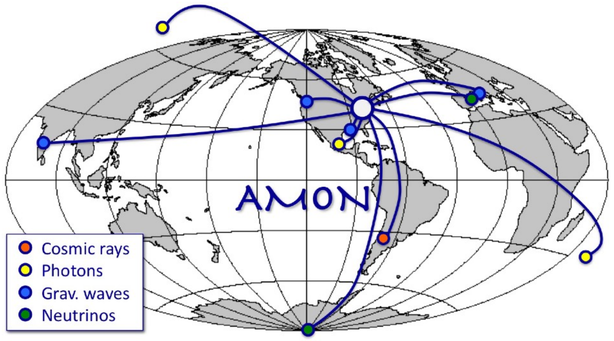
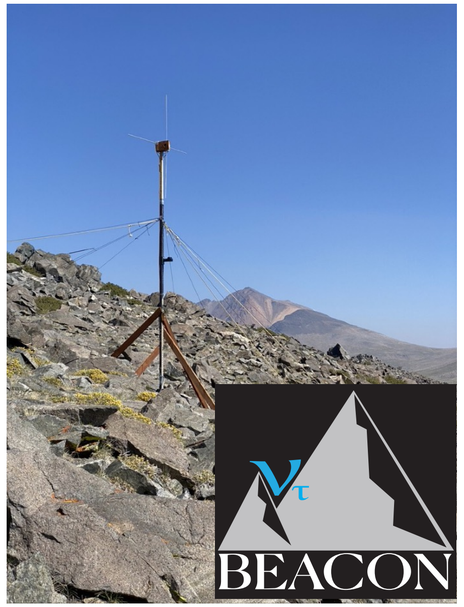
Welcome to Penn State

- **Hosted by the Institute for Gravitation and the Cosmos**

- **….and the Center for Multimessenger Astrophysics**





GRAND

GRAND-BEACON Workshop: General information

- **Program**
  https://indico.in2p3.fr/event/grand-beacon

- **Venue**
  Room 320 (3rd floor) at Whitmore Lab., 4575 Pollock Rd, University Park.
  In case of problems, call/text Whatsapp Steph +1 (773) 255-4919 or Whatsapp Kumiko +33 677799395.

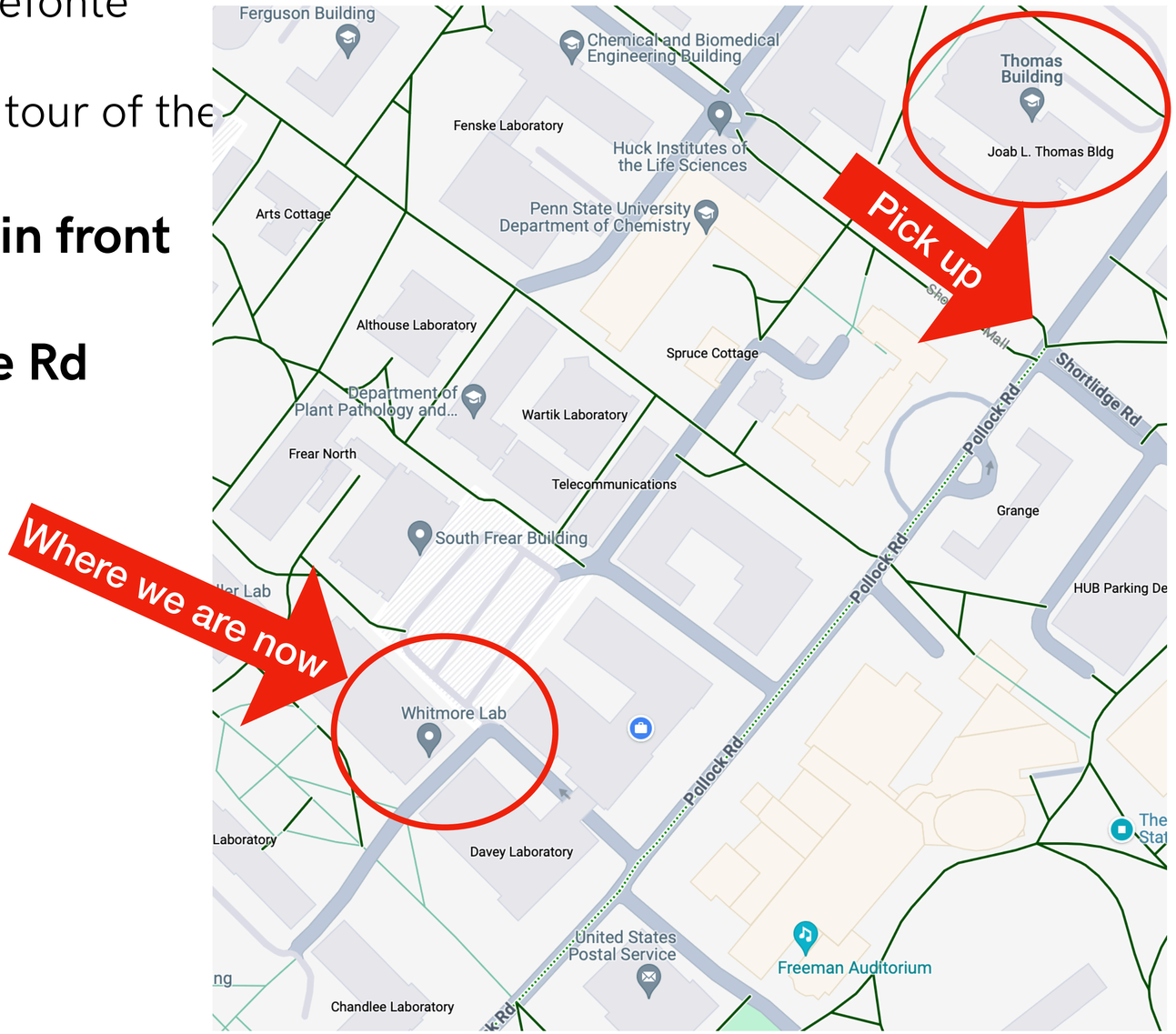
- **Zoom links**
  General links will be posted on the website https://indico.in2p3.fr/event/grand-beacon
  Links for the closed sessions will be sent out to registered participants.

