Community Summer Study

SN WMASS

July 17-26 2022, Seattle

The Instrumentation Frontier Enabling Physics Goals

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representing the Instrumentation Frontier and all its conveners, contributors and stakeholders (=all of you!)

Changes since last Snowmass/P5

- Today's IF key messages are almost identical to those from 2013 (independent development)
- Recommendation #27 & #28 in 2014 P5 report (out of 29)
- CF, EF, NF and RPF physics goals WILL NOT reach their maximum potential if the community (and P5) do not support detector instrumentation in MUCH stronger terms
- IF advances relate to ALL P5 science drivers!

IF Key Message #1

IF-1 Double the US Detector R&D budget over the next five years and modify existing funding models to enable R&D Consortia along critical key technologies for the planned long term science projects, sustaining the support for such collaborations for the needed duration and scale.

Since last Snowmass funding for Detector R&D in the US has been on the decline. Detector R&D shares pot of money (DOE) with detector facilities operations, which need to be protected at all cost. Any decline in research funds for detectors has direct hit on R&D.

CERN RD Collaborations for targeted and coordinated detector R&D wildly successful. We recommend the establishment of a similar model of R&D Consortia in the US, along strategic technological directions, and perhaps under the guidance of CPAD. We recommend a strong link to the newly formed R&D collaboration model at CERN, following the ECFA Roadmap.

IF Key Message #2

IF-2 Advance performance limits of existing technologies and push new techniques and materials, nurture enabling technologies for new physics, and scale new sensors and readout electronics to large, integrated systems using co-design methods.

The detector R&D community in the US is doing amazing things. We are at the forefront of pushing old technologies into new territories and of inventing new detectors and methods to enable breakthroughs in many areas of science.

In order to support the key science goals, the overall HEP community needs to get behind the detector instrumentation experts and help them achieve these technological feats going forward. We need you to help us get increased funding, a sustained and valued workforce, and world class facilities, so that we can build the detectors of your dreams.

IF Key Message #3

IF-3 Develop and maintain the critical and diverse technical workforce, and enable careers for technicians, engineers and scientists across disciplines working in HEP instrumentation, at laboratories and universities.

We need training opportunities for PhD students, including interdisciplinary studies and pure instrumentation PhDs. These need to be followed by realistic and sustainable career paths in instrumentation, both at the laboratories and universities.

We need to nurture our technical workforce of highly specialized technicians, engineers and scientists from other disciplines (e.g. chemists, material science, biology, nano science, etc.). These skills cannot be found on the street and take a long time to train and develop.

We cannot build these amazing HEP detectors without our technical workforce and without giving equal value to colleagues working in instrumentation.

IF Key Message #4

IF-4 Expand and sustain support for blue-sky, table-top RD, and seed funding. Establish a separate review process for such pathfinder R&D.

HEP needs both, evolutionary and revolutionary progress. Evolutionary R&D pushes existing technologies to their achievable limits (low risk, known reward). Revolutionary R&D (aka blue-sky) is of high risk and potentially high reward, pursuing completely new ideas with uncertain outcomes. Blue-sky R&D often leads to null results, but sometimes has the ability to open completely new realms of sensitivity or even new fields of science!

We need a balance of both kinds of R&D. Evolutionary R&D can address immediate science needs (e.g. e^+e^- Higgs factory), while revolutionary blue-sky R&D is needed to even get anywhere near what we need in the long-term future (e.g. FCC-hh).

Both streams of R&D are not easily compared with each other. We recommend to create a separate review process for blue-sky R&D and to reserve a certain fraction of the R&D budget for the most promising ideas.

IF Key Message #5

IF-5 Develop and maintain critical facilities, centers and capabilities for the sharing of common knowledge and tools, as well as develop and maintain close connections with international technology roadmaps,
other disciplines and industry.

Detector facilities in the US are at the heart of our field. Without them we would not be able to build the detectors that deliver our world class science data to us. Such facilities are expensive to maintain and to upgrade to the state-of-the-art. Similarly, the tools and methods we need to develop our detectors, including design and simulation software and licenses, need to be maintained and shared among institutes.

