Astroparticle Synergies with Particle Physics

Moderator: Kristi L. Engel

— Panelists —

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Regina Caputo
Tom Shutt
Albrecht Karle
Erin O’Sullivan
Jörg Hörandel
John Krizmanic
Bangalore Sathyaprakesh

Pat Harding

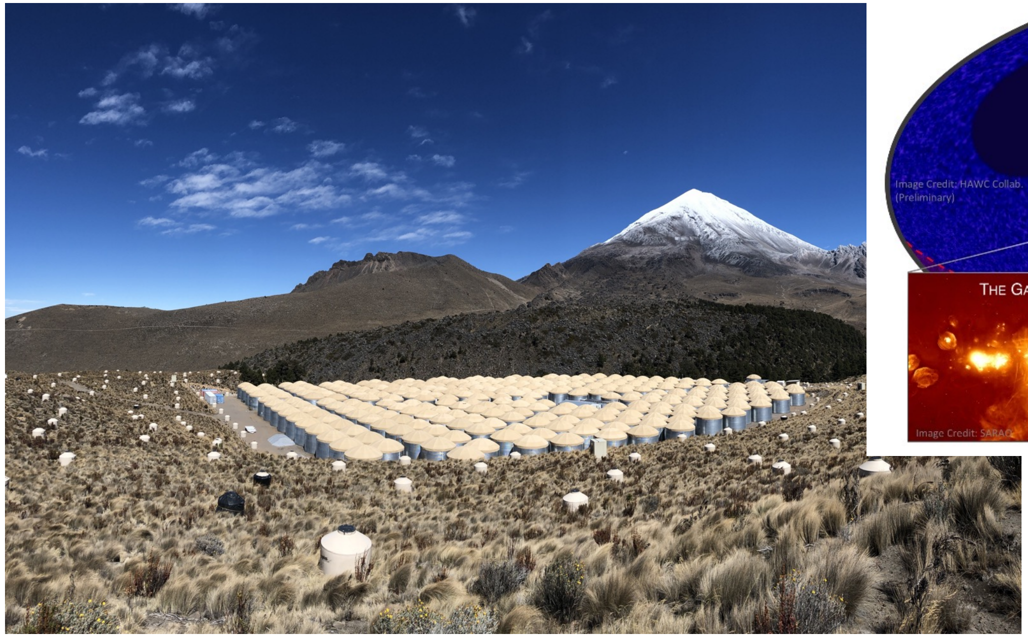
- TeV Astrophysics Observatories, Indirect Dark Matter Detection
- Collaboration Board Chair, High Altitude Water Cherenkov (HAWC) Collaboration
- US Lead, Southern Wide-Field Gamma-Ray Observatory (SWGO)

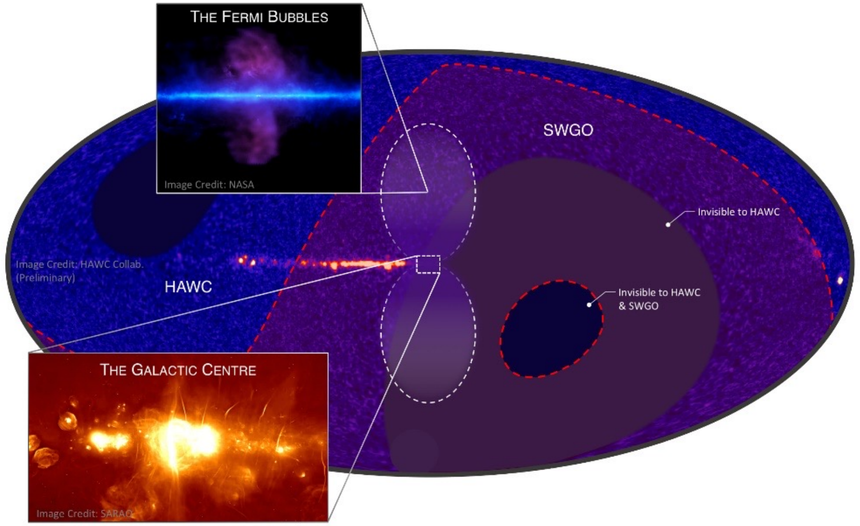
These Huge Beer Keg Tanks Will Study Cosmic Explosions

Share

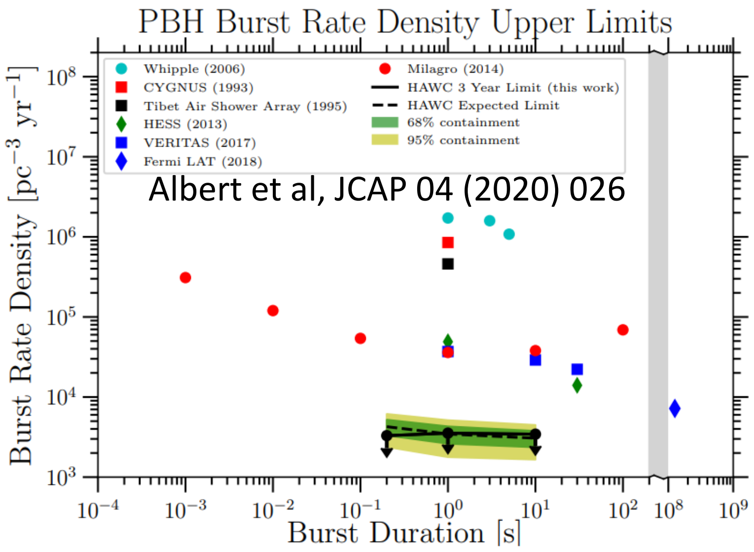
Attila Nagy

Published 7 years ago: March 24, 2015 at 3:30 pm - Filed to: HAWC

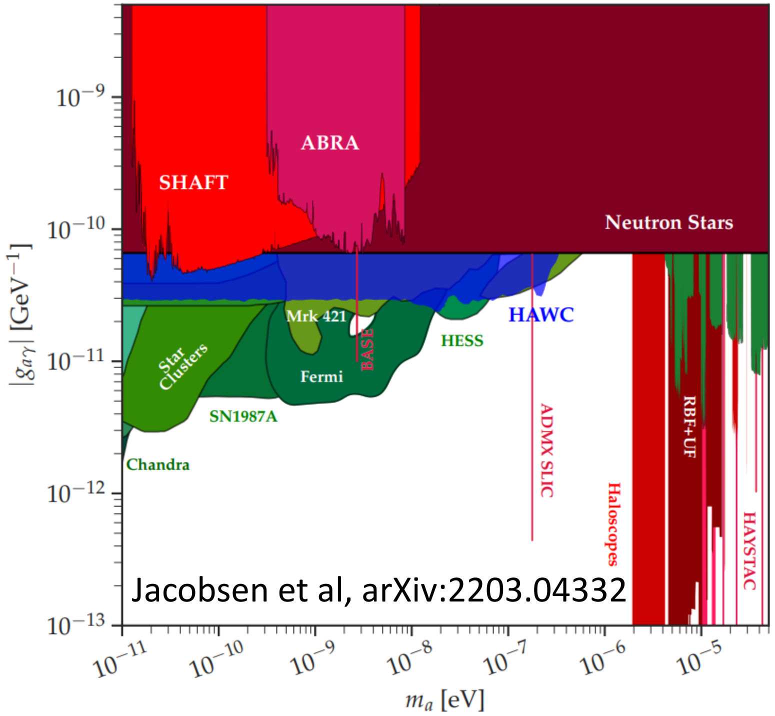




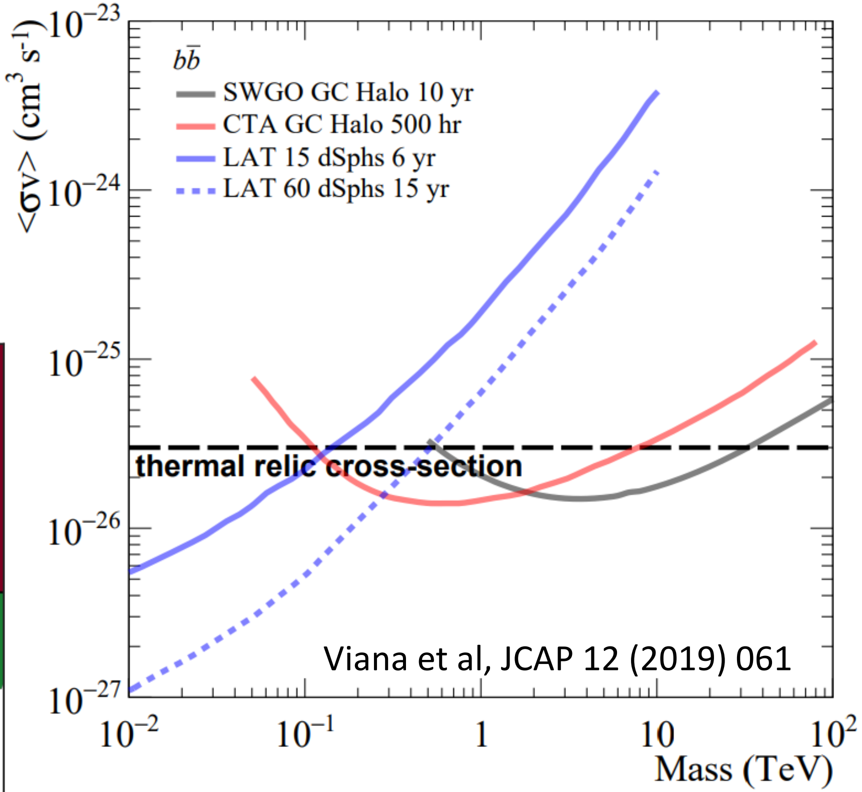
BSM Science with TeV Gamma-rays



Albert et al, JCAP 04 (2020) 026

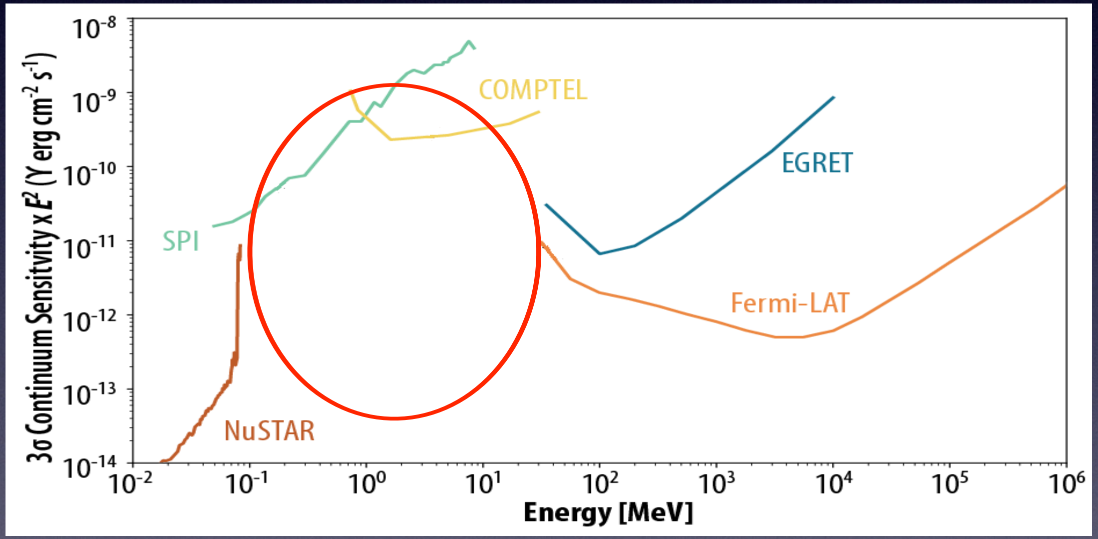


Jacobsen et al, arXiv:2203.04332



Viana et al, JCAP 12 (2019) 061

Why MeV Gamma ray observations?