GRAND-BEACON Workshop: Dinner

- **Workshop Dinner** (Wed. 10 Jan. - tonight)
  Big Springs Spirits, in the historical town of Bellefonte
  https://www.bigspringspirits.com/bellefonte
  We will go there together by bus, take a tasting tour of the

  Workshop dinner: meet @6:15pm *sharp* in front of the Thomas Building
  —> On Polluck Rd northeast of Shortlidge Rd

  Let us know if you are driving by yourself!



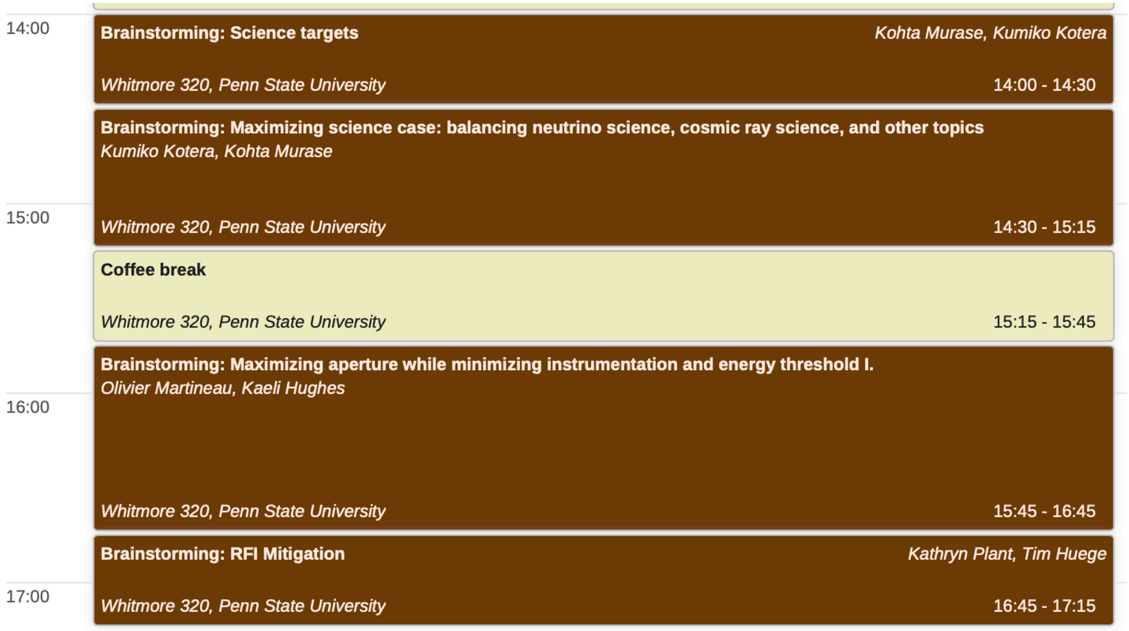
The Sessions

Overviews of several experiments
focussed on challenges/flaws/advantages/lessons

Open sessions in hybrid mode
everyday: a report of the discussions

Closed brainstorming sessions with limited hybrid mode
2 chairs - maximize discussions