It is essential that we seek close collaboration with national and international partners in HEP and other disciplines, as well as with industry in order to profit from the latest advancements in e.g. material science, or to bring new technologies to cost effective mass production.

Despite all the challenges, great things are happening

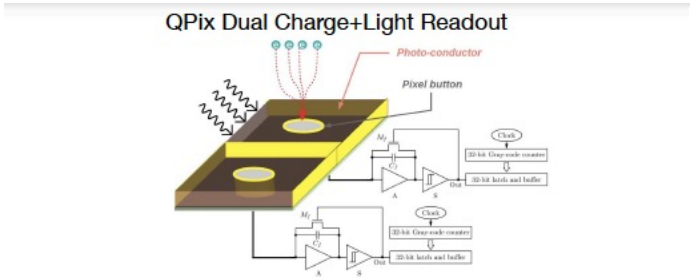
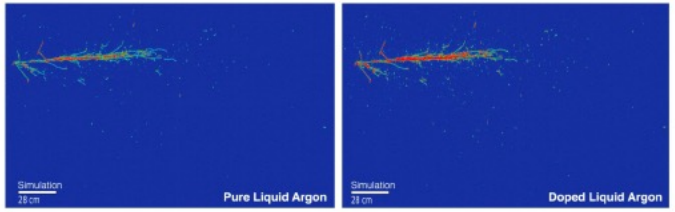
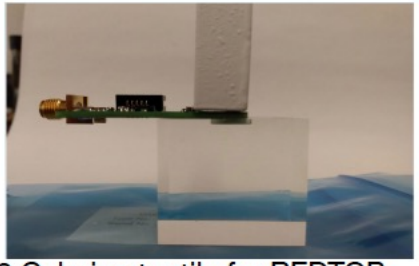


