# LBNL Introduction Detector R&D Review

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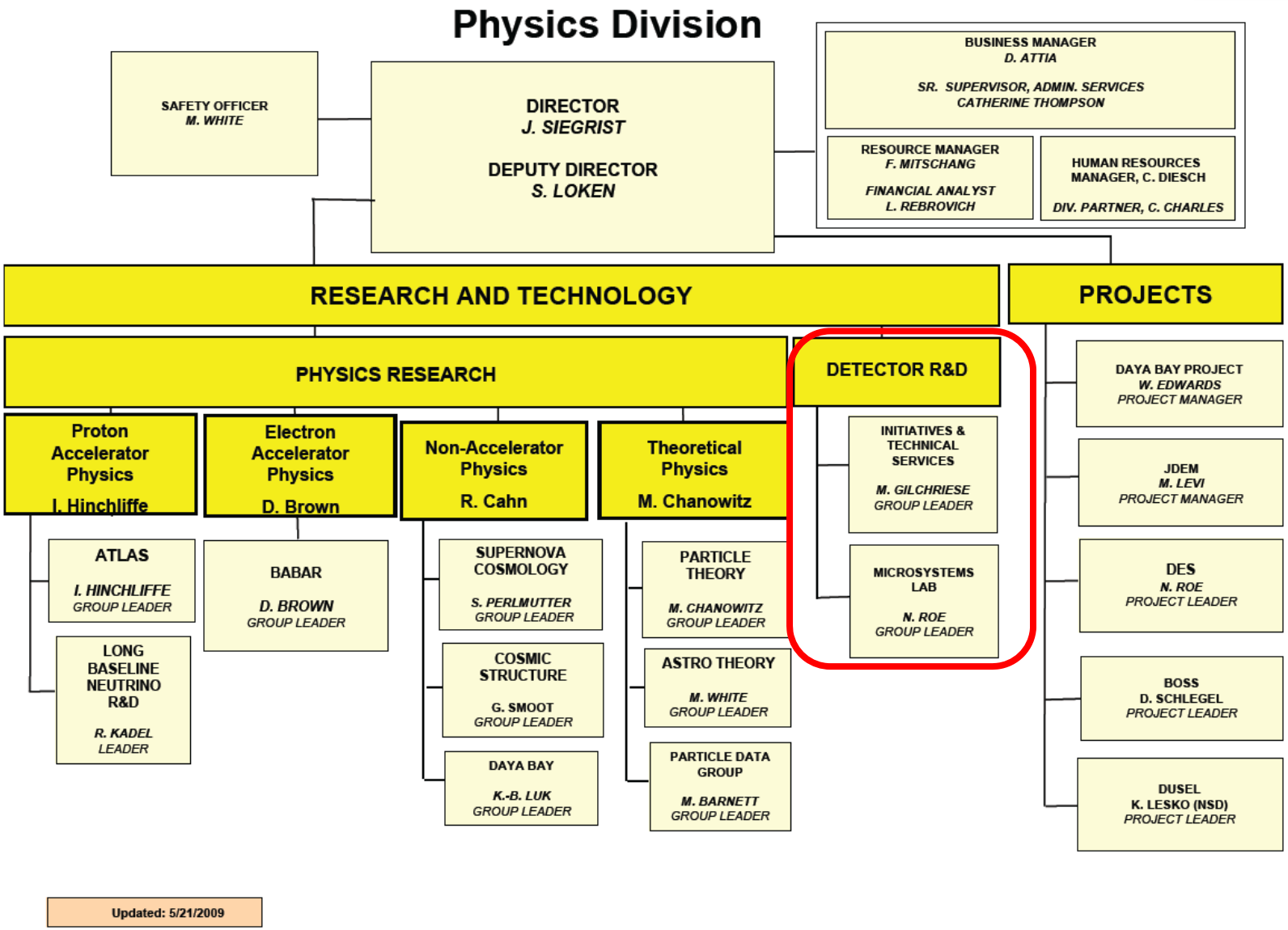
# Outline

- Background and organization
- Infrastructure and core capabilities
- One slide overviews of major detector R&D areas that will be covered in detail in later talks
  - Micro-systems Laboratory and CCD R&D
  - Integrated circuit sensors and electronics R&D
  - High Pressure Xenon TPC R&D
- Other R&D activities – this talk
- Resources/planning – my 2nd talk