Wed. 10/01 9am-5:15pm + dinner @6pm



The Sessions

Open sessions in hybrid mode
everyday: a report of the discussions

Closed brainstorming sessions with limited hybrid mode
2 chairs - maximize discussions

Thu. 11/01 9am-5pm (lunch: 12:30-2pm)

09:00
Brainstorming: Designing radio detectors efficient towards the horizon — *Tim Huege, Frank Schroeder*
Whitmore 320, Penn State University 09:00 - 10:00

10:00
Brainstorming: Advantages of phased vs unphased arrays — *Valentin Decoene, Stephanie Wissel*
Whitmore 320, Penn State University 10:00 - 11:00

11:00
Coffee break
Whitmore 320, Penn State University 11:00 - 11:30

Open discussion: Report & online brainstorming — *Tim Huege, Kumiko Kotera*
Whitmore 320, Penn State University 11:30 - 12:30

12:00
Lunch

13:00
Whitmore 320, Penn State University 12:30 - 14:00

14:00
Brainstorming: Lowering energy threshold — *Valentin Decoene, Austin Cummings*
Whitmore 320, Penn State University 14:00 - 15:00

15:00
Brainstorming: Maximizing aperture while minimizing instrumentation and energy threshold II.
Austin Cummings, Valentin Decoene

Coffee break
Whitmore 320, Penn State University 15:30 - 16:00

16:00
Brainstorming: DAQ for very large scale detectors; Sustainability; Optimizing power and comms distribution
Cosmin Deaconu, Olivier Martineau
Whitmore 320, Penn State University 16:00 - 17:00

17:00

The Sessions

Fri. 11/01 9am-3:30pm
(lunch: 12:30-2pm)

End: 3:30pm

Closed final brainstorming session

GRAND-BEACON Workshop: Dinner

- **Workshop Dinner** (Wed. 10 Jan. - tonight)
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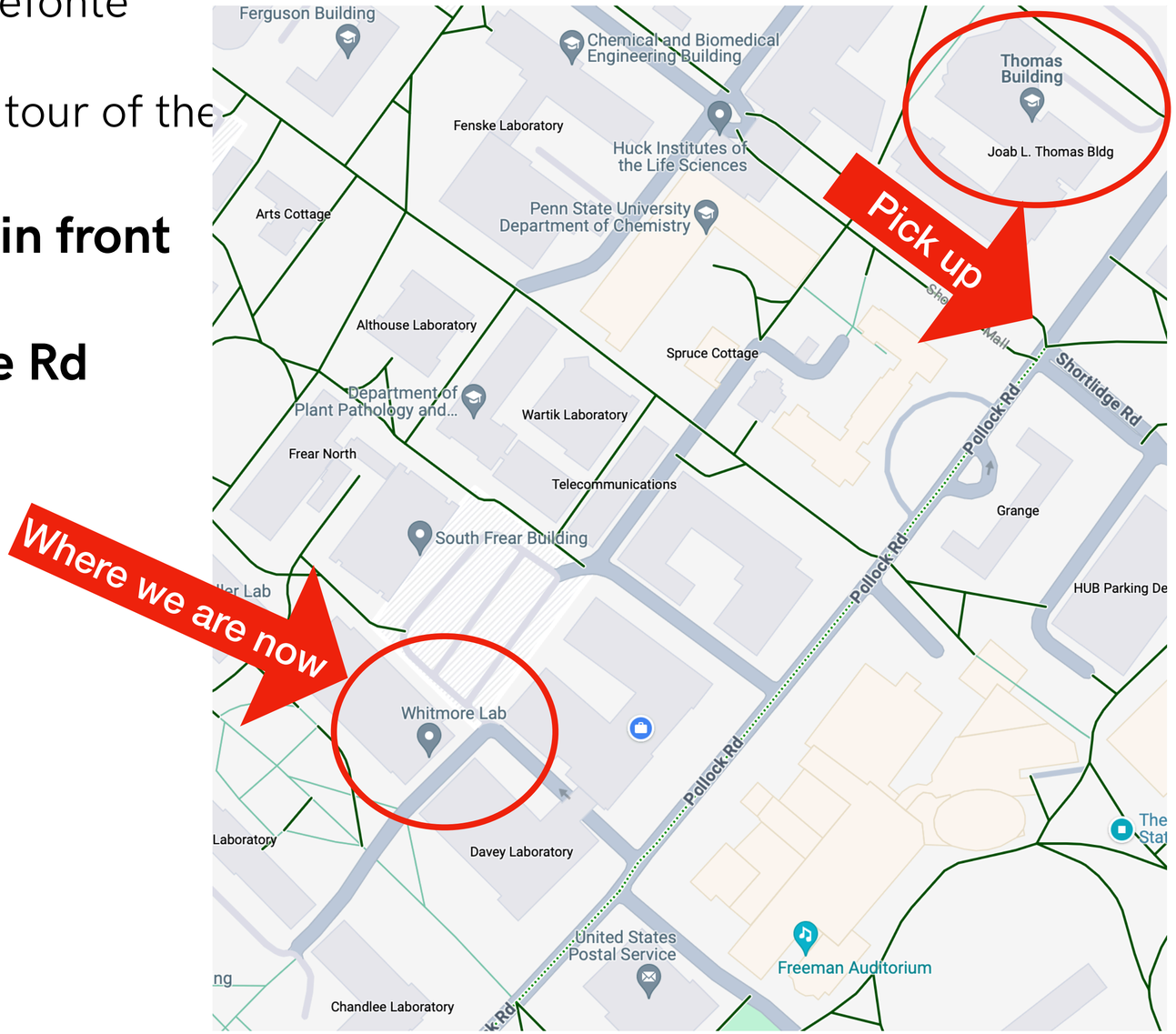


