A report from:

CPAD

NEW TECHNOLOGIES FOR DISCOVERY

Organized by the Coordinating Panel for Advanced Detectors of the Division of Particles and Fields of the American Physical Society

October 5 - 7, 2015 - University of Texas at Arlington

Marcel Demarteau
& Ian Shipsey
Co-Chairs CPAD

Outline

#1 Context

#2 Workshop

NEW TECHNOLOGIES FOR DISCOVERY

Organized by the Coordinating Panel for Advanced Detectors of the Division of Particles and Fields of the American Physical Society

Organized by:

#3 CPAD

CPAD

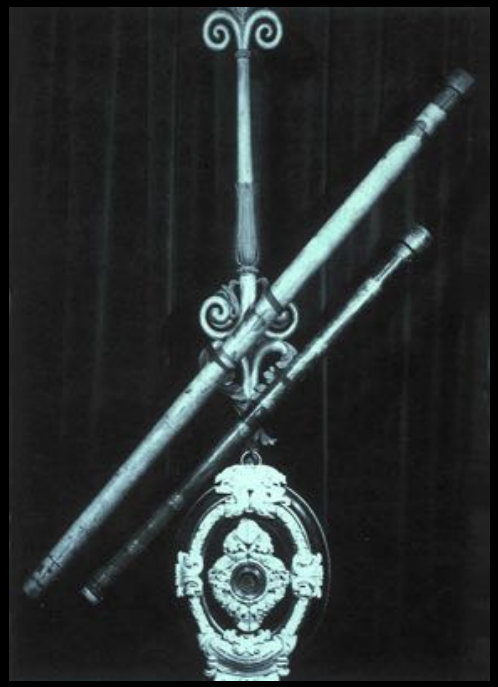
http://www.hep.anl.gov/cpad

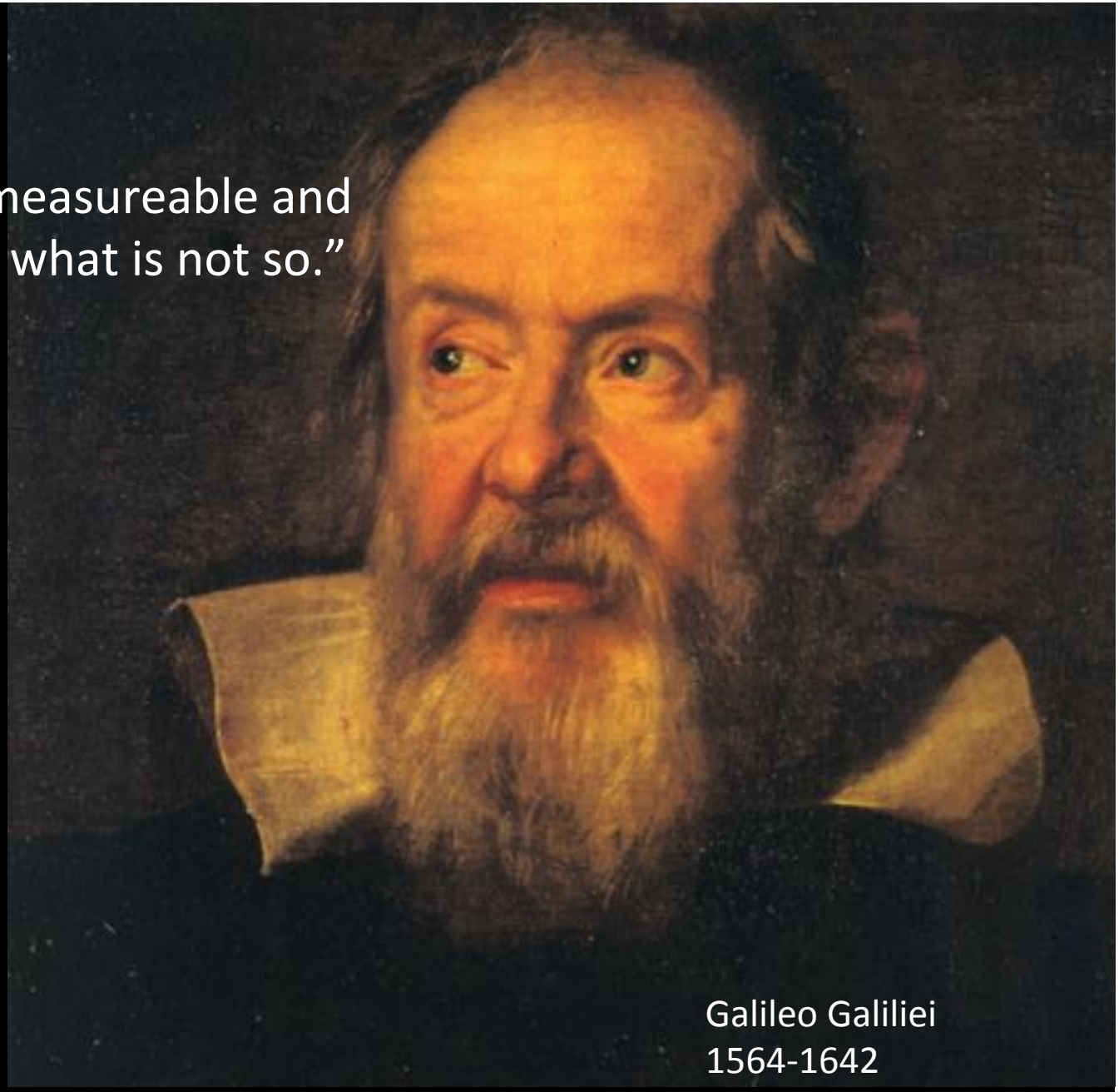
Coordinating Panel for Advanced Detectors

APS | DIVISION OF PARTICLES & FIELDS

#1 Context

"Measure what is measureable and make measureable what is not so."





Galileo Galiliei
1564-1642

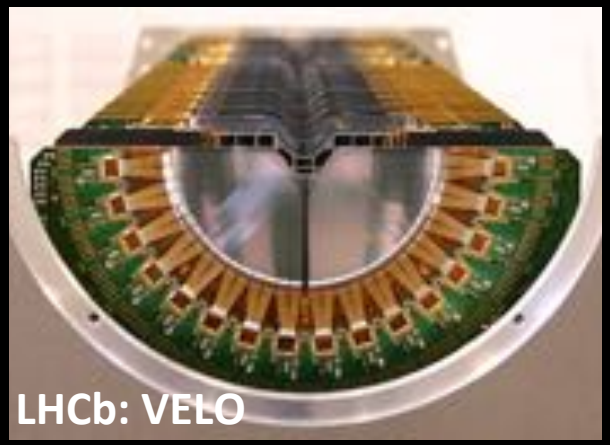
Instrumentation: The Great Enabler

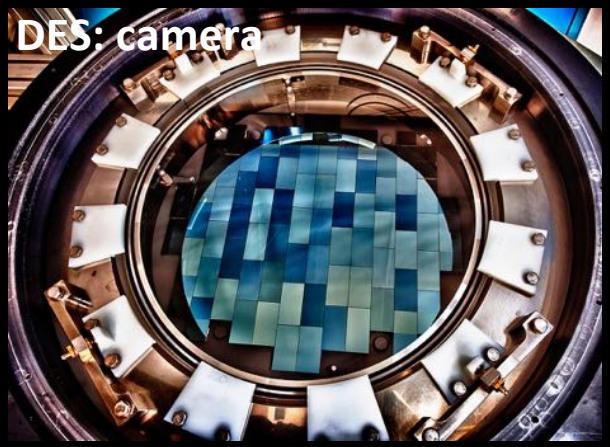
"New directions in science are launched by new tools much more often than by new concepts.

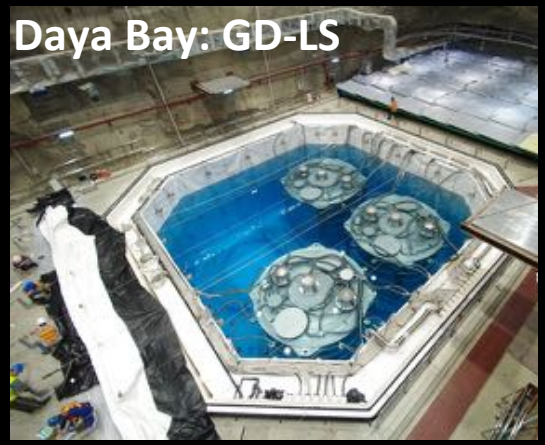
The effect of a concept-driven revolution is to explain old things in new ways. The effect of a tool-driven revolution is to discover new things that have to be explained"

Freeman Dyson

Instrumentation is the enabler of science, both pure and applied



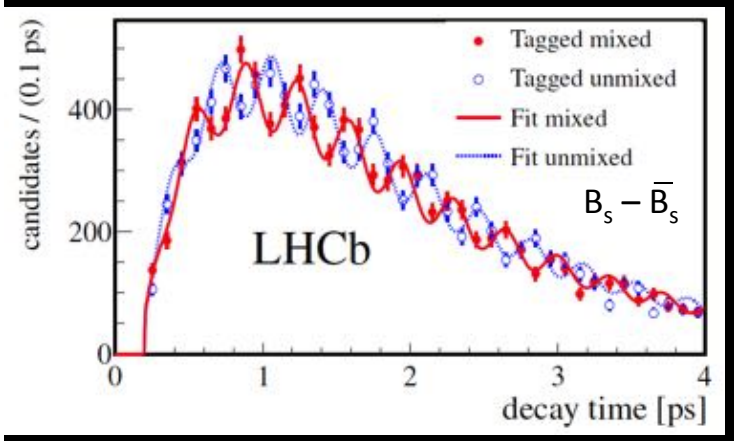




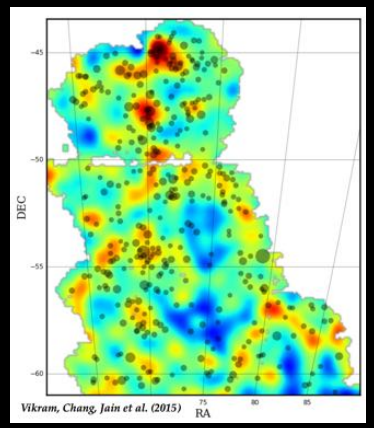
Based on an original slide from Demarteau

Enabler of Science

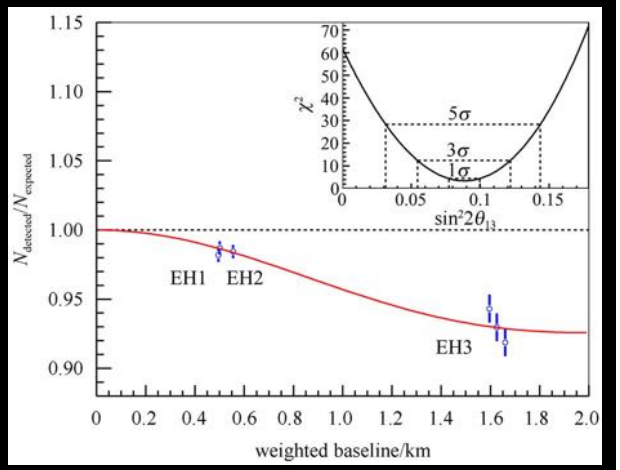
Instrumentation is the enabler of science, both pure and applied



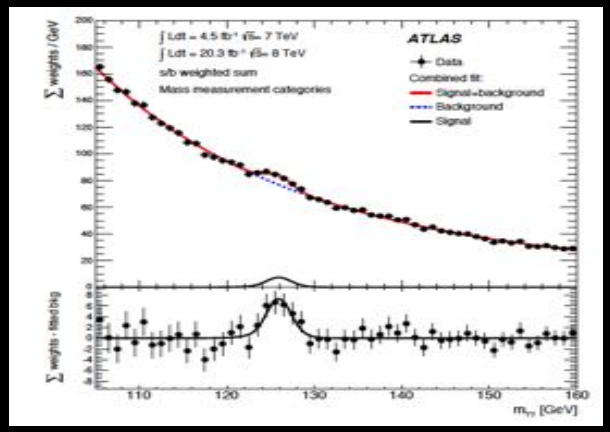
arXiv: 1304.4741



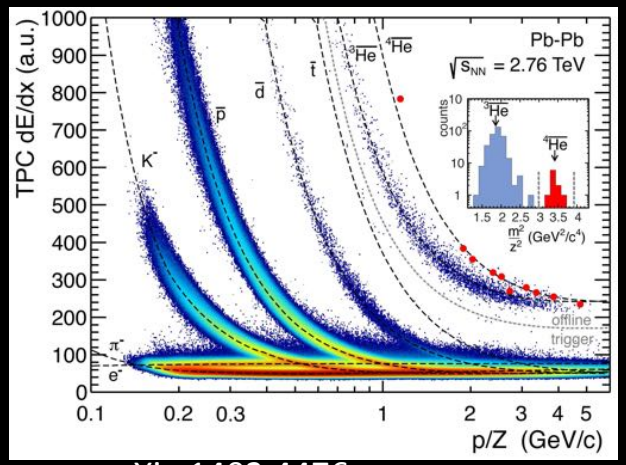
arXiv:1504.03002



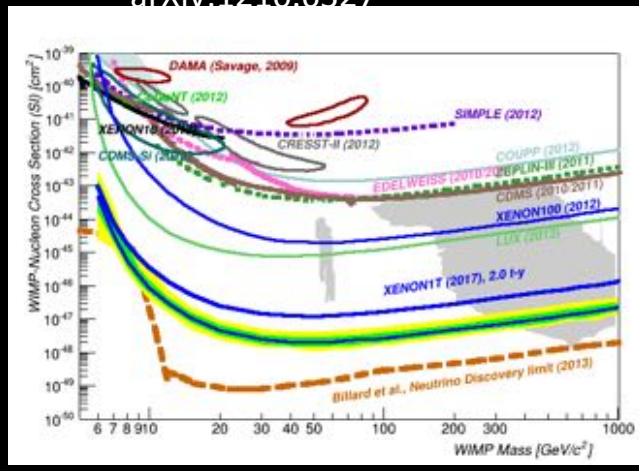
arXiv:1210.6327



arXiv:1406.3827



arXiv:1402.4476



arXiv:1501.03492

Based on an original slide from Demarteau

Outstanding Questions in Particle Physics *circa* 2011

Is there a Higgs boson?

Quarks and leptons:
- why 3 families ?
- masses and mixing
- *CP* violation in the lepton sector
- matter and antimatter asymmetry
- baryon and charged lepton number violation

Physics at the highest E-scales:
- how is gravity connected with the other forces ?
- do forces unify at high energy ?

Dark matter:
- composition: WIMP, sterile neutrinos, axions, other hidden sector particles, ..
- one type or more ?
- only gravitational or other interactions ?

Neutrinos:
- ν masses and and their origin
- what is the role of $H(125)$?
- Majorana or Dirac ?
- *CP* violation
- additional species → sterile ν ?

The two epochs of Universe's accelerated expansion:
- primordial: is inflation correct ? which (scalar) fields? role of quantum gravity?
- today: dark energy (why is Λ so small?) or gravity modification ?

Outstanding Questions in Particle Physics *circa* 2016

… there has never been a better time to be a particle physicist!

Higgs boson and EWSB

- ❑ m_H natural or fine-tuned ?
- → if natural: what new physics/symmetry?
- ❑ does it regularize the divergent $V_L V_L$ cross-section at high $M(V_L V_L)$? Or is there a new dynamics ?
- ❑ elementary or composite Higgs ?
- ❑ is it alone or are there other Higgs bosons ?
- ❑ origin of couplings to fermions
- ❑ coupling to dark matter ?
- ❑ does it violate CP ?
- ❑ cosmological EW phase transition

Quarks and leptons:

- ❑ why 3 families ?
- ❑ masses and mixing
- ❑ *CP* violation in the lepton sector
- ❑ matter and antimatter asymmetry
- ❑ baryon and charged lepton number violation

Physics at the highest E-scales:

- ❑ how is gravity connected with the other forces ?
- ❑ do forces unify at high energy ?

Dark matter:

- ❑ composition: WIMP, sterile neutrinos, axions, other hidden sector particles, ..
- ❑ one type or more ?
- ❑ only gravitational or other interactions ?

Neutrinos:

- ❑ *ν* masses and and their origin
- ❑ what is the role of *H*(125) ?
- ❑ Majorana or Dirac ?
- ❑ *CP* violation
- ❑ additional species → sterile *ν* ?

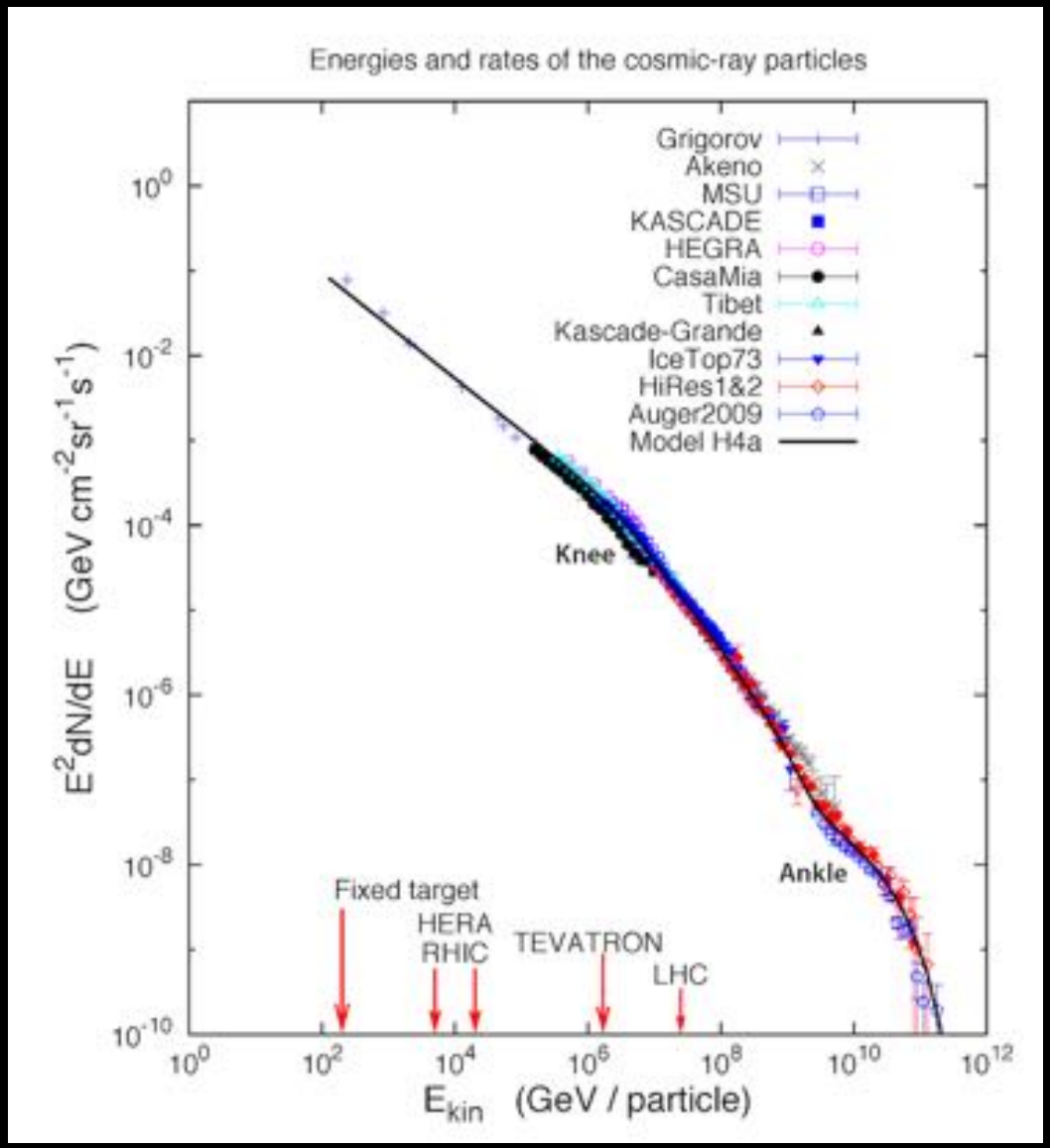
The two epochs of Universe's accelerated expansion:

- ❑ primordial: is inflation correct ? which (scalar) fields? role of quantum gravity?
- ❑ today: dark energy (why is Λ so small?) or gravity modification ?