# Background

- **Long and distinguished history of detector R&D at LBNL**
- **A significant component has been science driven – instrumentation development in order to do specific experiments**
- **New techniques developed for a specific experiment may be applied elsewhere.**
- **In addition, inventive personnel pursuing new ideas to address technical challenges, resulting in new capabilities.**

# Physics Division



# Detector R&D and Berkeley

- **Close connection with UC Berkeley for all LBNL activities including detector R&D – faculty, graduate and undergraduate students.**
- **Critical partnership with the LBNL Engineering Division for detector R&D**
  - **Many of the KA-15-supported personnel working on detector R&D are matrixed engineers and technical staff from the Engineering Division**
- **Detector R&D connections with UCB Space Sciences Laboratory (SSL) and expertise in other LBNL Divisions (germanium, scintillators)**

# Who Is Involved in Detector R&D?

**Other Heads**

C. Bebek(P)
M. Garcia-Sciveres(P)
M. Gilchriese(P)
C. Haber(P)
J. Kadyk(P ret.)
N. Roe(P)
J. Siegrist(P)
H. Spieler(P)
Graduate students
Undergraduate students
Visitors

**KA-15 Supported(Heads FY09)**

| Physics Division | Eng. Division/SSL |
|---|---|
| M. Battaglia(P) | S. Holland(E) |
| D. Contarato(P) | N. Palaio(E) |
| W. Kolbe(P ret.) | J.-P. Walder(E) |
| D. Nygren(P) | D. Gnani(E) |
| S. Dardin(T) | A. Karcher(E) |
| R. Witharm(T) | G. Wang(E) |
| J. Emes(T) | J. Lee(T) |
| R. Yee(S) | C. Tran(T) |
| | K. Chow(E) |
| | Y. Irwin(T) |

# Infrastructure & Core Capabilities(I)

- **Micro-Systems Laboratory (MSL)**
  - **Unique expertise and facilities for the development, fabrication and testing of advanced detectors for x-ray /visible/near IR imaging, and charged particle detection**
- **Integrated Circuits and Electronics**
  - **IC group with outstanding record of R&D, innovative design and implementation of integrated circuits for CDF, D0, BaBar, IceCube, ATLAS, SNAP etc for HEP and similarly for non-HEP.**
- **Will be covered in detail by Holland and Denes, respectively.**

# Infrastructure & Core Capabilities(II)

- **Physics Division Technical Infrastructure – non-MSL**
  - **Clean rooms(~1000 ft$^2$) with wire bonding, precision metrology and related equipment, primarily used for silicon detector systems**
  - **Laboratory space and equipment for electronics and related testing and general laboratory space**
  - **KA-15 supports two technicians(1 mechanical and 1 electrical) for operation, maintenance and support of <u>all</u> non-MSL lab work for Physics Division. There is no other technical support that is not project funded.**
  - **Technical support reduced significantly in last years(factor >2) through retirements and reductions in force.**
  - **Propose a modest enhancement in ongoing support – see my 2$^{nd}$ talk**

# Infrastructure & Core Capabilities(III)

- **Composite Fabrication Facility – Engineering Division**
  - **Design, prototype and fabricate novel carbon composite structures (primarily for tracking detectors).**
  - **Established for ATLAS, now used for STAR, PHENIX, ATLAS upgrades, etc. ~ 1500 $ft^2$**
  - **Allows close connection also with industrial partners, including recent development of new materials(new type of carbon foam) and techniques**
- **Additional clean room area (originally for large-scale ATLAS assembly, ~ 1000 $ft^2$) – Engineering Division**
- **Utilize other LBNL resources – test beams at Advanced Light Source, 88” cyclotron (irradiation), Molecular Foundry, extensive shop facilities, etc.**

# CCDs and Related Electronics R&D

- **Scientific goals**
  1. **Enable Dark Energy science through ground-based and space-based instruments based on CCDs**
  2. **Improvements to general astronomical/astrophysics instrumentation**
  3. **Connections to Photon Science, Homeland Security, medical imaging,…**
- **R&D Challenges**
  - **Faster**
  - **Lower noise**
  - **Single-photon sensitivity**
  - **Higher yield/lower cost**
  - **Better integration of CCDs and electronics**