Goals of this workshop

1. **What do we want to achieve?**
   - scientifically? *Wed. PM*
   - technically? *Wed. AM + all week*

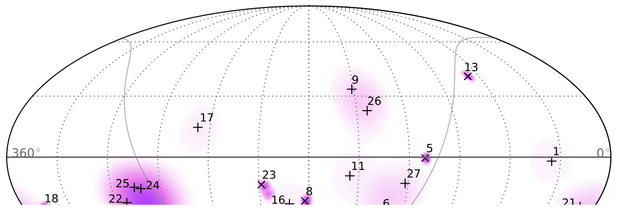
2. **What are the flaws and advantages of existing or projected instruments?**
   experimental overview *Wed. AM*

3. **How can we achieve our goals of point 1?**

   Brainstorming Sessions 2.5 days
   - Maximizing aperture while minimizing instrumentation and energy threshold
   - RFI mitigation
   - Designing radio detectors efficient towards the horizon
   - Advantage of phased-unphased arrays
   - Lowering energy threshold
   - DAQ for very large scale detectors; Sustainability; Optimizing power and comms distribution, accurate time synchronization of distributed detectors
   - Frequency range (science, commercial availability, signal discrimination)

What do we want to achieve? **Scientifically?** *Wed. PM (Kohta & Kumiko)*

RESEARCH ARTICLE



Ultra Evidence for High-Energy Extraterrestrial Neutrinos at the ~~IceCube~~ Detector

IceCube Collaboration*

We report on results of an all-sky search for high-energy neutrino events interacting within the

Selected for a Viewpoint in *Physics*

PRL **116,** 061102 (2016) PHYSICAL REVIEW LETTERS week ending 12 FEBRUARY 2016

UHE neutrinos source? Observation of ~~Gravitational Waves~~ from a Binary ~~Black Hole Merger~~

B. P. Abbott *et al.*[*]
(LIGO Scientific Collaboration and Virgo Collaboration)
(Received 21 January 2016; published 11 February 2016)

On September 14, 2015 at 09:50:45 UTC the two detectors of the Laser Interferometer Gravitational-Wave Observatory simultaneously observed a transient gravitational-wave signal. The signal sweeps upwards in frequency from 35 to 250 Hz with a peak gravitational-wave strain of 1.0×10^{-21}. It matches the waveform

The Astrophysical Journal Letters, 848:L13 (27pp), 2017 October 20 https://doi.org/10.3847/2041-8213/aa920c

UHE neutrinos or another source? ~~Gravitational Waves~~ and Gamma-Rays from a Binary Neutron Star Merger: GW170817 and GRB 170817A

LIGO Scientific Collaboration and Virgo Collaboration, *Fermi* Gamma-ray Burst Monitor, and INTEGRAL
(See the end matter for the full list of authors.)

