# Status of FNAL Detector R&D

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PAC Meeting
June 6, 2013

# A Successful
# Fermilab Detector R&D Program:

... addresses the highest priorities of the field

… builds on the strengths of the laboratory

… provides important facilities for the community

… forms broad collaborations

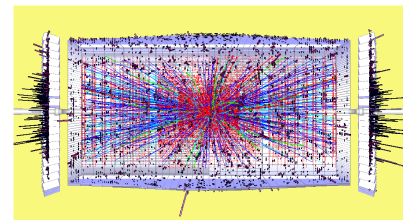
… transitions R&D into experimental projects

… has an eye for new developments

# FNAL Detector R&D Long Range Goals

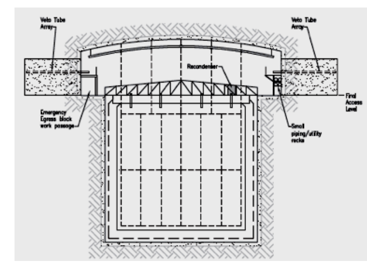
## Energy Frontier:

- Development of new detection and triggering techniques for the high rate, high radiation field environment of the HL-LHC
- Development of low-mass, high resolution detectors for a lepton collider
- Create new radiation hard, ultra-high speed DAQ systems



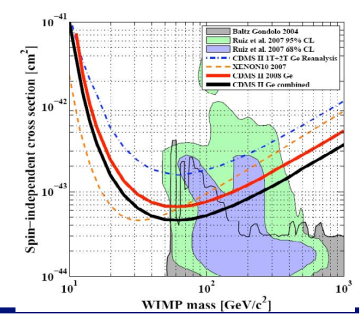
## Intensity Frontier:

- Development of high granularity and high rate detectors for the Intensity Frontier experiments at Fermilab.
- High-performance, low cost and large volume neutrino detectors with good background rejection



## Cosmic Frontier:

- Novel detection techniques for dark matter detectors with a background at the level of 1 nuclear recoil per ton per year
- Novel instrumentation for optical, wide-field galactic spectroscopy




*Note: These goals align with the priorities of the HEP community*

# Detector R&D Budget Supports 36 FTE of Engineering and Technical Support in a Coherent Set of Project Portfolios

| PORTFOLIO | DELIVERABLES | DESCRIPTION | THRUST |
| --- | --- | --- | --- |
| | | | |
| Tracking & | ASIC R&D | Collaborative development of 3D ASICs | Core & Infrastructure |
| Triggering | ASIC Support | Software tools for ASIC design and development | Core & Infrastructure |
| *(R. Lipton)* | Vertex Sensors | Multi-project integrated sensor/readout R&D | Sensors & Electronics |
| | Tracking Mechanical | Low mass mechanical support and cooling designs | Sensors & Electronics |
| | | | |
| Calorimetry & | Fast Calorimetry | Fast calorimetry for Intensity Frontier community | Detector Systems |
| Photodetection | Hadron Calorimetry | Dual readout techniques, SiPM testing, simulation, QIE10 | Sensors & Electronics |
| *(A. Para)* | Scintillator R&D | Scintillator/WLS co-extrusion and testing | Sensors & Electronics |
| | psec Time-of-Flight | Collaborative LAPPD phototube program at ANL | Sensors & Electronics |
| | Simulations | Simulation of backgrounds in a muon collider | DAQ & Computing |
| | | | |
| Liquid Argon | Materials Test Stand | Testing contamination potential of materials for LAr TPC | Core & Infrastructure |
| *(S. Pordes)* | 20-Ton Demonstrator | Large scale LAr purification test system | Detector Systems |
| | Low Background Ar | Production of low-background Ar for Dark Matter community | Detector Systems |
| | Cold Electronics | Collaborative cold electronics development w/ BNL & MSU | Detector Systems |
| | Light yield at low E | Small chamber to test light yield in LAr | Detector Systems |
| | | | |
| Astrophysics | Laser Interferometry | High finesse laser laboratory | Detector Systems |
| Detectors | Bubble Chamber | Acoustic rejection of $\alpha$ background / testing in pion beam | Detector Systems |
| *(J. Estrada)* | Solid Xenon | New type of dark matter / axion / $\beta\beta$ detector | Detector Systems |
| | CCD R&D | Low noise readout/dark matter/neutron imaging | DAQ & Computing |
| | MKID | Multiplexed array for spectrophotometry | DAQ & Computing |
| | | | |
| DAQ | Sensor DAQ | Radiation hardness testing of new sensors | DAQ & Computing |
| *(S. Kwan)* | μTCA and ATCA | Evaluation of new data-flow architecture | DAQ & Computing |
| | Optical DAQ | Collaborative development of multi-Gbit data links | DAQ & Computing |
| | | | |
| Facilities & | Facilities / Contingency | Facility maintenance & repairs / management reserve | Core & Infrastructure |
| Community Support | Detector Tools | Upgrade of R&D tools | Core & Infrastructure |
| *(E. Ramberg)* | Test Beam Equipment | Pixel telescope support for test beam | Core & Infrastructure |
| | Workshops / Schools | Conferences, workshops and schools for HEP community | Core & Infrastructure |
| | MCenter Upgrades | Preparation of Mcenter area for use as LAr test beam | Core & Infrastructure |

*(Each portfolio has a manager in the Detector Advisory Group)*

# Fermilab Detector R&D Organization

- The **"Detector Advisory Group"** consists of:
  - Technical Point of Contact (Erik Ramberg)
  - Tracking and Triggering (Ron Lipton)
  - Calorimetry and photodetection (Adam Para)
  - Liquid Argon R&D (Stephen Pordes)
  - Astrophysics detectors (Juan Estrada)
  - Intensity Frontier (Bob Tschirhart)
  - Head, Particle Physics Division (Mike Lindgren) (ex-officio)
  - Assoc. PPD head for Engineering (Peter Wilson) (ex-officio)
  - Scientific Computing (Panagiotis Spentzouris) (ex-officio)
- Two outside members:
  - Ulrich Heintz (Brown University)
  - Luciano Ristori (INFN/Fermilab)
- The group meets every other week and monitors and reports on the activities in each of their portfolios.
- Members give advice on the future of the program and organize reviews of projects in each portfolio. TPOC informs Division Heads and Directorate of status and plans.

# An Example of Collaborations & Funding Sources in Tracking/Triggering

HL-LHC

- 3D-Based module design – CERN, UC Davis, Brown U., Cornell U., U. Paris
- Associative memory R&D – Pisa, U. Chicago
- Off detector processing – Cornell, CERN
- Via-last modules – CERN, UC Davis
- Data transmission – CERN, SMU
- 65 nm radiation studies – CERN, LBNL, Colorado, others
- Pixel ASIC design – INFN, CERN
- Advanced Sensor R&D – Colorado, Purdue, TAMU, SUNY, Milano, Torino, UMiss, Strasbourg, Florida
- Forward calorimetery - Virginia, Notre Dame, Iowa, Florida State, Minnesota, Cal.Tech, Fairfield

Lepton Collider

- MARS background models – Carnegie Mellon, Lecce, SLAC
- Low Mass Mechanics – U. Washington
- 3D/Active edge integration – Cornell, SLAC, Brown U.
- SOI integrated electronics – KEK, American Semiconductor,
- Dual readout homogenous hadron calorimetery - ANL, CalTech

*Primarily funded by:*
*FNAL KA25*
*CMS Project*
*CDRD grant*

# Collider Detector R&D (CDRD) Funding Opportunity

Fermilab was a part of several proposals prepared for the CDRD funding opportunity (FY2012-14). We worked to enhance our collaborative efforts with universities, other national labs and industrial partners.

Fermilab-led projects selected for funding (annual awards) include:

- *A Proposal to Develop a High Speed Data Link for Collider Experiments*
  - *(ANL, U.Mn., OSU., FNAL, SMU)*
  - *$300 K – ($68 K for FNAL)*
- *Development of 3D Vertically Integrated Pattern Recognition Associative Memory*
  - *(FNAL, U.Chicago, ANL, INFN (Padova), Tezzaron)*
  - *$150 K – ($140K for FNAL)*
- *Forward Calorimetry for a High Luminosity LHC*
  - *(Virginia, Notre Dame, Iowa, Florida State, Minnesota, Cal.Tech, Fairfield)*
  - *$410 K ($0 for FNAL)*

These projects are about 10% of the Fermilab Detector R&D budget

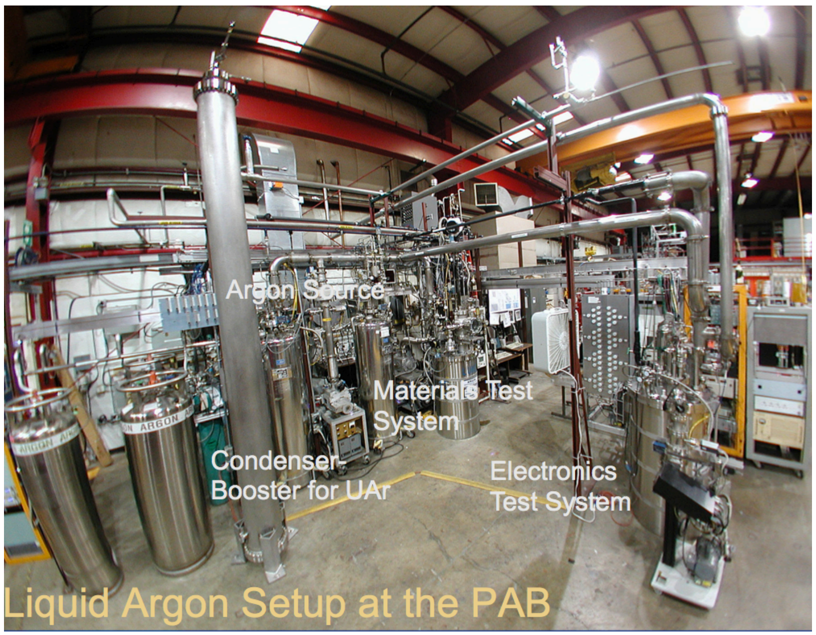
# Liquid Argon: A Major Detector R&D Effort by Fermilab

