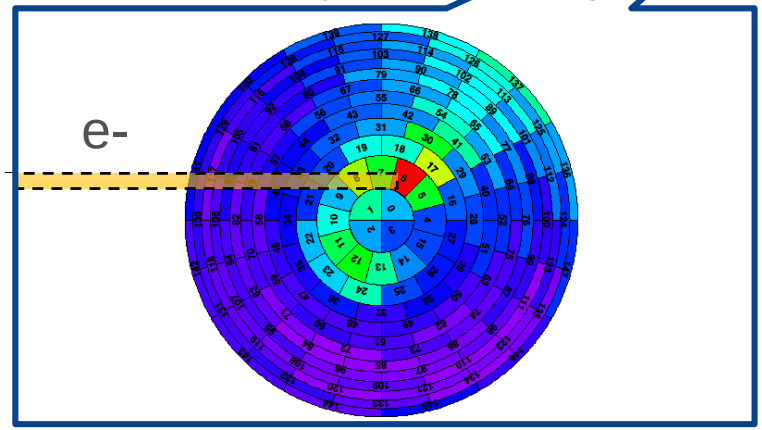


first tritium end of 2017





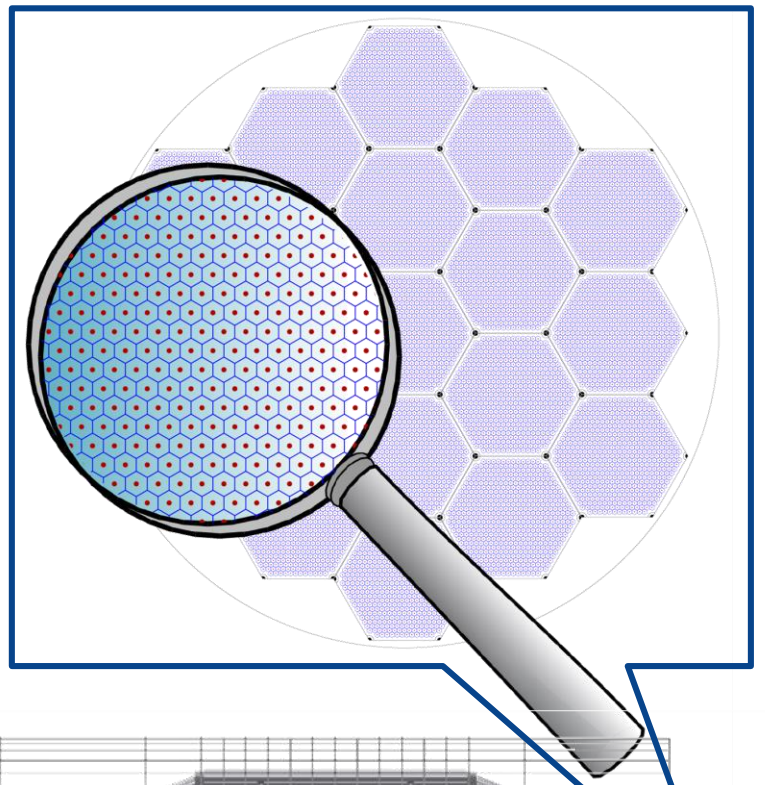
D_3^+

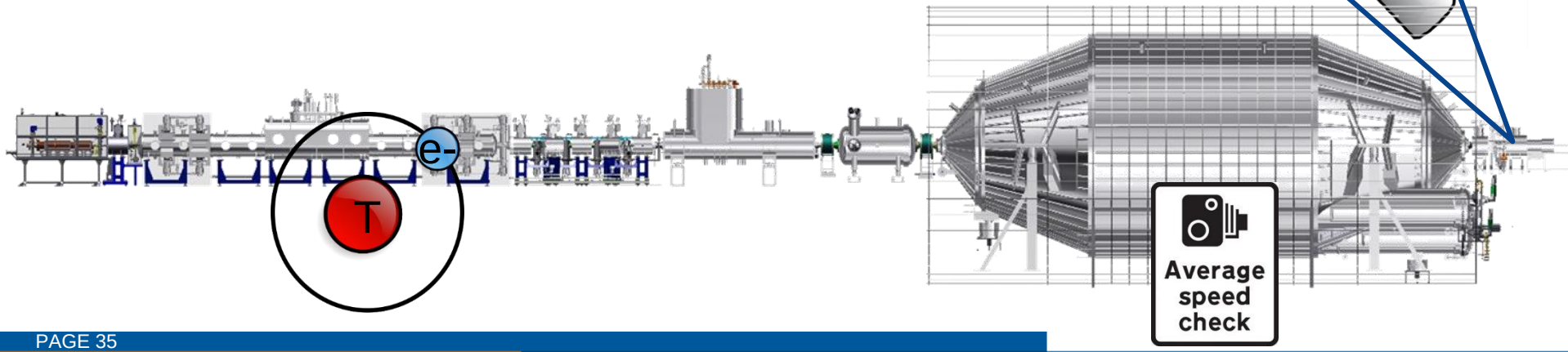


KATRIN – Future

- goal-I: push sensitivity to ~ 0.1 eV
  - differential read-out methods (ToF, others), measure bg-free
  - novel source concepts (atomic T)