Received 2017 October 6; revised 2017 October 9; accepted 2017 October 9; published 2017 October 16

Abstract

On 2017 August 17, the gravitational-wave event GW170817 was observed by the Advanced LIGO and Virgo detectors, and the gamma-ray burst (GRB) GRB 170817A was observed independently by the *Fermi* Gamma-ray Burst Monitor, and the Anti-Coincidence Shield for the Spectrometer for the *International Gamma-Ray Astrophysics Laboratory*. The probability of the near-simultaneous temporal and spatial observation of GRB 170817A and

Program

- Science Targets
- Maximizing science case: balancing neutrino science, cosmic ray science, and other topics

Questions

- We want to dream
- We want to be funded
- Trade-off? Adequacy?
- Experimental needs for the priority science case?
- Any ancillary Science Case? At what cost?

What do we want to achieve? **Technically?** *all days*

Why Radio In-Air?

- Because that's our expertise… ;-p
- Benchmarked/mature technique for vertical showers
- Robust, scalable, cost-efficient
  —> in principle ideal for large apertures
- Radio In-Ice is complementary and has its drawbacks
  —> good to move in parallel

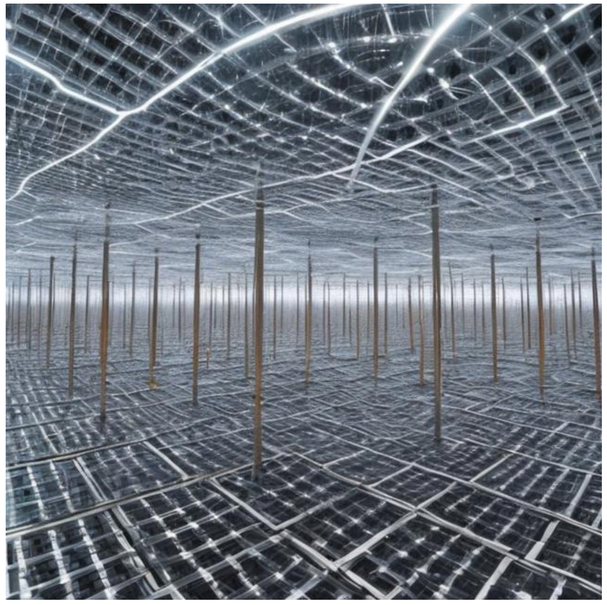
Program

- Radio in-air
- Robustness, simplicity, size, …
- Are there unavoidable technical constraints?

Ideas from OpenAI

Seems like the human brain can still do better…

future generation ultra-high energy neutrino radio detector



large-scale ultra-high energy neutrino radio antenna array

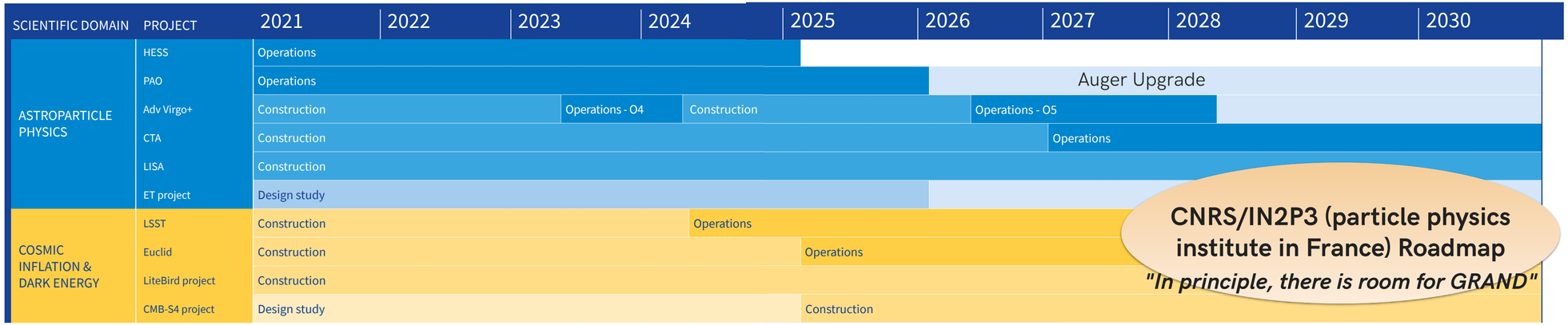
deploying 1000s of radio antennas in the desert from a helicopter

giant radio array for neutrino detection

Some background - Why now?