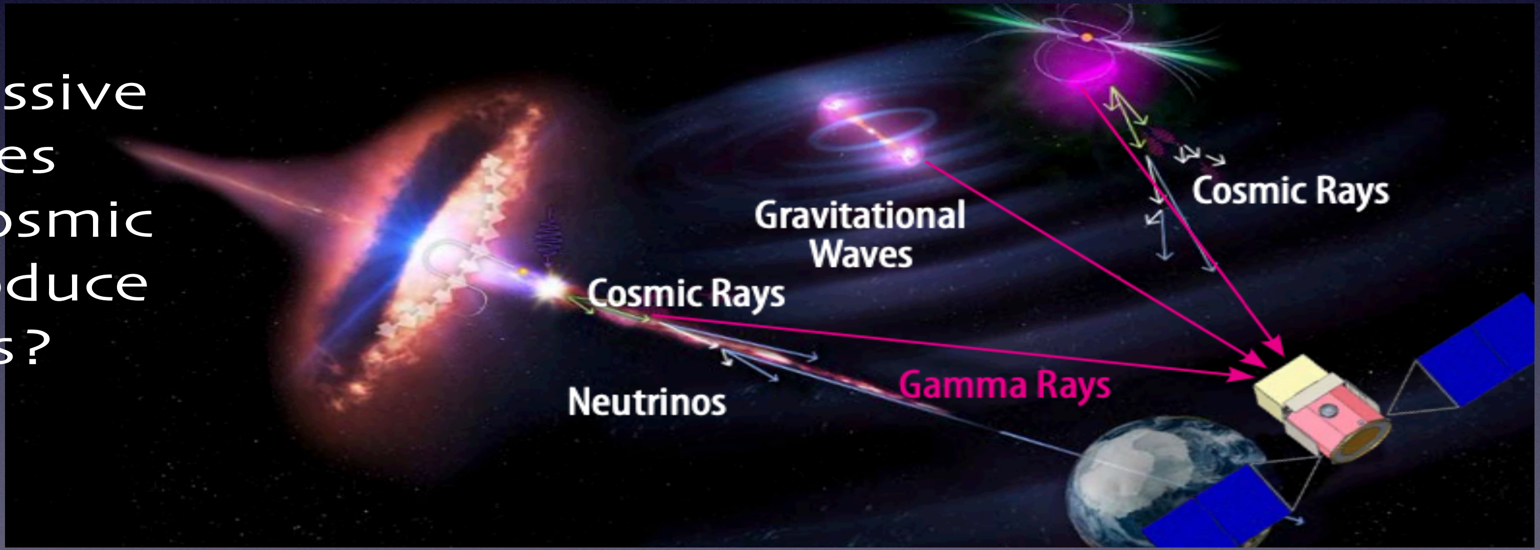


The next revolution will come with observations of the MeV sky

Why MeV Gamma ray observations?

The next revolution: multimessenger astrophysics.
Perfect synergies with particle physics

Do supermassive black holes accelerate cosmic rays and produce neutrinos?

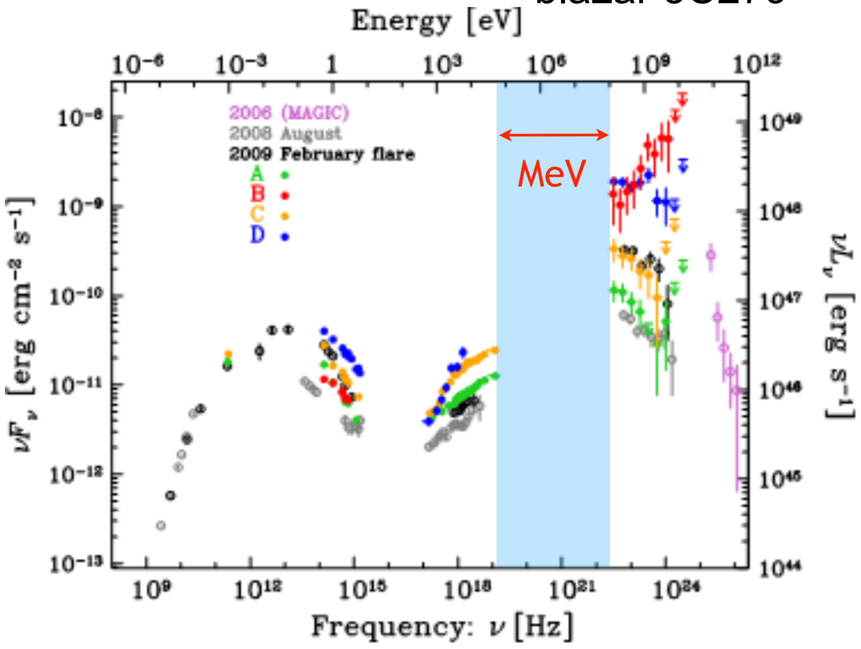


Where are cosmic rays accelerated in the Galaxy?

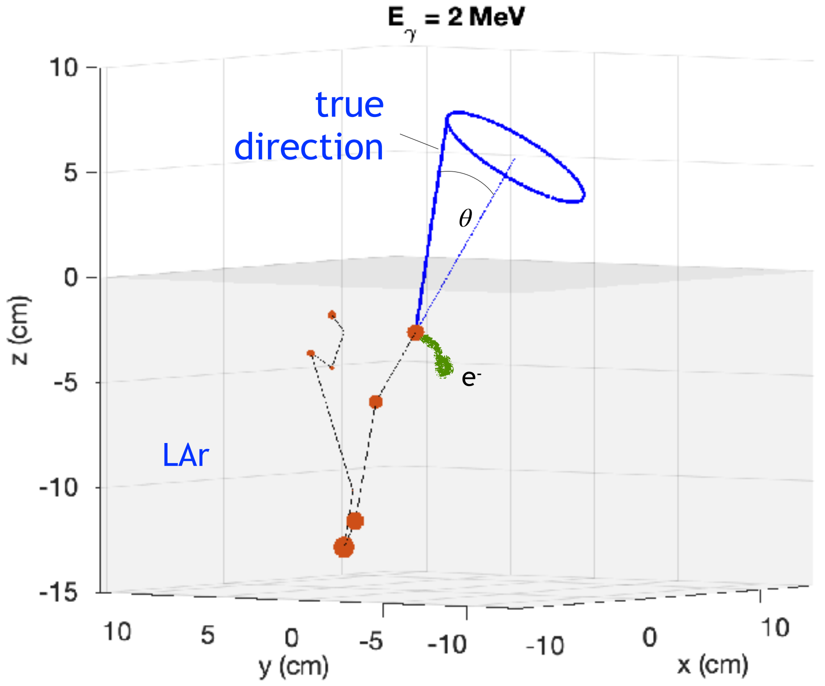
How do binary neutron star mergers produce relativistic jets and what is the structure of those jets?

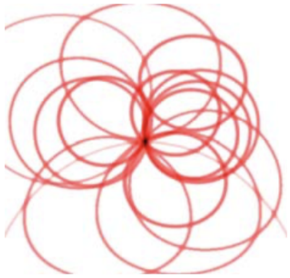
Astrophysical MeV Gamma Rays

blazar 3C279



Compton Telescope





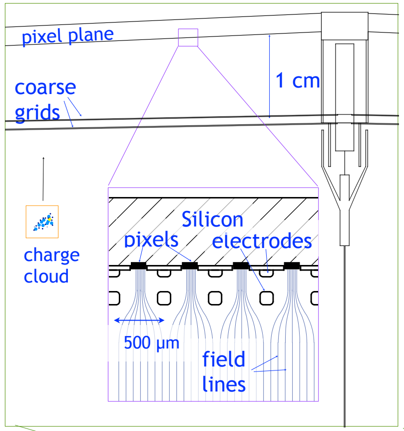
e^- track direction unmeasured

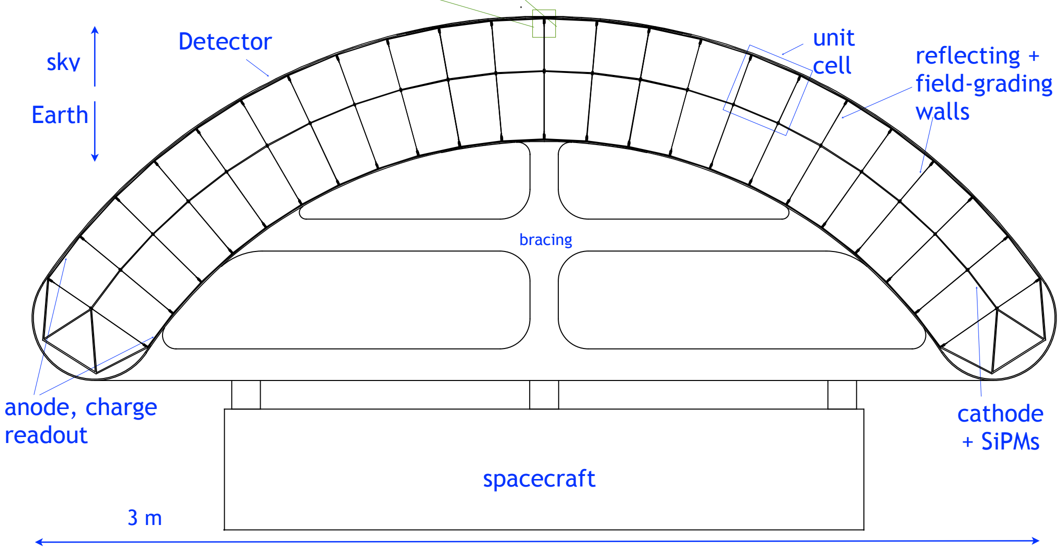
e^- track measured

- MeV gamma ray sky largely unexplored. Sub GeV DM, BH DM, AGNs, NS mergers, supernovae
- Powerful multi-messenger probe
- Challenge is measuring multiple interactions in fine detail over large volume

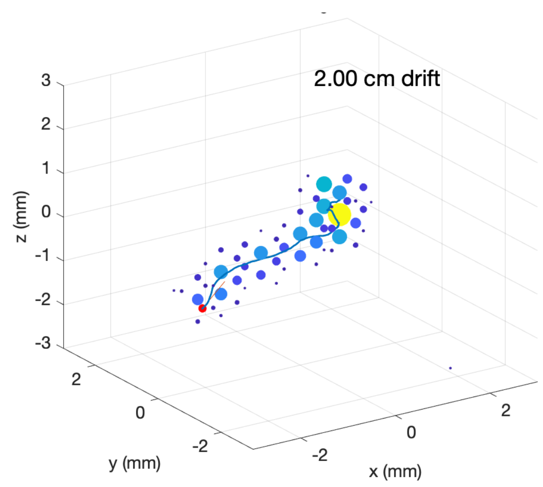
GammaTPC

Dual Scale Charge Readout

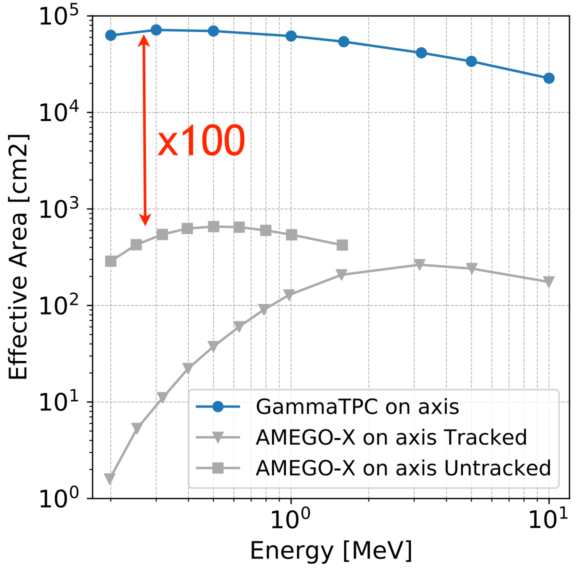




1MeV electron recoil track



- LAr TPC
- 10 m², ~4 ton configuration shown.
- Target MIDEX scale: Falcon 9 launch, identifiable hardware costs: ~ few $10M
- Significant development needed
- Good pointing, energy resolution
- Very high sensitivity
- Strong synergy with DUNE technology
- Opens major window in sky