- Liquid Argon R&D will be covered by Brian Rebel after this talk.
- Quick note:
  - LAPD, a 30 ton prototype with the first ever non-evacuated pure fill, has shown drift times of better than 4 msec – good news for LBNE !
  - Instrumented with the longest TPC in the U.S. – 'Long Bo'

Long Bo TPC with In-liquid electronics from MSU

LAPD (in PC4) - 30 tons LAr

# Overview of Generic Liquid Argon R&D Projects




- Materials Test Stand
- ArgoNeut at NUMI hall
- In-liquid electronics
- Light yield test bed
- SCENE – scintillating efficiency for nuclear recoils
- Low-radioactivity distillation column
- LARIAT test beam
- Low recoil background measurements at Booster target

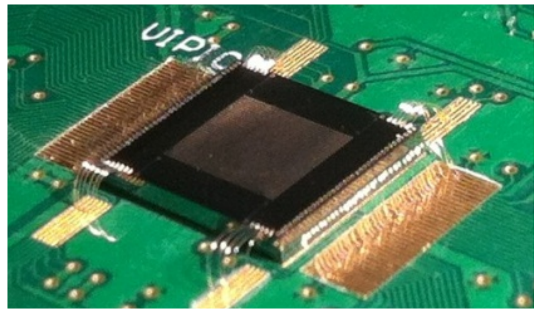
*Determining priorities for future liquid Argon research will be difficult in a declining detector R&D budget*

# ASIC Development

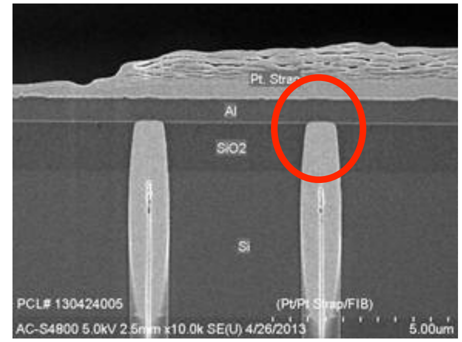
- 3D paradigm for mixed analog and digital signals has been pioneered at Fermilab
- Has resulted in adoption of 3D techniques by silicon brokers MOSIS, CMP and CMC
- 2013 has seen successful examples of 3D bonded circuits from 1$^{st}$ submission to Tezzaron. Yield is still poor because of alignment troubles.
- "Application Specific" Integrated Circuits means what it says - the applications are specific:
  - QIE = extremely high dynamic range readout for calorimetry
  - VICTR = 3D track-trigger for HL-LHC
  - VIP = High density, low mass (thinned) sensor readout for the ILC
  - VIPRAM = Associative memory arrays for very fast collider trigger decisions
  - VIPIC = Buffered fast frame photon counting chip for X-ray science

# Status of 3 Dimensional and Deep Submicron I.C Design

Status of 3D-IC demonstration run:
- good results on individual chips
- Copper-copper wafer bonding yields low due to wafer misalignment
- DBI oxide bonding is preferred solution – licensed to Tezzaron from Ziptronix. Wafers due this month.
- attachment of ROICs to sensors + tests with radiation is priority now

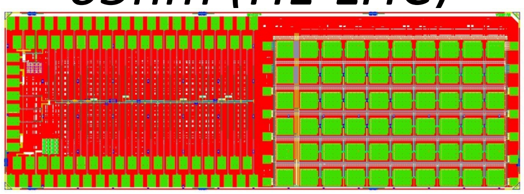


*VIPIC1 (3D chip for X-ray Photon Counting); collaborating with BNL; 64x64 pixel @ 80μm pitch*




*SEM image of W TSVs providing contact to back-side Aluminum pad on VIPIC1*

65nm (HL-LHC)



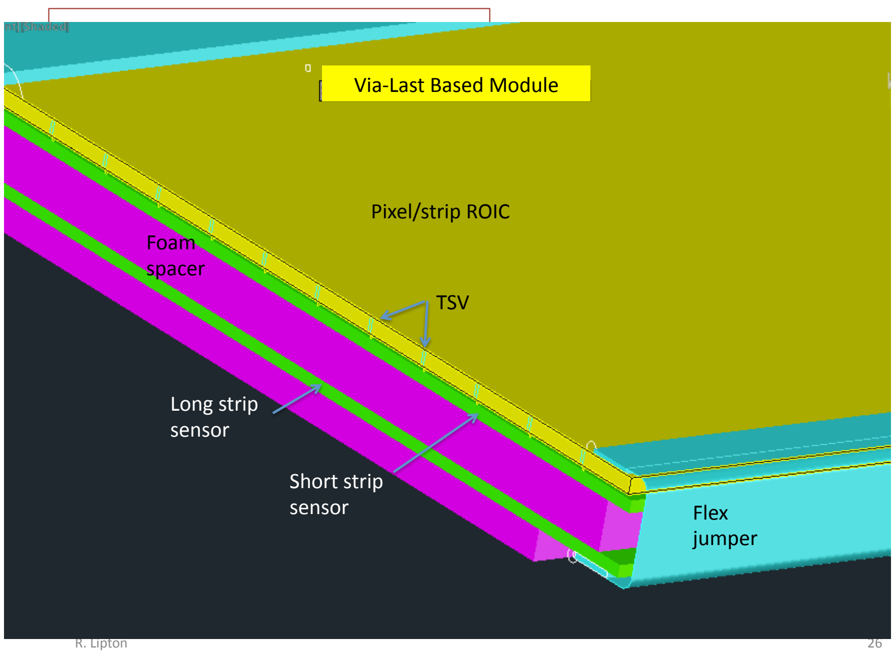
*First Fermilab submission in 65nm MPW April 2013, 2x6mm$^2$ TSMC CMOS test struct.: single devices: active and passive of various types and geometries*

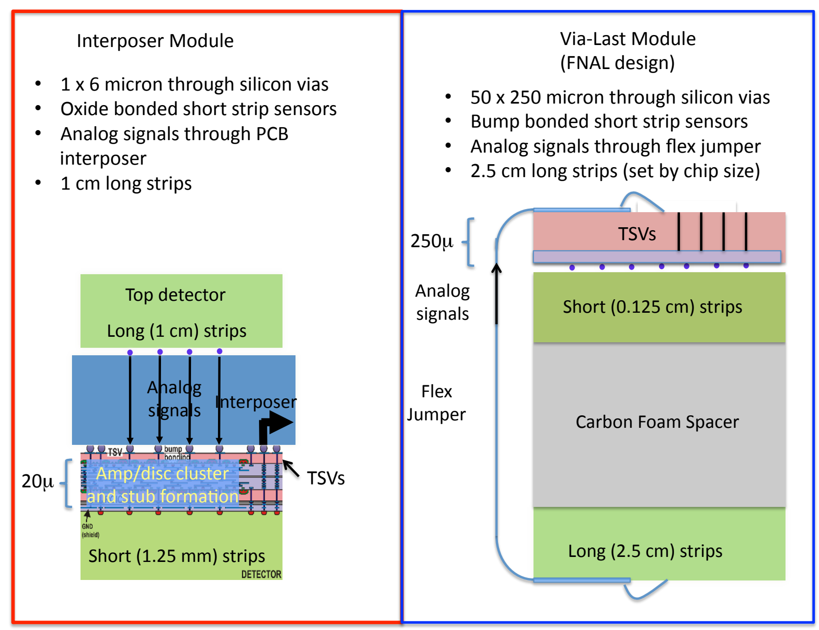
*65nm process is a new direction for us, and will allow us to work on HL-CMS pixel readout*
*Status is:*
- *carrying out radiation hardness characterization of the process with target of up to 1Grad (irradiation at SNL on $^{60}$Co source)*
- *need to meet obligations resulting from working in collaborations (CERN, LBL, INFN, and others).*
- *high costs: process and software tools for design*

# Track Trigger R&D for Phase II

Goal is to form track 'stubs', which can give quick, correlated information on what momentum a track has. A full 3D solution is possible, but the 4 micron interconnect pitch of that approach is not necessary for CMS Phase 2 (0.1 x 1.5 $mm^2$ pixels)