- **GRAND and BEACON prototypes are (almost) running**
  - confident that detection techniques will be validated
  - time to think of the larger-scale phase

- **In Europe: many other experiments are finishing their commissioning or R&D phase**
  - learn from these experiments
  - interest for next R&D and manpower will be available

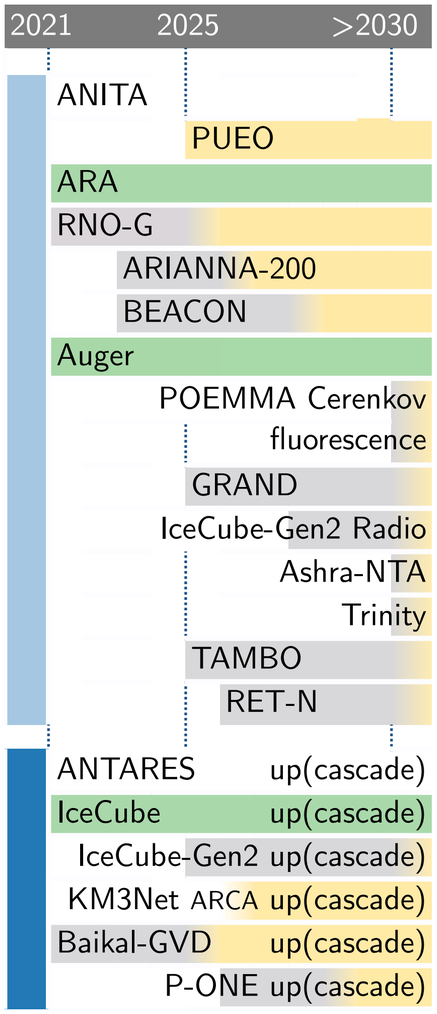


CNRS/IN2P3 (particle physics institute in France) Roadmap

"In principle, there is room for GRAND"

- **No other large-scale ground detector planned**
  - What next after Auger?
  - GCOS: unclear perspectives and likely to be merged with this project
  - IceCube-Gen2 Radio is complementary + aligned timescale?
  - The existing community will need a next project

Roadmap of projected HE/UHE neutrino instruments



Guépin, KK, Oikonomou, Nat. Rev. 2022

Some background - Our assets

- **A good timing - NOW is the time to position ourselves**
  - in Europe: many experiments finishing their R&D phases —> interest & personpower
  - no next generation large-scale ground detector validated yet
  - unclear perspectives in-ice
  - multi-messenger astronomy is the new trend

- **Strong Science Case & Technical Challenges**
  - Frontier challenge (energy frontier, "new" particle frontier)
  - MM astronomy is the trend
  - Radio detection technique + large scale comms/data volume challenges + later industrial production could trigger interest

- **We can build on existing grounds**
  - Expertise from prototypes —> technically important + for funding agencies
  - An excellent existing infrastructure to build on:
    —> the Auger site is looking for new projects. Could host a mid-scale array (~1000 antennas)
  - At the cross-road of several existing communities with excellent expertise
    —> radio, large-scale arrays, data analysis, particle physics, MM alerts...

Some background - Political situation

In Europe

GRAND

- Mid-term review of the **APPEC** strategy
- Roadmap of **Astronet**
- Physics briefing book: Input for the **European Strategy for Particle Physics** Update 2020, section 7.3 http://cds.cern.ch/record/2691414
- **Nikhef** strategic plan 2017-2022 and beyond, p. 43 https://www.nikhef.nl/strategisch-plan/
- **CNRS** Prospective INSU Astronomie & Astrophysique 2020-2025, p. 34 https://www.insu.cnrs.fr/sites/institut_insu/files/news/2021-04/Prospective_INSU_AA_2019.pdf

IceCube-Gen2, RNO-G, KM3Net, GCOS

- Strong community around IceCube-Gen2: Germany, Belgium, …
- Around radio + large arrays: Netherlands, Germany, Belgium, France