"What we know is a droplet, what we don't know is an Ocean"

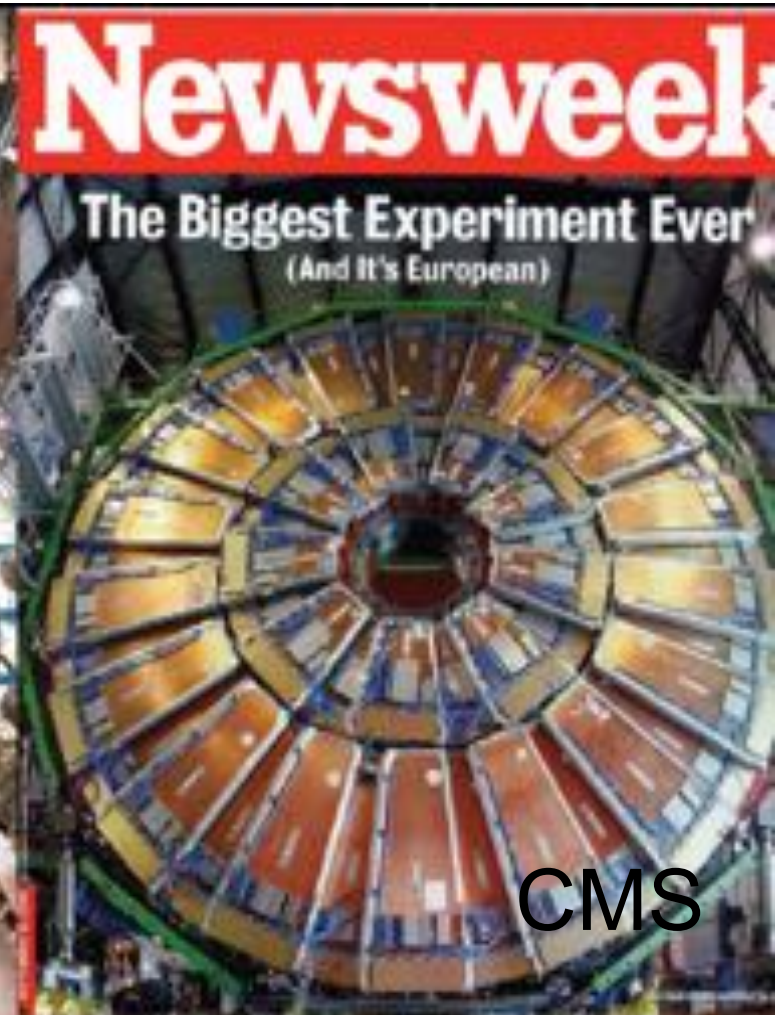
Sir Isaac Newton (1643-1727)

Detect & Measure over 24 orders of magnitude



A Rich Spectrum of Technologies

Object	Weight (tons)
Boeing 747 [fully loaded]	200
Endeavor space shuttle	368
ATLAS	7,000
Eiffel Tower	7,300
USS John McCain	8,300
CMS	12,500



Instrumentation triumph

CMS

ATLAS

DIGITAL CAMERAS THE SIZE OF CATHEDRALS

Object	Weight (tons)
Boeing 747 [fully loaded]	200
Endeavor space shuttle	368
ATLAS	7,000
Eiffel Tower	7,300
USS John McCain	8,300
CMS	12,500

CMS

Instrumentation triumph

Instrumentation Challenge

ATLAS

DIGITAL CAMERAS THE SIZE OF CATHEDRALS

Object	Weight (tons)
Boeing 747 [fully loaded]	200
Endeavor space shuttle	368
ATLAS	7,000
Eiffel Tower	7,300
USS John McCain	8,300
CMS	12,500

CMS

Instrumentation triumph

Instrumentation Challenge

A

Instrumentation R&D has the potential to transform this situation, from novel new acceleration techniques such as plasma wake-field, to novel new detectors that provide enhanced capabilities with significantly reduced cost.

DIGITAL CAMERAS THE SIZE OF CATHEDRALS

Report of the DPF Taskforce on Instrumentation in Particle Physics

Instrumentation in Particle Physics

Commissioned by the Executive Committee of the Division of Particles and Fields, American Physical Society

October 2011

Prepared by the Task Force Members:

Authors: Marina Artuso (Syracuse), Ed Blucher (Chicago), Ariella Cattai (CERN), Marcel Demarteau (co-chair, ANL), Murdock Gilchriese (LBNL), Ron Lipton (FNAL), David Lissauer (BNL), David MacFarlane (SLAC), Bill Molzon (UCI), Adam Para (FNAL), Bruce Schumm (UCSC), Gabriella Sciolla (Brandeis), Ian Shipsey (co-chair, Purdue), Harry Weerts (ANL) Ex-officio: Chip Brock (Michigan State), Patricia McBride (FNAL), Howard Nicholson (Mount Holyoke).

http://www.hep.anl.gov/cpad/

October, 2011

Recommended creation of a standing a community panel for instrumentation

CPAD

Coordinating Panel for Advanced Detectors

- CPAD: to promote, coordinate and assist in the research and development of instrumentation for High Energy Physics nationally, and to develop a detector R&D program to support the mission of High Energy Physics for the next decades within the P5 vision in an international context

Membership:

- From Universities
  - Jim Alexander (Cornell)
  - Marina Artuso (Syracuse)
  - Rick van Berg (Penn)
  - Bonnie Fleming (Yale)
  - Ulrich Heintz (Brown)
  - Howard Nicholson (Mt. Holyoke)
  - Gabriella Sciolla (Brandeis)
  - Ian Shipsey* (Oxford)
  - Wesley Smith (Wisconsin)
  - Matt Wetstein (Chicago)

http://www.hep.anl.gov/cpad/

- From Laboratories
  - Clarence Chang (Argonne)
  - Marcel Demarteau* (Argonne)
  - Juan Estrada (Fermilab)
  - Maurice Garcia-Sciveres (LBNL)
  - David MacFarlane (SLAC)
  - Ron Lipton (Fermilab)
  - Vinnie Polychronakos (BNL)
  - Pete Siddons (BNL)
  - Bob Wagner (Argonne)
  - Graham Wilson (BNL)
- International
  - Ariella Cattai (CERN)
  - Junji Haba (KEK)

(*) = co-chair

CPAD

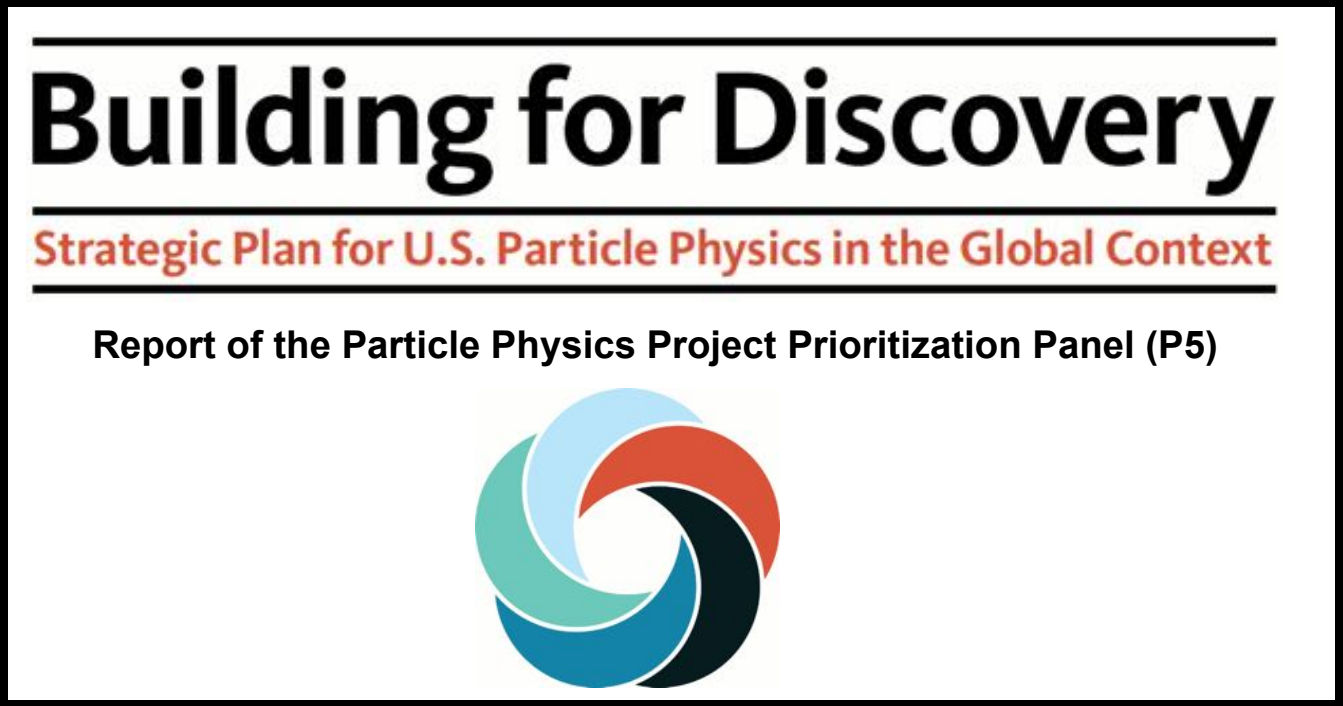
NEW TECHNOLOGIES FOR DISCOVERY

Organized by the Coordinating Panel for Advanced Detectors of the Division of Particles and Fields of the American Physical Society

October 5 - 7, 2015 - University of Texas at Arlington

Goals of the Workshop

Goal: #1 Evaluation of the Detector R&D program being carried out in support of the High Energy Physics science mission, to determine if the existing program meets the science needs of the 5 P5 science drivers* within the twenty year P5 vision.

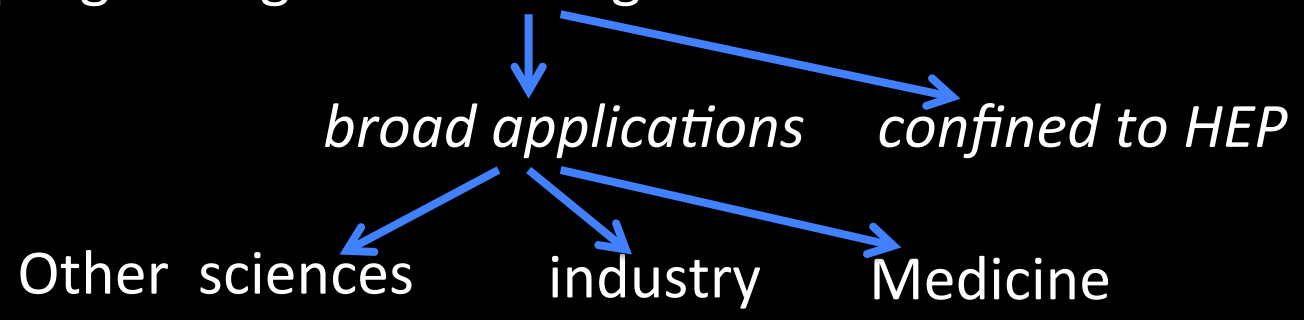


* Science drivers are compelling lines of inquiry that show great promise for discovery over the next 10 to 20 years.

Goals of the Workshop

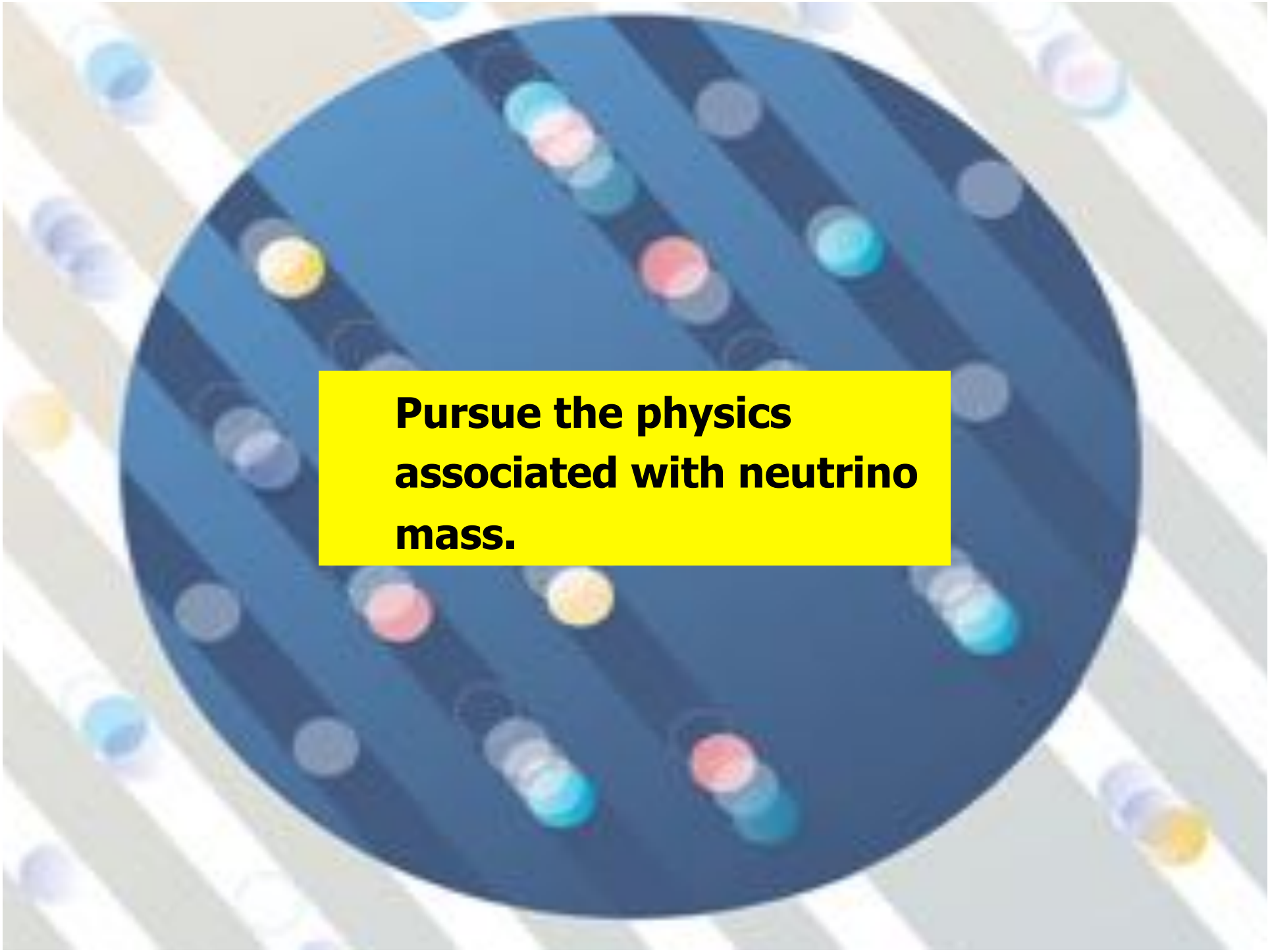
Goal #2 Increase interaction between instrumentationalists from distinct communities within HEP : energy frontier, precision frontier and cosmic frontier

Goal #3: identify instrumentation opportunities to enhance the program : grand challenges



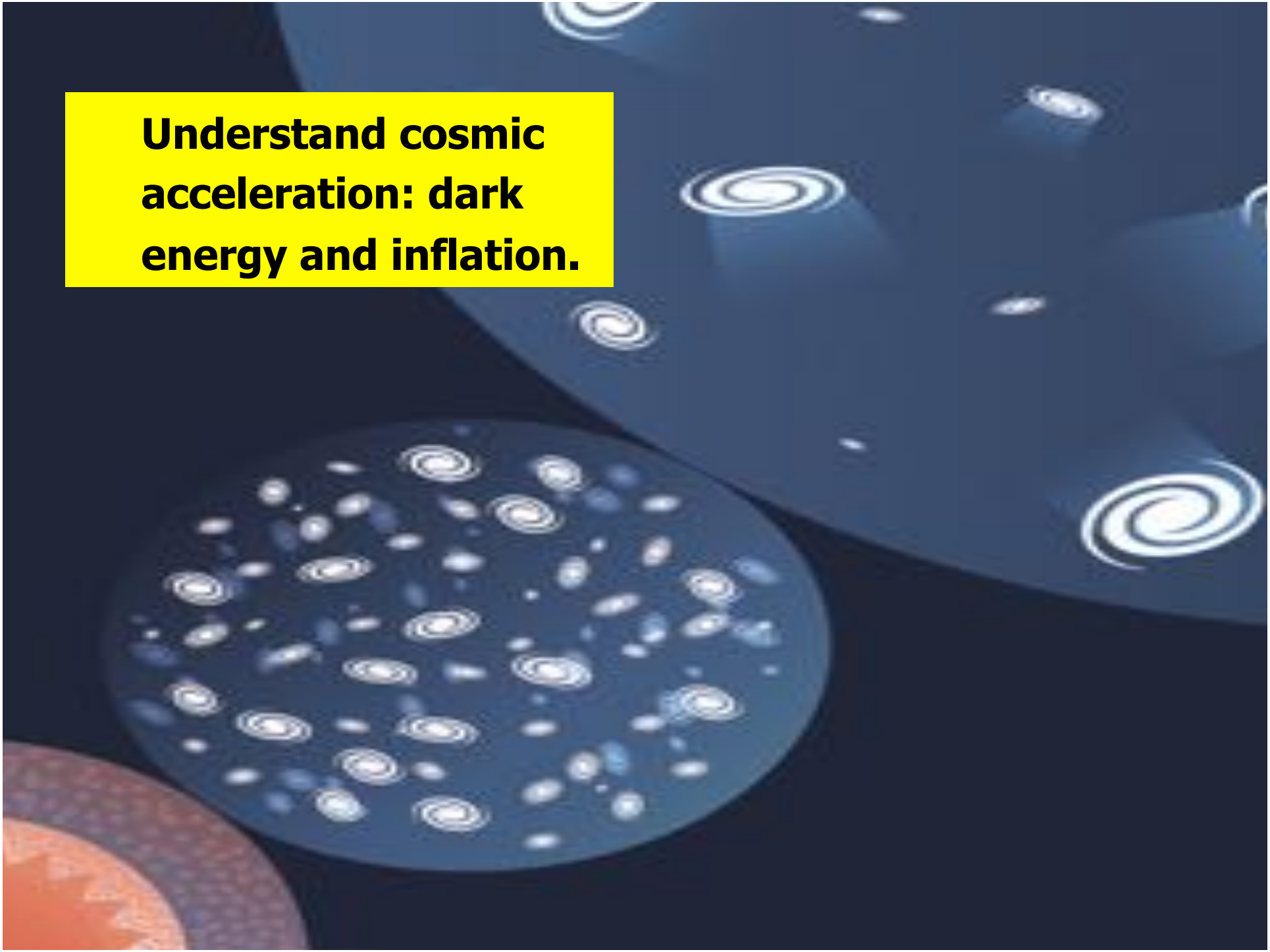
The 5 P5 science drivers are…….