# Micro-Electronics Enabled Tracking Detectors

- **Scientific goals**
  1. **Enable future tracking detectors for physics at energy-frontier colliders**
  2. **Connections to Photon Science, electron microscopy and Homeland Security**
- **R&D Challenges**
  - **High rate{up to ~ 10 particles/(Å$^2$ – year)}**
  - **High radiation(up to ~ 1 GRad)**
  - **Low power**
  - **Improved resolution**
  - **Lower cost**
  - **Less material**
  - **Increased on-board intelligence**
  - **Follow technology(-> 45nm, 3D,…)**

# High Pressure Xenon TPC

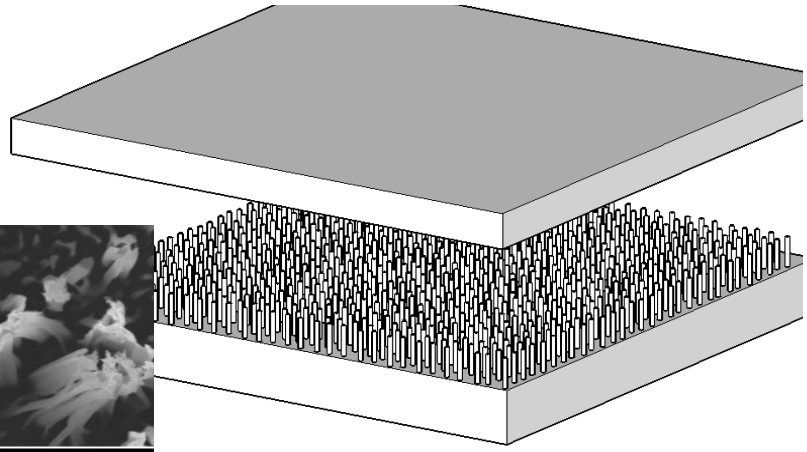
- **Scientific goals**
  1. **Improved detectors for $0\nu\beta\beta$ decay and WIMPs**
  2. **Connection to neutron detection /measurement for Homeland Security**
- **R&D challenges**
  - **Achieve expected energy resolution in high pressure Xe gas**
  - **Simultaneous high resolution energy measurement and track imaging**
  - **Control backgrounds**

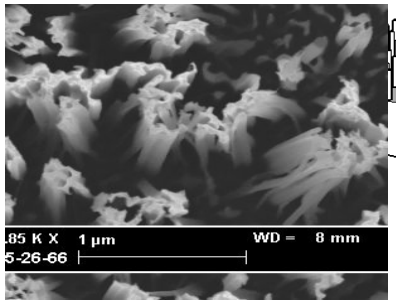
# Other R&D Areas

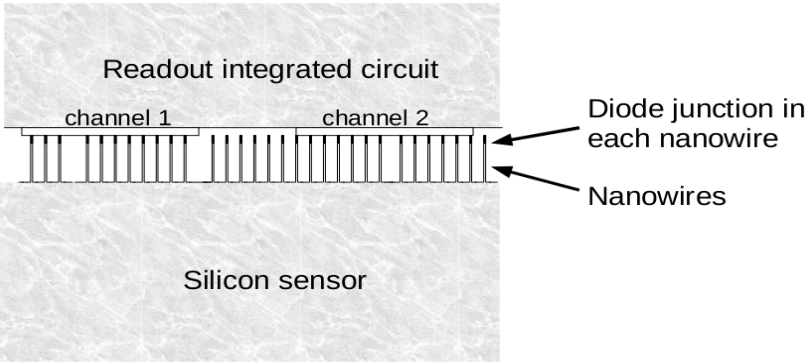
- **In addition to our major ongoing/planned R&D activities, we have small efforts in a few speculative, but interesting areas.**
- **In general, these have been initiated by Laboratory Directed Research and Development (LDRD) proposals or by non-HEP support.**
- **Or take advantage of particular Berkeley expertise with anticipated external funding.**
  - **Multi-channel plate expertise in support of Large-Area Fast Photo-detectors (ANL)**
  - **Scintillating material expertise in support of crystal hadronic calorimetry (FNAL)**