- goal-II: cover entire ß-phase space with high-res. Si-array (TRISTAN)
  - search for keV-scale BSM particles (sterile ν´s,…) with mixing ~10^{-6}
  - shape modification via exotic CC

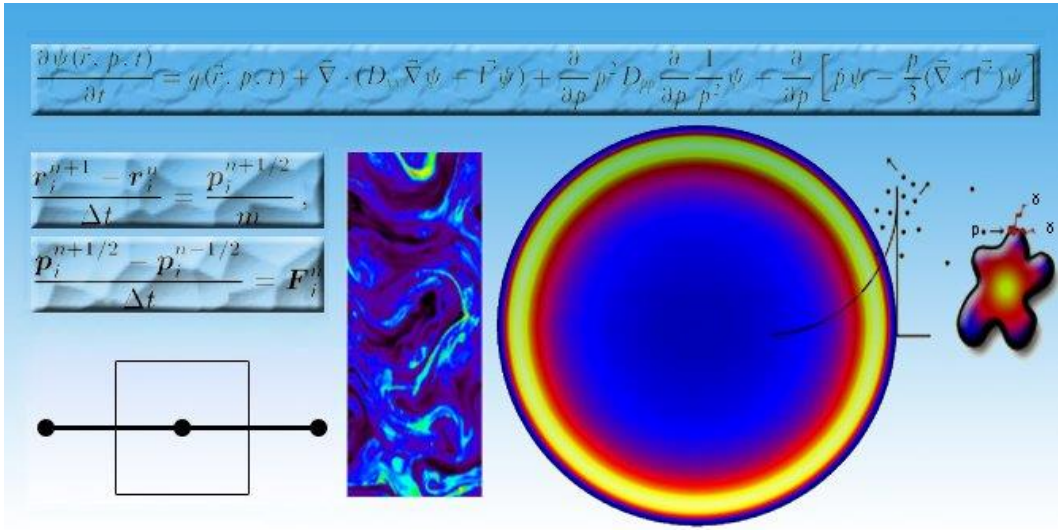




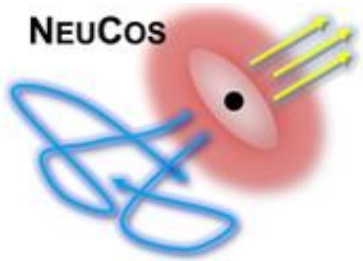
Theoretical Astroparticle Physics - DESY

High energy astrophysics, ν´s, dark matter & cosmology

- theoretical description of particle acceleration in SNR, AGN, GRB,...
- source physics of GRBs & particle propagation
- microphysics of cosmic plasmas
- neutrino physics: flavour oscillations, NEUCOS (neutrinos & the origin of cosmic rays)



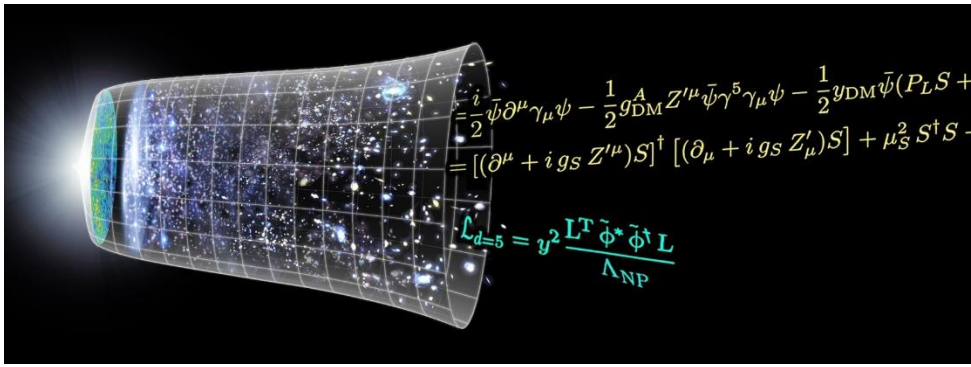
speaker: Martin Pohl



Theoretical Astroparticle Physics - KIT

phenomenology in neutrino and dark matter physics

- global analysis of neutrino oscillation data
  www.nu-fit.org
- standard and non-standard neutrino properties, sterile neutrinos
- WIMP dark matter: simplified models, direct detection phenomenology
- Axion dark matter: cosmological signatures