Use the Higgs boson as a new tool for discovery.

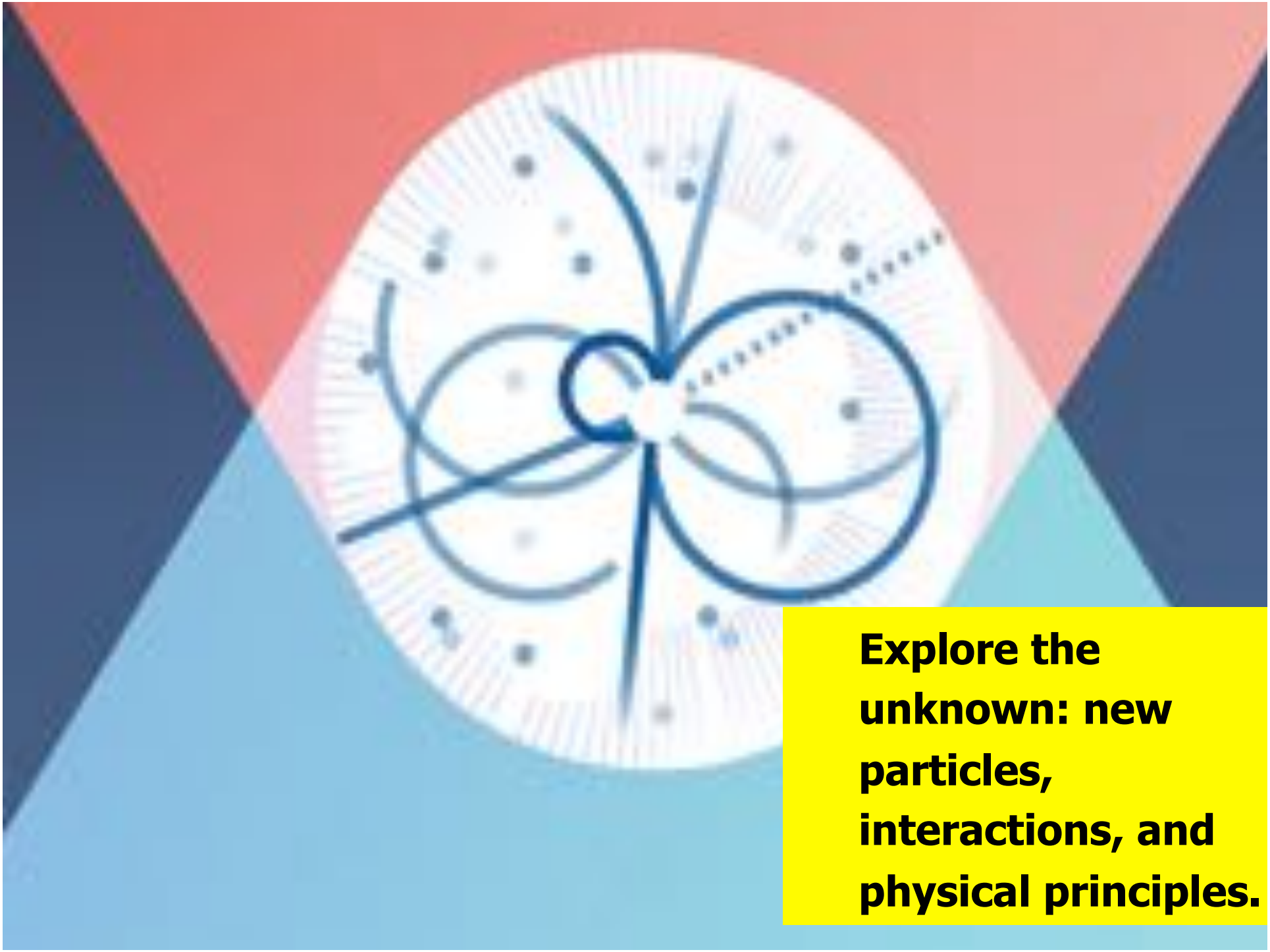


Pursue the physics associated with neutrino mass.

Identify the new physics of dark matter.



Understand cosmic acceleration: dark energy and inflation.


Explore the unknown: new particles, interactions, and physical principles.

The Science Drivers are enabled by 6 technology areas

Noble Liquids

Tracking and vertex detectors & muon detectors

Photodetectors

Solid State Detectors/ Quantum sensors

Calorimetry

Trigger and DAQ

Structure of workshop to meet goals:

11 groups: 5 P5 science driver 6 technology
Each participant in at least 1 science and 1 technology group

Each group asked to assess state of program identify critical needs, make recommendations, suggest grand challenges

Day 1: Plenary overview session & 5 P5 science driver groups meet in parallel
Day 2: 6 technology groups meet in parallel
Day 3: (1/2 day) Summary of 11 groups

Total of 100 talks 120 participants

Workshop outcome: begin to formulate of the needs of the field to ensure a vibrant future.

The deliverable: a report (shared with DOE and NSF) that will summarize the workshop findings

Begin process of developing a proposed program to deliver the grand challenges

Linkage between science drivers and technologies

The P5 Science Drivers:	Technologies:
The Higgs as a tool for discovery	**Noble Liquids**
Physics associated with neutrino mass	**Tracking and vertex detectors & muon detectors**
The nature(s) of dark matter	**Photodetectors**
Early and late time cosmic acceleration	**Solid State Detectors/ Quantum sensors**
Exploring the unknown	**Calorimetry**
	Trigger and DAQ

Linkage between science drivers and technologies

The P5 Science Drivers:

The Higgs as a tool for discovery

Physics associated with neutrino mass

The nature(s) of dark matter

Early and late time cosmic acceleration

Exploring the unknown

Technologies:

Noble Liquids

Tracking and vertex detectors & muon detectors

Photodetectors

Solid State Detectors/ Quantum sensors

Calorimetry

Trigger and DAQ

Linkage between science drivers and technologies

The P5 Science Drivers:

The Higgs as a tool for discovery

Physics associated with neutrino mass

The nature(s) of dark matter

Early and late time cosmic acceleration

Exploring the unknown

Technologies:

Noble Liquids

Tracking and vertex detectors & muon detectors

Photodetectors

Solid State Detectors/ Quantum sensors

Calorimetry

Trigger and DAQ

Linkage between science drivers and technologies

The P5 Science Drivers:

The Higgs as a tool for discovery

Physics associated with neutrino mass

The nature(s) of dark matter

Early and late time cosmic acceleration

Exploring the unknown

Technologies:

Noble Liquids

Tracking and vertex detectors & muon detectors

Photodetectors

Solid State Detectors/ Quantum sensors

Calorimetry

Trigger and DAQ

Linkage between science drivers and technologies

The P5 Science Drivers:

The Higgs as a tool for discovery

Physics associated with neutrino mass

The nature(s) of dark matter

Early and late time cosmic acceleration

Exploring the unknown

Technologies:

Noble Liquids

Tracking and vertex detectors & muon detectors

Photodetectors

Solid State Detectors/ Quantum sensors

Calorimetry

Trigger and DAQ

Linkage between science drivers and technologies

The P5 Science Drivers:

The Higgs as a tool for discovery

Physics associated with neutrino mass

The nature(s) of dark matter

Early and late time cosmic acceleration

Exploring the unknown

Technologies:

Noble Liquids

Tracking and vertex detectors & muon detectors

Photodetectors

Solid State Detectors/ Quantum sensors

Calorimetry

Trigger and DAQ

Linkage between science drivers and technologies

The P5 Science Drivers:

- The Higgs as a tool for discovery
- Physics associated with neutrino mass
- The nature(s) of dark matter
- Early and late time cosmic acceleration
- Exploring the unknown

Technologies:

- Noble Liquids
- Tracking and vertex detectors & muon detectors
- Photodetectors
- Solid State Detectors/ Quantum sensors
- Calorimetry
- Trigger and DAQ

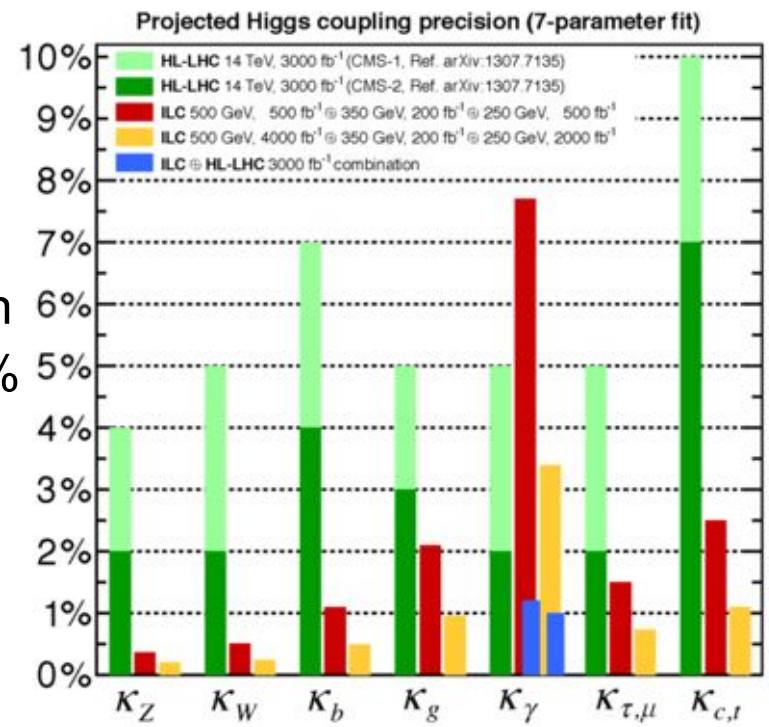
Use the Higgs boson as a new tool for discovery.

Evolution of Higgs boson physics

Typical slide from
a talk at the workshop

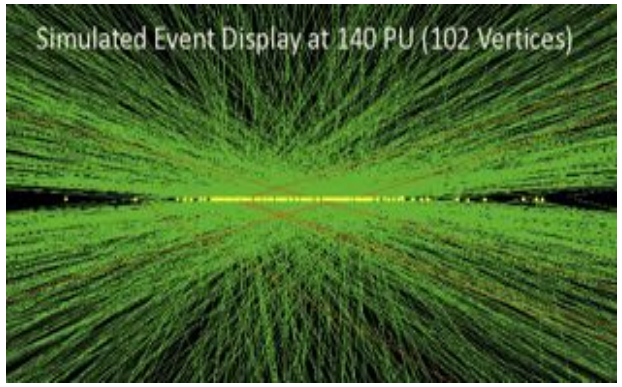
- LHC
  - The facility we have to study the Higgs boson in the next decade
  - Measure couplings to 5-10%, mass to 50 MeV, spin-parity structure
  - Probe rare decays
  - Measure Higgs trilinear coupling to 50%
  - Search for extended Higgs sector
- e^+e^- colliders
  - Measure of total ZH cross-section
    - Absolute normalization of all couplings
    - Access total width and invisible decays
  - Measure most couplings to sub% precision
  - Measure Higgs trilinear coupling to 50-10%
- 100 TeV pp collider
  - Measure Higgs trilinear coupling to 8%
- All
  - Higgs as a tool for discovery

Projections based on arXiv:1310.8361

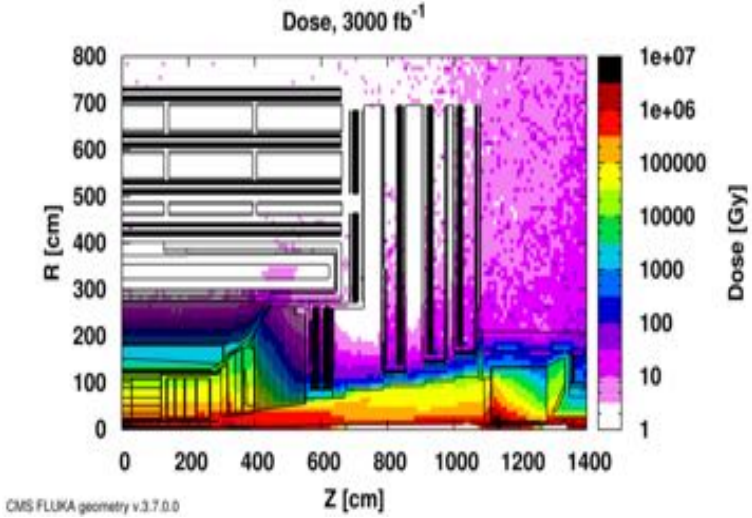


HL-LHC detector upgrade challenges

- Pile up
  - Detector performance degraded (e.g. pattern recognition)
  - Offline reconstruction complexity



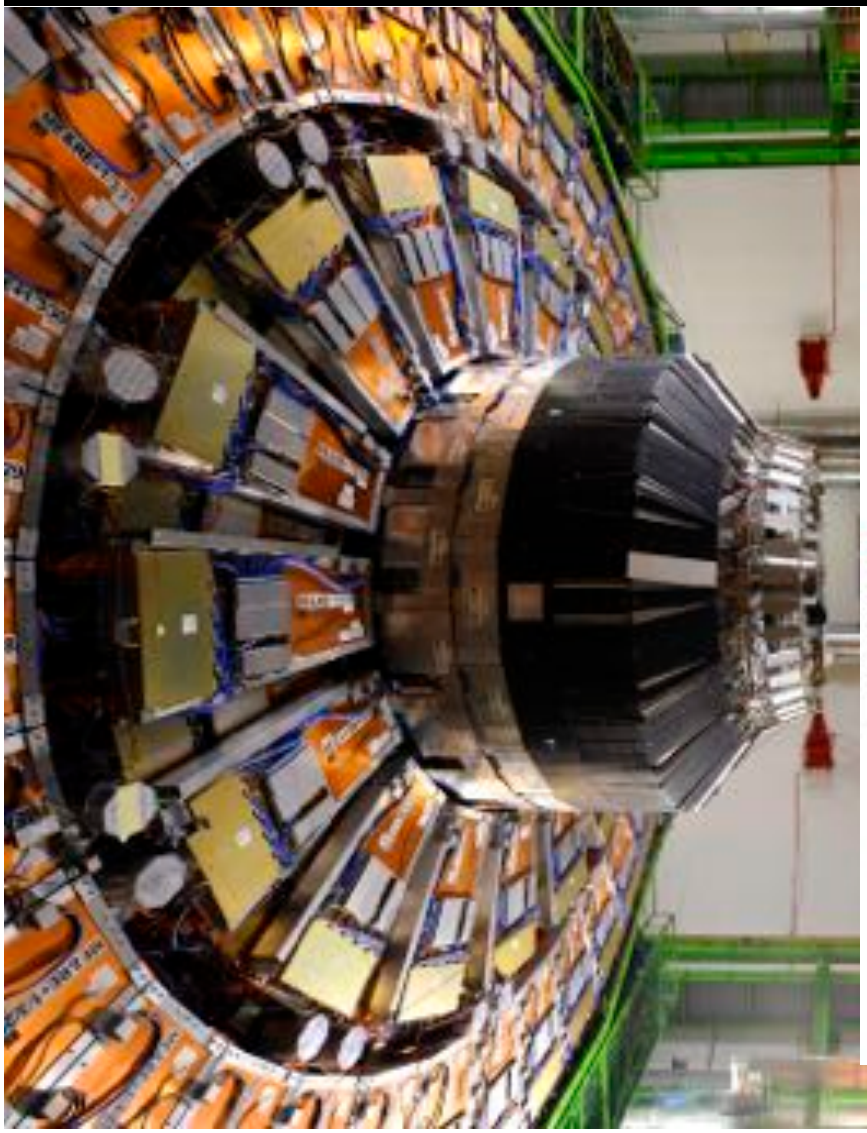
- Radiation
  - High fluencies and high doses for trackers and endcap calorimeters
  - Degraded performance

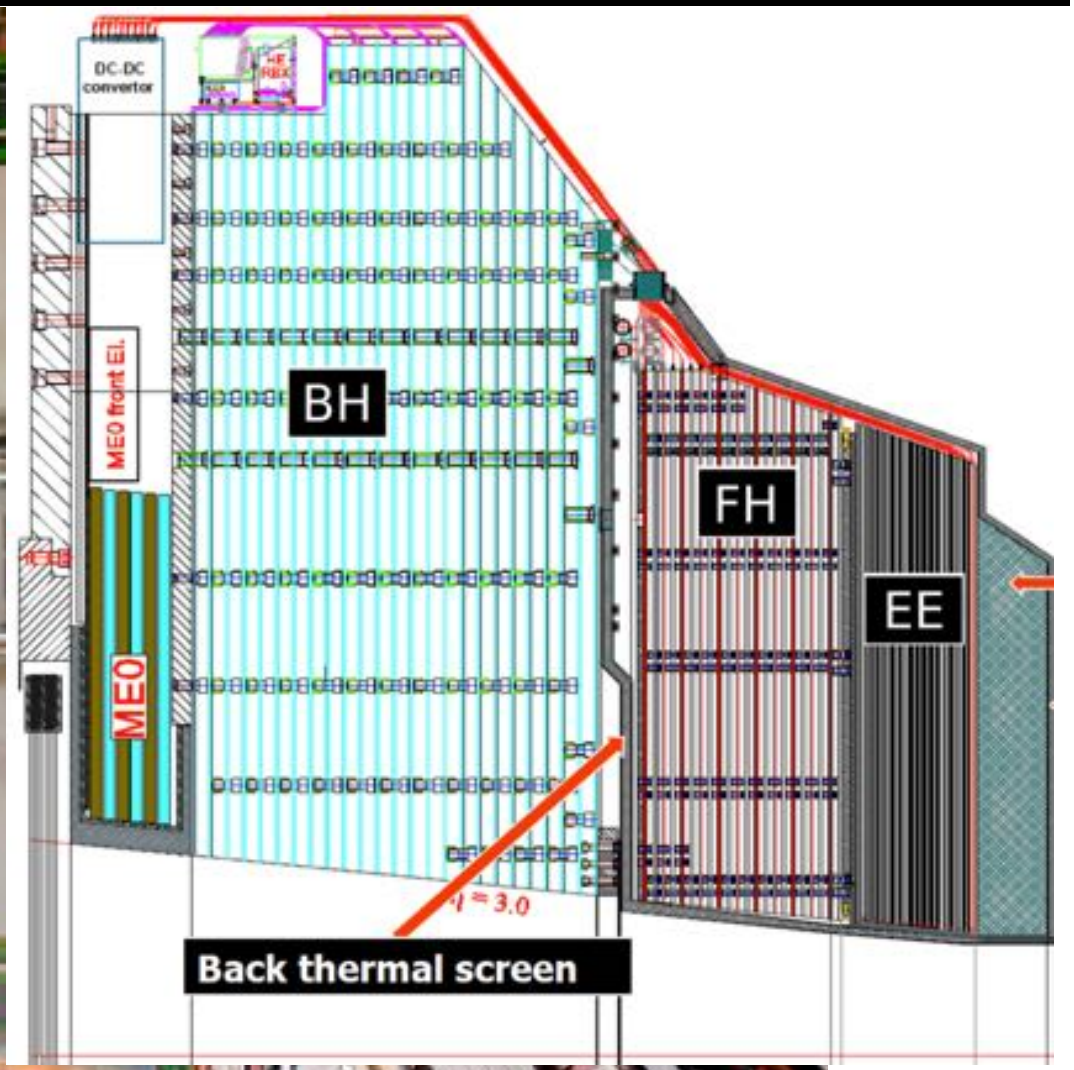


- Rates
  - Trigger rates increase with instantaneous luminosity and performance degrades with pile up (e.g. isolation)