In Latin America - GRAND

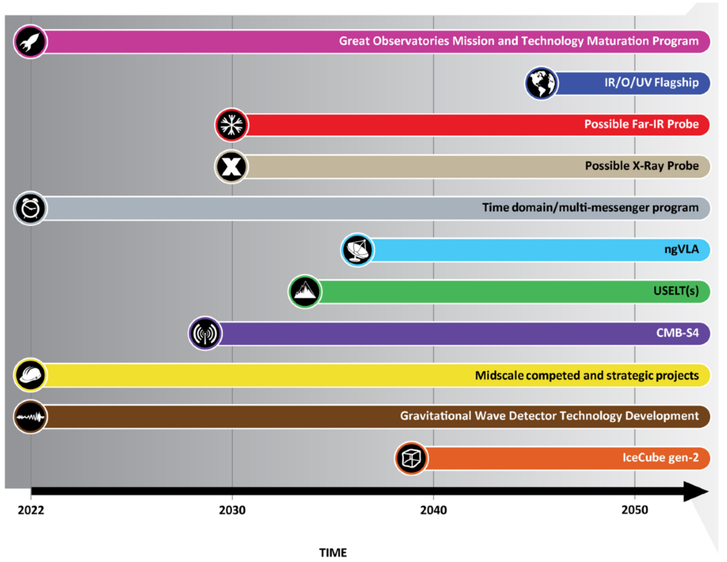
- **Latin American** Strategy for Research Infrastructures for High Energy, Cosmology, Astroparticle Physics LASF4RI for HECAP https://drive.google.com/file/d/1muqdLMMQaZ-yBxFdYLPuCpOQgeSfsvtV/view

Some background - Political situation

In the USA

Astro2020 Decadal Survey

- Priority Area: New Windows on the Dynamic Universe
- Key recommendations:
  - Time domain / multi-messenger program
  - IceCube-Gen2 endorsed but since not funded by NSF Astrophysics not included in the planning (NSF Physics instead…)



P5 Report

- Neutrinos are included as a key element in the "Decipher the Quantum Realm"
- Recommend a portfolio of major projects that collectively study nearly all fundamental constituents of the universe and their interactions
  - MM Astrophysics noted for unique role funded via NSF Physics
  - CMB-S4 and IceCube-Gen2 heavily supported in the Cosmic Frontier

Figure 1 – Program and Timeline in Baseline Scenario (B)

Index: Operation Construction R&D, Research P: Primary S: Secondary

§ Possible acceleration/expansion for more favorable budget situations

Science Experiments	Timeline 2024–2034	Neutrinos	Higgs Boson	Dark Matter	Cosmic Evolution	Direct Evidence	Quantum Imprints	Astronomy & Astrophysics
		Science Drivers						
LHC			P	P		P	P	
LZ, XENONnT				P				
NOvA/T2K		P				S		
SBN		P				S		
DESI/DESI-II		S		S	P			P
Belle II				S		S	P	
SuperCDMS				P				
Rubin/LSST & DESC		S		S	P			P
Mu2e							P	
DarkSide-20k				P				
HL-LHC			P	P		P	P	
DUNE Phase I		P				S	S	S
CMB-S4		S		S	P			P
CTA				S				P
G3 Dark Matter §		S		P				
IceCube-Gen2		P		S				P
DUNE FD3		P				S	S	S
DUNE MCND		P				S	S	
Higgs factory §			P	S		P	P	
DUNE FD4 §		P				S	S	S
Spec-S5 §		S		S	P			P
Mu2e-II							P	
Multi-TeV §	DEMONSTRATOR		P	P		P	S	
LIM		S		P	P			P

Technical challenges with current experiments *to be discussed in the Open Discussion*

- **Difficulties in finding large geographical sites meeting criteria**
  - usually local government very enthusiastic
  - military/too many landowners/natural reserve permits/…
  - installation & maintenance & site access issues

  —> limit actual geographical implantation and increase aperture by geometry?

  —> improve trigger efficiency to deploy on noisier sites?