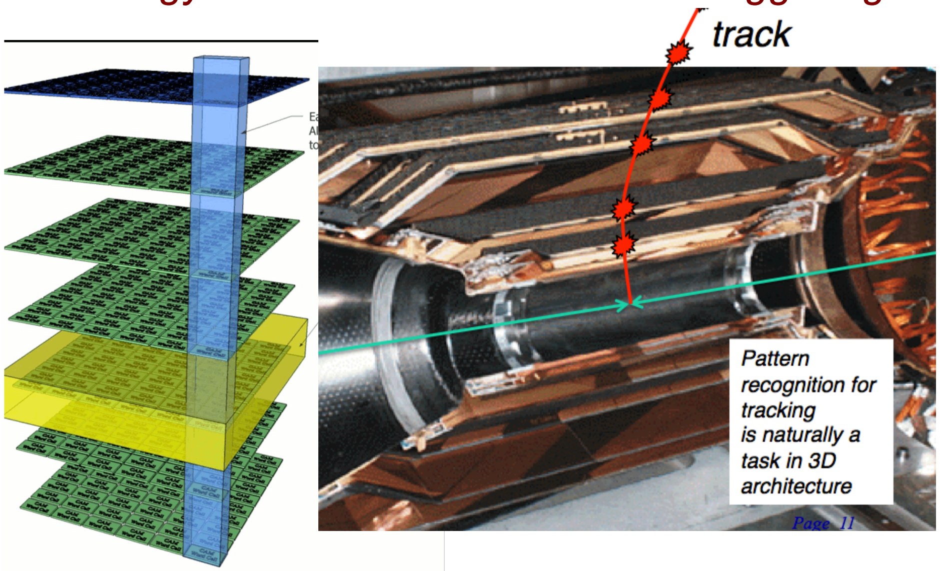
The capability to provide 3D interconnect, even with larger pitch, is an enormous advantage in a two-layer module design
We are collaborating with CERN on a "via last" 3D solution which retains the advantages of 3D without dependence on a specific foundry process



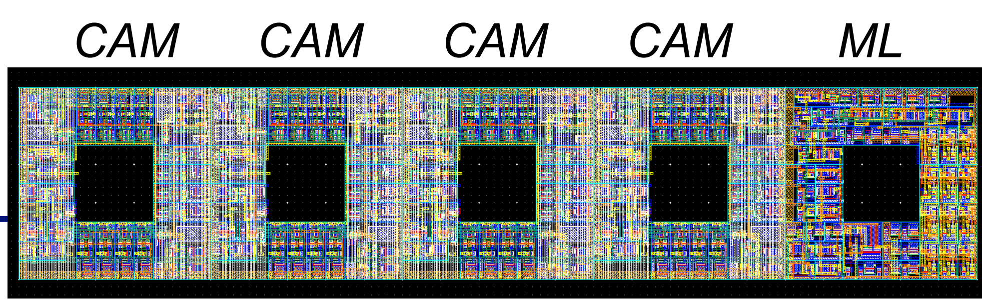



# "VIPRAM" = Vertically Integrated Pattern Recognition Associative Memory

*Using 'Content Adressable Memory' (CAM) technology for use in collider detector triggering*




The challenge: Increase the pattern density by 2 orders of magnitude and increase the speed by a factor of >3, while keeping the power consumption more or less the same

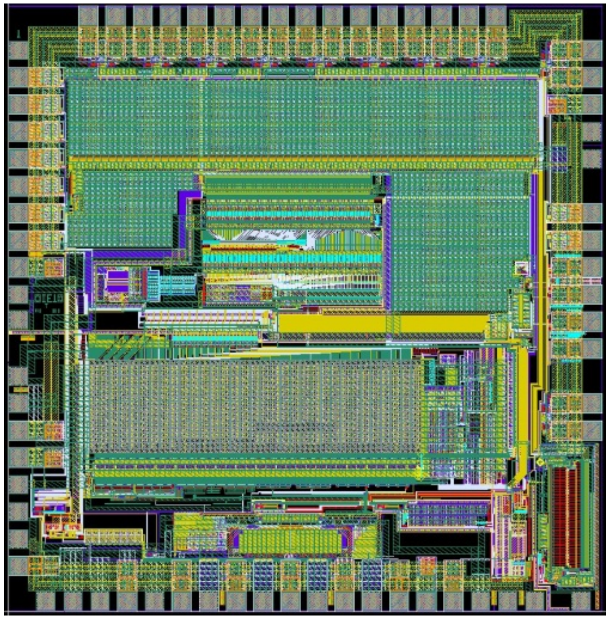



First VIPRAM prototype in 2D submitted Dec. 2012

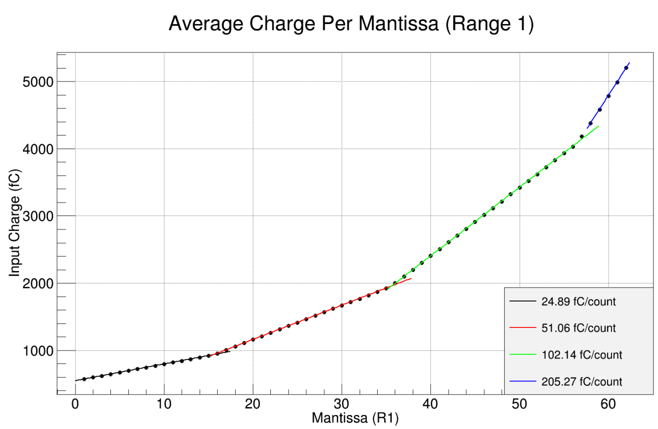
# The Versatile QIE Technique

QIE10: a charge integrating, floating point digitizer for calorimetry at CMS/ATLAS

- 40 MHz dead-timeless operation
- Very high dynamic range: 3 fC to 350 pC (equivalent to ~17 bits)
- "Floating point" gives approx. constant resolution
- Programmable threshold TDC with 500 ps binning
- First full-chip prototype is fully functional
- QIE11 for SiPMs is in design (CMS funds)

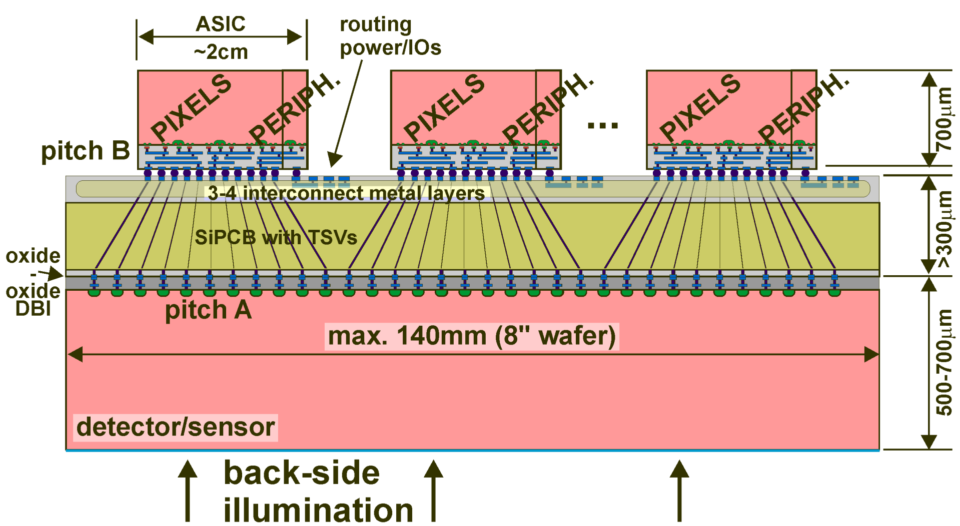


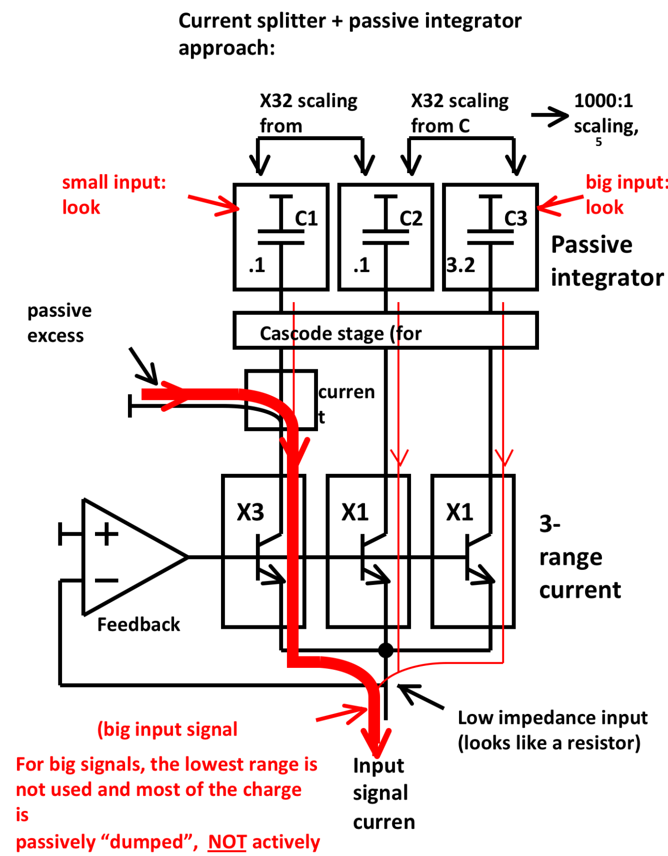
Pre-production prototype with 0.35µm SiGe process was delivered at end of March 2013. Bench and larger quantity tests underway



# A 3D Path to X-ray Counting

In collaboration with ANL, we are investigating a new idea for a full-wafer X-ray detector, useful in counting, and inspired by elements of the high dynamic range of the QIE, along with 3-D interposer readout. This is very preliminary and contingent on outside funding.




This project would fit well within our agreement for collaborative ASIC work with ANL

# High Rate Data Links Program

This program is a three year collaborative effort and was awarded a CDRD grant at $300K annually.

The goal is to develop optical communications techniques for HEP to enable fast tracking and triggering applications. Transmission rates of 10 Gbps/fiber or greater, and radiation hardness up to 100kGy and $10^{15}$ neutrons/$cm^2$. Extremely low mass and non-susceptibility to magnetic fields are also desired. This goes beyond the specs of any commercially available optical data communication technology.