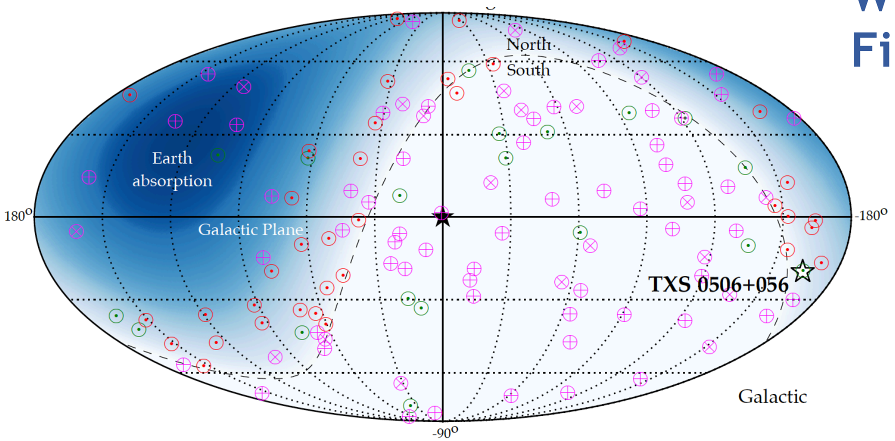


X

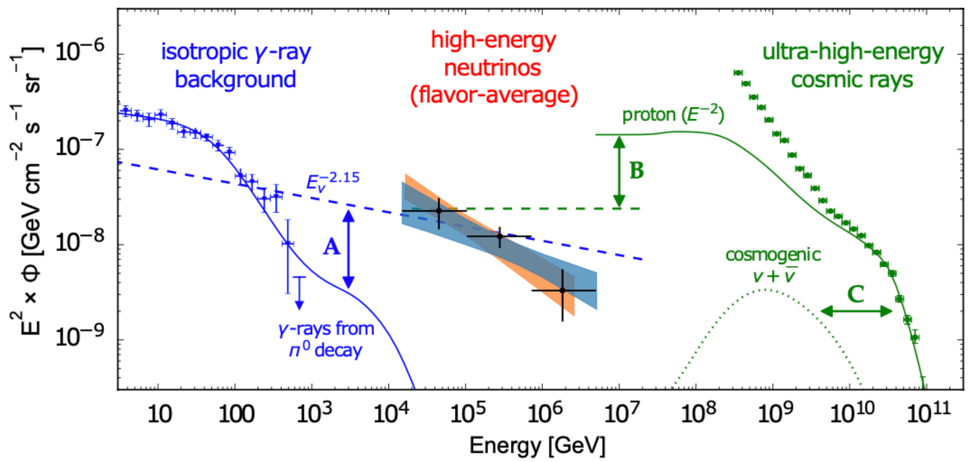
10 years of IceCube: The high energy neutrino sky

x

What are the sources of IceCube's high energy neutrinos?
First evidence: Particle accelerators powered by black holes.



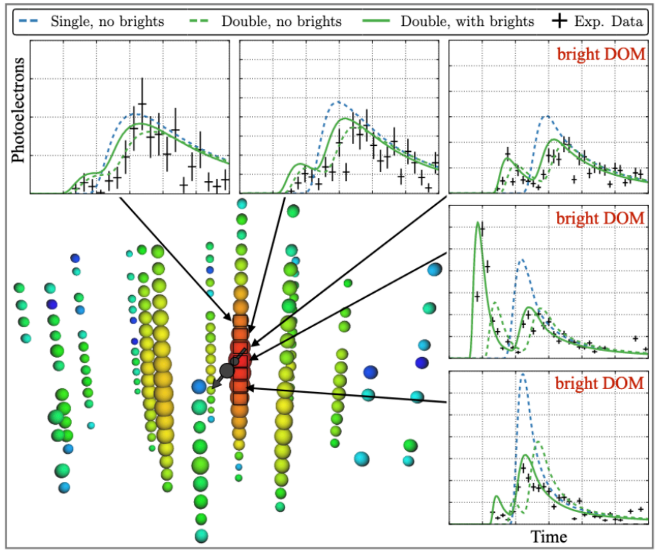
What's in there from a particle physics perspective?



An cosmic neutrino beam closely linked to gamma rays and cosmic rays.

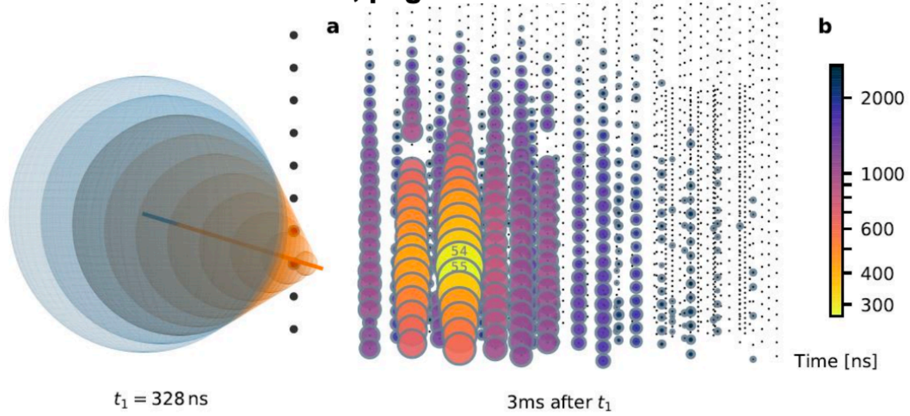
A 200 TeV tau neutrino

arxiv:2011.03561

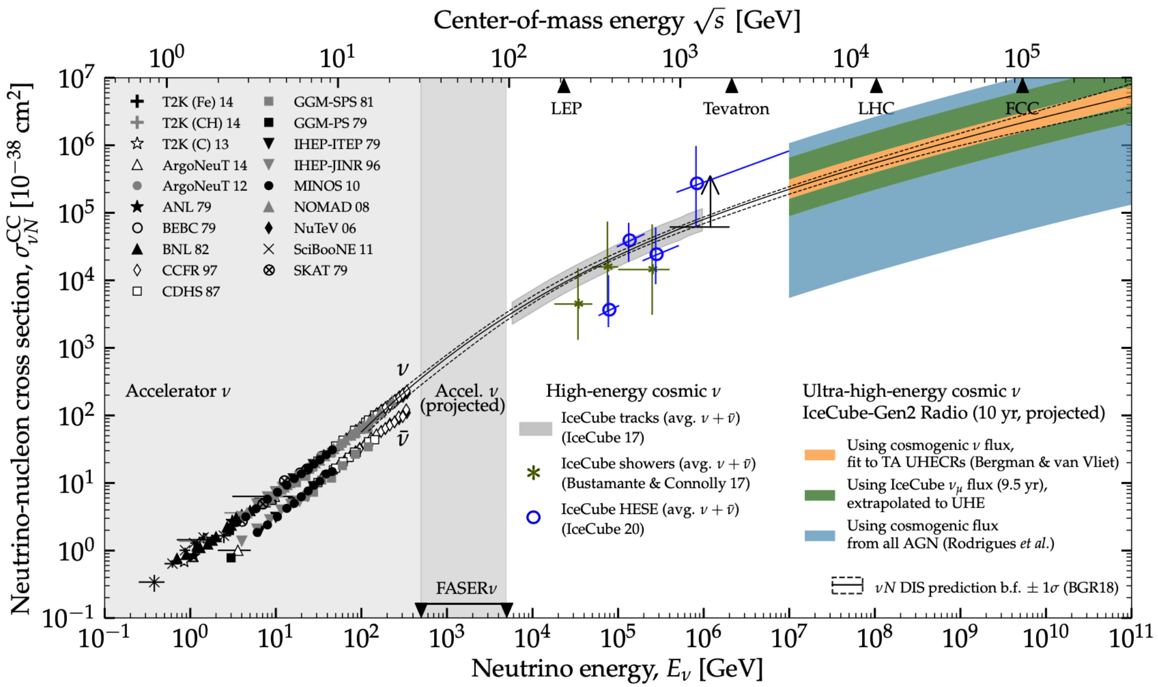


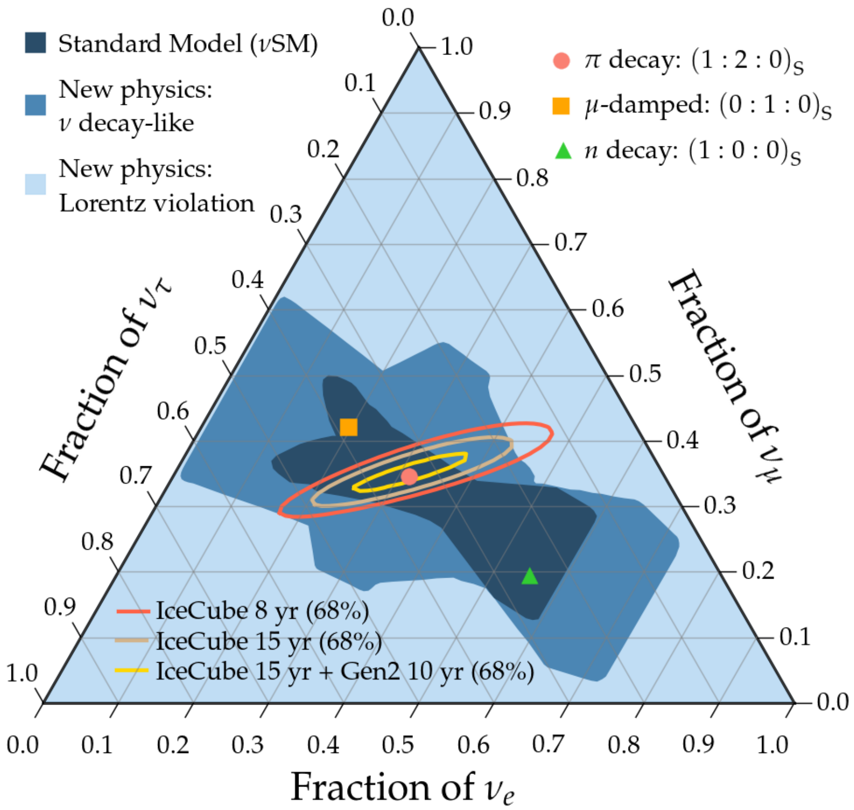
A 6 PeV electron antineutrino

"Detection of a particle shower at the Glashow resonance with IceCube". **Nature. Vol. 591, pages220–224.**



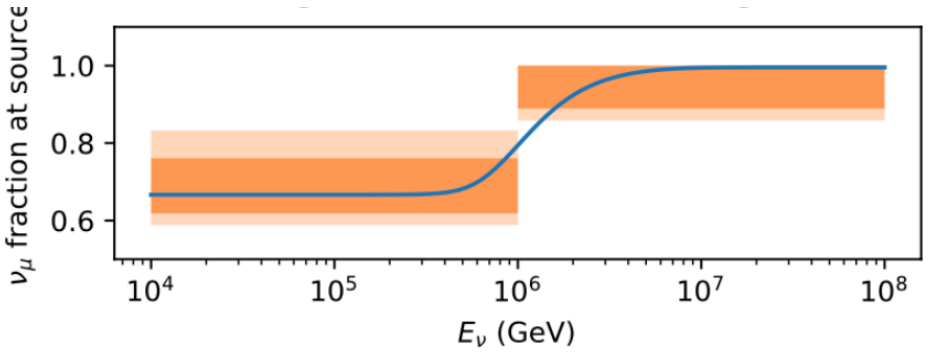
High energy detectors of next generation: explore energy scales beyond the reach of accelerators