Run	W→lν rate
Run1	80 Hz
Run 2	200 Hz
Run 3	400-600
HL-LHC	1KHz

CMS: Phase 2 Calorimeter upgrade

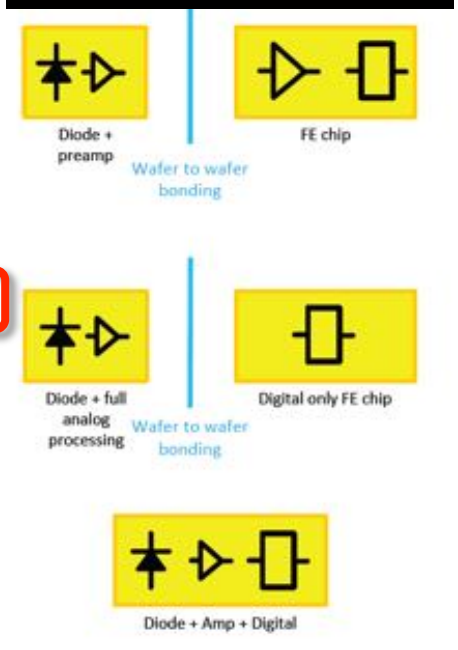




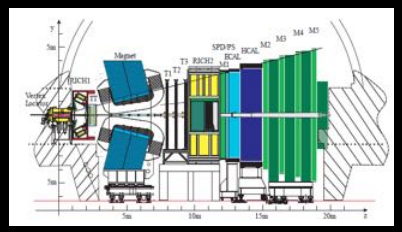
CMOS

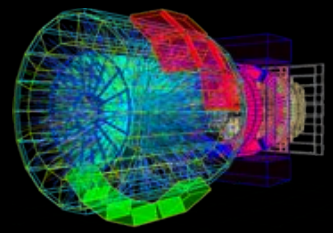
- Low mass, low cost, if rad hard
- Different variants of CMOS sensors for different applications and different timescales
- HL-LHC timescale make very large area deployments of HV/HR-CMOS challenging despite the significant R&D progress
- However, options are being actively studied within ATLAS for tracker upgrade
- Future hadron colliders will benefit from these game-changing technologies for tracking & calorimetry
- Other possible future colliders as well as high intensity fixed target experiments will benefit from an extensive programme of R&D in this technology

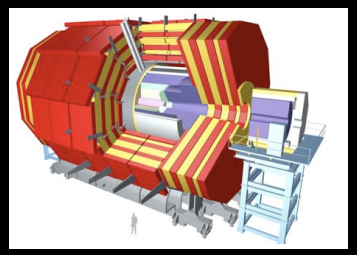
- Hybrid Pixels with "smart" diodes
  - HR- or HV-CMOS as a sensor (8")
  - Standard FE chip
  - Ex: CCPD on FE-I4
- CMOS Active Sensor + Digital R/O chip
  - HR- or HV-CMOS sensor + CSA (+Discriminator)
  - Dedicated "digital only" FE chip
- Monolithic Active Pixel Sensor on a fully depleted substrate (DMAPS)
  - HR-CMOS process



TDAQ and the LHC Experiments

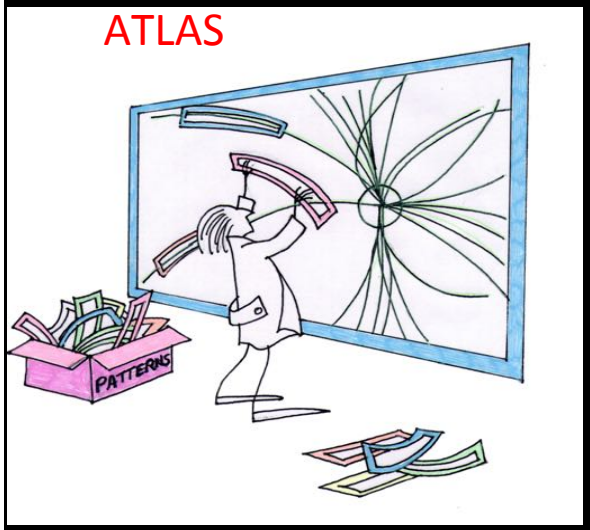




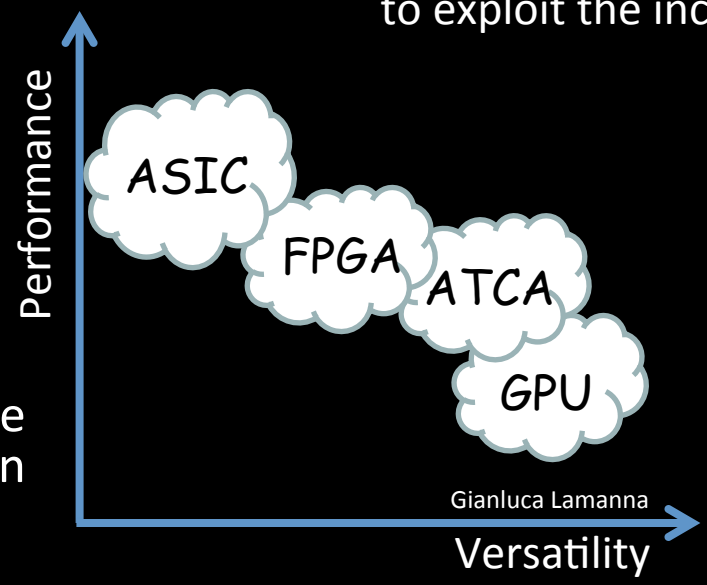


40 MHz	50 kHz	40 MHz	40 MHz
40 Tb/s	1 TB/s	50 Tb/s	50 Tb/s
DAQ	DAQ	DAQ	DAQ
LLT m, e, g, h	Reco + Compression	Level 0/1	Level 1
5 - 40 MHz		0.5 - 1 MHz	1 MHz
HLT Event reco		Level 2	Level 2
20 – 100 kHz	50 kHz	5 - 10 kHz	7.5 – 10 kHz
Offline	Offline	Offline	Offline
2 GB/s	75 GB/s	10 - 20 GB/s	40 GB/s

Trigger Tools



For Phase 2 ATLAS and CMS will need to retain trigger thresholds close to those used in Run 1 to exploit the increased luminosity of HL-LHC

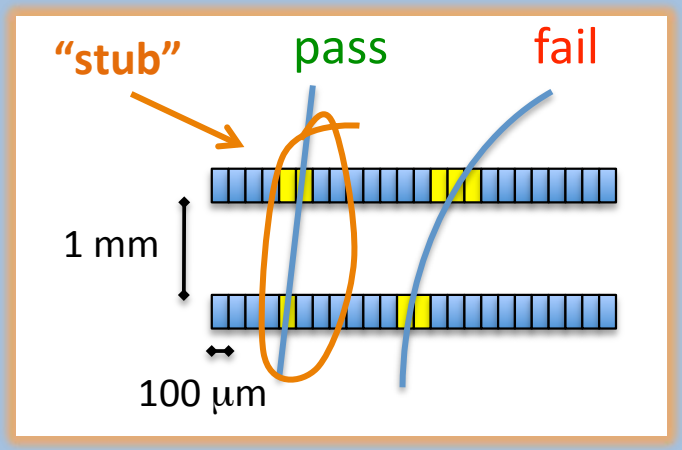


- For Track Trigger store billion(s) of patterns in dedicated Associated Memory
- Region of Interest Builders
- Advanced FPGA for data processing and transmission

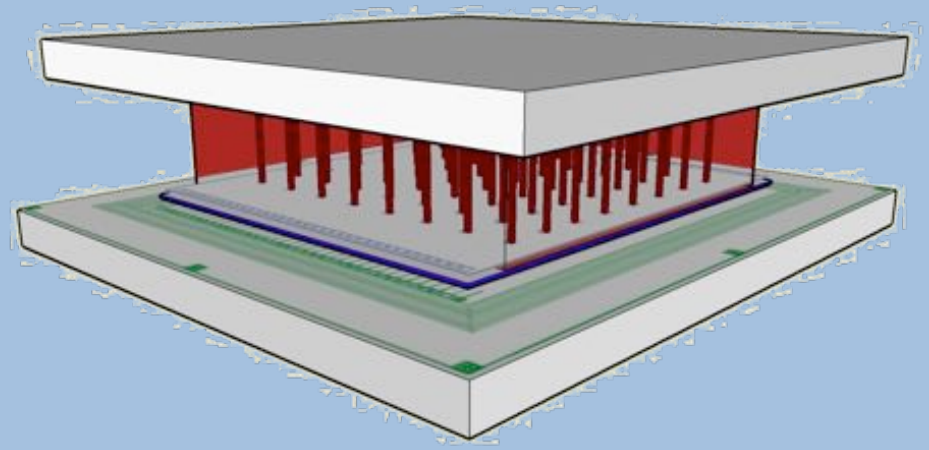
ATLAS & CMS will depend on tracking information in the Level 1 trigger

Track Trigger

- HL-LHC: pile-up O(140) @ 5×10^{34} cm^{-2} s^{-1} leveled with 25 ns bunch crossing
- True trigger challenge to make tracking information available at Level 1



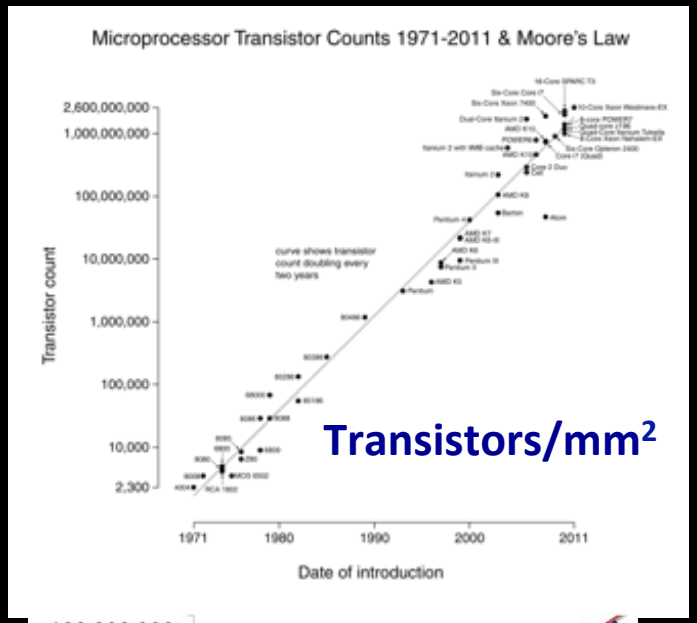
Mitigation through new trigger primitives

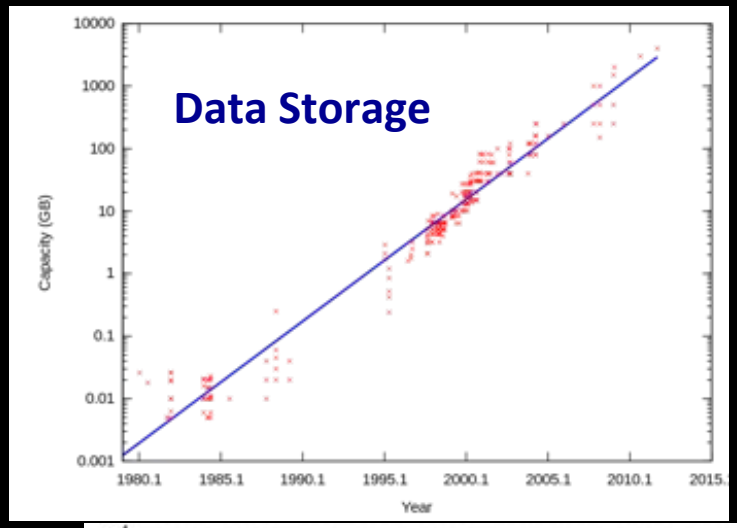


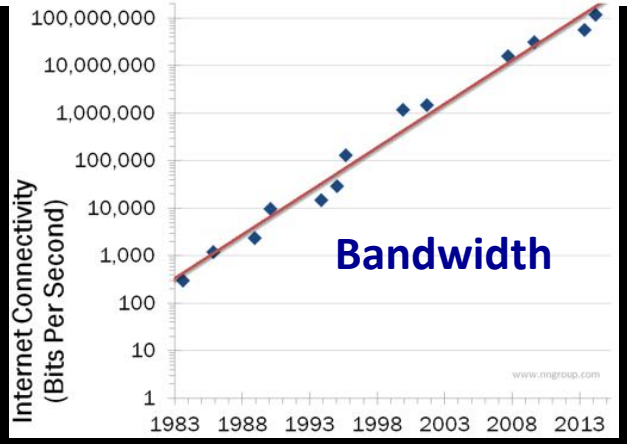
CMS Tracker Upgrade

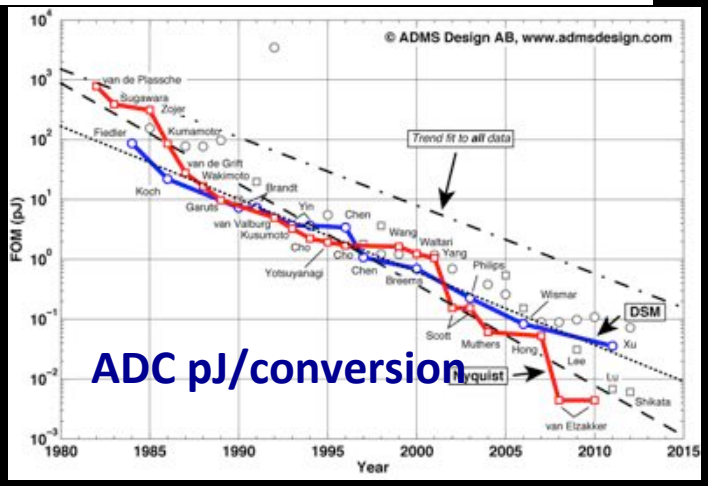
- Combine information from two closely spaced layers to form track stubs as trigger primitive
- Key technology is Through Silicon Via (TSV)

Reasons for Optimism









Doubling times of < 2 years up to now. Some scalings will stop, but new approaches...

TDAQ Recommendations

Increase coordination and cooperation between National Labs & Universities where similar research is underway in technologies, architectures and devices.

HEP should systematically enhance engagement with the engineering departments at universities

High-Speed serializers and optical links are a key enabling technology. Radiation hardened versions (a HEP specialty) have not kept pace with commercial counter-parts. The community should think "bigger" & increase participation in this field and also play an active role in testing and evaluating new technology commercial developments that are not rad-hard.

The community should pursue active R&D in Associative Memories, FPGAs, GPUs, CPUs, Communications Industry Architectures and Link Technologies, particularly to understand better their relative capabilities and suitability for the specific experimental requirements.

Operating System standards are becoming increasingly important. The DAQ community should take a more active role in their standardization process assuring its requirements (specifically in the real-time arena) are incorporated. The offline community's participation in the specification of Scientific Linux would serve as a good example.

TDAQ Recommendations

.

FPGAs are a key enabling technology. The community should play an active role in testing and evaluating new technology commercial developments in FPGAs, both I/O and processing. Encourage a more focused and "far sighted view" on key emerging technologies. This would include for example, photonics, wireless communication, SOCs, GPUs, power conversion and the IOT (*Internet of Things*).

Encourage more collaboration on High Level Synthesis Tools by establishing a venue for collaboration on this and other FPGA tools (e.g. embedded systems). This can be a hot-line or collection of experts on various topics with contacts made available as a means of sharing information on common problems (or uncommon).

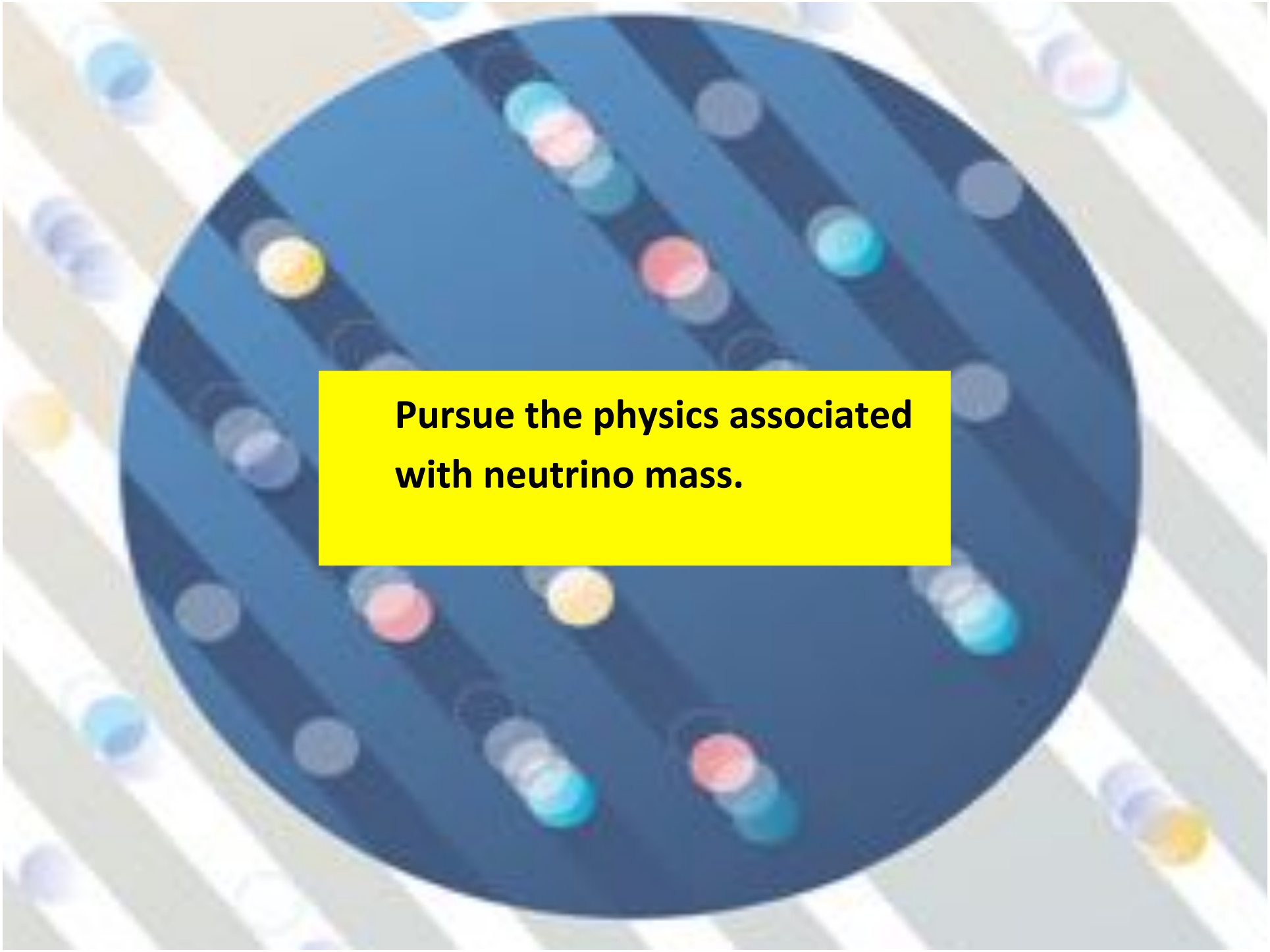
Establish a Forum within the US to facilitate the exchange of information, experience and expertise on FPGA firmware synthesis, firmware designs, and design tools.