Photo-ionizing dopants in LArTPCs

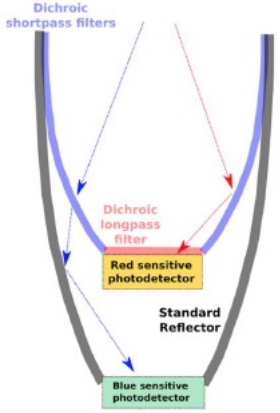


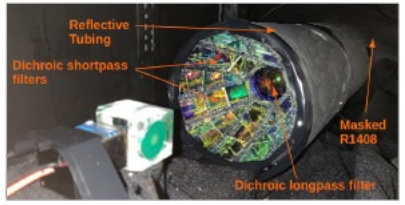
PIONEER Tracker design

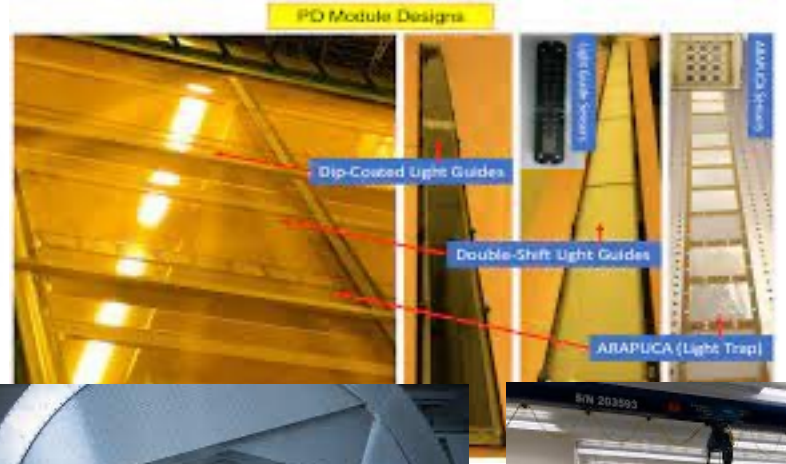


ARIADNO2 Calorimeter tile for REDTOP

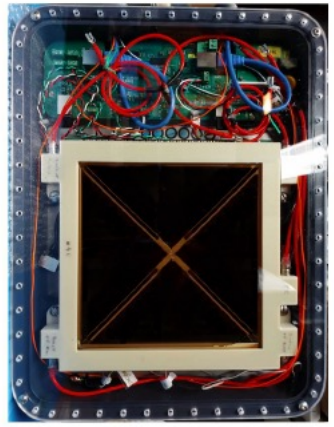
Dichroic filter design



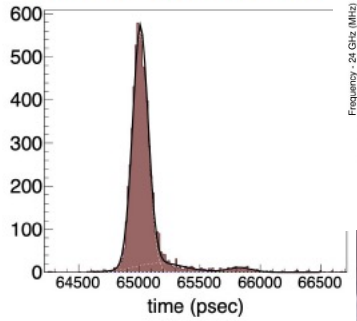


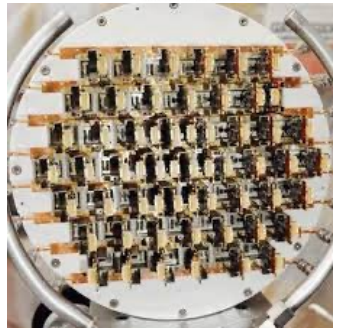


Fast timing with LAPPDs

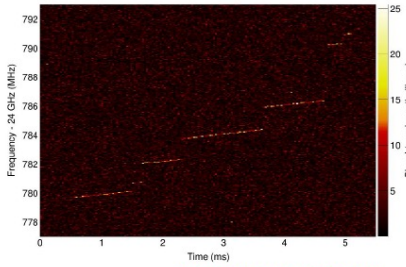


Transit-time spread in ANNIE

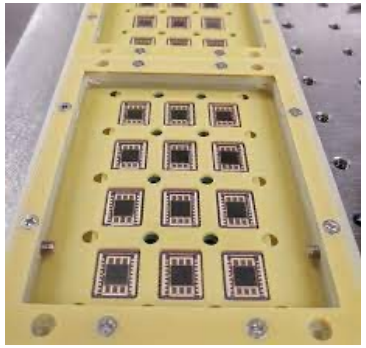




Demonstration of CRES Method from Project8



https://arxiv.org/abs/2203.07349



for neutrinos and rare and precision physics

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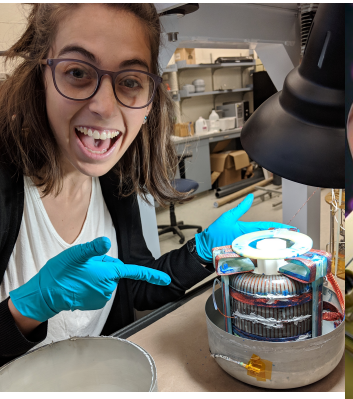
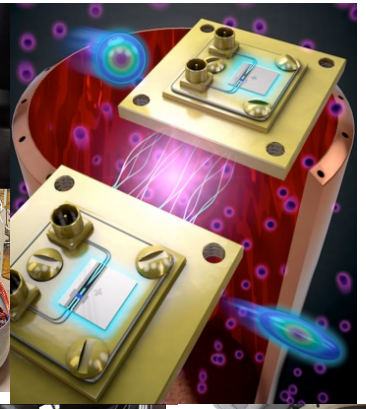
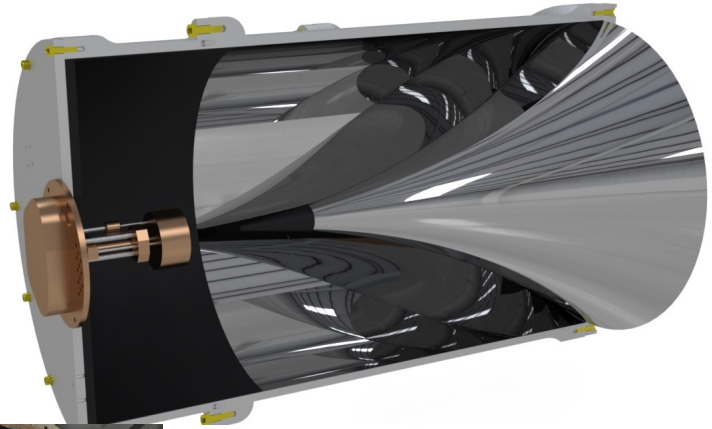