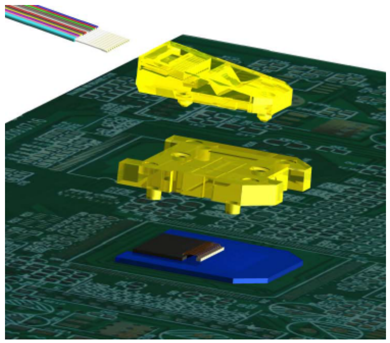
Collaborating Institutions:

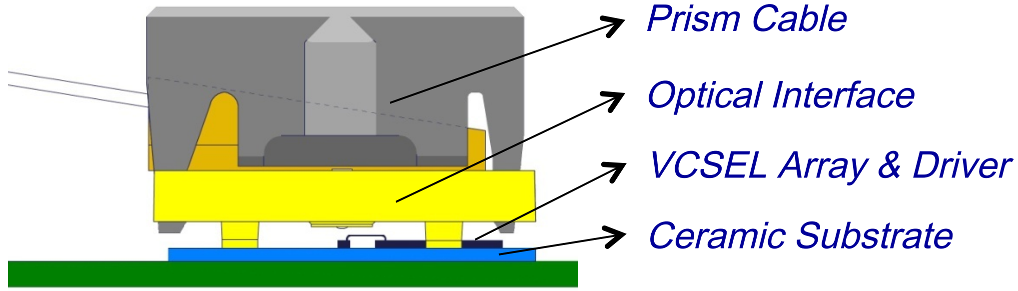
- Argonne National Laboratory
- Fermi National Accelerator Laboratory
- Ohio State University
- Southern Methodist University
- University of Minnesota

Major Activities of R&D:

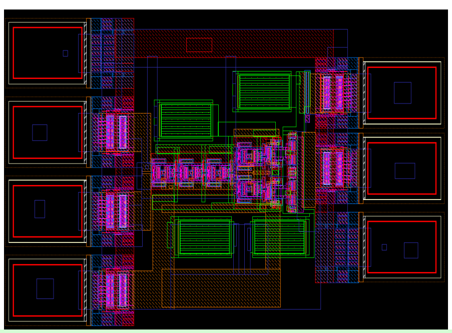
- Electro-Optic Modulators (based on material's linear electro-optic Pockels effect)
- Parallel Optical Modules (VCSEL array, parallel laser driver, and lens array)
- High rate irradiation testing at Fermilab's MTA (first time customer at this facility)

# Parallel Optics R&D
# (Fermilab, OSU, SMU)

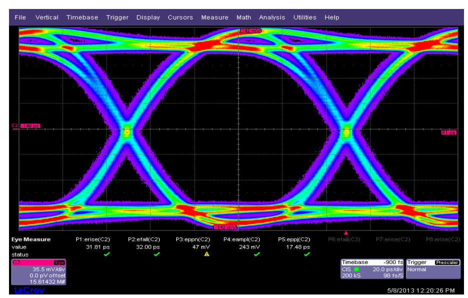


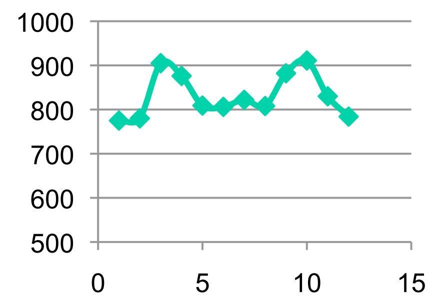



One avenue is to develop a highly parallel transmitter module using Vertical Cavity Surface Emission Lasers (VCSEL). The design of a 12 channel module is shown here.



10 Gbps Driver Prototype Layout

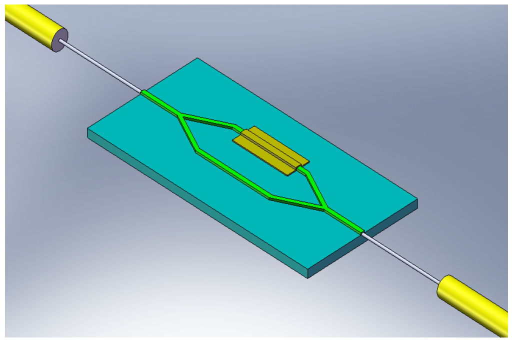


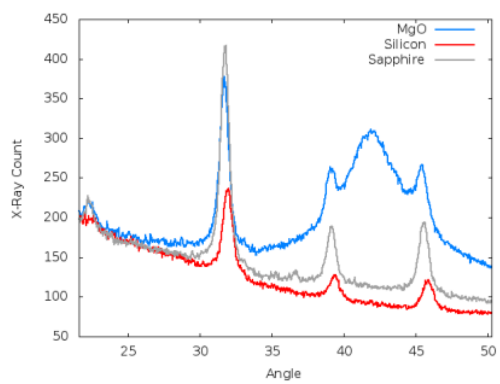



Testing of COTS Driver Array (left: Electrical Eye, right: optical modulation vs channel number

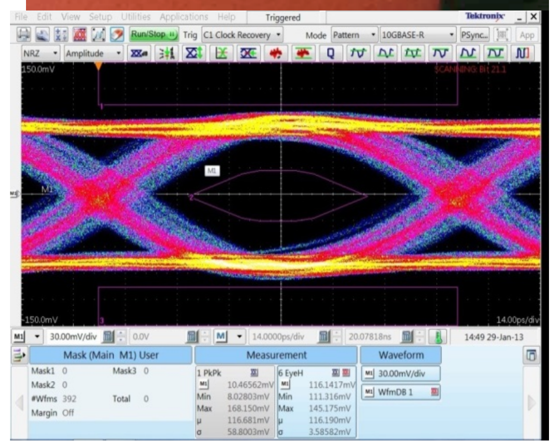
# Electro-Optic Modulator R&D (Minnesota, ANL)

*Mach Zehnder Electro-Optic Modulator (MZM). Modulating the applied electric field changes, by the Pockells effect, the optical path length in each arm, producing optical modulation*





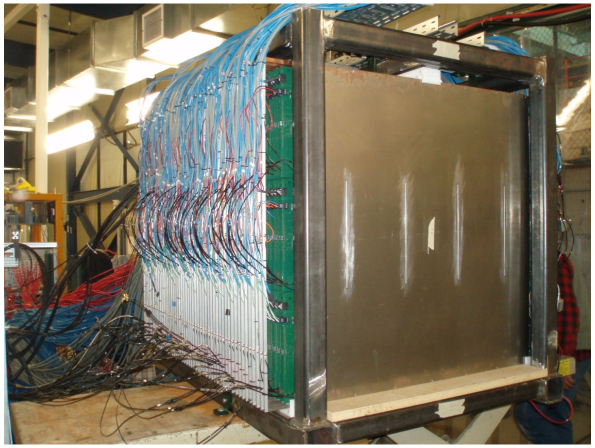

Testing depositions of BSTO upon various substrates.  Optimized MZM will then be developed.

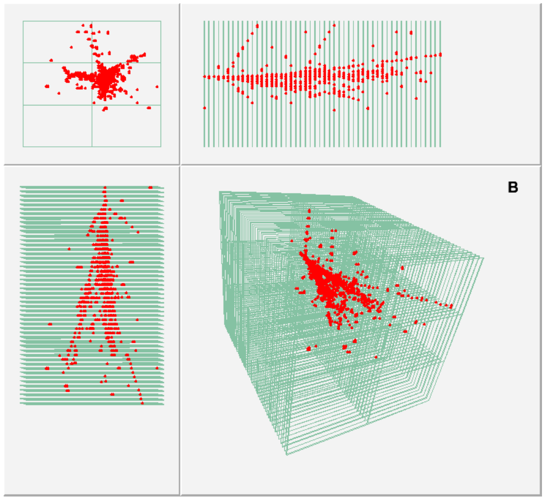


Electrical Eye Measurements of commercial COTS MZM.

# Digital Hadron Calorimeter

- ANL project with Fermilab contribution to electronics design
- Conceived within the context of the ILC, aimed at providing the most accurate measurements of hadronic showers
  - One of the most successful technologies of CALICE
  - Most finely segmented calorimeter in existence (1cm$^2$ pads)
  - Embedded electronics
- Ran in Fermilab and CERN test beams
- Successful completion of project






- Can be used as a tool for the community by embedding calorimeter test structures within it at a test beam. Can monitor flow of shower into test structure
- Potentially useful technologies for THCAL, g-2, CMS forward calorimetry)

# Development of Crystals for Dual Readout, Total Absorption Hadron Calorimetry (THCAL)

- Fermilab – CalTech – Argonne – SICCAS collaboration on the development of cost-effective crystals for total absorption homogenous hadron calorimetry (funded under CDRD)
- The ideal crystal has a high density, to provide fast Cerenkov light, and modest , relatively slow scintillation.