Use Earth to measure the cross section at highest energies

arxiv:2203.08096 (CF7)

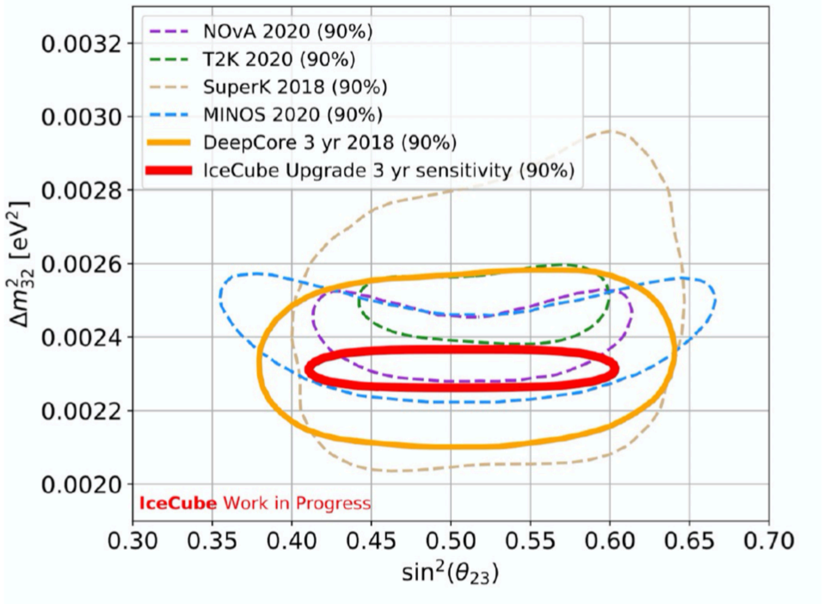


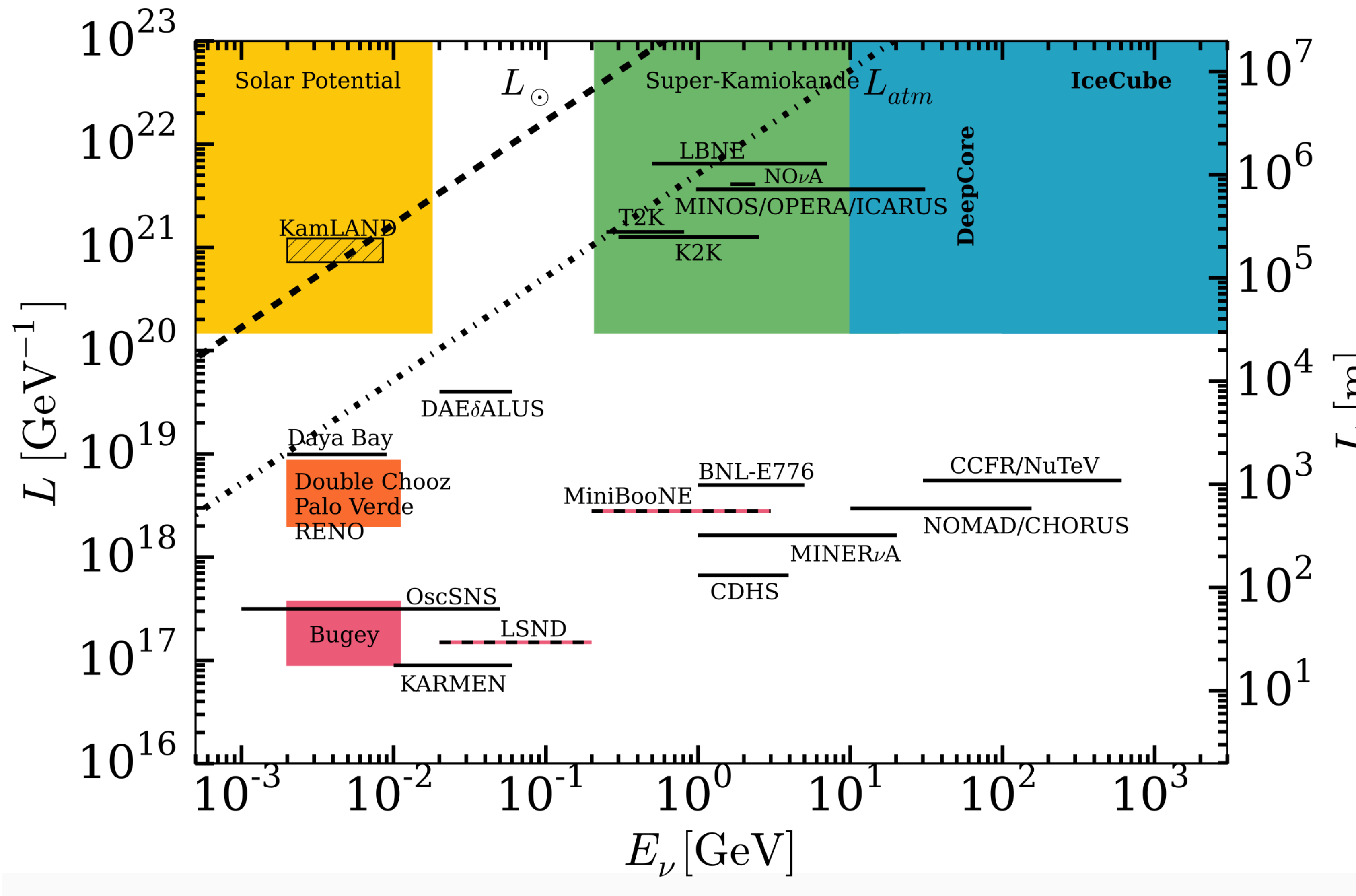
BSM physics
Indirect dark matter

At lower energies:
Neutrino properties - atmospheric

Use 200,000 atmospheric neutrinos, 7000 nu_taus atmospheric neutrinos (10 yrs IceCube) to measure neutrino properties with extreme statistics,
incl. nonstandard interaction.

IceCube Upgrade sensitivity
(run start: 2026)

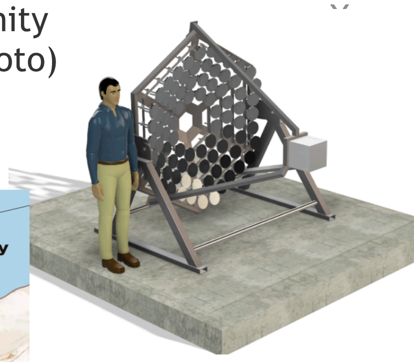


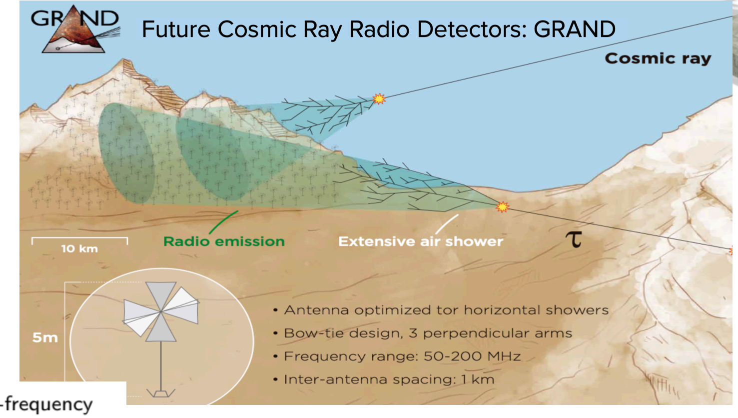


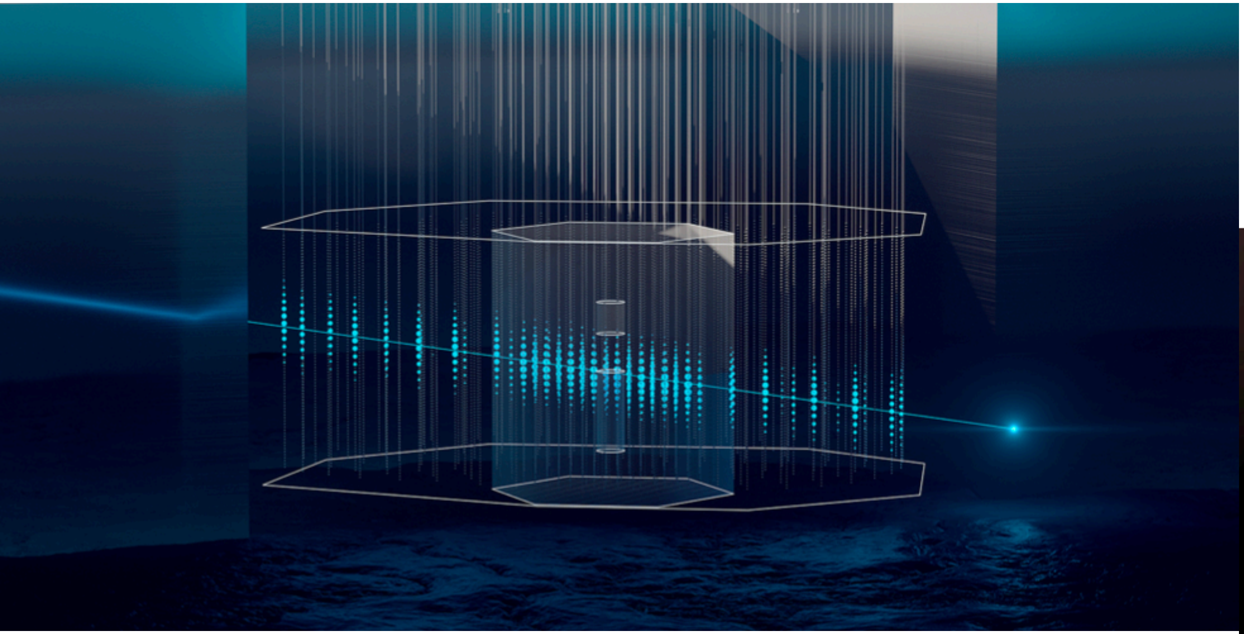
Beam source: cosmic

Detectors:
Targets: air and ice
Energy range: 5 GeV to 100 EeV

Trinity (proto)





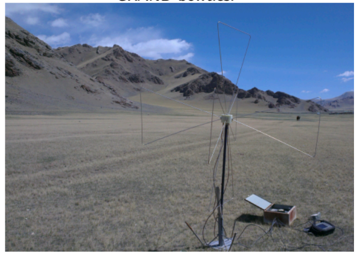


- **IceCube-Gen2 reference design:**
  - Optical array (8km^3)
  - Air shower array on top
  - Radio array

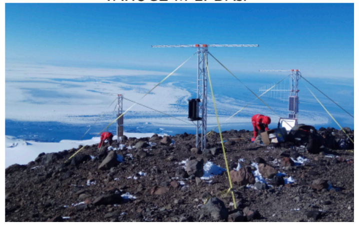
PUEO, including low-frequency dropdowns:

EACON short crossed-dipoles

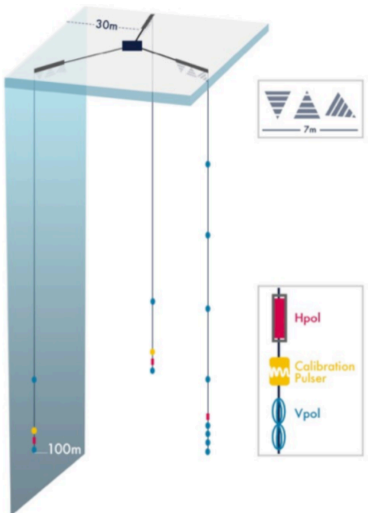
GRAND bowties:



TAROGE-M LPDAs:



RNO-G



Particle physics

Deficit of neutrinos (oscillations)

Proton decay experiments are sensitive to astrophysics

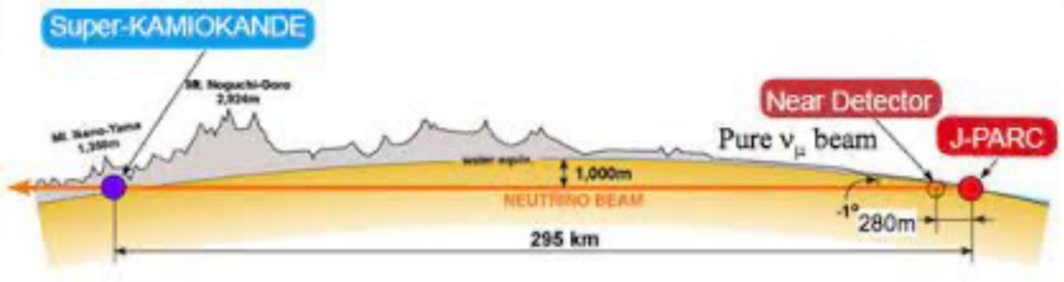
New messenger from the Sun

SN produce burst of neutrinos

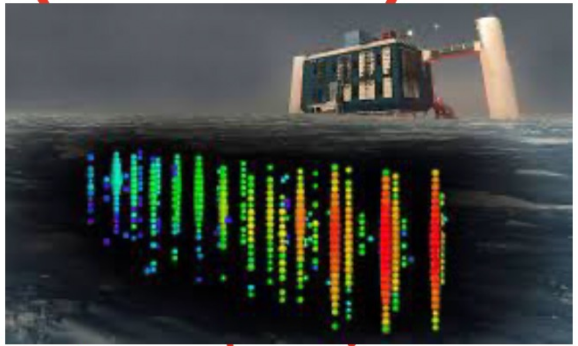
Astrophysics

Particle physics

Neutrino beams, direct mass experiments



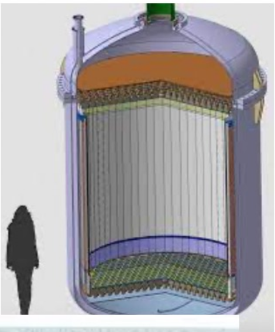
Neutrino telescopes

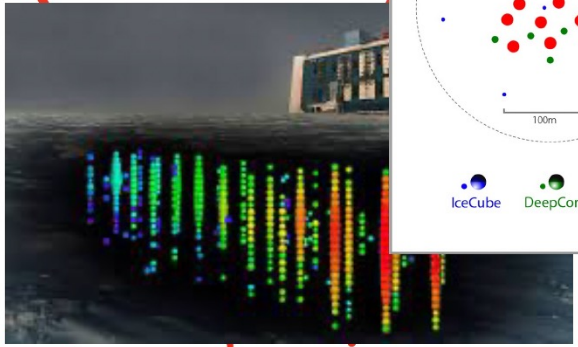


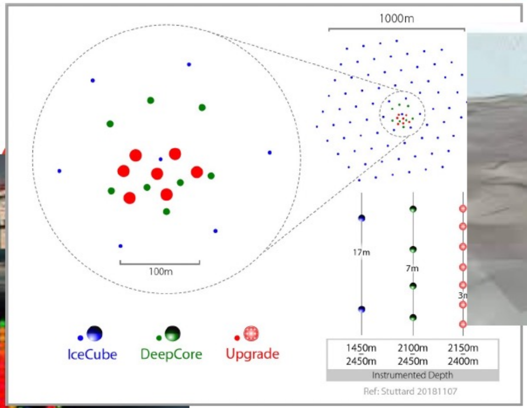
Astrophysics

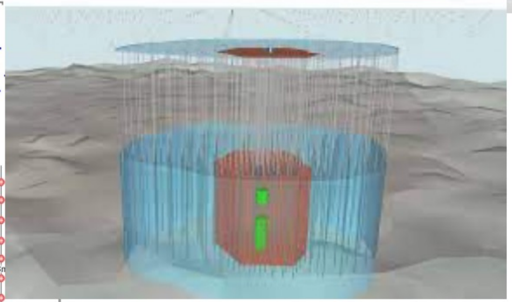
Particle physics

Many future neutrino and dark matter experiments will have sensitivity to astrophysical neutrinos









Astrophysics

Neutrino telescopes make excellent neutrino detectors (DeepCore, Upgrade, flavour physics in IceCube-Gen2)

Ground based measurement of extensive air showers

Physics and origin of particles at extreme energies

protons, nuclei, gamma rays, neutrinos

2.3 Astroparticle Physics

- What are the properties of Standard Model particles and their interactions beyond the reach of terrestrial accelerators?
- Could an enhancement of strangeness production in hadronic collisions be the carrier of the observed muon deficit in air-shower simulations when compared to ultra-high- energy cosmic-ray data? Alternatively, do new particles and interactions exist at the highest energies?
- Do the Lorentz and CPT symmetries that underpin the Standard Model break down in extreme cosmic environments?
- Does the QED domain (extreme magnetic fields) produce exotic particles or dark matter?

2.4 Multimessenger Synergies in Particle Astrophysics

- How are particles accelerated in the cosmos to ultra-high energies? Is the cosmic ray maximum energy a fingerprint of physics beyond the Standard Model?
- What role do hadrons play in the extreme-energy Universe?

Ground based measurement of extensive air showers

Experimental facilities

Telescope Array

2800 km² (USA)
Ground array (scintillators)
Fluorescence telescopes

Pierre Auger Observatory

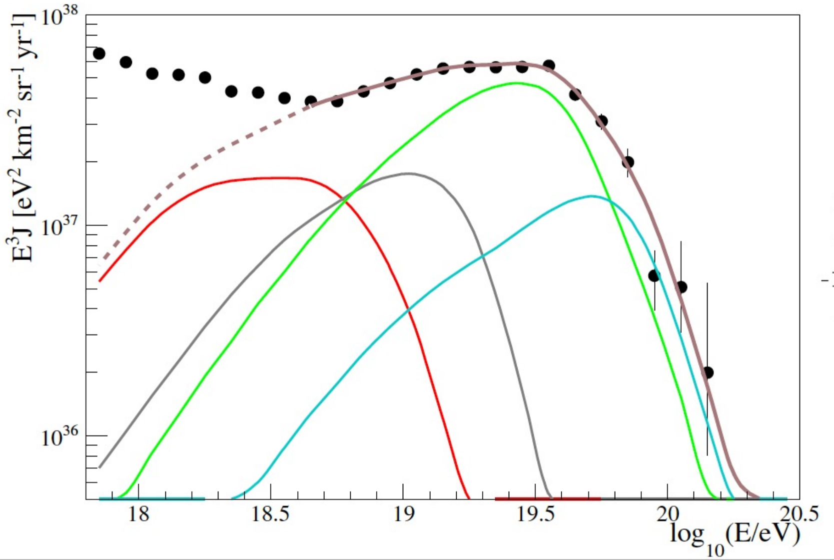
3000 km² (Argentina)
Ground array (water Cherenkov detectors, scintillators, radio)
Fluorescence telescopes

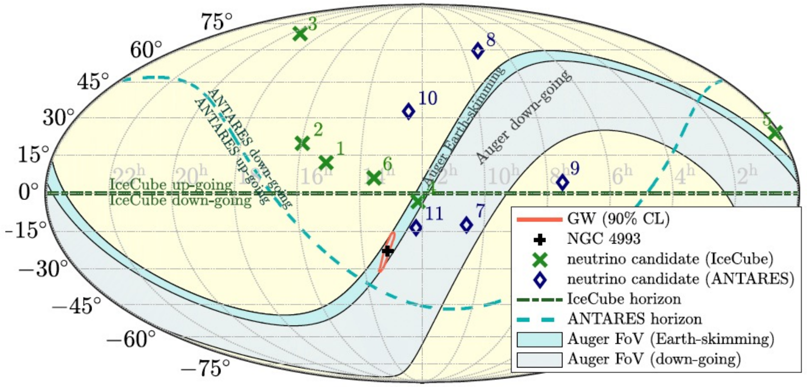
~2035 →

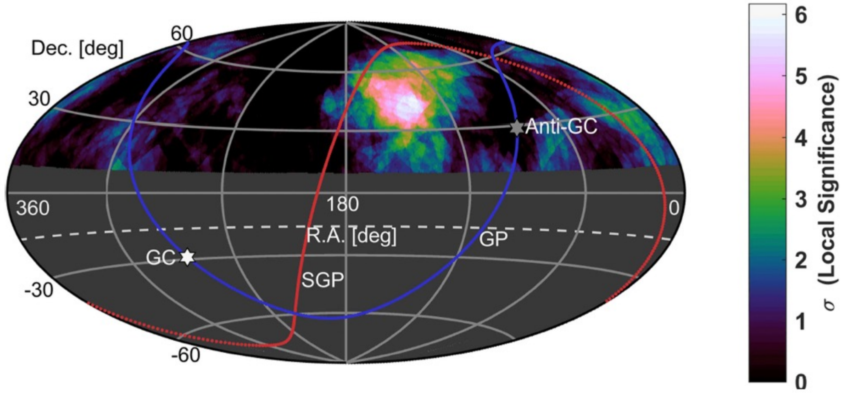
Global Cosmic Ray Observatory - GCOS

2x 30000 km² (northern and southern hemisphere)
Ground array (water Cherenkov detectors, radio)
Fluorescence telescopes

identify energy, type, direction
for each incoming particle
(hadron, gamma ray, neutrino)
with high-precision

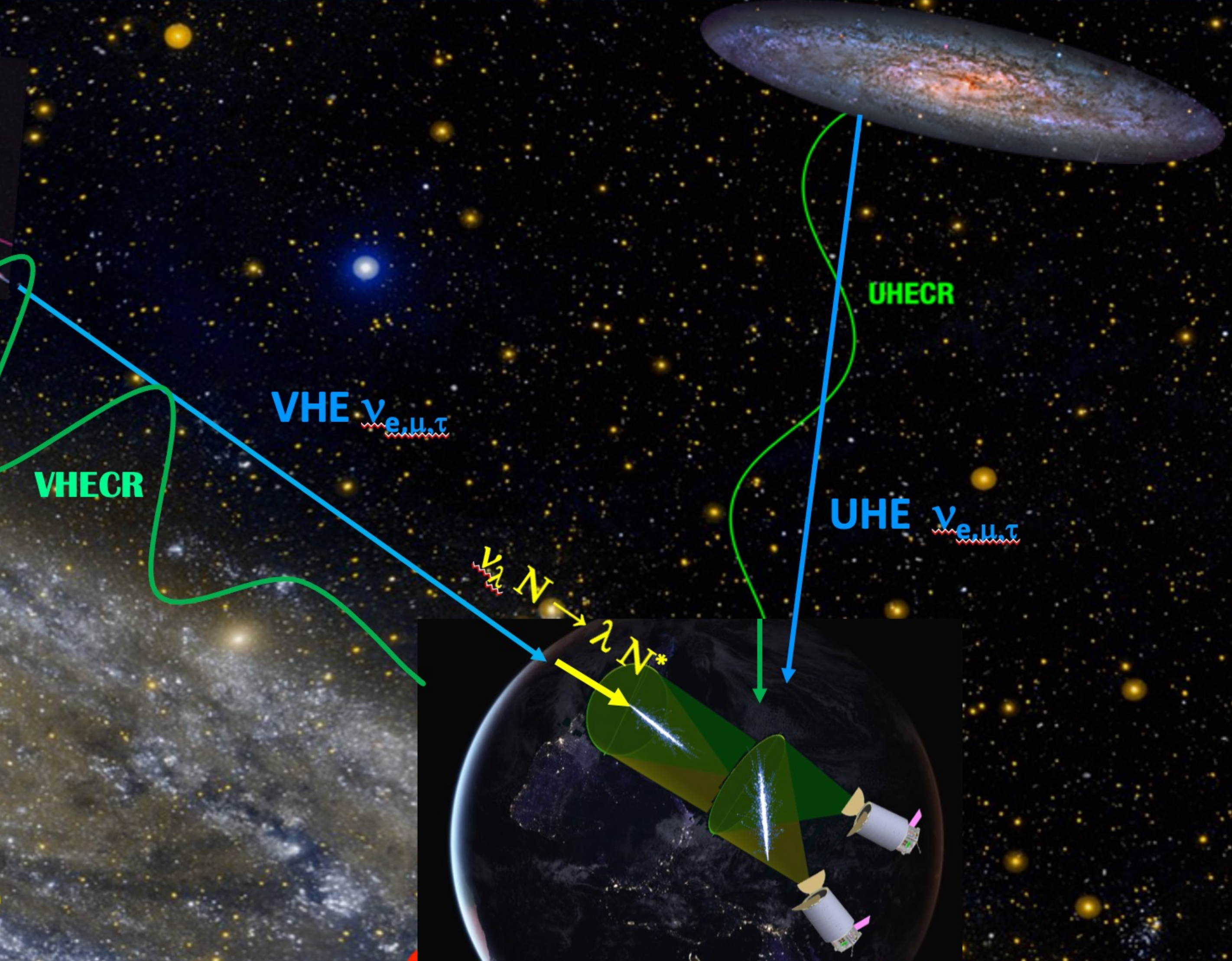






Astrophysics Science Goals:

- Discover the origin of Ultra-High Energy Cosmic Rays and Search for UHE ν's ($\gtrsim$ 10 EeV) via high exposure, precision measurements
- Observe VHE Neutrinos ($\gtrsim$ 10 EeV) from Transient Astrophysical Events via Earth-emerging τ-leptons and muons & EAS Cherenkov light.
- Measure VHECR Cosmic Rays via the above-the-limb EAS Cherenkov light.



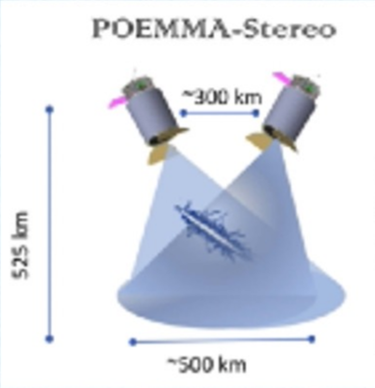
John F. Krizmanic
Laboratory for Astroparticle Physics
NASA/Goddard Space Flight Center

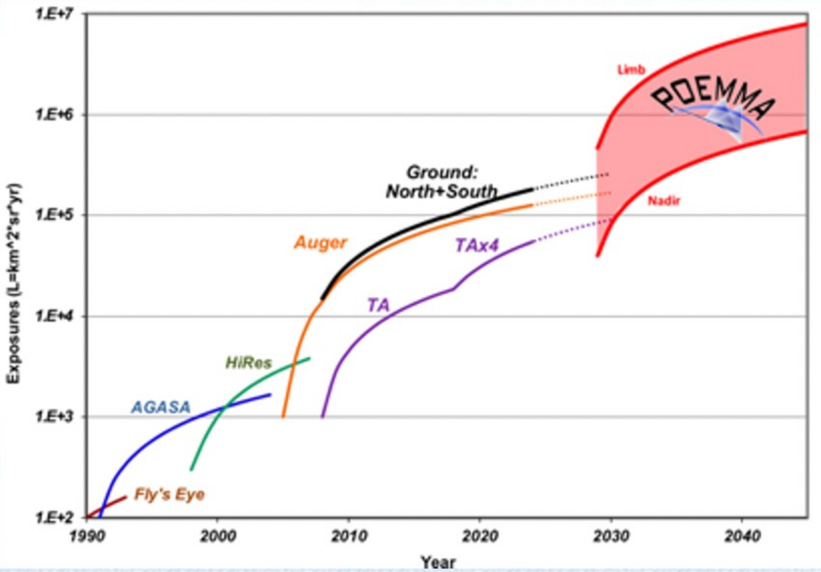
UHECR & UHE ν Astro- & Particle-Physics Symbiosis : *see PhysRevD.101.023012*

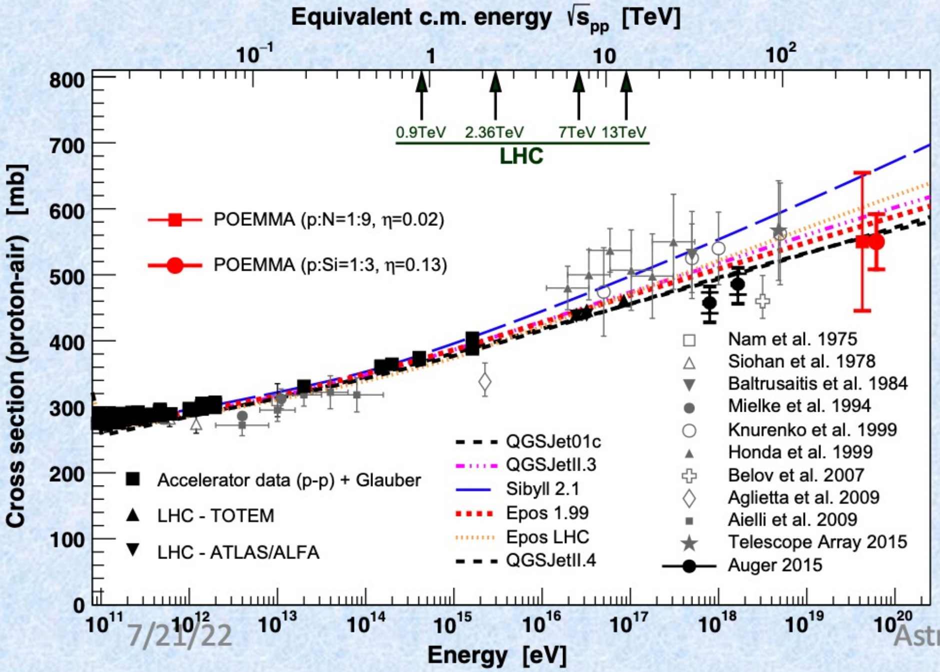
Will use POEMMA performance as an example:

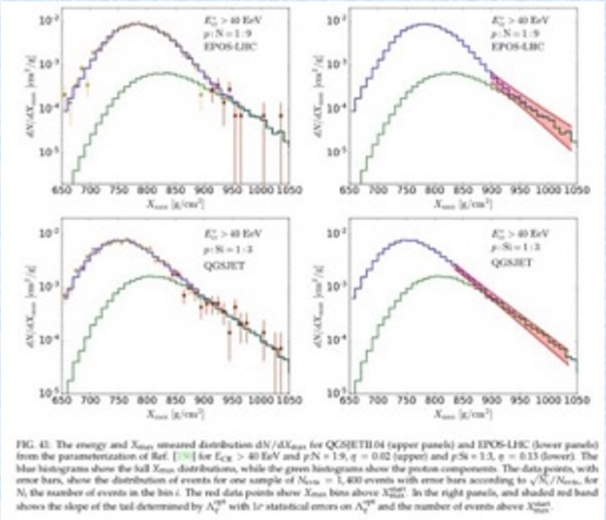
Requires measurement of UHECR composition, spectrum, and full-sky distribution: *stereo fluorescence*
→UHE neutrino sensitivity.
This coupled with the needed exposure to explore the end of the CR spectrum allows for HEP approaching √s ≈ 450 TeV @ 100 EeV :