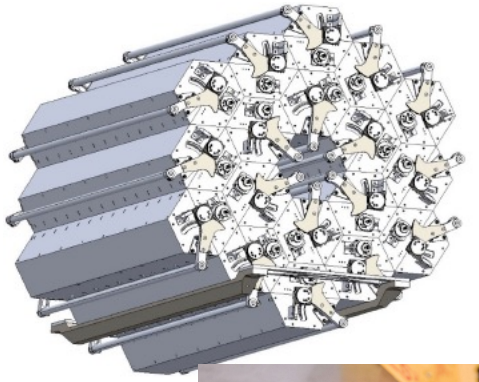
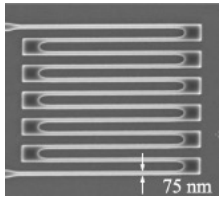

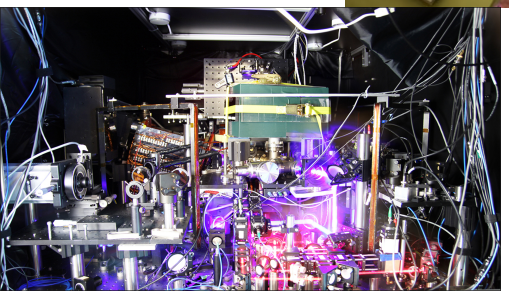

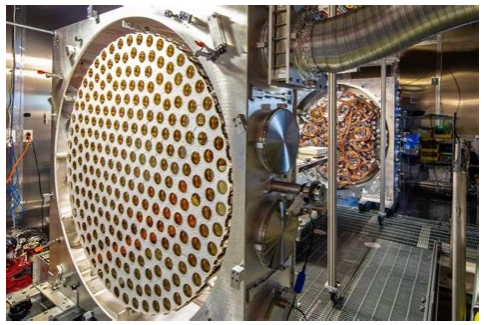
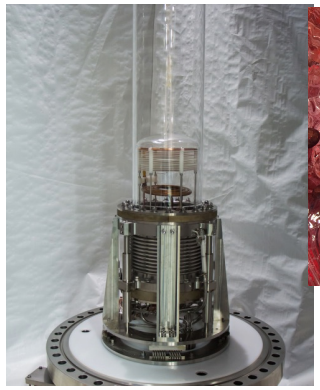

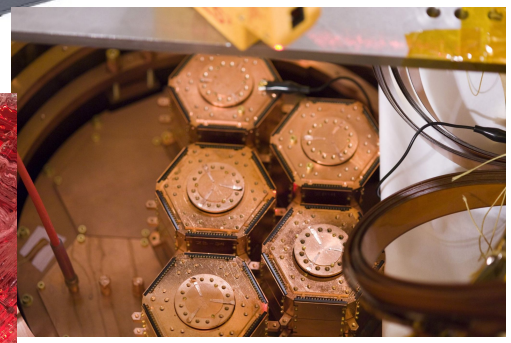
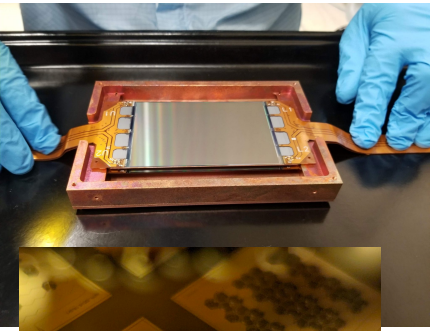
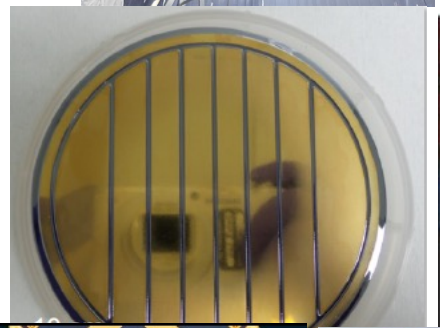
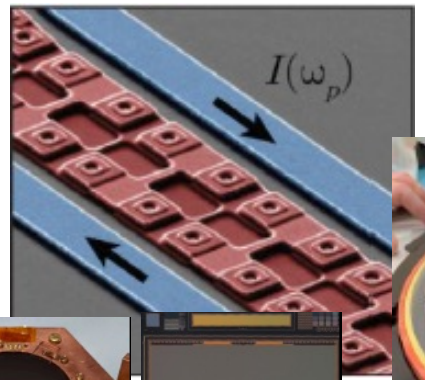