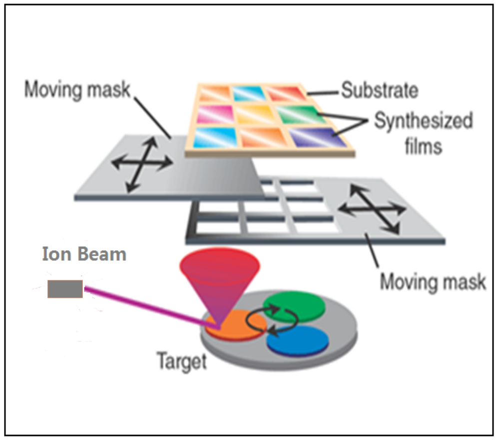
- Strategy:
  - Make existing Cherenkov radiators scintillate
  - Develop new crystals that are more cost-effective
  - Combinatorial Screen
  - Explore glasses (and ceramics)

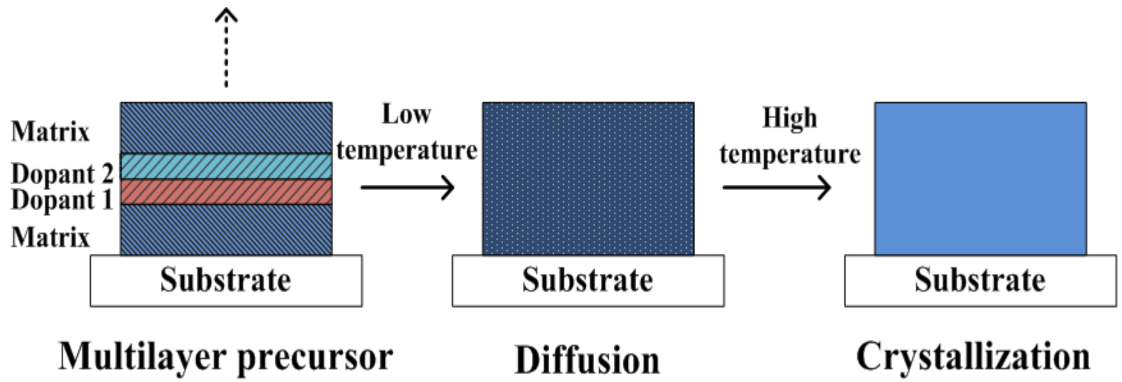
| Parameters | $Bi_4Ge_3O_{12}$ (BGO) | $PbWO_4$ (PWO) | $PbF_2$ | PbFCl | $Bi_4Si_3O_{12}$ (BSO) |
|---|---|---|---|---|---|
| $\rho$ ($g/cm^3$) | 7.13 | 8.29 | 7.77 | 7.11 | 6.8 |
| $\lambda_I$ (cm) | 22.8 | 20.7 | 21.0 | 24.3 | 23.1 |
| n @ $\lambda_{max}$ | 2.15 | 2.20 | 1.82 | 2.15 | 2.06 |
| $\tau_{decay}$ (ns) | 300 | 30/10 | ? | 3 | 100 |
| $\lambda_{max}$ (nm) | 480 | 425/420 | ? | 420 | 470 |
| Cut-off $\lambda$ (nm) | 310 | 350 | 250 | 280 | 300 |
| Light Output (%) | 100 | 1.4/0.37 | ? | 17 | 20 |
| Melting point (°C) | 1050 | 1123 | 842 | 608 | 1030 |
| Raw Material Cost (%) | 100 | 49 | 29 | 29 | 47 |

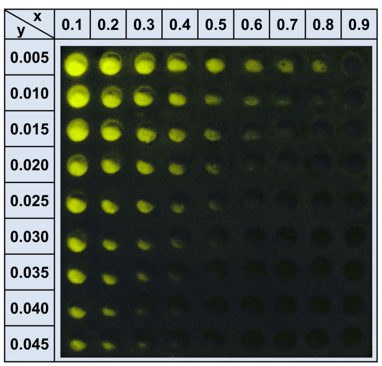
Candidate, dense, crystals

The SiPM photodetector enables new compact geometries

# Combinatorial Screening of Crystals for Total Absorption Hadron Calorimeter (THCAL)




Matrix under UV light

Fermilab funding for work carried out at SICCAS in Shanghai

Samples studied includes:

- $PbF_2$/CsI($Tl^{+1}$) composite film samples
- $Pb_{1-x}(Ca,Eu)_xF_2$ powder samples
  $Pb_{1-x5}(Ca_{0.995}Eu_{0.005})_{x5}F_2$ ceramic
- $Pb_{1-x}Pr_xF_{2+x}$ powders

Luminescence centers applicable for dual readout have been identified. Next step is to transfer to crystal growth technique

# Fast Timing in MCP's and SiPM's

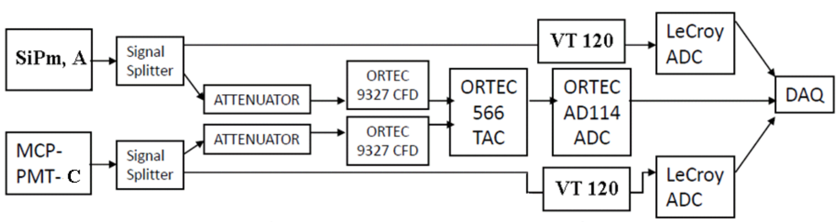
We have an active program in fast timing for photodetectors.

MicroChannel Plate phototubes and Silicon PhotoMultipliers have been investigated in detail.

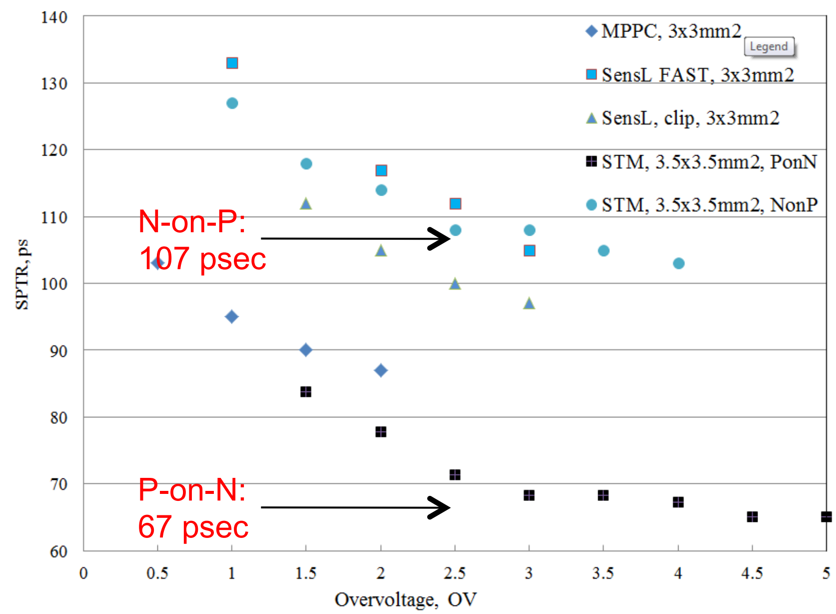
Electronic resolution is approx. 3 psec.

For all measurements reported here, we use Ortec electronics for splitting/amplification/discrimination/timing digitization:

**Schematic DAQ :**




CFD = 'Constant Fraction Discriminator'
TAC = 'Time to Amplitude Converter'
ADC = 'Analog to Digital Converter'

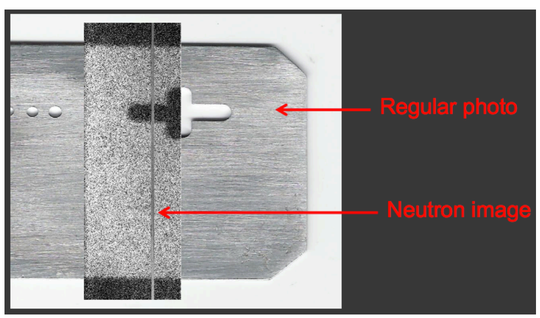


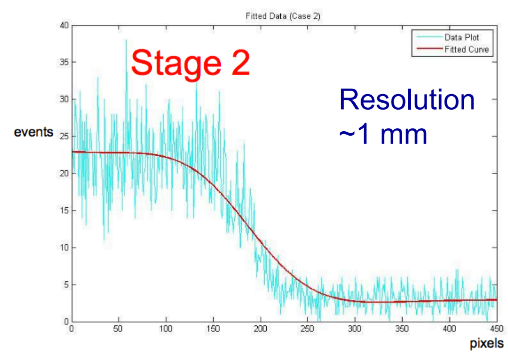

## SPTR, SiPMs, 405 nm

Given proper attention to fabrication details, it is possible to get extremely good timing resolution from SiPM's

# CCD Research at Fermilab

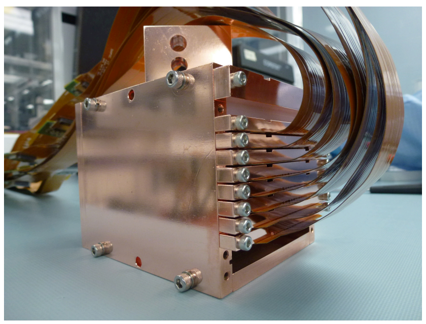
- We have had a very dynamic program combining high quality LBNL CCD’s and Fermilab low-noise system engineering and readout:
  - DAMIC = using thick CCD’s as a dark matter detector
  - CONNIE = using CCD’s as a coherent neutrino scattering detector
  - Neutron Imager = high resolution neutron imagery using $^{10}B$ deposited on CCD’s



# DAMIC - A New Type of Dark Matter Detector

- Uses DES CCD's to search for low mass dark matter
- Installation in SNOLAB shows significant reduction in background
- Transitioned from detector R&D to project status this fiscal year