- **Number of channels**
  - detection unit robustness, simplicity, power consumption
  - production, maintenance, shipping volumes
  - data volume
  - trigger complexity & RFI robustness

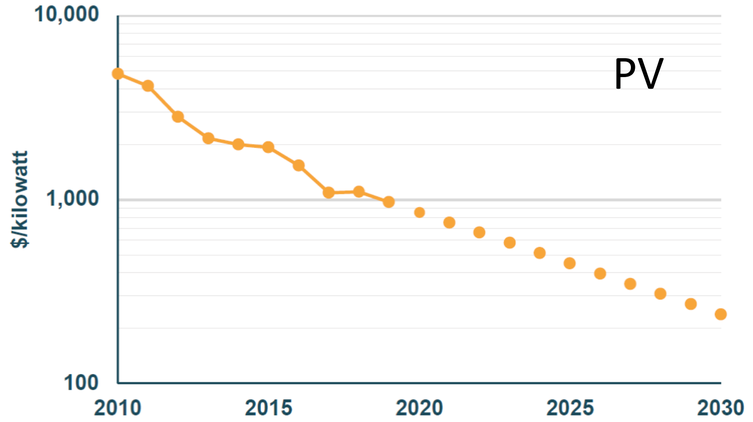
- **Complexity**
  - trigger
  - distributed comms vs independent arrays
  - mechanics
  - logistics

… Add your thoughts!

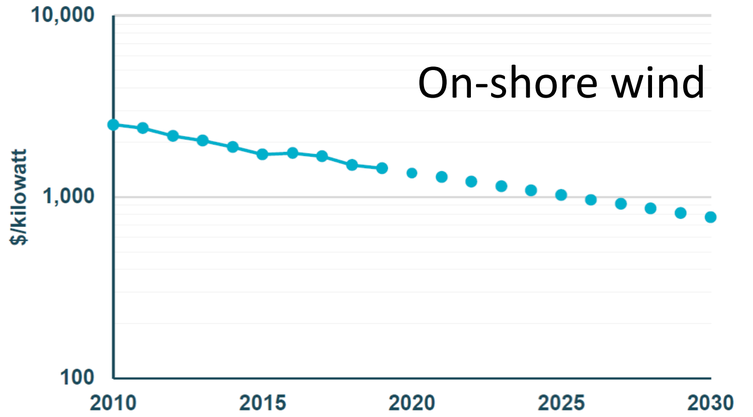
Exponential versus linear scaling

to be discussed in the Open Discussion

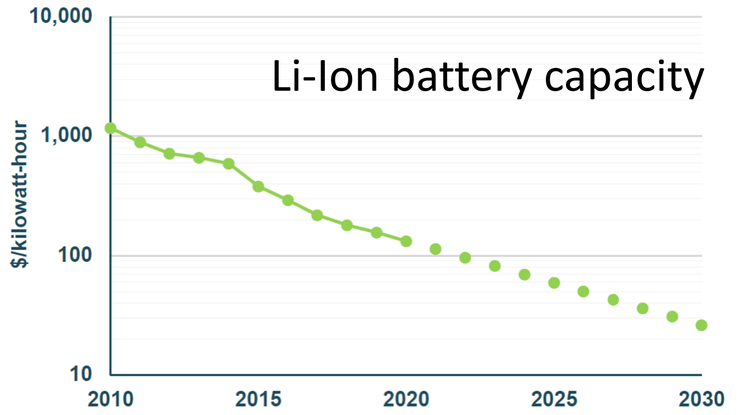
- Very hard to think exponentially for humans – because it is counterintuitive!
- Where exponential scaling applies, big numbers are not a problem.
  - Cost of solar and wind power drops exponentially.
  - Cost of battery capacity drops exponentially.
  - Computing capacity grows exponentially (Moore's law).
  - Communications bandwidth? Not sure.
    Fast growth for sure.
  - …?
- Where linear scaling applies, big numbers seem prohibitive.
  - Cost of mechanics (steel, …).
  - Cost of deployment („classical way").
  - Cost of maintenance (i.e., need „maintenance free").
  - Cost of personpower.
  - …?



Source: NREL, 2018.[1] RethinkX projections 2019-2030.



Source: Lawrence Berkeley National Laboratory, 2018.[3] RethinkX projections 2019-2030.



Source: BNEF, 2019. [4,7,8] RethinkX projections 2020-2030.

Brainstorming Sessions

	Chairs
• Science targets and maximizing science case	*Kohta & Kumiko*
• Maximizing aperture while minimizing instrumentation and energy threshold	*Steph & Olivier*
• RFI mitigation	*Kathryn & Tim*
• Designing radio detectors efficient towards the horizon	*Tim & Frank*
• Advantage of phased-unphased arrays	*Valentin & Kaeli*
• Lowering energy threshold	*Austin & Valentin*
• DAQ for very large scale detectors; Sustainability; Optimizing power and comms distribution, accurate time synchronization of distributed detectors	*Olivier, Cosmin & Kathryn*
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