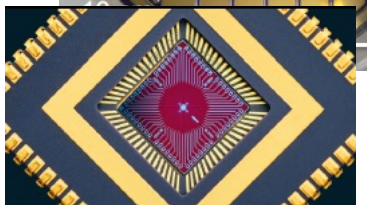


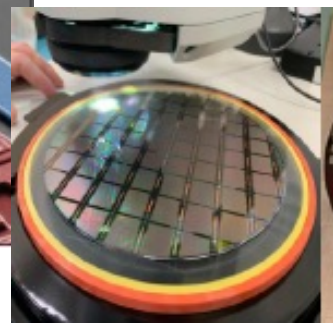
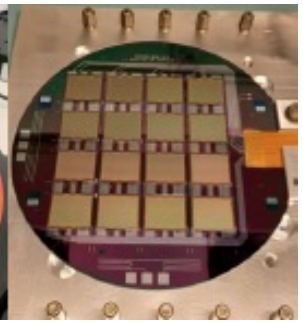

for astro particle physics

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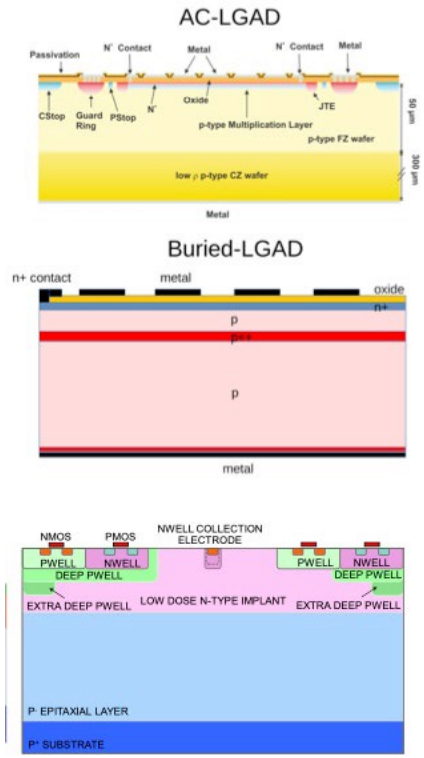
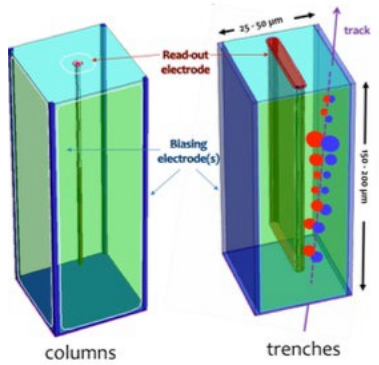