Higgs Group

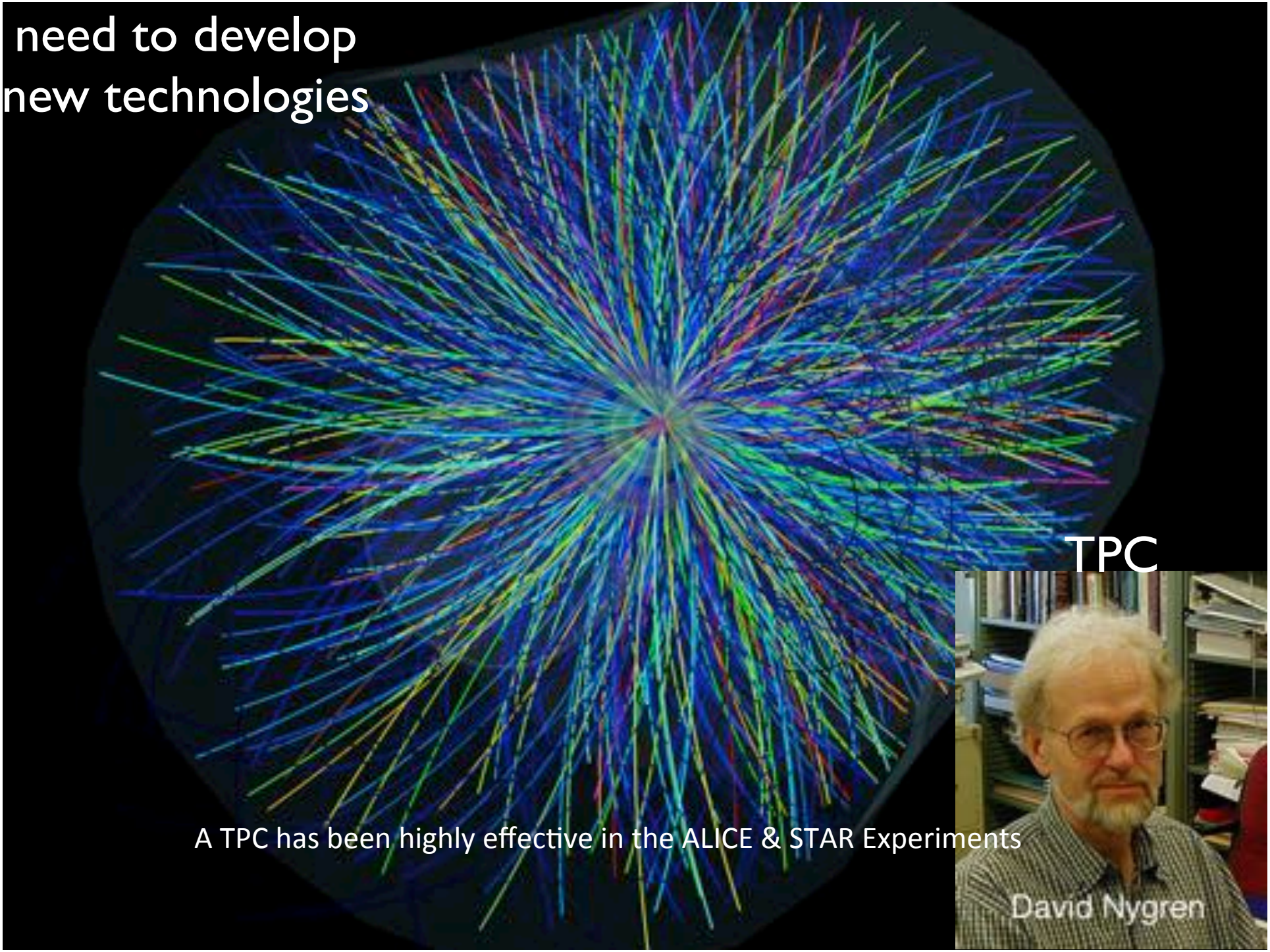
HL-LHC ATLAS and CMS Phase II designs well suited to the task while a 100 TeV pp collider pushes the envelope in all aspects

Grand Challenge Ideas

- Precision timing for all subdetector systems
- Low mass cooling systems
- Highly granular tracking detectors
- Calorimeters for multi TeV showers

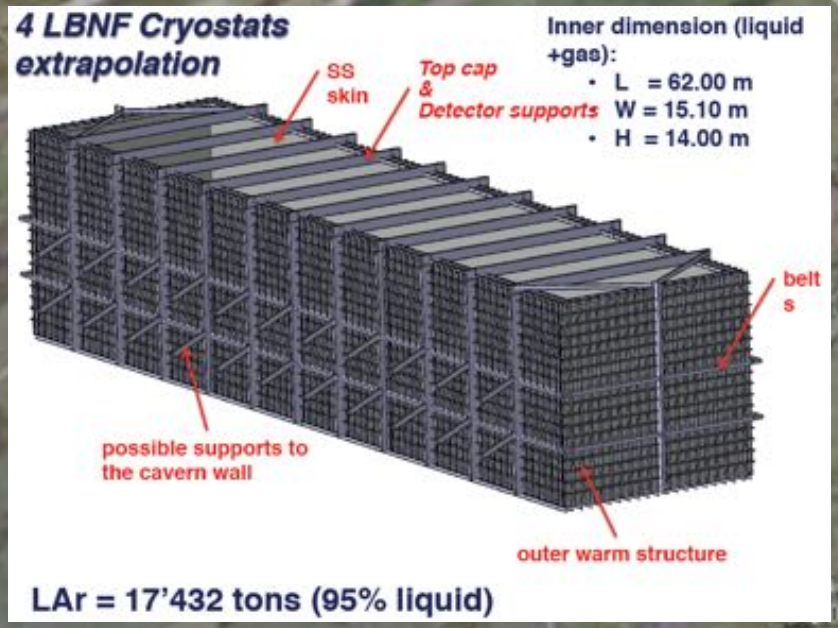


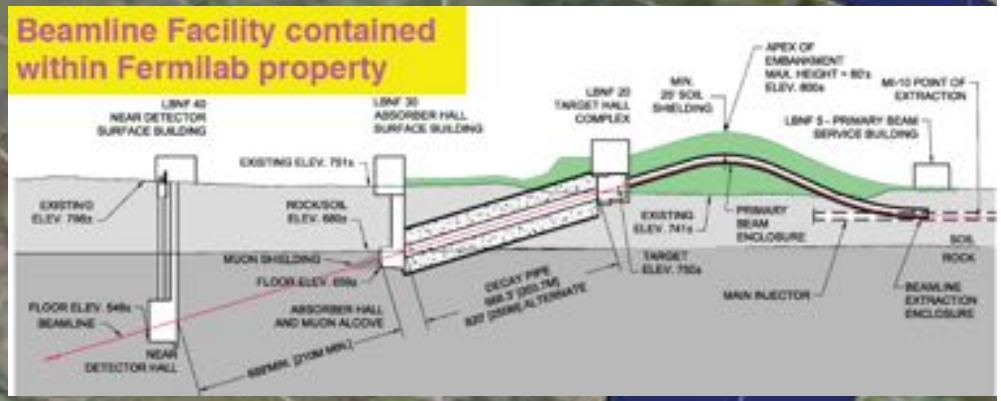
Pursue the physics associated with neutrino mass.

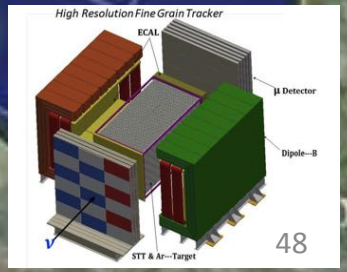

need to develop
new technologies
TPC
A TPC has been highly effective in the ALICE & STAR Experiments
David Nygren

Deep Undergound Neutrino Experiment

- The largest liquid argon TPC in the world: 4 x 10 kton.
- neutrino CP violation
- Core collapse supernova
- Search for proton decay

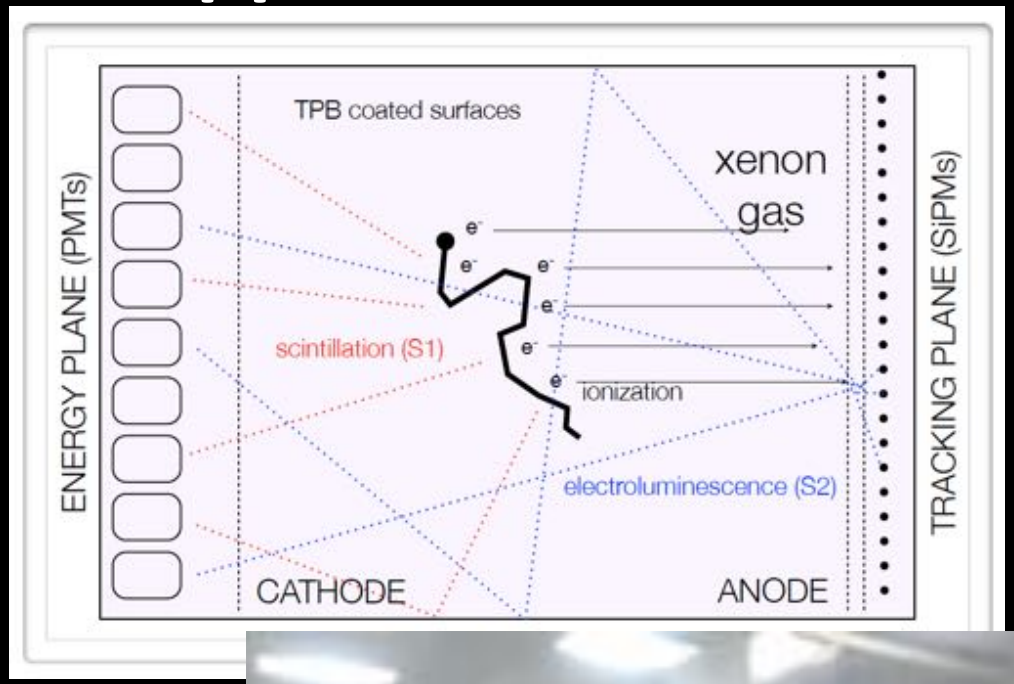






The NEXT Step in 0νββ Detection?

- Uses pressurized (10 atm) gaseous Xenon TPC.
- Intrinsic resolution of ~1% FWHM - best in the business
- Will image beta tracks ~10 cm long, with 'electroluminescent TPC'
- SiPM tracker array can distinguish energy blobs at one end for normal betas and blobs at both ends for double betas.
- Installing "NEW" 1st stage of NEXT in Canfranc Laboratory in Spain – 10 kg

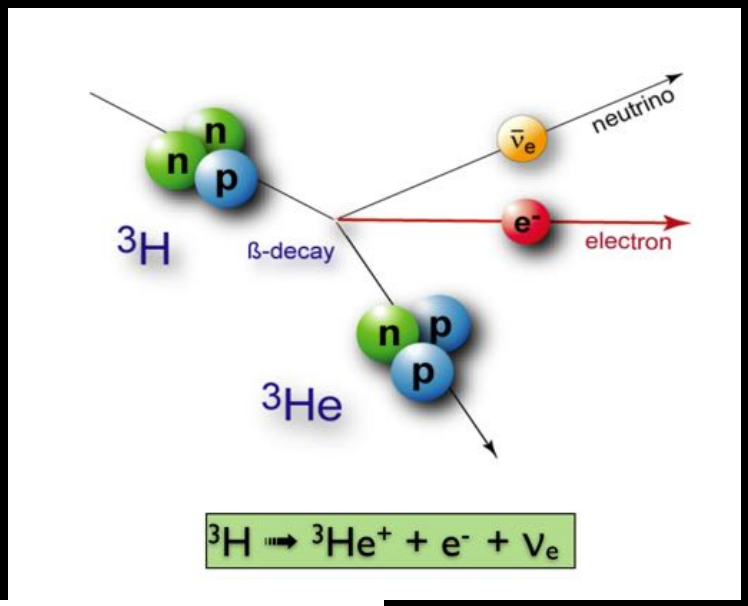


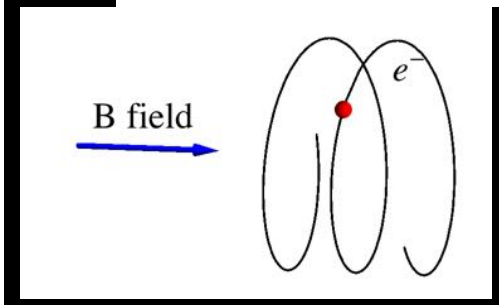
Pressurized Xenon detector also for Dark Matter detection
Studies on using columnar recombination as signal for dark matter direction

J.J. Gómez Cadenas (2014)

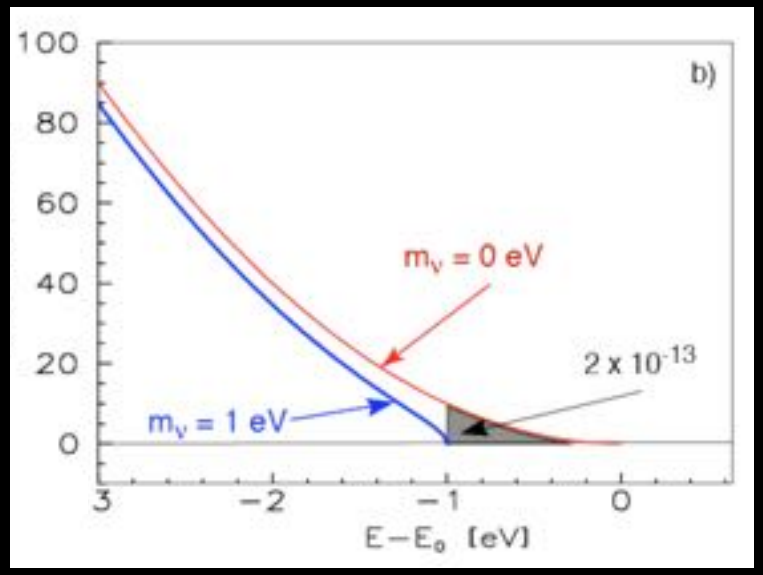
Neutrino Mass

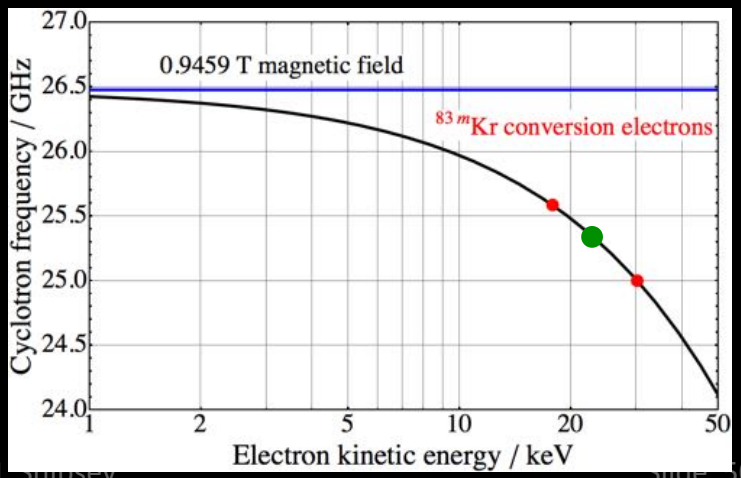
- Project 8 uses measurement of cyclotron frequency of a single electron in a uniform magnetic field from Tritium decay to measure electron energy and set limit / measure neutrino mass





$$f = \frac{1}{2\pi}\frac{eB}{m_e + E_{kin}}$$





Mass reach 0.05 eV

Neutrino Physics Grand Challenges

DUNE - an LArTPC on unprecedented scale

Large-area, inexpensive, efficient photosensors would be a "game-changer" for large, homogeneous detectors for neutrino oscillations and neutrino astrophysics.

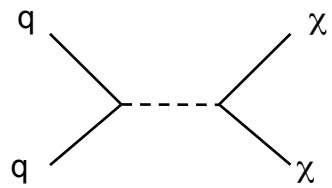
Neutrinoless double beta decay daughter tagging: if one could identify with high efficiency, event-by-event, the unique daughter nucleus from double beta decay, one could approach a zero background NLDBD experiment.

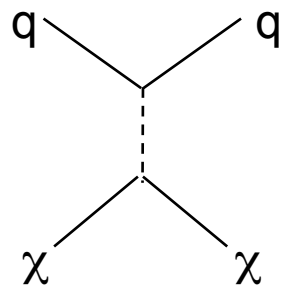
Magnetized liquid-argon TPC: a magnetized LArTPC could distinguish neutrinos from antineutrinos, and provide momentum information.

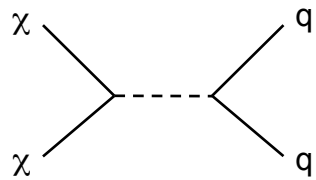
The dark matter and neutrino communities have connections via technologies for dark matter and neutrino physics which should be exploited.

Identify the new physics of dark matter.