www.nu-fit.org

group leader: Thomas Schwetz-Mangold

Time Schedule of Major Projects

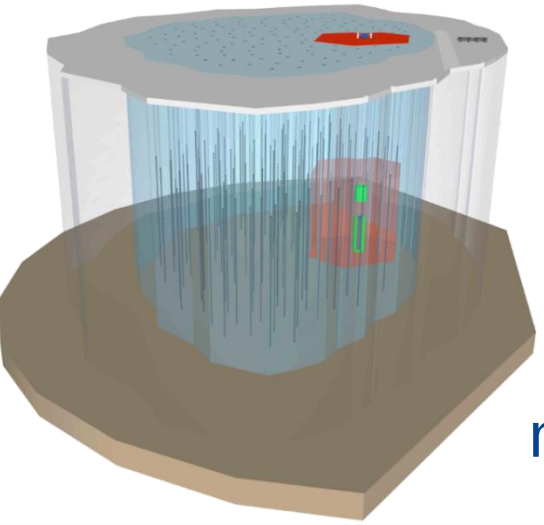
- very rough time schedule as input to develop a strategy beyond PoF-3

PoF-3 | PoF-4

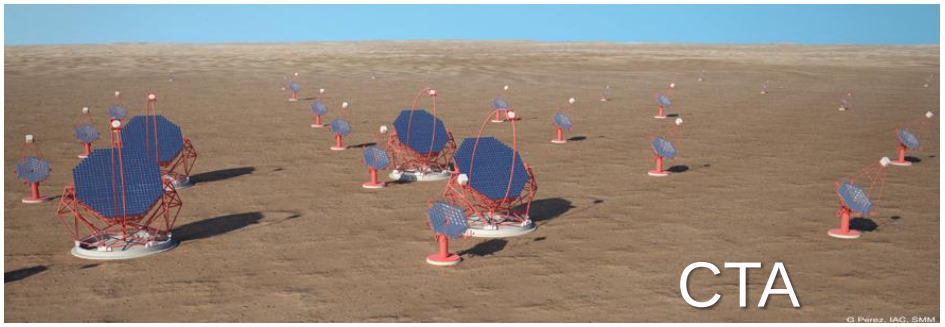
Project	HGF	2017	2018	2019	2020	2021	2022	2023	2024	2025
AugerPrime	KIT	construction		operation						
IceCube-Gen-2	DESY/KIT	preparation (R&D)			construction				operation	
CTA	DESY	construction				operation				
KATRIN	KIT	D2 →T2	operation (integral scan)					install	oper. (diff.)	
DARWIN	KIT				preparation (R&D)					const.

evaluation(?)

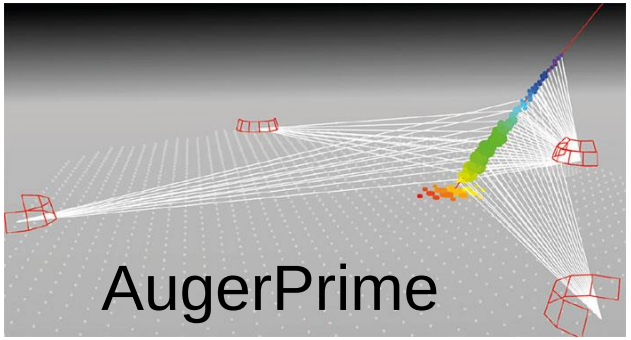
The future – PoF4 and beyond

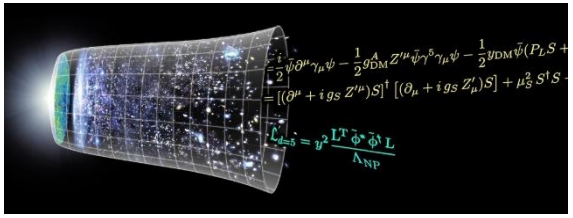


IceCube-Gen2



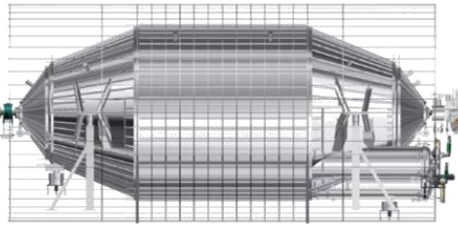
world-class instruments: multi-messenger cosmos, neutrinos & dark matter

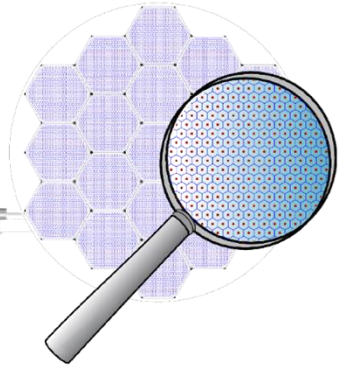




Theory

DARWIN





KATRIN (Tristan)

Thank you