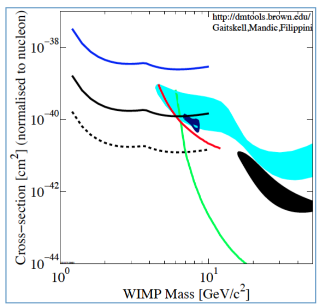



Fig.1.2.1 Cross section limit as a function of mass for spin independent DM search using CCDs. The blue solid curve shows the limit produced by the engineering run at NuMI near detector hall d
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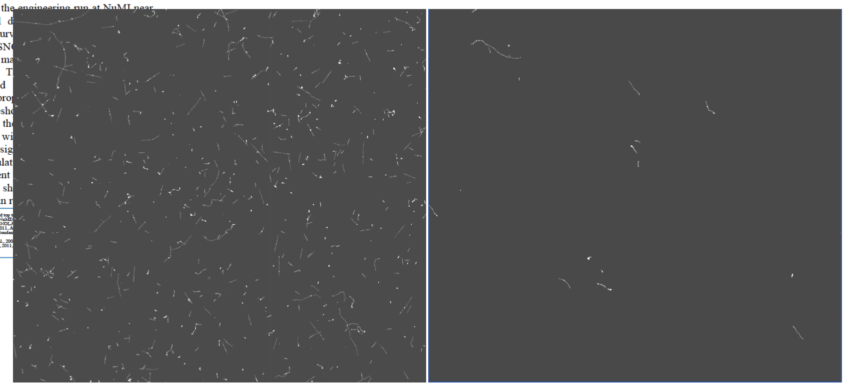
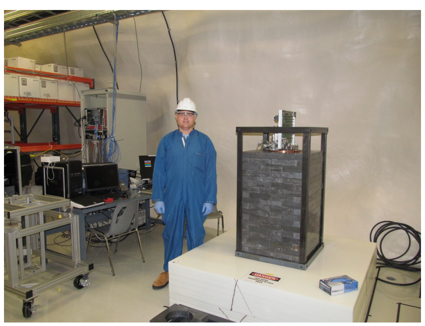


5 hrs at surface (FNAL)

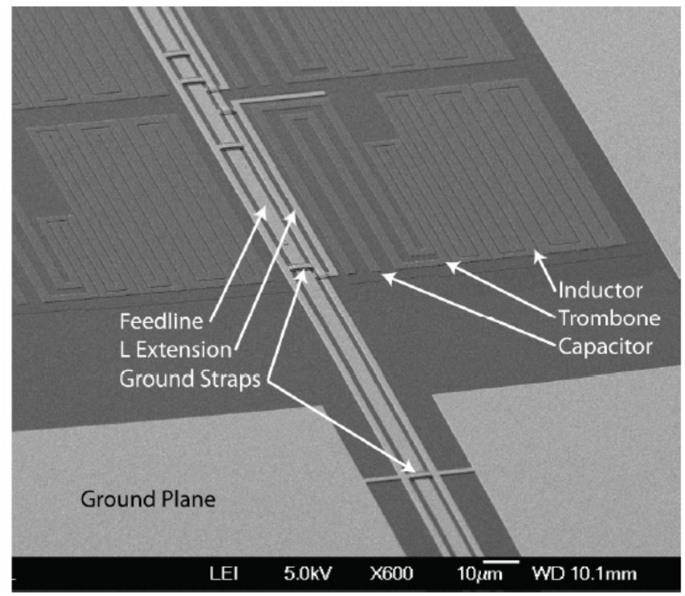
5 hrs at 6800 ft UG (SNOLAB) …with partial shield



*DAMIC is an experiment with members from U.S., Zurich, Paraguay, Mexico*

# A New Tool for the Cosmic Frontier: MKIDS='Microwave Kinetic Inductance Detectors'

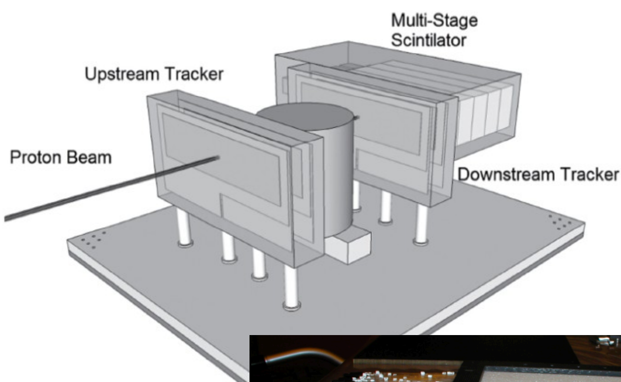
- A relatively new cryogenic technology that can provide real-time photon energy measurements for a wide variety of experiments, including galactic surveys and X-ray science
- Goal is to use Fermilab expertise in cryogenics, CCD's and RF to create an array of 10,000 pixels, monitored by a few RF feed lines

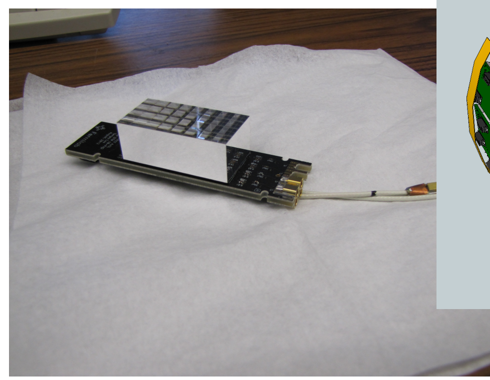

*Adiabatic Demagnetization Refrigerator (ADR) commissioning 4/24-4/26*
*33 mK : Coldest temperature achieved at FNAL?*

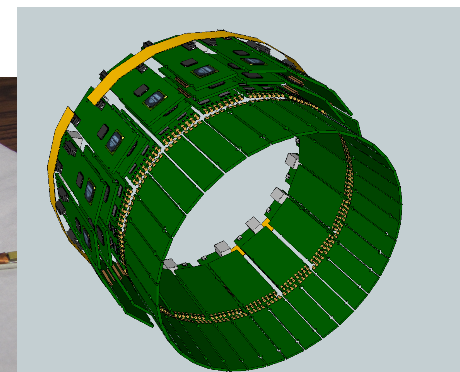
# Two efforts in Medical Detector technology development, with great HEP synergy

- Proton computed tomography
- Tracks incoming high intensity protons and measures range.
- Uses fiber tracker/scintillator/SiPM for detection
- CRADA with Northern Illinois U.



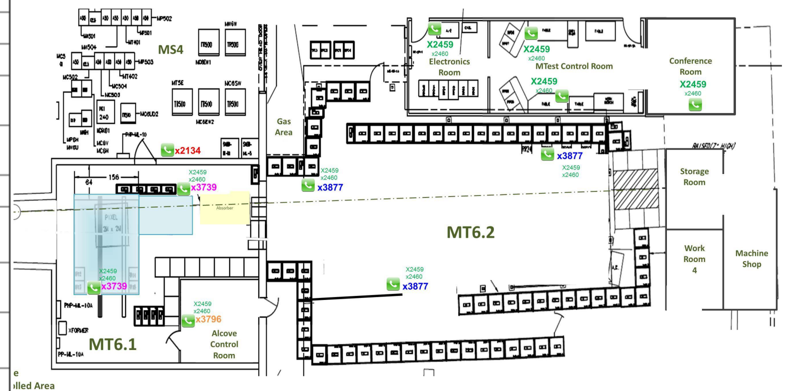

- Time-of-flight PET
- Uses SiPM coupled to LYSO crystals (same crystals in Intensity Frontier?)
- Transmission line readout into high speed waveform digitization.
- SEED grant with U.C.
- Proposal to NIH in August





# The Fermilab Test Beam Facility

| Experiment Title | Location | TSW Approved | Started | Complete |
|---|---|---|---|---|
| T-1042: Muon g-2 straw tracker | MTest | Under Review | | |
| T-1041: CMS Forward Calorimetry R&D | MTest | Under Review | | |
| T-1038: PHENIX Muon Piston Calorimeter APD and Prototype MPC Extension Tests | MTest | Under Review | | |
| T-1037: FLYSUB: Consortium Tracking and RICH Performance Evaluation | MTest | Under Review | | |
| T-1036: Tests of high rate pixel detector | M03 | Under Review | | |
| T-1034: LArIAT: Liquid Argon TPC In A Test beam | MC7 | 18-Mar-2013 | | |
| T-1031: ATLAS Tile Calorimeter Upgrade Electronics Test | M03 | 24-Oct-2012 | | |
| T-1025: IU SciBath-768 Detector Tests | MI12 | 12-Mar-2012 | 13-Mar-12 | 5-May-12 |
| T-1024: GridPix/Gossip Tests | MTest | Withdrawn | | |
| T-1020: NaI Crystal Test for DM-Ice | MINOS Undrgnd Areas | 28.Nov.2011 | 20.Nov.2012 | Taking Data |
| T-1019: Belle II iTOP counter prototype evaluation | MTest | 10.Nov.2011 | 14.Dec.2011 | Taking Data |
| T-1018: UCLA Spacordion Tungsten Powder Calorimeter | MTest | 4.Jan.2012 | 18.Jan.2012 | Taking Data |
| T-1017: COUPP Iodine Recoil Threshold Experiment (CIRTE) | MTest | 8-Sep-11 | 21-Sep-11 | Taking Data |
| T-1015: Dual Readout Calorimetry with Glasses | MTest | 23-Jun-11 | 29-Jun-11 | Taking Data |
| T-1014: IU SciBath-768 Detector | MINOS Undrgnd Areas | 16-Sep-11 | 24-Oct-11 | 28-Feb-12 |
| T-1013: NOvA Near Detector On the Surface (NDOS) | NOvA SB | Under Review | | Taking Data |
| T-1012: TAUWER Test | MTest | 24-Jan-11 | 3-Mar-11 | Taking Data |
| T-1011: Rad-hard Silicon Microstrip Sensors for CMS | MTest | 21-Feb-11 | 16-Mar-11 | Taking Data |
| T-1010: GEM Chamber Characteristics Test | MTest | 11-Jan-11 | 3-Aug-11 | Taking Data |
| T-1008: SuperB Muon Detector Prototype | MTest | 15-Nov-10 | 1.Dec.2010 | Taking Data |
| T-1006: Directly Coupled Tiles | MTest | 2-Apr-10 | 27-May-10 | Taking Data |
| T-1005: Muon g-2 Calorimeter Prototypes | MTest | 3-May-10 | 14-May-10 | Taking Data |



