Community Summer Study

SN WMASS

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Instrumentation Frontier for Mid- and Small-Scale Experiments/Facilities

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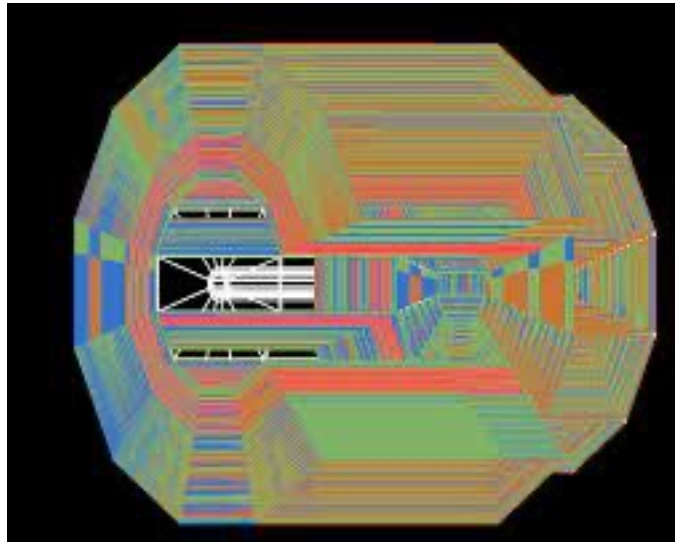
General Remarks

- CF, EF, NF and RPF have a broad range of exciting mid- and small-scale experiments, which require equally broad detector R&D
- Note that technology R&D for small-scale experiments is not necessarily less challenging, quite often the opposite
- The associated instrumentation needs to cross many (if not all) IF topical areas, therefore we will not repeat the key messages presented, rather highlight a few technological challenges

Example from RPF: the REDTOP Experiment

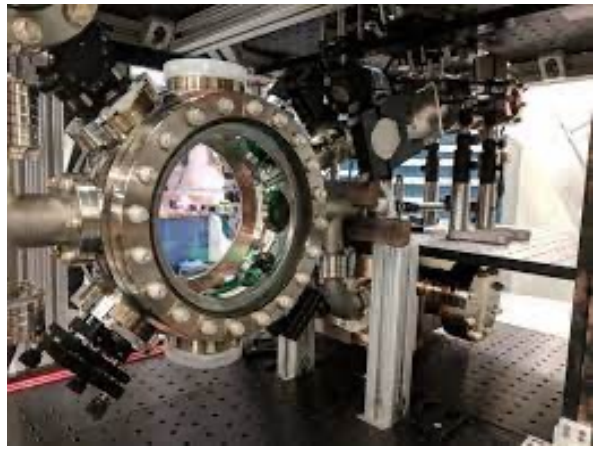
Need hermetic detector covering entire solid angle to correctly identify final state particles

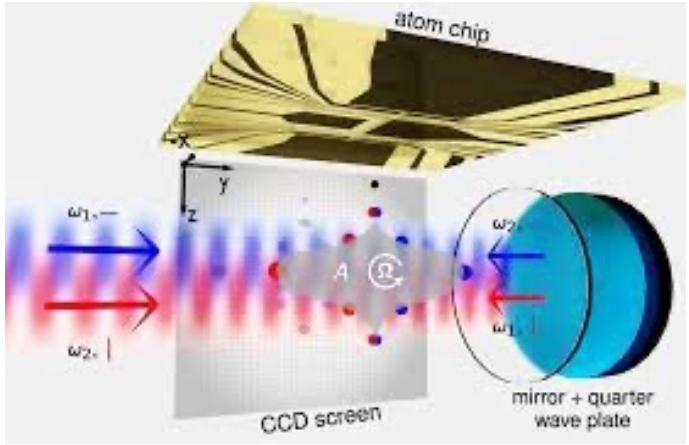
- **Vertex Detector:** Fiber tracker (LHCb style) or wafer-scale silicon sensor (ALICE ITS3 style)
- **Central tracker,** LGAD technology: to reconstruct relatively low momentum, very low material budget, 4D tracking
- **Calorimeter**, ADRIANO2 duo-readout: good energy and time resolution; fast response
- Thin **Cerenkov radiator** layer to measure particle TOF with quartz tiles, **Optional AC-LGAD** timing layer based on design planned for the EIC
- **Multi-level trigger** system