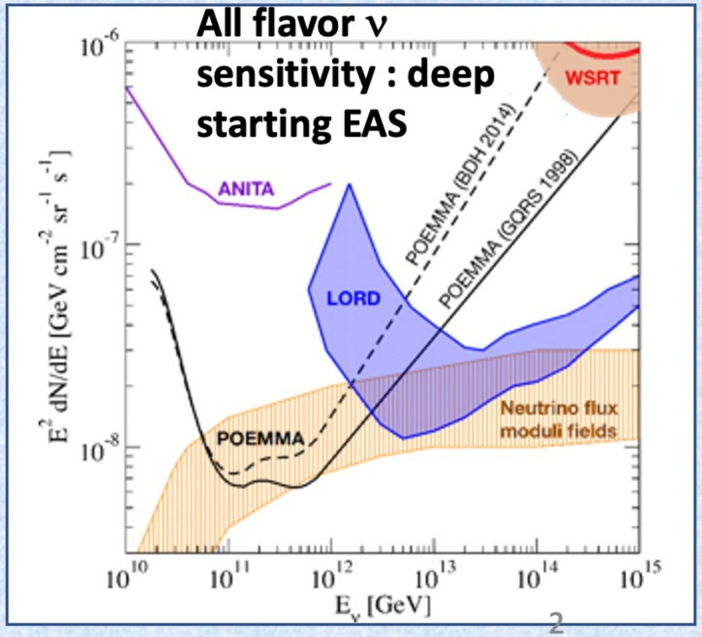
p-Air and UHE ν cross sections …



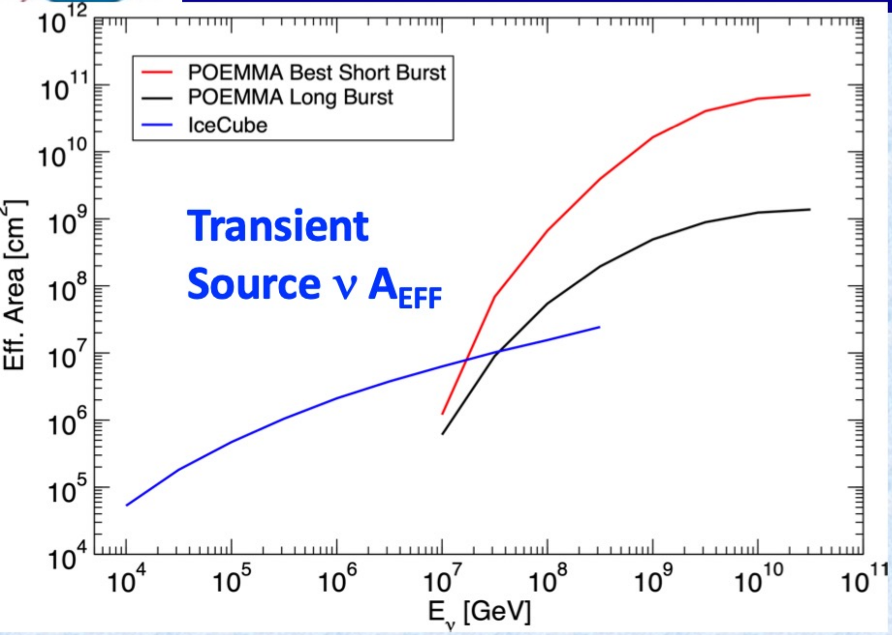


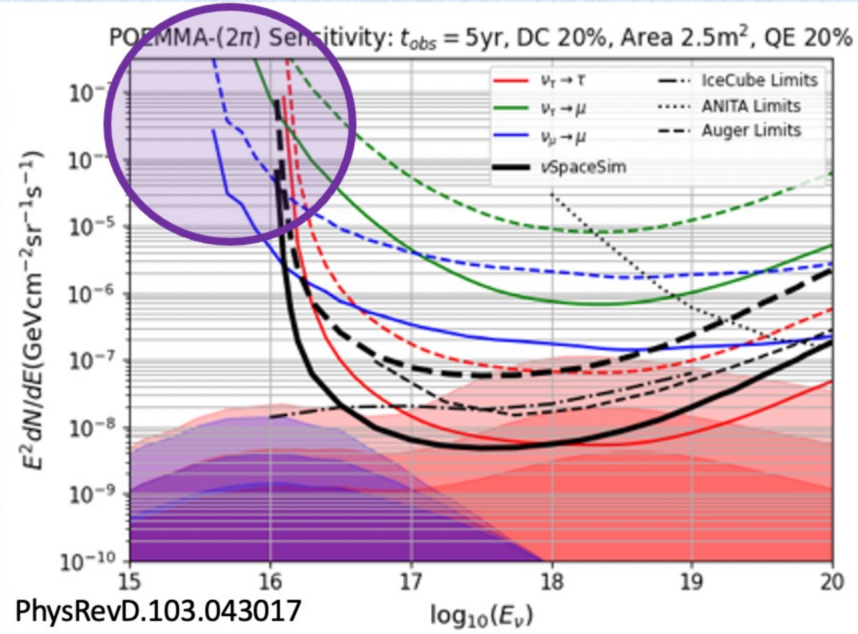






VHE ν Astro- & Particle-Physics Symbiosis : *see reference page*

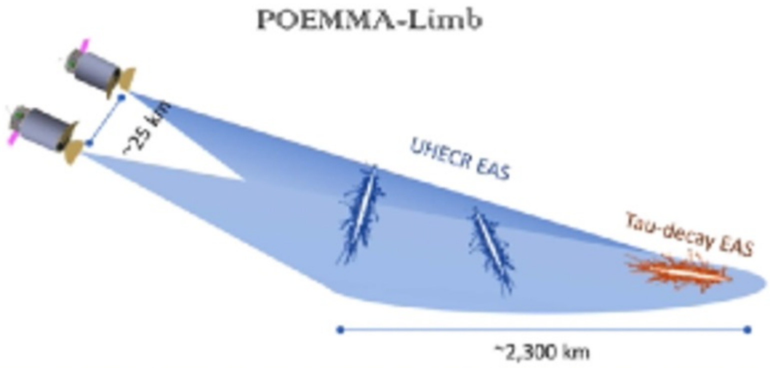


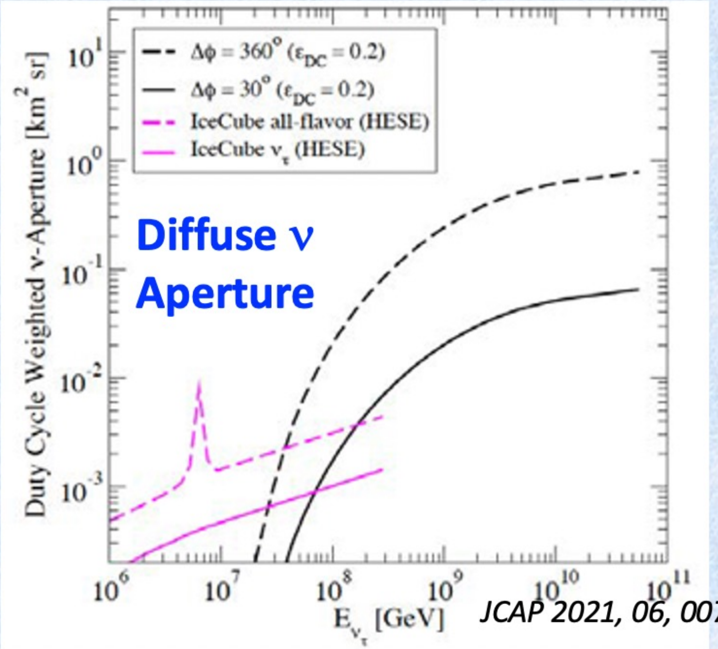


PhysRevD.103.043017

Neutrino Flavor 'filter'

EAS from Earth-emergent muons dominant below 10 PeV





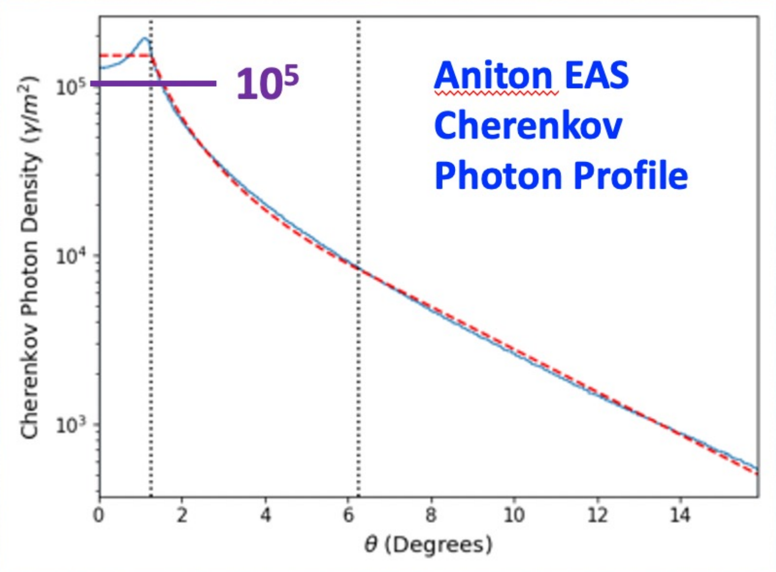
JCAP 2021, 06, 007

TABLE I: *ANITA-I,-III anomalous upward air showers.*

event, flight	3985267, ANITA-I	15717147, ANITA-III
date, time	2006-12-28,00:33:20UTC	2014-12-20,08:33:22.5UTC
Lat., Lon.[(1)]	-82.6559, 17.2842	-81.39856, 129.01626
Altitude	2.56 km	2.75 km
Ice depth	3.53 km	3.22 km
El., Az.	$-27.4\pm0.3°, 159.62\pm0.7°$	$-35.0\pm0.3°, 61.41\pm0.7°$
RA, Dec[(2)]	282.14064, +20.33043	50.78203, +38.65498
$E_{shower}^{(3)}$	0.6 ± 0.4 EeV	$0.56^{+0.3}_{-0.2}$ EeV

[1] Latitude, Longitude of the estimated ground position of the event.
[2] Sky coordinates projected from event arrival angles at ANITA.
[3] For upward shower initiation at or near ice surface.

arXiv:1803.05088v1



Sensitivity to ν and photons from SHDM decay/annihiliation

Photon Channel

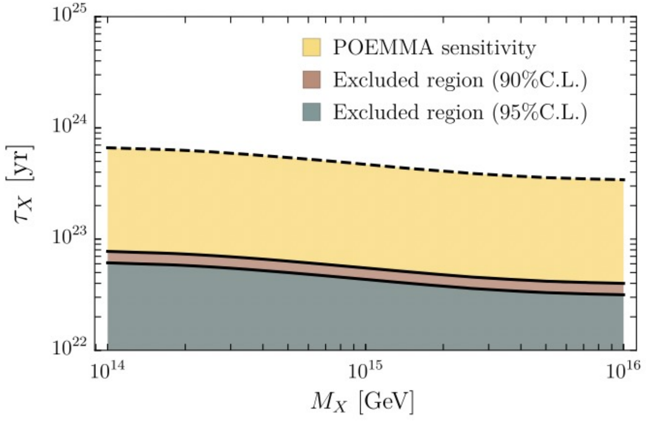


FIG. 27. Lower limit on the lifetime of SHDM particles together with the sensitivity (defined as the observation of one photon event above $10^{11.3}$ GeV in 5 years of data collection) of POEMMA operating in stereo mode [122].

PhysRevD.101.023012

CLAIRE GUÉPIN *et al.* PHYS. REV. D **104,** 083002 (2021)

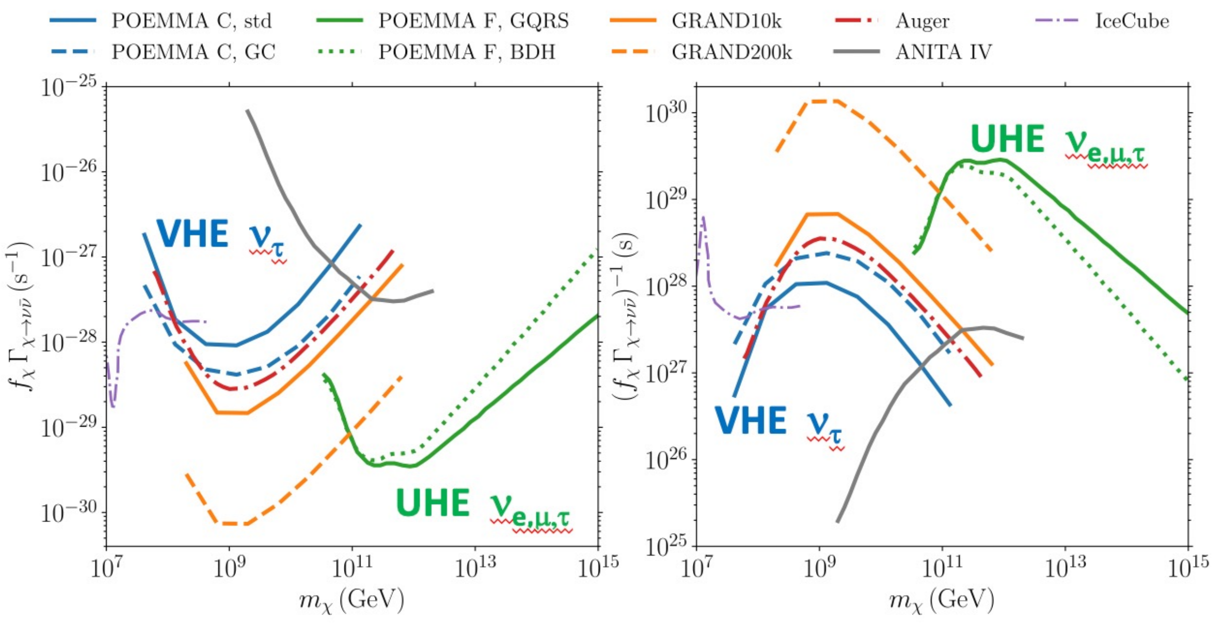


FIG. 4. Sensitivities to dark matter decay width (left) and inverse of the decay width (right), $\nu\bar{\nu}$ channel. Five-year sensitivities of POEMMA for the Cherenkov standard [(std), solid blue] and Galactic Center [(GC), dashed blue], and the fluorescence (green) observation modes, GRAND10k (solid orange), and GRAND200k (dashed orange). Sensitivities of ANITA IV (gray), Auger (dot-dashed red), and the IceCube [84] (dot-dashed purple). Allowed regions are below (above) the curves in the left (right) figure.

Other DM Related papers

1. L. A. Anchordoqui, M. E. Bertaina, M. Casolino, J. Eser, J.F. Krizmanic, A.V. Olinto, A.N. Otte, T.C. Paul, L.W. Piotrowski, M.H. Reno, F. Sarazin, K. Shinozaki, J.F. Soriano, T.M. Venters, L. Wiencke, **Prospects for macroscopic dark matter detection at space-based and suborbital experiments,** Europhysics Letters 135, id.51001, arXiv: 2104.05131
2. M.H. Reno, L. A. Anchordoqui, A. Bhattacharya, A. Cummings, J. Eser, C. Guépin, J.F. Krizmanic, A.V. Olinto, T. Paul, I. Sarcevic, T. M. Venters, ***Neutrino constraints on long-lived heavy dark sector particle decays in the Earth***, PhysRevD.105.055013

UHECR and VHE & UHE neutrino tests of Lorentz Invariance

Community Summer Study
SN WMASS
July 17-26 2022, Seattle
Seattle Snowmass Summer Meeting 2022

arXiv > hep-ph > arXiv:2202.01183

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High Energy Physics – Phenomenology

[Submitted on 2 Feb 2022 (v1), last revised 4 Feb 2022 (this version, v2)]

Testing Lorentz Invariance with Neutrinos

Floyd W. Stecker

The search for a theory that unifies general relativity and quantum theory has focused attention on models of physics at the Planck scale. One possible consequence of models such as string theory may be that Lorentz invariance is not an exact symmetry of nature. We discuss here some possible experimental and observational tests of Lorentz invariance involving neutrino physics and astrophysics.