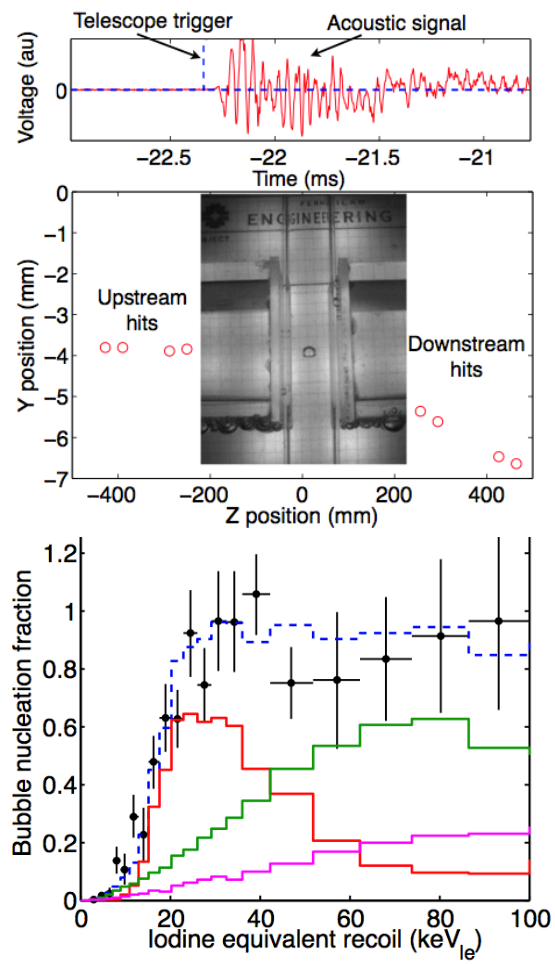

- In 2012:
  - 11 experiments
  - 229 collaborators
  - 64 institutions
  - 14 countries

# Bubble Chamber Nucleation in the Test Beam

- COUPP bubble chamber is insensitive to electron ionization – only nuclear ionization can initiate a bubble in this relatively cold detector
- Thus you can use pion elastic scattering to test for nucleation threshold at low E, without worrying about bubbles forming along the pion track
- Tests Seitz model of nucleation:

$$E_T = 4\pi r_c^2 \left(\sigma - T\left(\frac{\partial\sigma}{\partial T}\right)_\mu\right) + \frac{4\pi}{3} r_c^3 \rho_b \left(h_b - h_l\right) - \frac{4\pi}{3} r_c^3 \left(P_b - P_l\right)$$

- Confirms that a sharp turn-on in efficiency is a good model

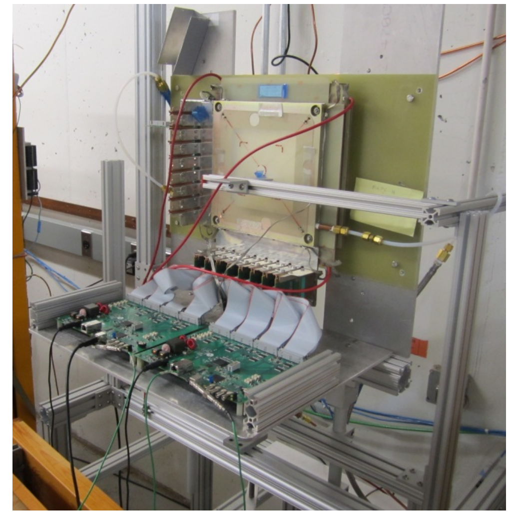



Example of fundamental work performed at FTBF (arXiv:1304.6001)

# Upgrades to FTBF

Completely new insulation

Climate controlled motion table



Upgraded digital wire chamber readout

New control room

Practice Controlled Access door

# Silicon Strip Telescope for FTBF

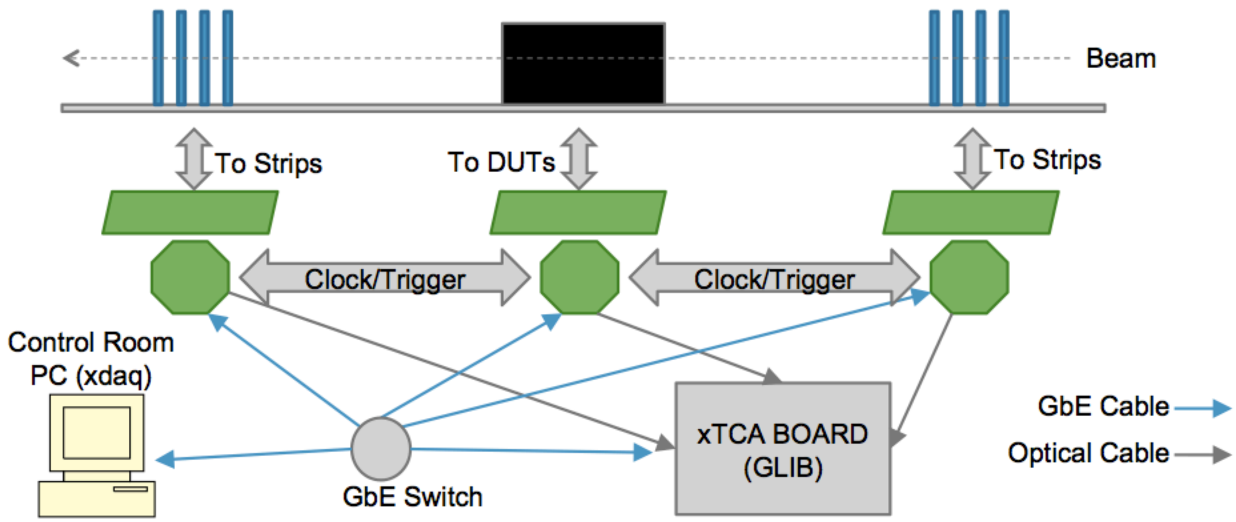
• The Detector Instrumentation Group of ESE/SCD in collaboration with Purdue University will commission a new strips telescope when the beam returns this summer. The telescope will be available to provide precision tracking for users as part of the Fermi Test Beam Facility.

• Telescope DAQ includes CAPTAN (Fermi design), MicroTCA GLIB (CERN design), and xdaq (CMS software framework).

• Will leverage past experience of CMS pixels-based telescope and CAPTAN DAQ.

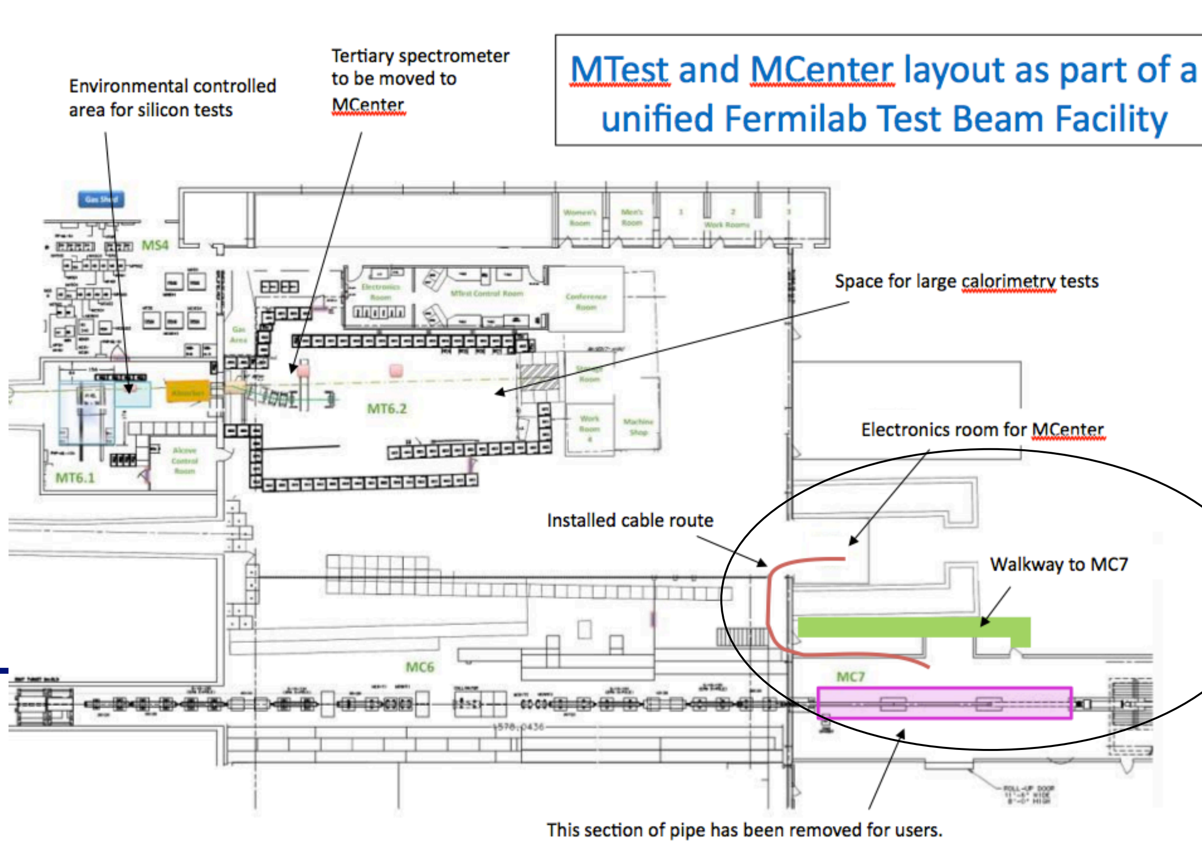
• Features: up to 16 planes with 60 micron D0 strip sensors, large active area (up to 8cm x 8cm, 25x area of pixel telescope), ~5 micron resolution anticipated, real-time track reconstruction in MicroTCA form factor.