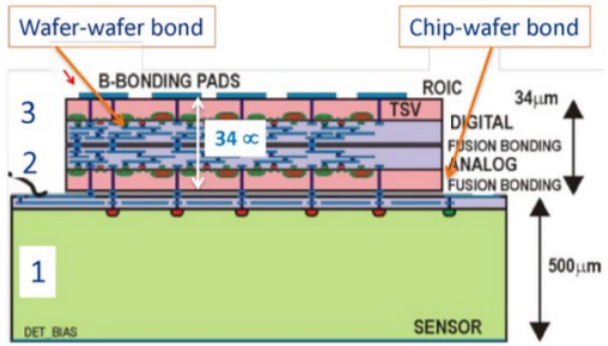
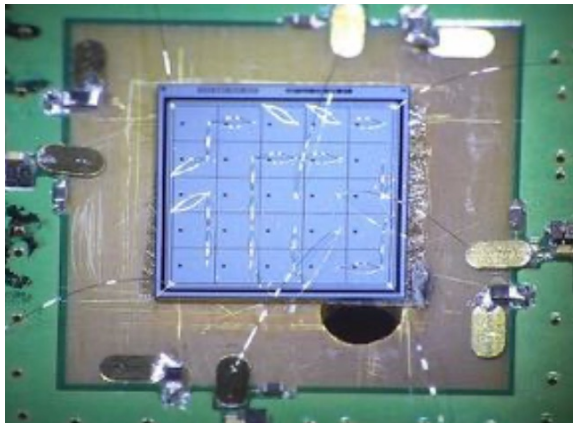
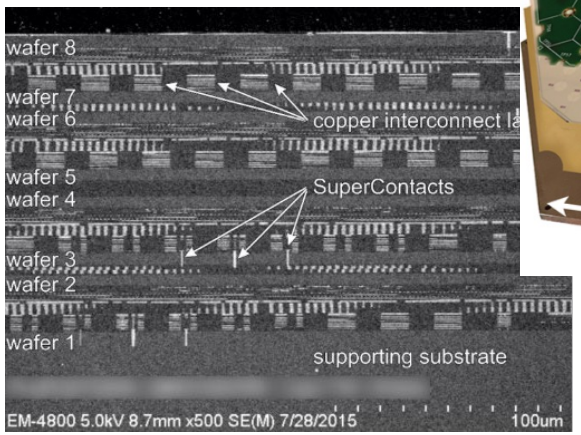
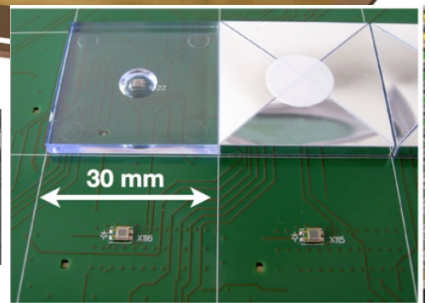
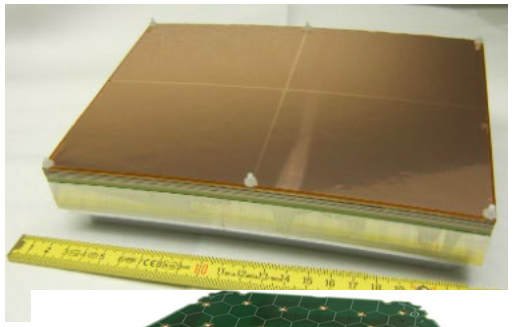


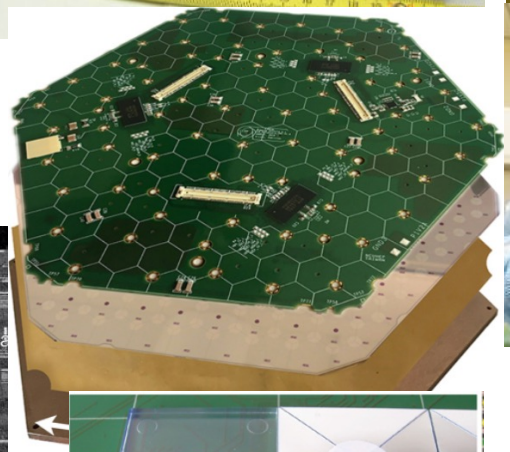
Figure 1: Example of 3D integration of sensor and readout chip.

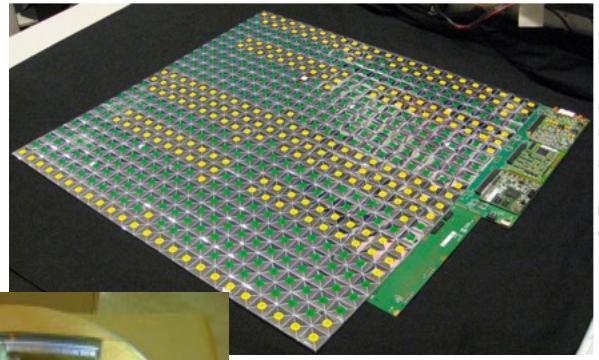












and for collider physics

Conclusion

The community needs to rally behind its detector colleagues, or it won't have the detectors it needs to achieve its science breakthroughs in the future.