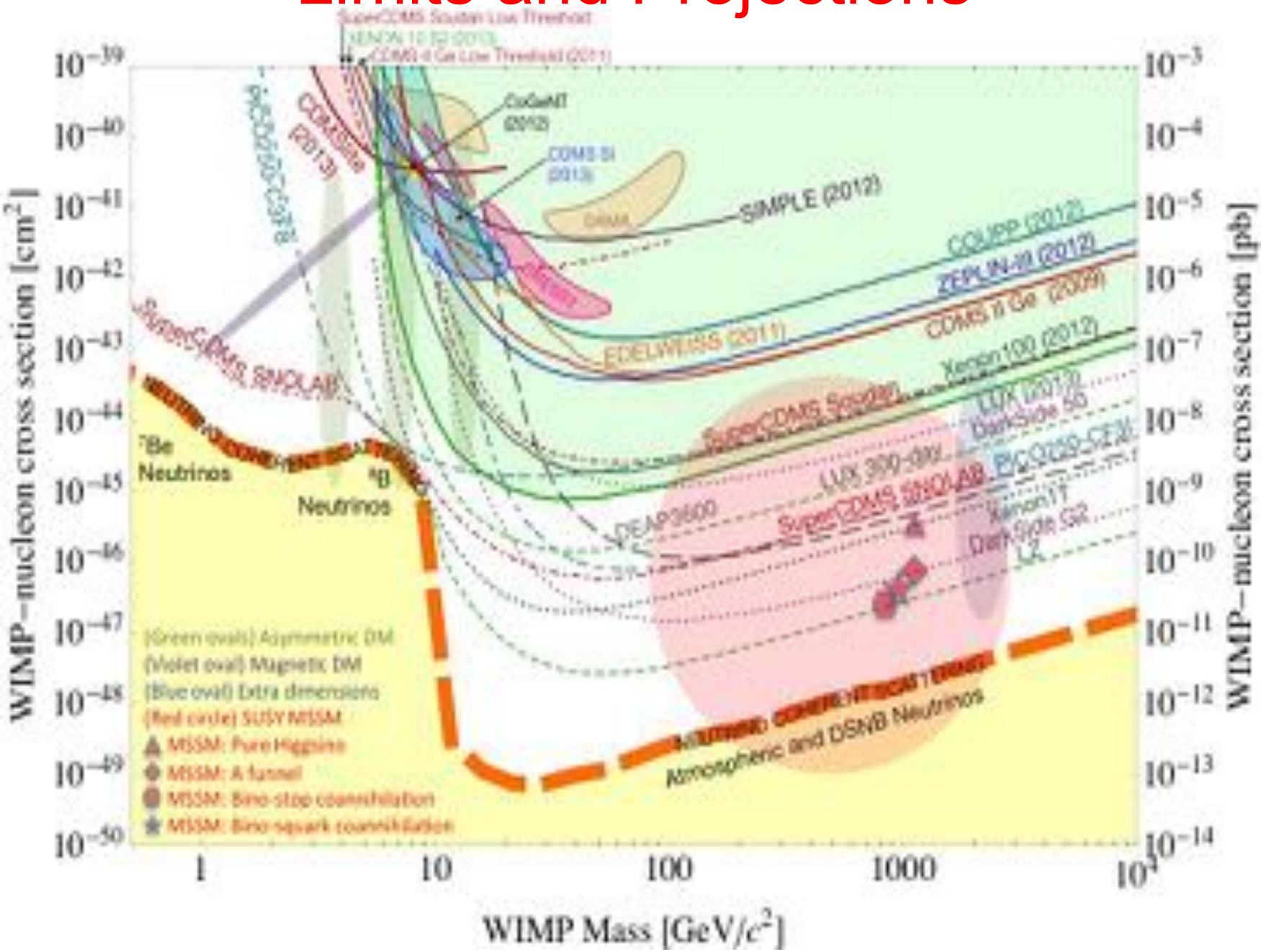
Dark Matter Search Techniques



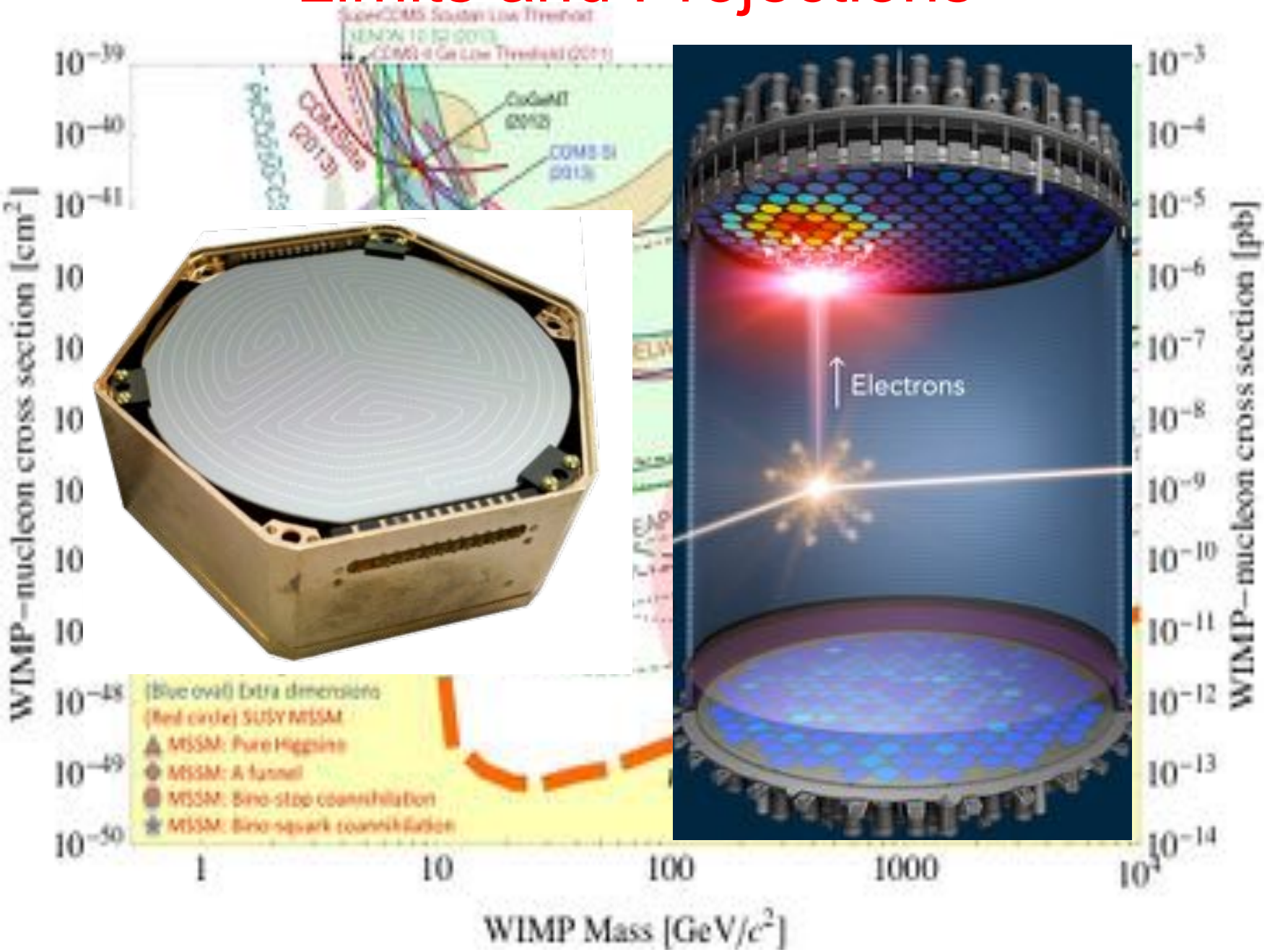




Limits and Projections



Limits and Projections



Dark Matter Grand Challenges

Direct Detection

Large directional detectors will be necessary to reduce backgrounds near the neutrino floor in certain mass regions where the spectral shapes are similar.

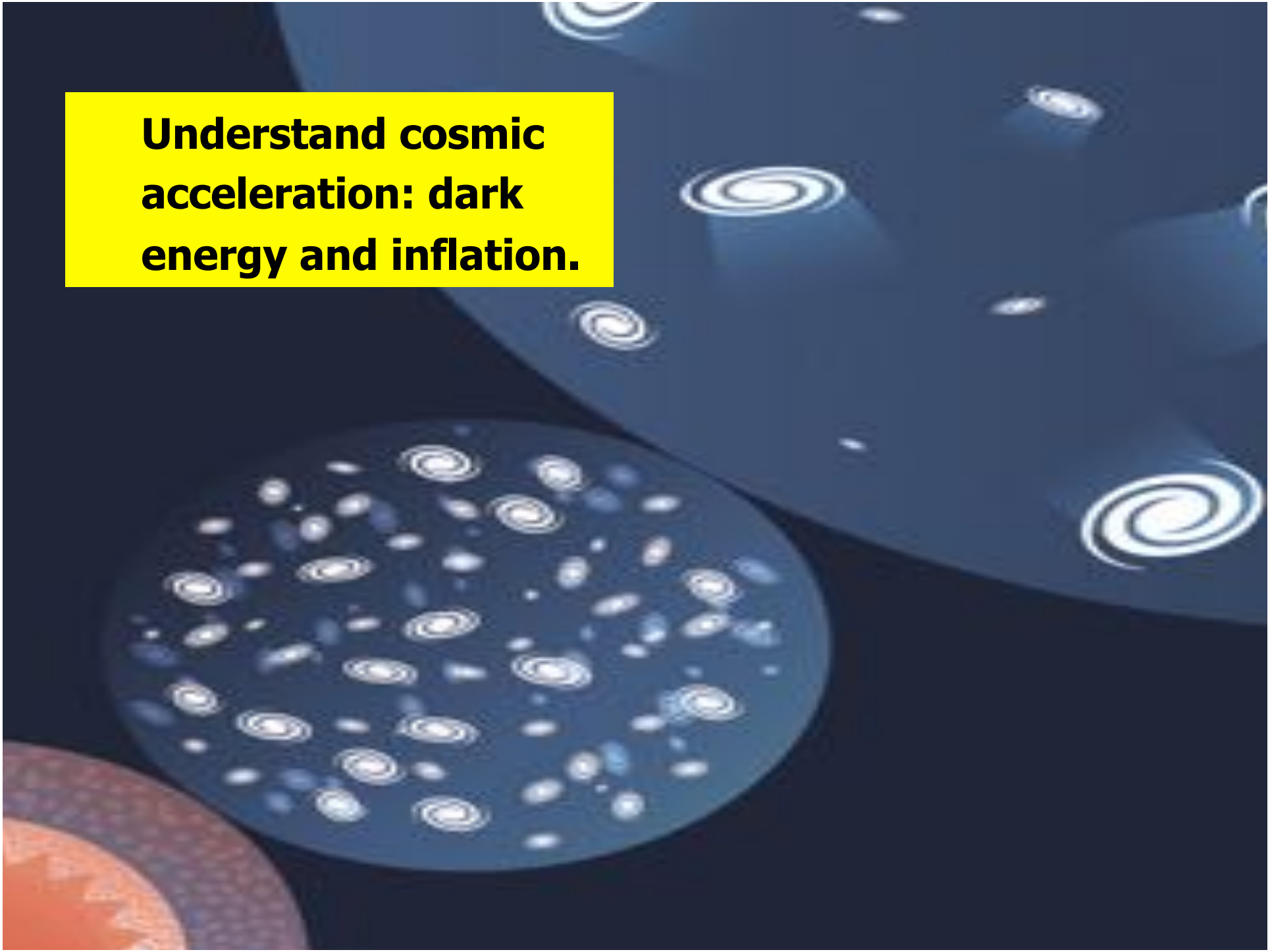
Signals need to be confirmed with different technologies.

Deciphering the physics of the interaction and narrowing down the mass of the particle require different targets.

Joint programs between High Energy Physics and Nuclear Physics would help both the neutrino-less double β decay and dark matter detectors improve background rejection by sharing information on radiopure materials and assay facility infrastructure.

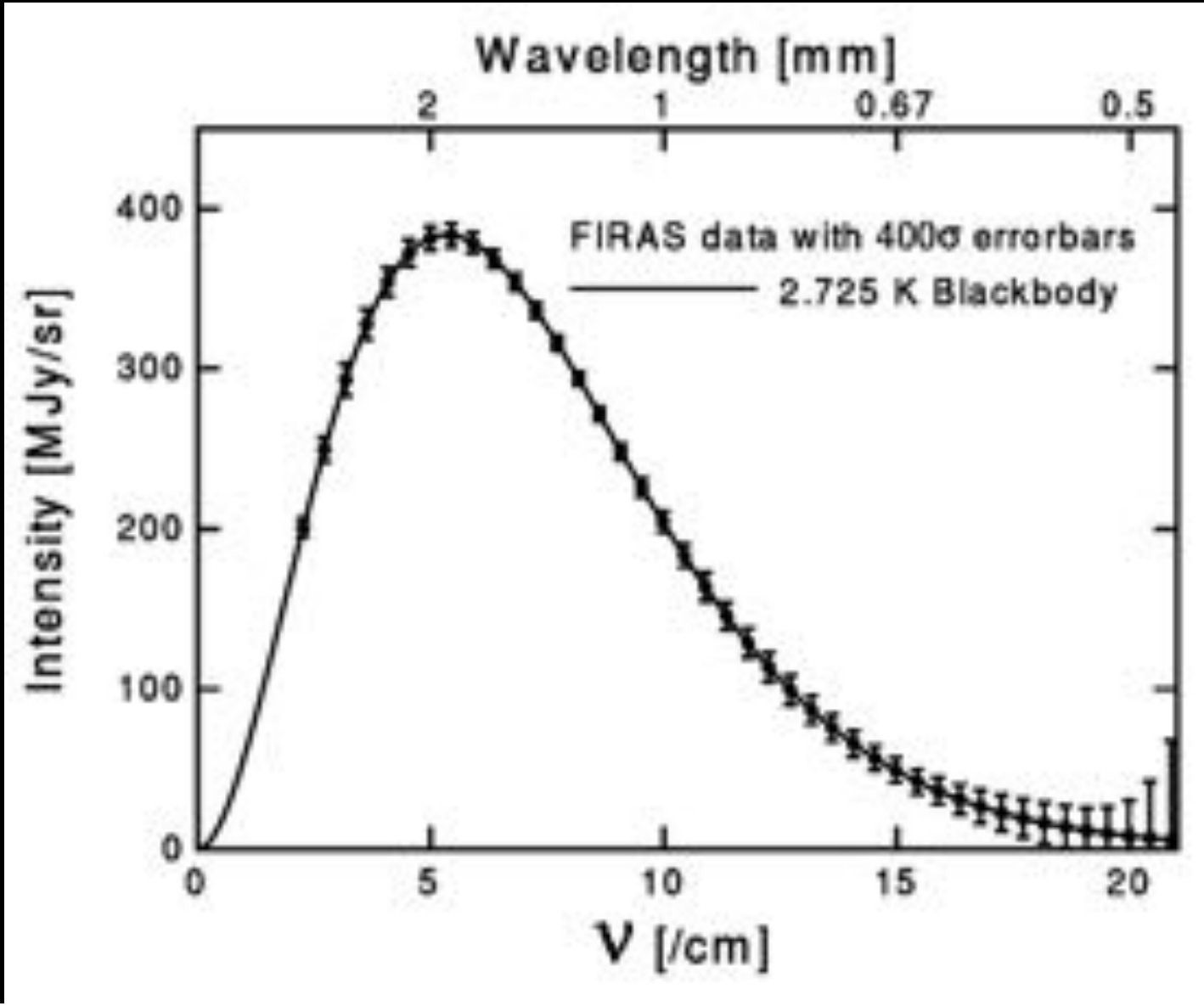
High purity germanium detectors, radiopure materials, shielding, sensitive photodetectors and low noise amplifiers are some of the core technology needs.

(For indirect detection and collider production see workshop talks)

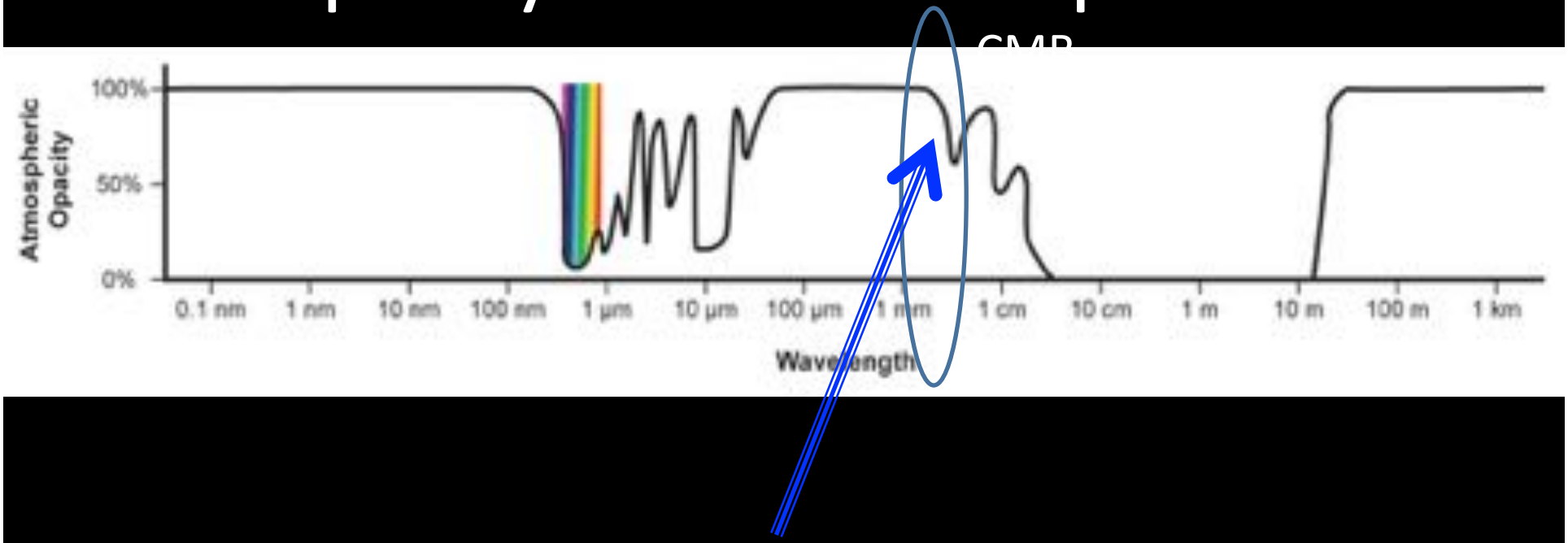


Understand cosmic acceleration: dark energy and inflation.

CMB Blackbody Spectrum



Opacity of the atmosphere



Water vapor and oxygen are what make the atmosphere opaque here – ground-based observations have to be from high, dry sites.

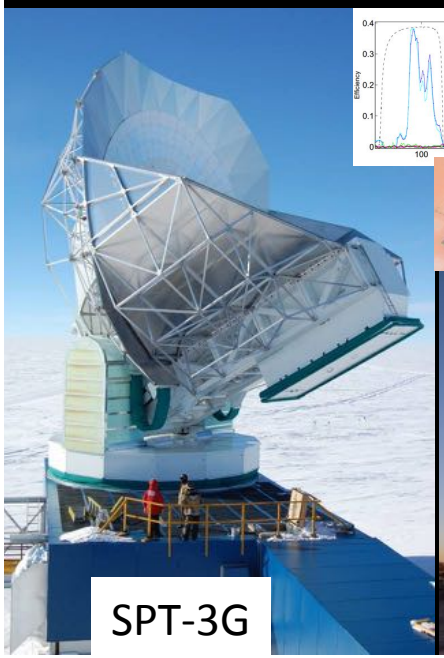
The current premier sites:

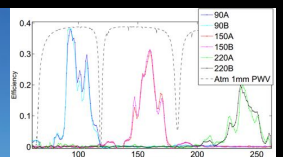
- South pole (3,000 m)
- Cerro Toco in Northern Chile (5,000 m)

Stage 3 CMB Experiments deployed/deploying

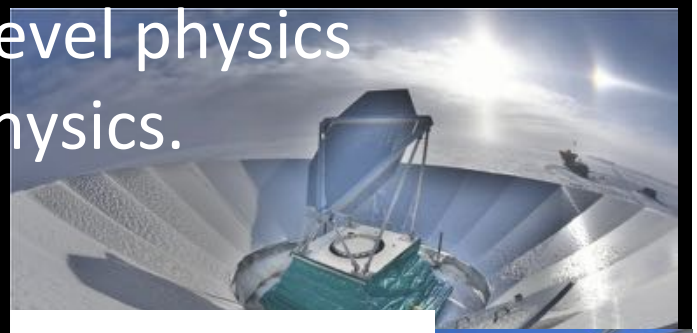
- All employ multiplexed bolometer arrays
- All measure in multiple spectral bands

CMB-S4: Capture technological momentum and scale up -unique window onto GUT-level physics and the cosmic history of neutrino physics.