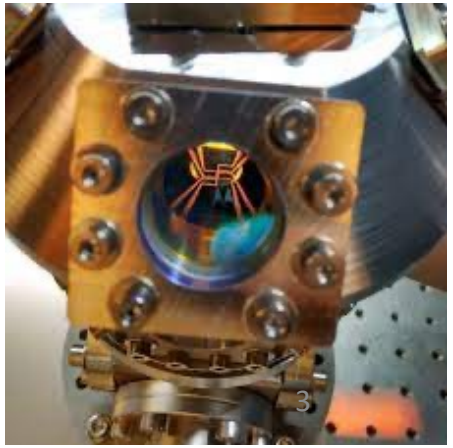


Quantum Sensors

- Have been used in searches for dark matter (particle and wave), fifth forces, dark photons, EDM measurements, variations in fundamental constants, and gravitational waves, etc.
- A wide range of technologies: atom interferometers and atomic clocks, magnetometers, quantum calorimeters and superconducting sensors, etc.
- We need small-scale R&D, tabletop experiments, and scaling up to large experiments



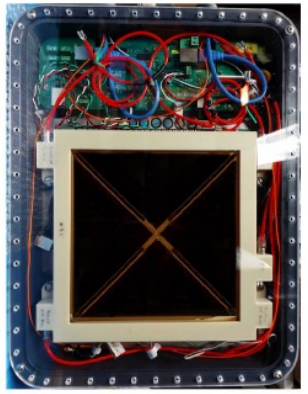


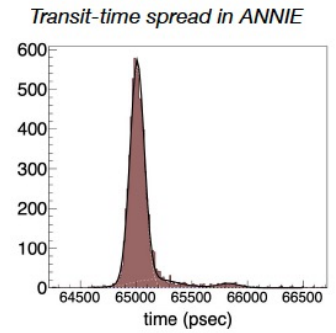


Photon Detectors

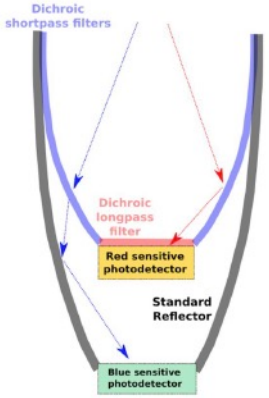
- The development of detectors with the capability of counting single photons from IR to UV has been a very active area in the last decade. We now need to pursue R&D to implement these in HEP experiments by making larger arrays, extending the wavelength coverage and improving energy resolution.
- New photon detector developments are being considered for planned future neutrino experiments going beyond the current technologies. Concept demonstrations have been done, and we now need to move from a conceptual phase to working detectors. of novel light collectors (dichroicons), and new materials (a-Se, organic semiconductors, GaN) that could be directly sensitive to the VUV light and large area photon detectors with fast timing (LAPPD).