• The strip redout chip is the FSSR2, which was designed at FERMILAB for the BTeV strip detector.

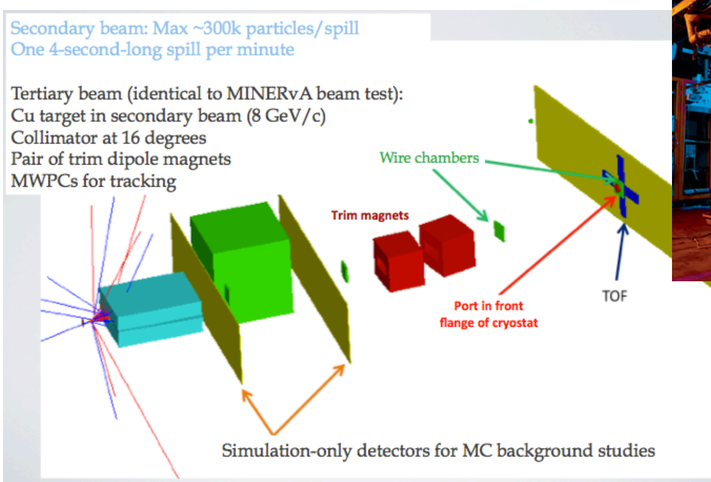


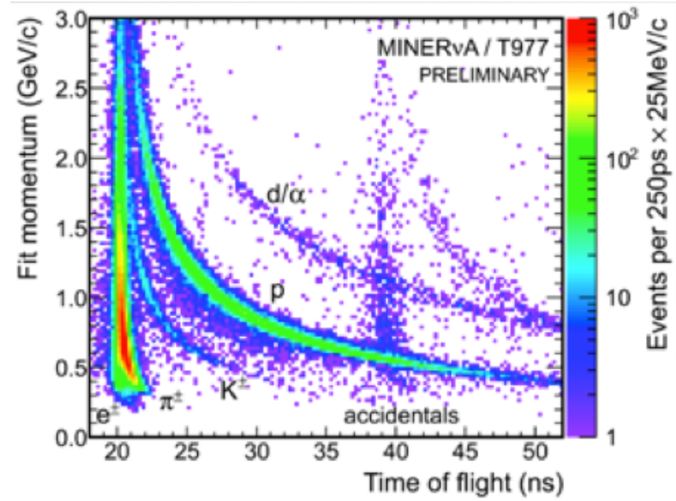
# A New Facility for the Community: The MCenter Test Beamline

- Will have similar characteristics of MTest beamline
- We are waiting on official radiation safety assessment
- 4 magnets have slow water leaks–will replace these before turn-on
- Tertiary beam is moved to MCenter user area for low momentum capability
- Cryogenic detectors will be supported.



# LARIAT = ‘Liquid Argon In A Testbeam’




Test beam experiment T-1034. Reviewed in December, 2012. Approved in March, 2013

Detector is modified ArgoNeut with low mass window.

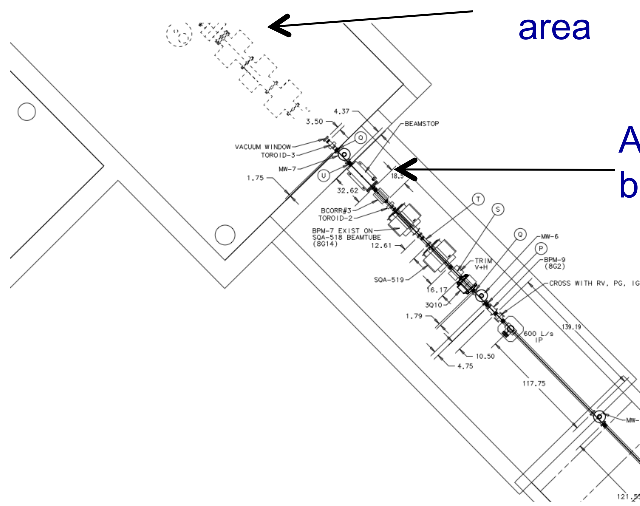
Will be using the same tertiary spectrometer as MINERVA’s test, but located in Mcenter.

Beam will have very low rate, (10 events/spill) but will contain a quite varied particle content and very good particle i.d. Low energy kaon beam is very relevant for proton decay experiments

# New R&D Irradiation Facilities

- A new area is being developed in the area upstream of the target for the MTest beamline, to support high intensity tracking tests.
- Maximum flux will be ~2E11 / minute

- The MTA experimental hall has now accepted beam.
- It will likely be possible to support detector irradiation studies there
- Flux as high as 1E13/minute in the experimental hall, and higher upstream



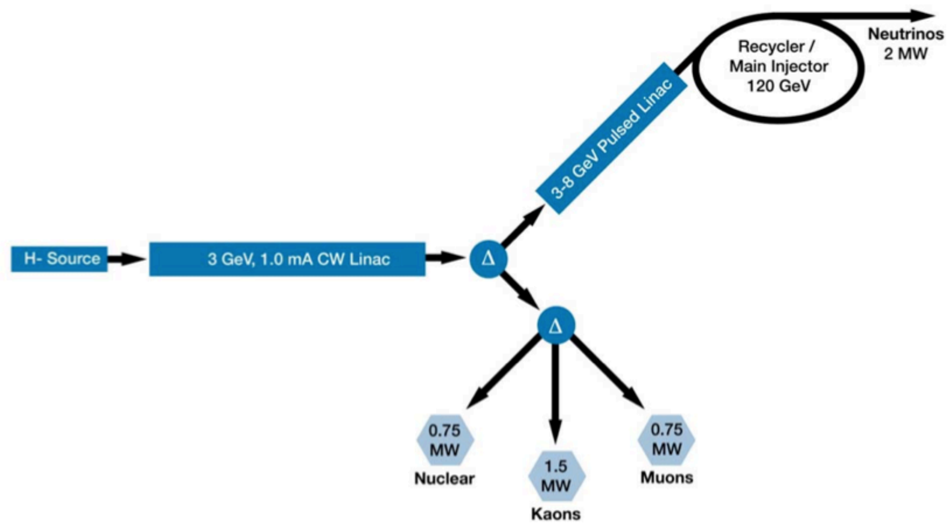
General experimental area

Area upstream of beam stop

*Both areas will receive Technical Statement of Work (TSW) requests this year*

# The High Intensity Frontier at FNAL

- Project X will provide a staged approach to a new high intensity frontier of particle physics, supporting neutrino, kaon, muon and nuclear programs.
- Detector technology must advance to meet the program’s requirements.





The Project X Physics Study last year was a workshop to identify the theory motivation and detector requirements for the Project X era.

# Detector R&D for High Intensity

**Detector challenges studied at Project X Physics Study (with conveners):**

High rate Precision Photon Calorimetry:

(David Hitlin (Caltech), Milind Diwan (BNL))

Used in Kaon program – both neutral and charged

Very Low-Mass High-Rate Charged Particle Tracking:

Ron Lipton (FNAL), Jack Ritchie (U. of Texas, Austin)

**For $\mu$ ––> 3 electrons**

Time-of-Flight System Performance below 10 psec:

Mike Albrow (FNAL), Bob Wagner (ANL)

**For neutral Kaon $K^o \rightarrow \pi\ \nu\ \nu$bar vertex reconstruction**

High Precision Measurements of Neutrino Interactions:

Kevin McFarland (Rochester U.), Jonghee Yoo (FNAL), Rex Tayloe (U. of Indiana)

**Detection of neutrino coherent scattering and magnetic moments**

Large Area Cost Effective (LACE) Detector Technologies:

Mayly Sanchez (Iowa State U.), Yury Kamyshkov (U. of Tennessee)

**n- nbar oscillation program needs large area coverage**

**These map well onto our current program. We plan to establish R&D projects based on these summaries**

# Summary

- Fermilab has a very active detector R&D community
- The lab has based its detector R&D organization on a “Detector Advisory Group”, consisting of representatives of the major detector efforts.
- R&D efforts have been centered on several major portfolios, linked to the highest priorities of HEP:
  - **High luminosity tracking and triggering**
  - **Liquid argon detectors for neutrino and dark matter experiments**
  - **High speed calorimetry and photodetection**
  - **Astrophysics dark matter/dark energy**
- As the priority for HEP research moves to the Intensity Frontier, detector R&D at Fermilab will need to evolve.
- We request that the PAC recognize the importance of detector R&D for the lab’s future and to endorse support for the new efforts outlined in the Project X physics study.