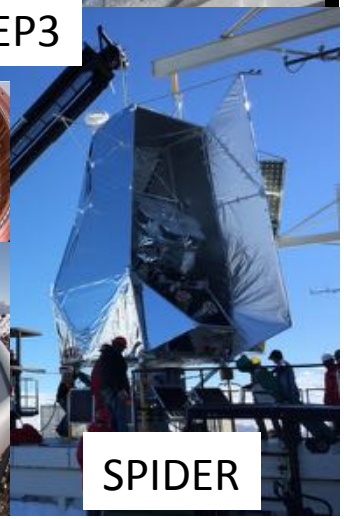

SPT-3G




POLARBEAR / Simons Array


Keck Array / BICEP3


Advanced ACT

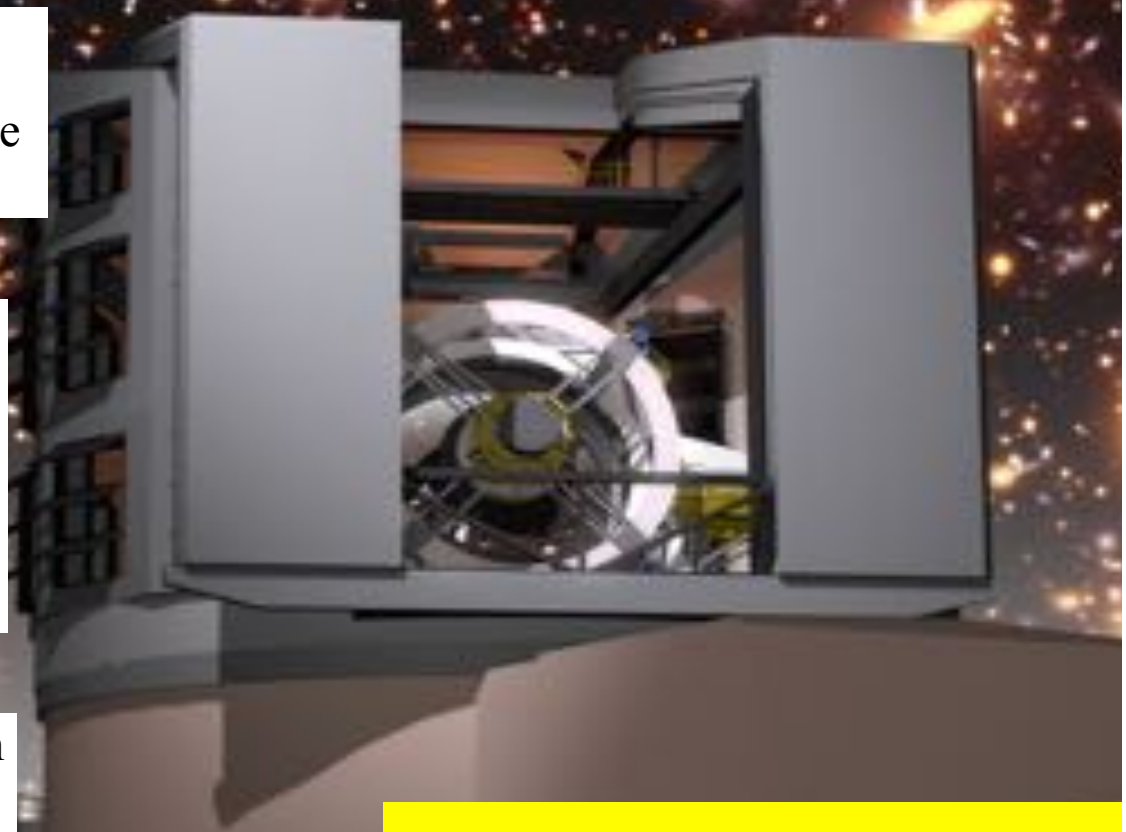

SPIDER

The Large Synoptic Survey Telescope

LSST is a large-aperture, wide-field, ground-based telescope that will survey the entire southern hemisphere in six color bands.

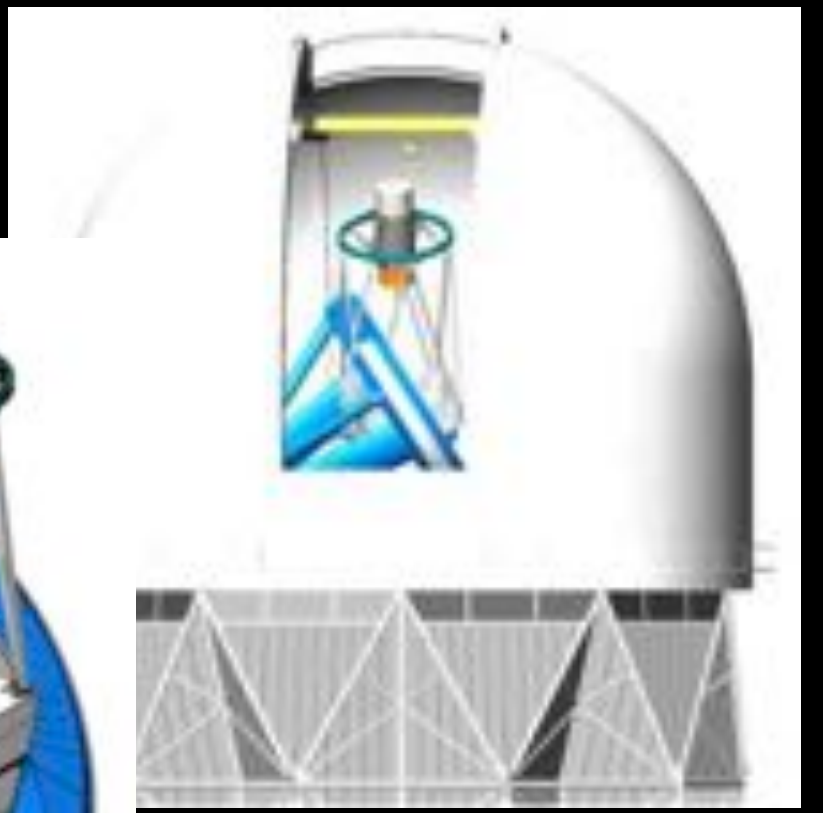
Over ten years of operation, LSST will measure the shapes, colors, and magnitudes of over 4 billion galaxies, and detect several million Type 1a SNe. It will enable tight constraints on dark energy to be derived using all of the probes discussed above.

LSST is currently under construction with funding from both NSF and DOE. The ten-year survey is scheduled to begin in October, 2022.



The next major ground base
Imaging experiment

Dark Energy Spectroscopic Instrument



Demarteau/Shipsey

The next major ground based spectroscopic experiment

Future Instrumentation Directions:

#1 Energy Resolving Imaging Detectors

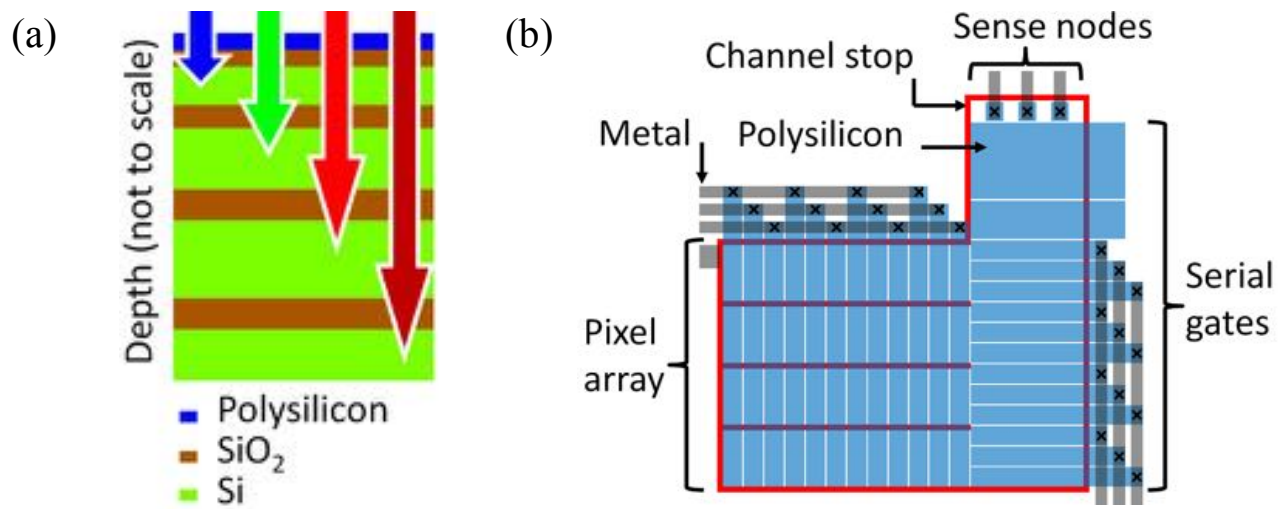
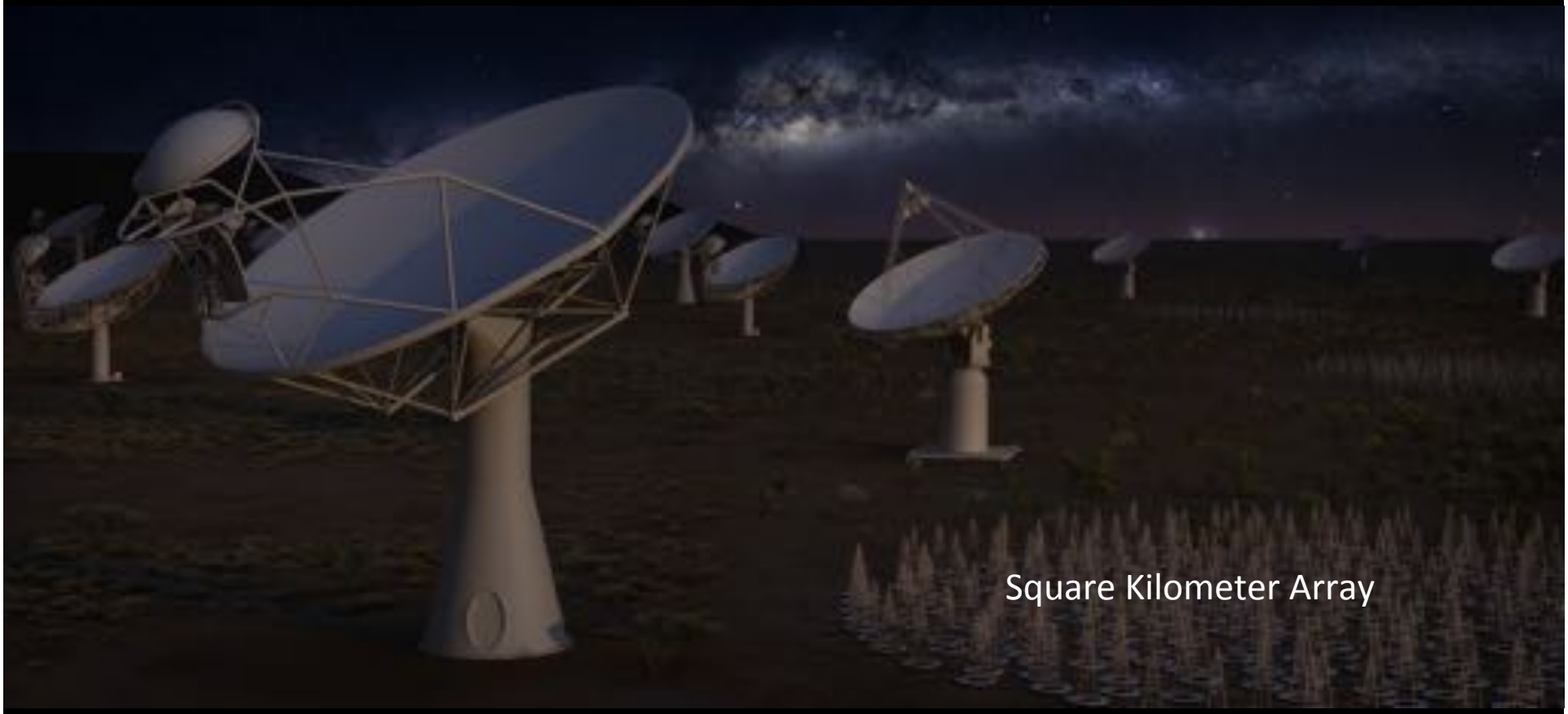


Fig. 1. SOI multiband CCD concept. (a) Each device layer in the SOI substrate interacts differently with different optical bands. (b) The layout is similar to that of conventional CCDs, except that a separate sense node is required to exclusively extract charge from each layer to avoid crosstalk. Charge collection and transfer for all layers are handled by the same set of gates that are on either the front or the back side.

#2 Quantum sensors (TES, KID) have higher energy resolution
R ~ 10 in optical but need to scale up

#3 Future Instrumentation Direction: 21 cm cosmology



#4 a range of table top experiments

Cosmic Inflation & Dark Energy Grand Challenges

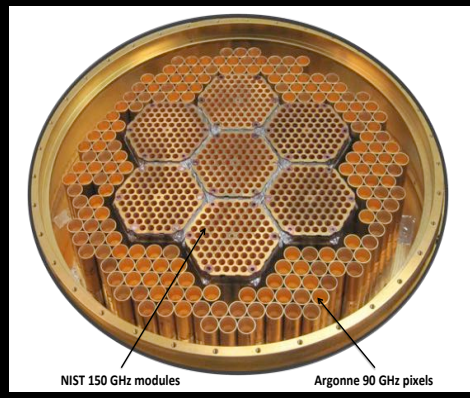
Leave no mode behind: Measure all the modes in the universe, to make the definitive measurement to constrain early and late time acceleration. The case for a Stage V cosmology experiment will likely need to span the electromagnetic spectrum to accomplish this goal.

Extract the entire primordial information content of the CMB.

Invest in "quantum sensors". Superconducting detector and readout technology will be important for next generation experiments across a range of research topics (e.g., CMB, photon science, dark matter searches, neutrino research, a potential Stage-V cosmology project, security applications). (see later)

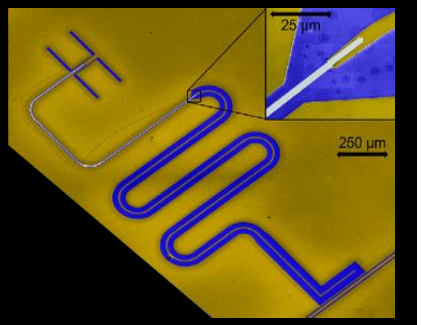
Quantum Sensors a grand challenge

Applications:
Dark Matter detection,
coherent neutrino nuclear scattering,
precision Cosmic Microwave Background(CMB) measurement,
neutrino mass studies via beta & double-beta decay spectroscopy,
hidden photon/axion-like Dark Matter searches,
x-ray spectroscopy



A generic detector R&D program should target four specific goals.

An exponential increase in detector production & testing throughput to stay on "Moore's law" -an increase of 10-100X the current throughput capacity.



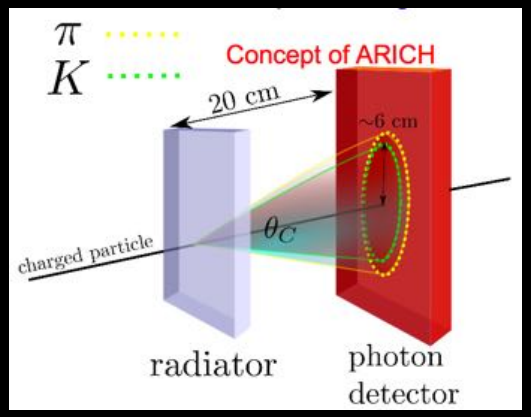
Development of large-mass background-discriminating detectors with thresholds that are 10-100X lower than current detectors.

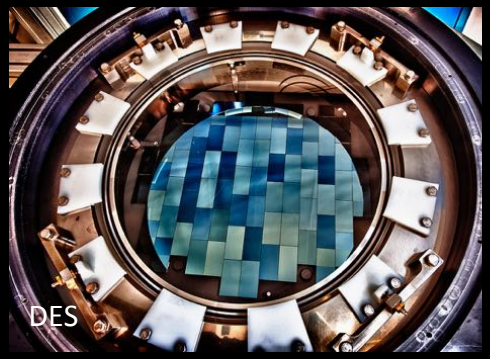
Improving multiplexer density by 100-1000X over currently fielded systems.

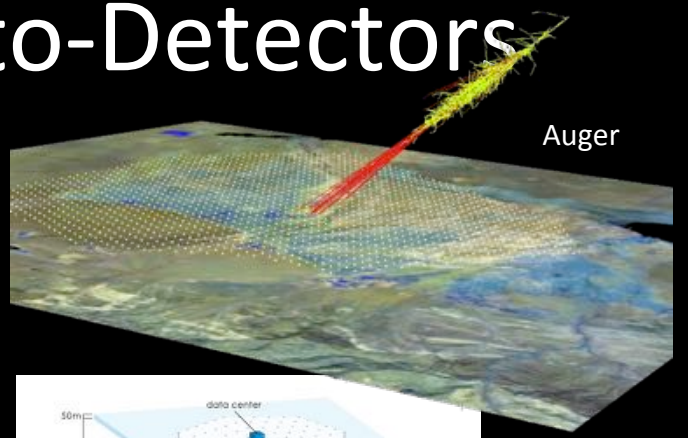
Developing quantum-limited and subquantum-limited amplifiers spanning an additional 100-1000X bandwidth over current amplifier systems.

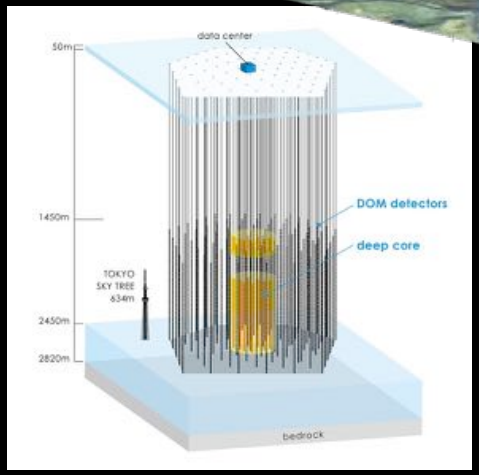
The Broad Reach of Photo-Detectors

BELLE-II

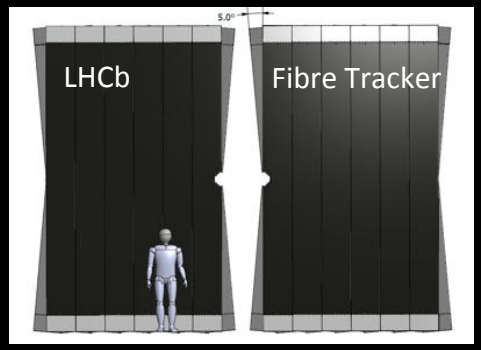


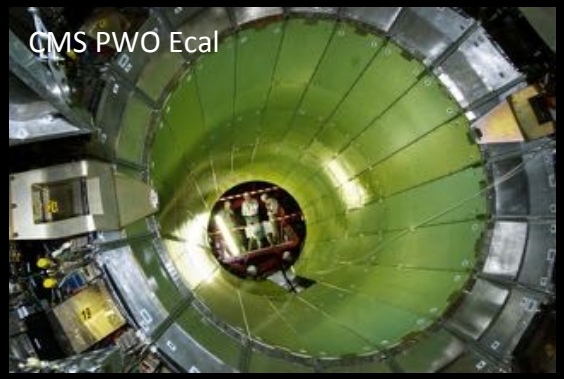


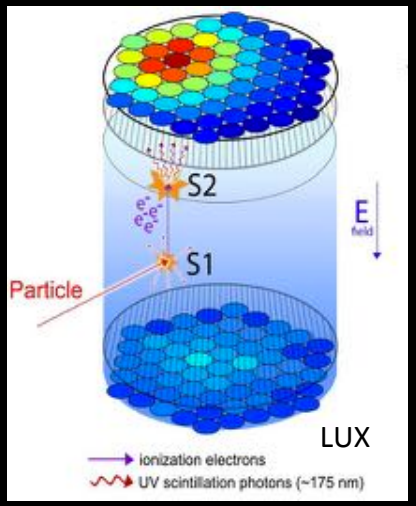




Ice Cube







Photosensors a grand challenge

Applications:
dark matter
neutrino experiments
Rare decays
collider detectors
medicine, industry, and other scientific fields.