2 *Floyd W. Stecker*

Contents

POEMMA Performance References

1. C. Guepin, F. Sarazin, J. Krizmanic, J. Loerincs, A. Olinto, and A. Piccone, ***Geometrical Constraints of Observing Very High Energy Earth-Skimming Neutrinos from Space***, JCAP 2019, 03, 021, arXiv:1812.07596
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Gravitational-wave physics and astronomy in the 2020s and 2030s,

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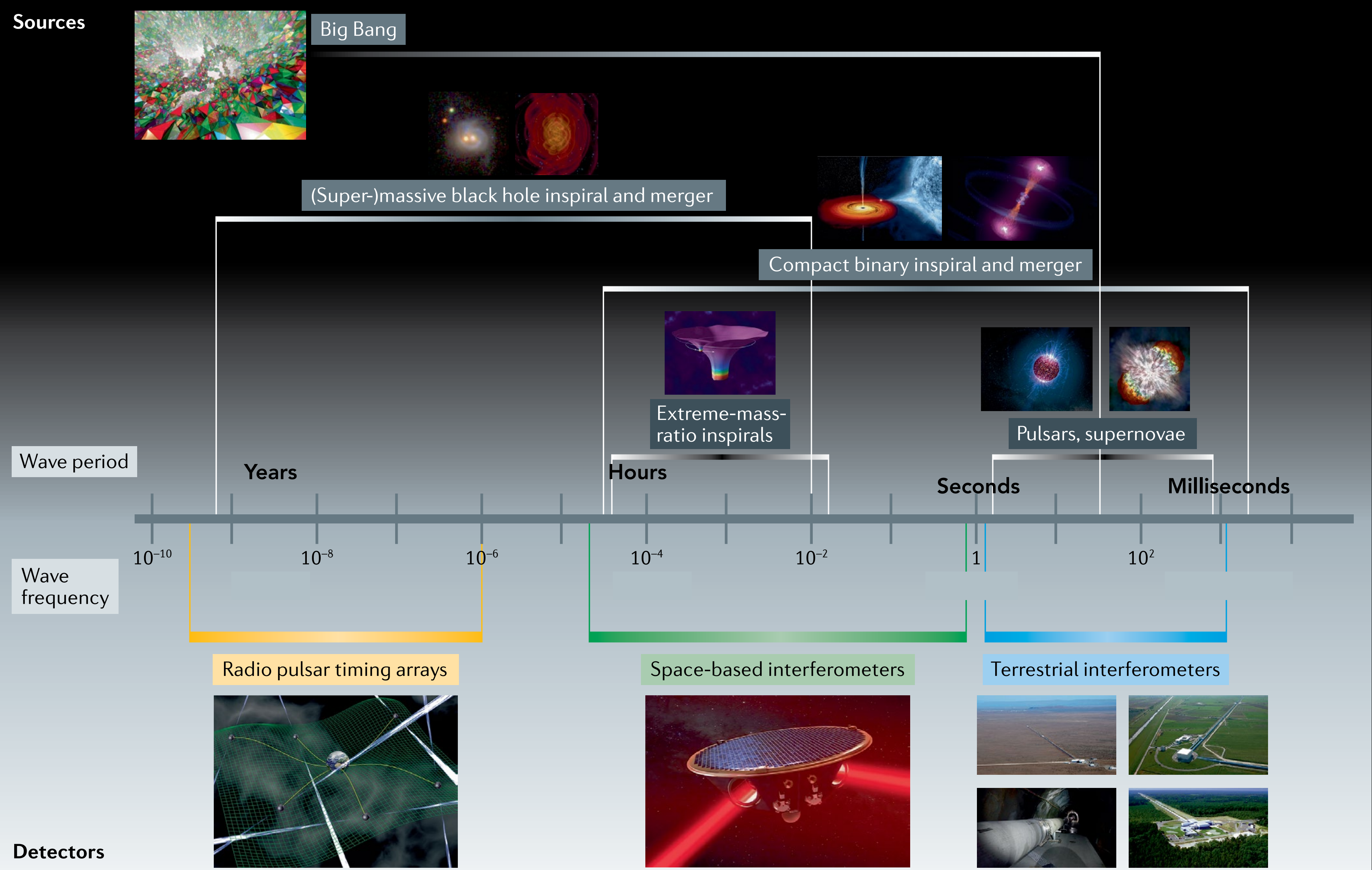
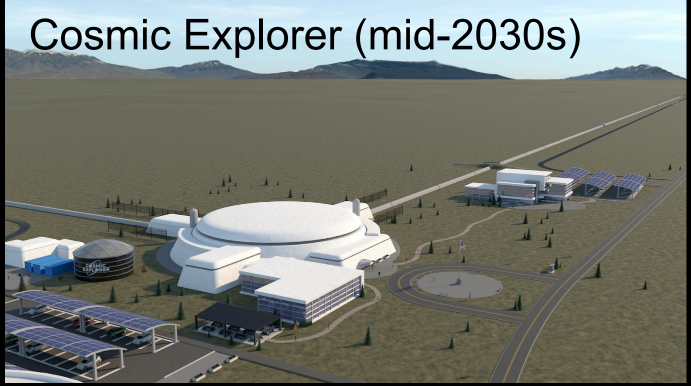


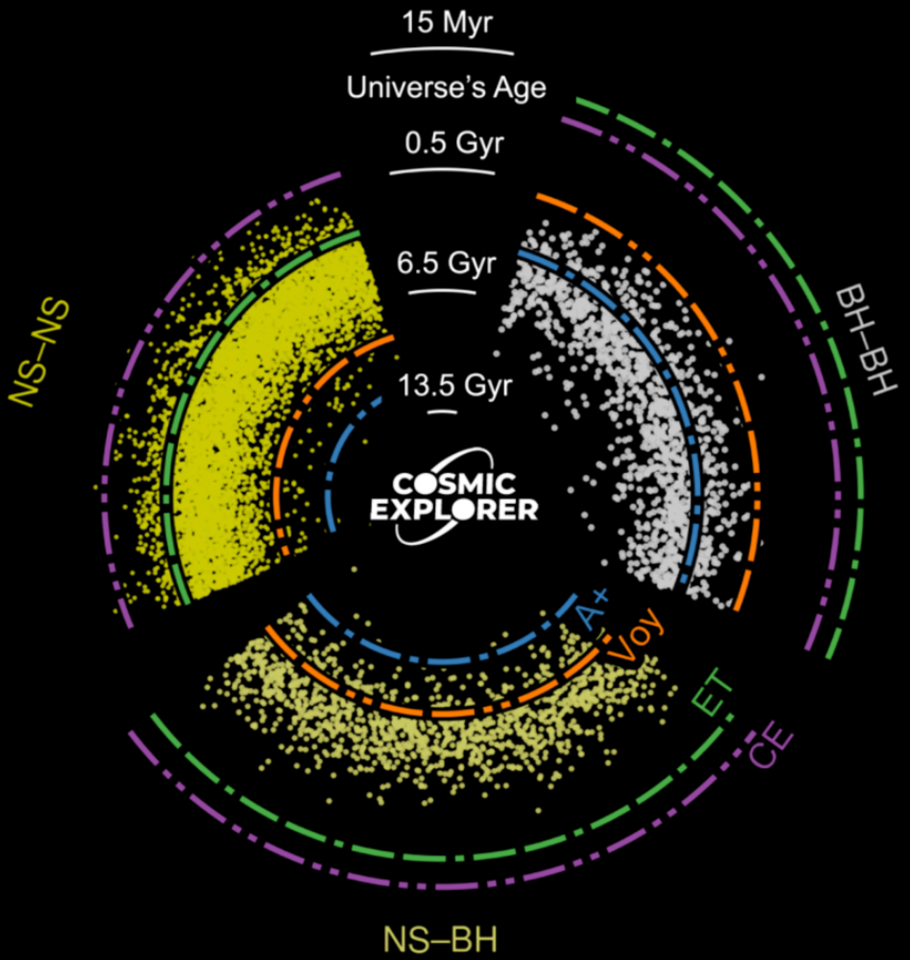
discoveries so far

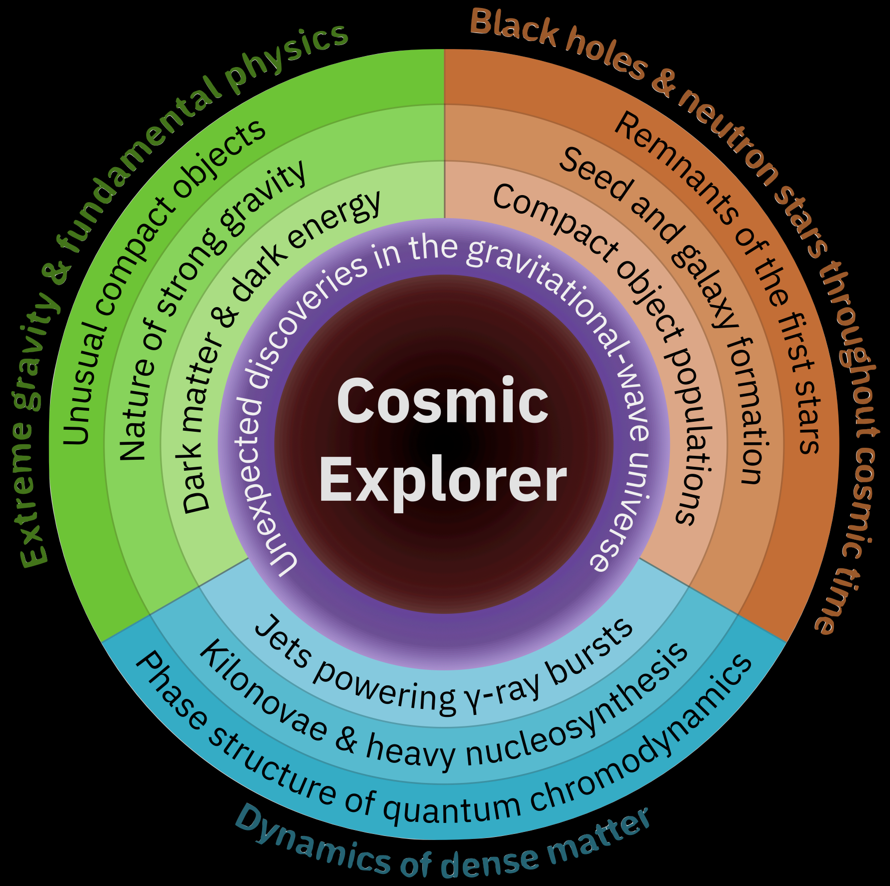
- possible primordial origin of black holes
- ruled out alternative gravity theories
- Identified sites of heavy element nucleosynthesis
- bright and dark sirens: a new tool for precision cosmology
- dense matter equation of state

LIGO Voyager and Cosmic Explorer

requires technology and expertise at national labs







Voyager and Cosmic Explorer will measure H_0 to within a few percent to fraction of a percent, observe black holes in dark ages should they exist, potentially detect QCD axions around black holes and observe EW and other phase transitions in the EarlyUniverse

Question #1:

What do you think will be the most promising advance in fundamental physics with astrophysical probes in the coming decade?

Question #2:

What are the specific ways in which cosmic experiments can help answer some of the questions that the HEP community cares most about?

Question #3:

What new physics is otherwise inaccessible?

Question #4:

What progress in technology would be needed to accomplish such goals?

Question #5:

What are the synergies between the science of CF07 and collider physics?