# Silicon Nanowires(NW)

- **A new fabrication method for low cost, generic hybrid pixels.**
  - **Generic because the same NW sensor can be read with any pixel IC.**
- **This is <u>not</u> a replacement for bump bonds, it is a new method of silicon sensor fabrication exploiting the "self assembly" aspect of nanotechnology (As a bonus it does not need bump bonding).**
- **FY06-FY08: initial concept and development. Preliminary patent filed.**
- **FY09: Conclude proof of principle. File full patent**
- **FY10-11: produce demonstrator devices big enough for FE-I4**
- **FY12: Tech transfer to Industry? Or more R&D...**



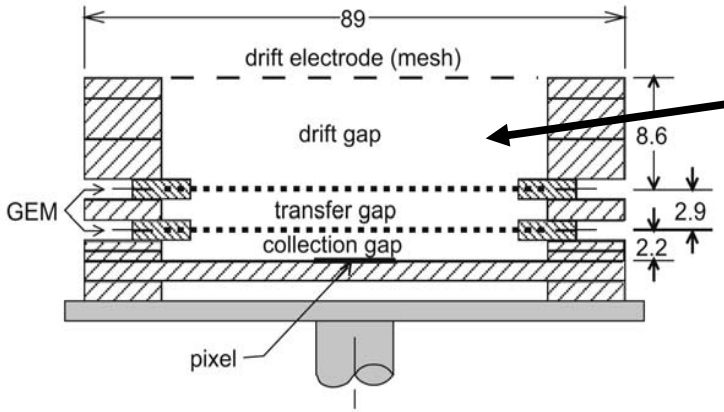


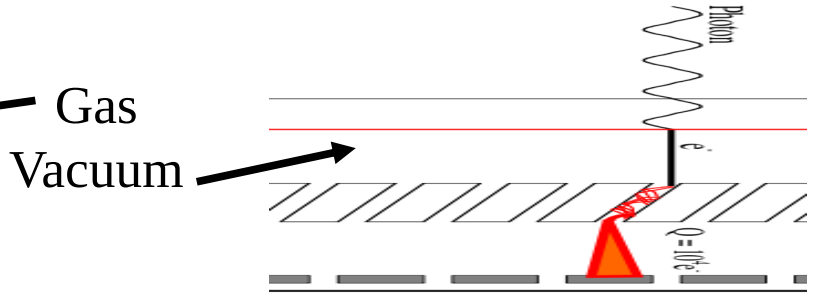




Note: we did not invent NWs. We simply use them.
Utilize fabrication capabilities of LBNL Molecular Foundry

# Pixel Readout of non-Silicon Devices

- **Pixel readout chips are very powerful general purpose devices.**




Use MCP+pixel chip in vacuum as tracking detector?

Readout of Gas Electron Multiplier using ATLAS pixel chip.
Potential use: TPC readout
LBNL: Nucl.Instrum.Meth.A589:173 (2008)

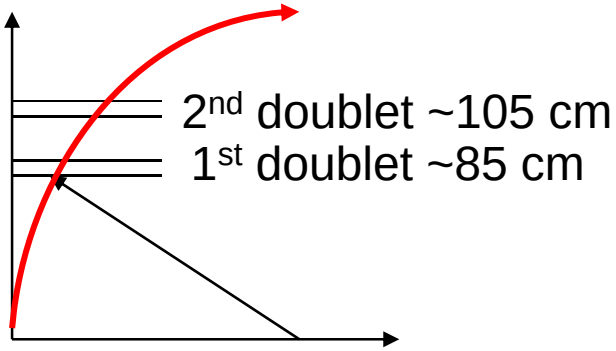
Readout of Micro Channel Plate using Medipix pixel chip
Currently in use: Adaptive optics system
UCB SSL: EEE Trans. Nucl. Sci. 52:1021 (2005)

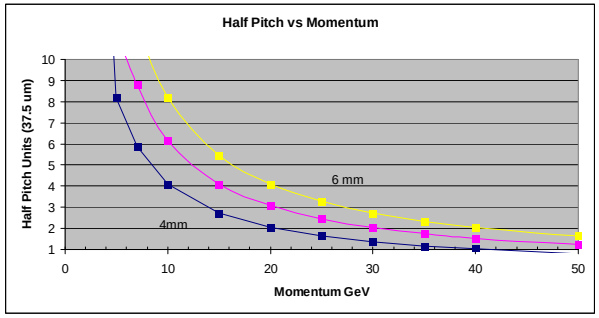
- **FY10: Develop directional detection of neutrons using double GEM TPC setup (contingent on Homeland Security (HS) funding). Implement MCP readout using ATLAS pixel chip to study particle detection. Implement simulations of electron avalanche.**
- **FY11-12: Continue HS program to produce demonstration neutron detection system. Develop "packaging" concepts for MCP for particle detection**