Speed, spectral response,
radiation hardness, cryogenic adaptation,
radiopurity, cost

Specialization for a specific use. E.g. SiPM's are not low cost compared to PMT's performance is selling point if cost is not a major part of the total cost of the experiment.

Large-area fast photosensors: 50-100 picosecond, inexpensive photodetectors would be a "game-changer" for large, homogeneous detectors for neutrino oscillations and neutrino astrophysics, and also for neutrinoless double beta decay. They would also have significant impact in areas outside of high energy physics.

Next steps

Workshop outcome: begin to formulate of the needs of the field to ensure a vibrant future.

The deliverable: a report (shared with DOE and NSF) that will summarize the workshop findings (in process)

Begin process of developing a proposed program to deliver the grand challenges

Seek international perspective

The next workshop:

NEW TECHNOLOGIES FOR DISCOVERY

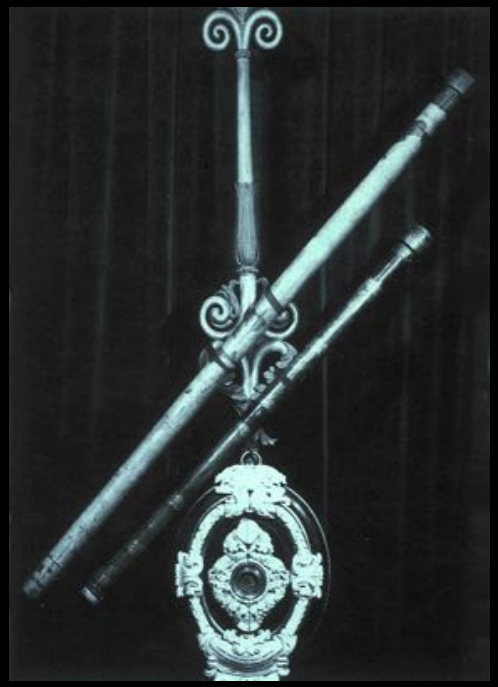
Organized by the Coordinating Panel for Advanced Detectors of the Division of Particles and Fields of the American Physical Society

#2 Development of a solicitation for instrumentation grand challenges

NEW TECHNOLOGIES FOR DISCOVERY

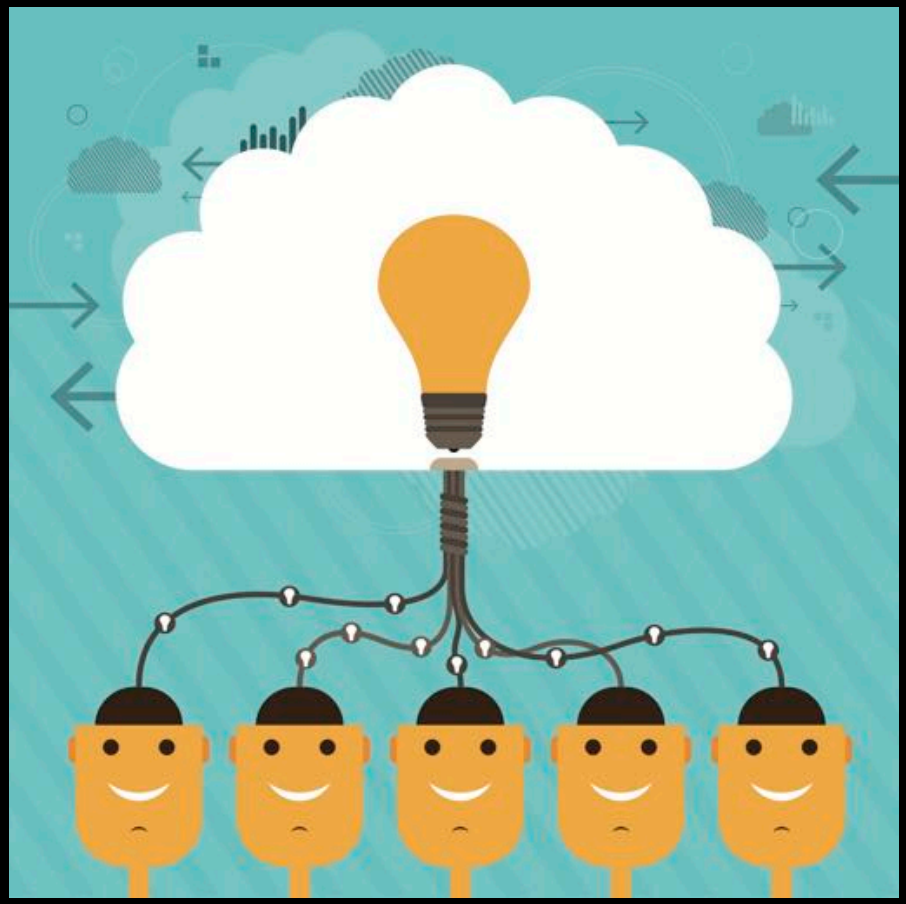
Organized by the Coordinating Panel for Advanced Detectors of the Division of Particles and Fields of the American Physical Society

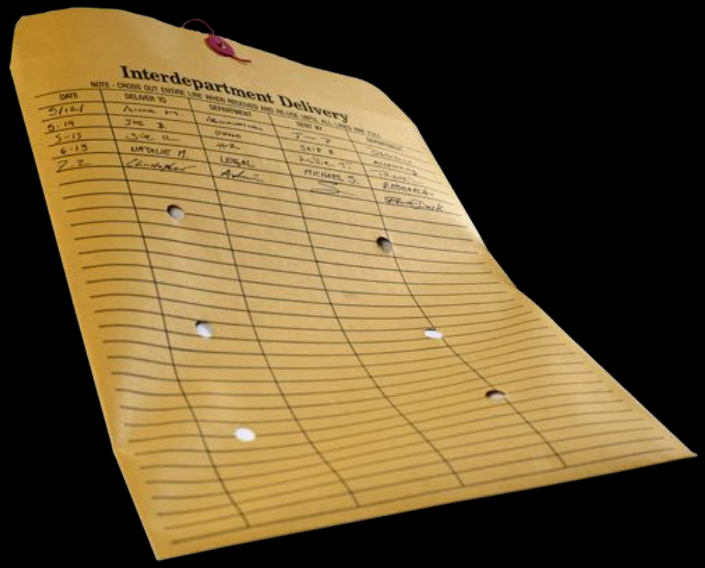
October 5 - 7, 2015 - University of Texas at Arlington



These workshops have a key role to play

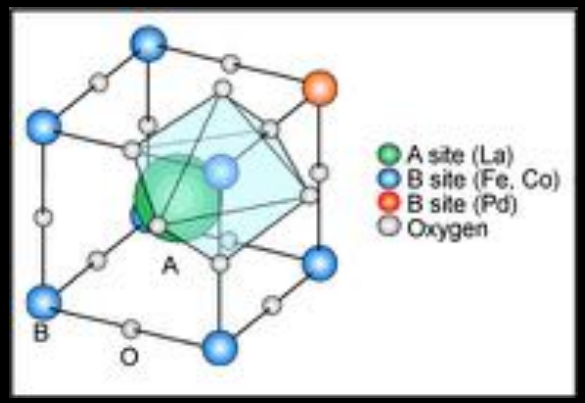
#3 The enhancement of interdisciplinary aspects of instrumentation including a closer relationship with Nuclear Physics, Basic Energy Sciences, the medical community, NASA, and the national security community in part through a series of interdisciplinary workshops



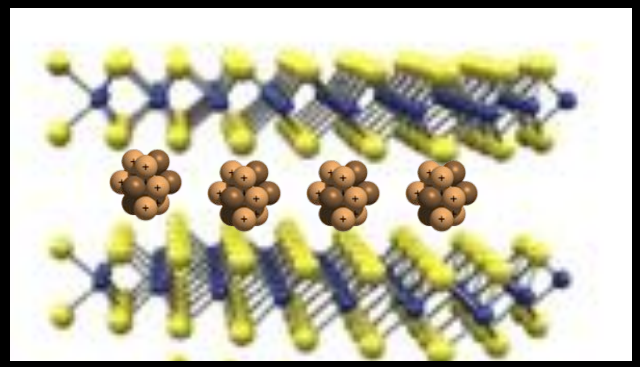


#4 Develop a plan to establish and maintain a repository of new developments in other fields that might benefit the development of new sensors or instrumentation in HEP

Perovskites



Trans Metal Di-chalcogenides



Wavelength shifting through Quantum Dots

Additive manufacturing

……

#5 Creation of a National Instrumentation Fellowship program for both post docs and graduate students

CPAD

National Science Foundation
WHERE DISCOVERIES BEGIN

+
Private
Sector

U.S. DEPARTMENT OF ENERGY | Office of Science

#6 A program to support existing instrumentation schools and further develop instrumentation schools and education

#7 Coordination of instrumentation resources (including engineering) at National Labs for the HEP community at the universities and the National Labs

#9 Working with DOE OHEP on which topics in instrumentation should be encouraged in the yearly SBIR/STTR proposal calls. (Started with 2015 call.)

CPAD

#10 The creation of an APS DPF Award for Excellence in Instrumentation Research and Development

Message to members of the APS Division of Particles & Fields
Approved by Ian Shipsey, DPF Past Chair

Announcement of the DPF Instrumentation Award

Nomination deadline August 1

Dear Colleagues:

The Division of Particles and Fields of the American Physical Society has established a new award to honor exceptional contributions to instrumentation. This APS Unit Award will be bestowed annually.

The Award will be given for advancing the field of particle physics through the invention, refinement, or application of instrumentation and detectors. In particular, the award will be given for one or more of the following:

- Conceptualization and development of unique instrumentation that has made a significant impact on the field.
- Demonstration of the innovative use of instrumentation.
- Stimulation of other researchers to use new techniques and methods.
- Authorship of research papers or books that have had an influential role in the use of instrumentation.
- Achievement in particle physics instrumentation through dedication over an entire career, or through significant impact at an early career stage.

The 2015 DPF Instrumentation Award

is presented to

David Nygren and Veljko Radeka

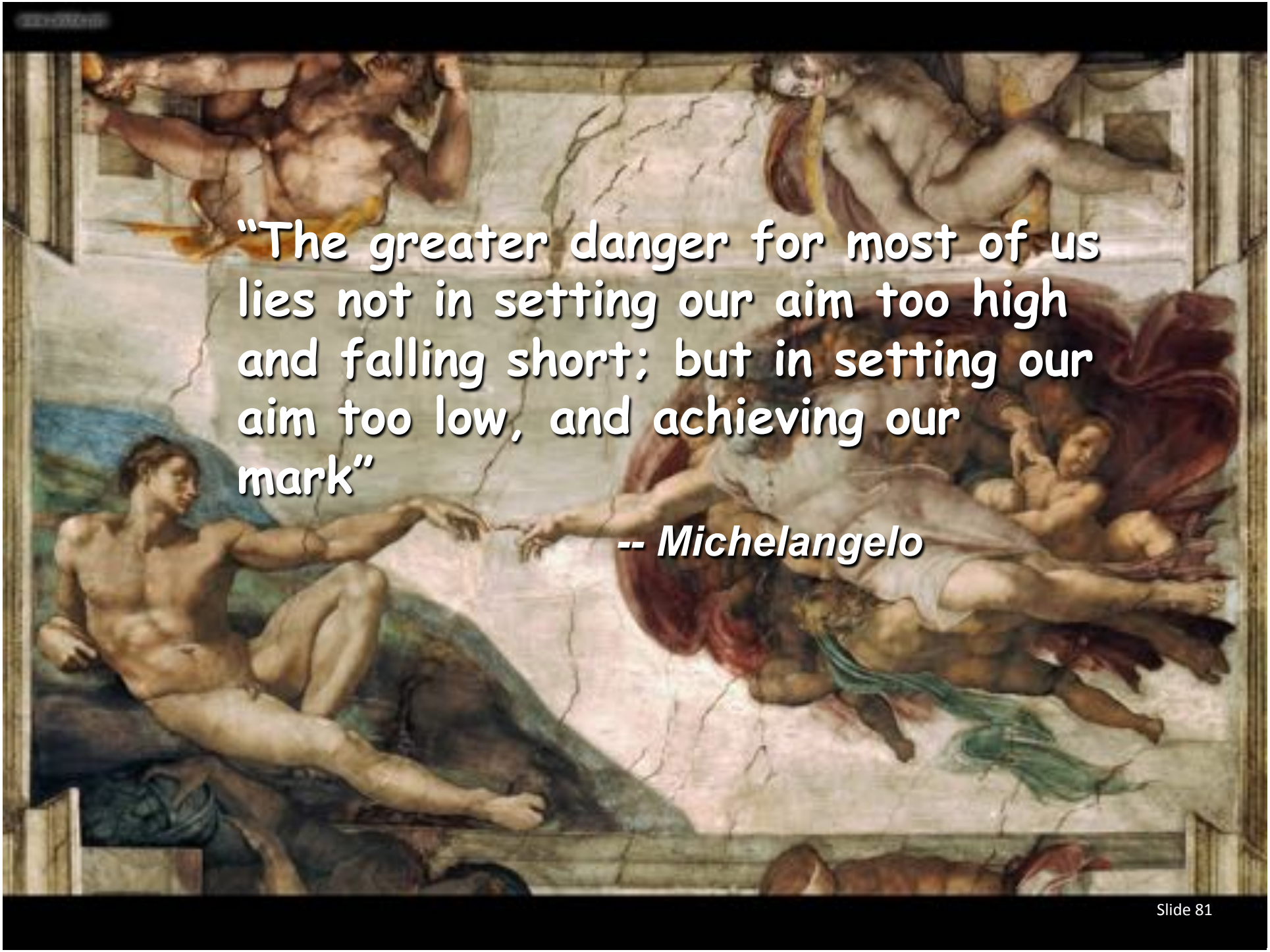
for widespread contributions and leadership in the development of new detector technologies and low-noise electronics instrumentation in particle physics as well as other fields, and in particular work leading to the development and instrumentation of large volume liquid argon time projection chambers that are now a key element in the global particle physics program.

The 2016 DPF Instrumentation Award

is presented to

Steve Holland and Gary Varner

For the development of technologies for detection of signals in frontier experiments, especially the fully depleted charge coupled device and the 'oscilloscope on a chip' integrated circuit


"The greater danger for most of us lies not in setting our aim too high and falling short; but in setting our aim too low, and achieving our mark"
-- Michelangelo

Innovation

In Instrumentation

is

DISCOVERY

in action

With many thanks to:
the speakers and conveners of the workshop
DOE: Glen Crawford, Helmut Marsiske, Jim Seigrist
NSF: Jim Whitmore, Jim Shank
University of Texas at Arlington: Andy White, Dave Nygren
The Executive Committee of the Division of Particles and Fields of the American Physical Society
The Coordinating Panel for Advanced Detectors

The workshop conveners:

The P5 Science Drivers:

The Higgs as a tool for discovery (Rick van Kooten, Ulrich Heinz, Ariel Schwartzman)

Physics associated with neutrino mass (Jae Yu, Kate Scholberg)

The nature(s) of dark matter (Priscilla Cushman , Rupak Mohapatra)

Early and late time cosmic acceleration (Brad Benson, Mike Niemack)

Exploring the unknown (Jim Alexander, Doug Glenzinski)

Technologies:

Noble Liquids (Marty Breidenbach, Cristiano Galbiati, Tom Shutt)

Tracking and vertex detectors & muon detectors (Marina Artuso, Ron Lipton)

Solid State Detectors/quantum sensors (Clarence Chang, Yury Kolomensky, Kent Irwin)

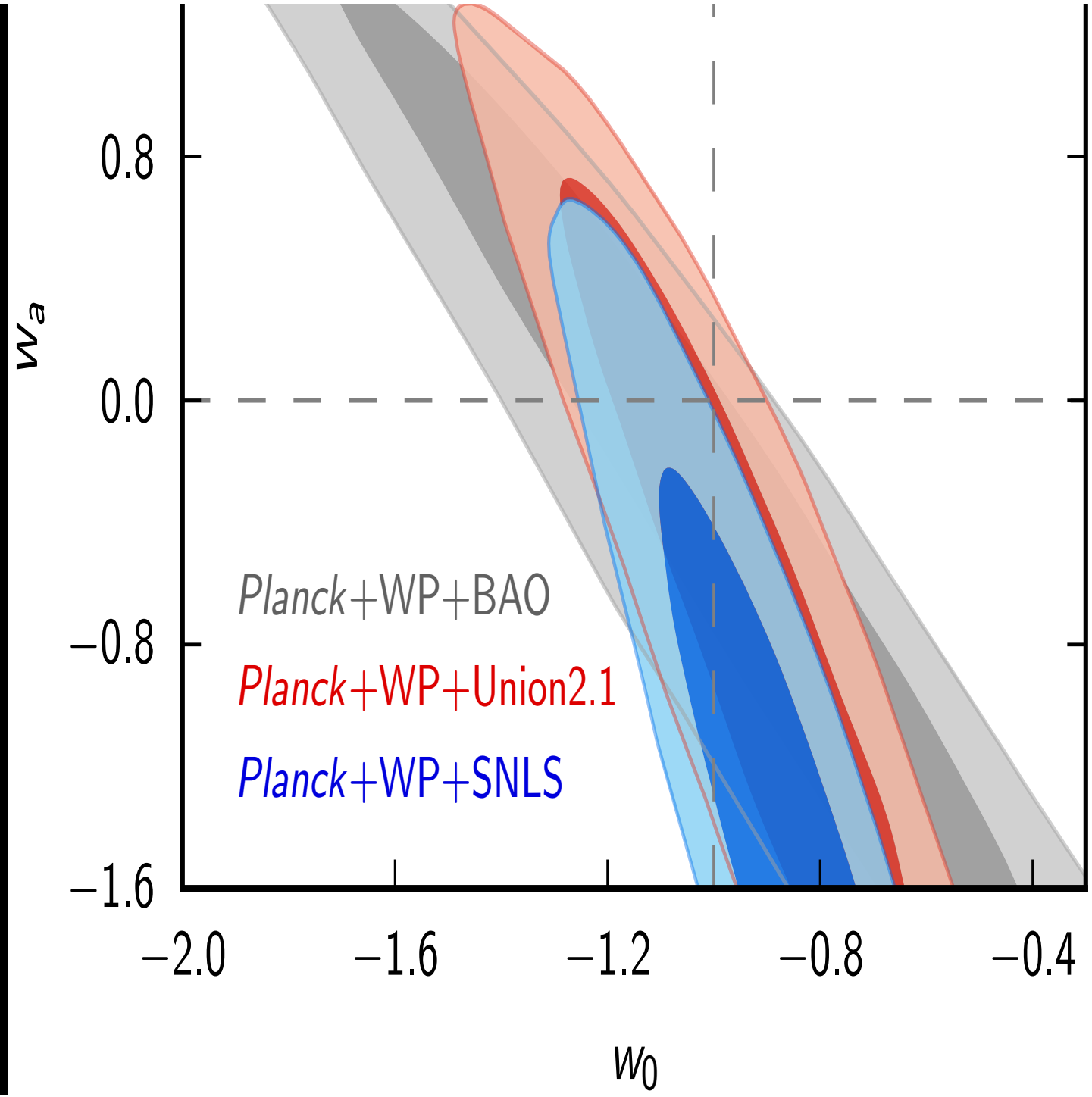
Calorimetry (Burak Bilki, Roger Rusack, Erik Ramberg)

Photodetectors (Adam Para, Bob Svoboda, Matt Wetstein)

Trigger and DAQ (Wesley Smith, Mike Huffer)

Extra material

Present state of knowledge



Present state of knowledge