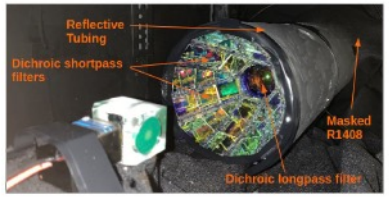
Fast timing with LAPPDs





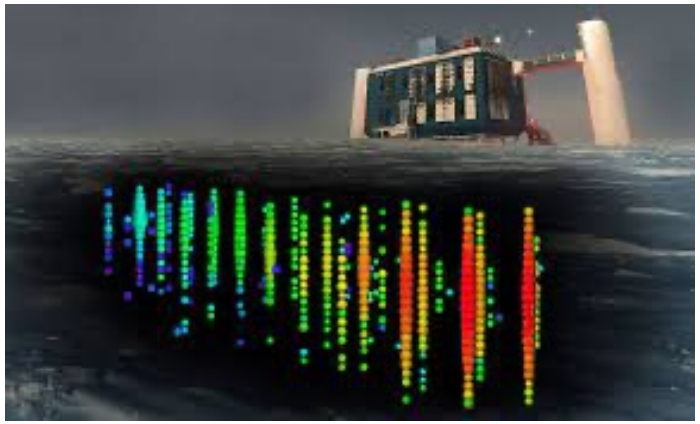
Dichroic filter design





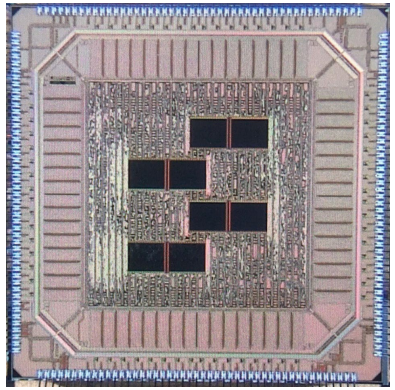
Radio Detection

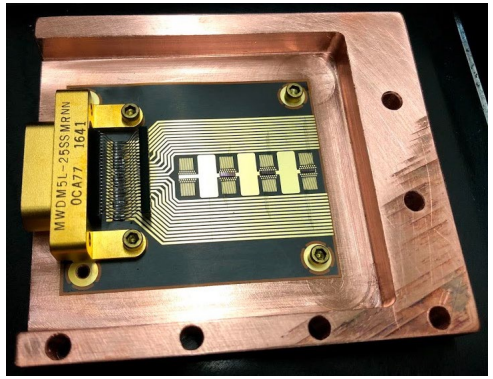
- Pursue dedicated R&D for remote power and communications approaches of very large extended arrays, and explore synergies with other experiments, like DUNE, SKA, CTA, …
- Enable future mm-wave cosmic probes through R&D and pathfinder experiments of new mm-wave detectors with higher channel density relative to current CMB detectors

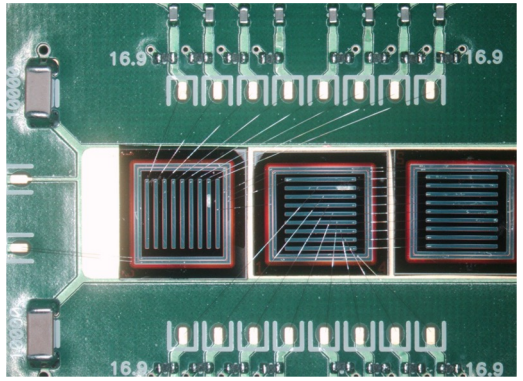


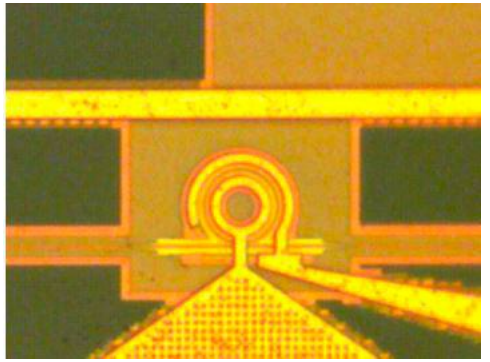
Electronics/ASICs

- Develop methodologies to adapt the technology for operation in extreme environments. Deep cryogenics, ultra-radio pure materials, radiation-harsh environments with limited power budget and long lifetime for all cases.
- Develop novel techniques to manage very high data rates. Data reduction and optimization needs to be as close as possible to the generation point with acceptable power consumption.









Not a Summary

- Solid State detectors, Noble Element detectors, Micro Pattern Gas Detectors, Calorimetry, TDAQ will be critical as well
- Collaborative R&D and common solutions are desirable, and we need to take advantage of industry
- It is even more important to develop and maintain the critical and diverse technical workforce at laboratories and universities