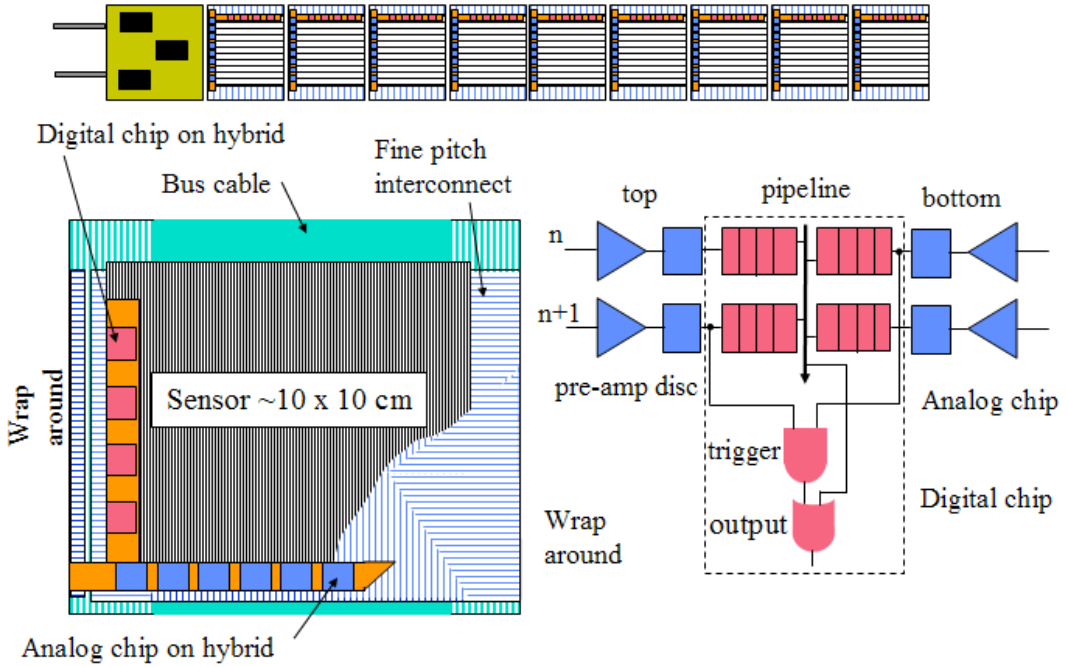
# Intelligent Silicon (I)

- This is a potential new area of generic research for LBNL but one that is a natural evolution based on our extensive experience with silicon systems
- Past developments in silicon detector readout have relied on improvements in local processing of signals from single or nearby sensor elements
- New goal is to use increased processing and high density interconnections to correlate information from multiple silicon strip or pixel sensors, including at very high rates.
- Key R&D areas: packaging, architecture and processing, data transmission, system issues.
- FY10: explore components and architecture
- FY11-12: significant program to integrate this into a prototype concept, demonstrator built and tested.

# Intelligent Silicon(II) - Example




- **Utilize detector doublets, high rate prompt track trigger?**
  - **Basic structures (staves) are already a key development area for LBNL**
  - **Radial spacings of ~few mm: resolve momenta in the 10-30 GeV range**
  - **Local interconnects and coincidence logic provide momenta and position at high rate**
- **Preliminary indications of strong community interest.**
- **Workshop early 2010 for generic R&D plan, applicable to multiple expts.**

# Connections to Other Fields

- **The LBNL HEP detector R&D program has strong connections with non-HEP detector R&D**
- **Broadens base of technical support (funding by multiple sources).**
- **Results from other fields benefit HEP.**
- **In subsequent talks you will see connections to NASA, Basic Energy Sciences(for photon detection, electron microscopy), Domestic Nuclear Detection Office, National Nuclear Security Administration(NA-22), Nuclear Science, industry**

# Remaining Agenda

- **Micro-Systems Laboratory and CCD R&D – S. Holland**
- **Microelectronic-enabled Detectors – P. Denes**
- **High Pressure Xenon TPC R&D – D. Nygren**
- **Planning and Summary – M. Gilchriese**