

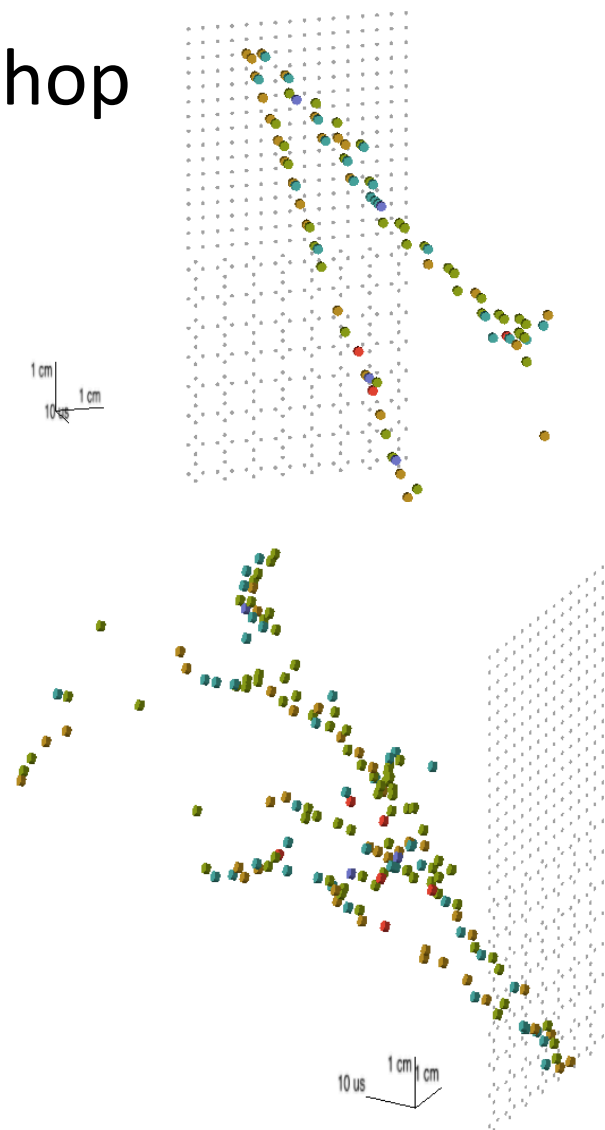
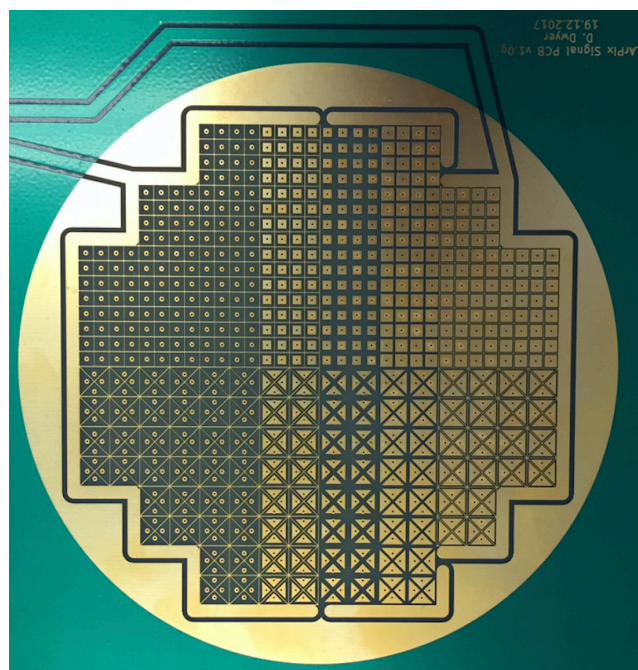
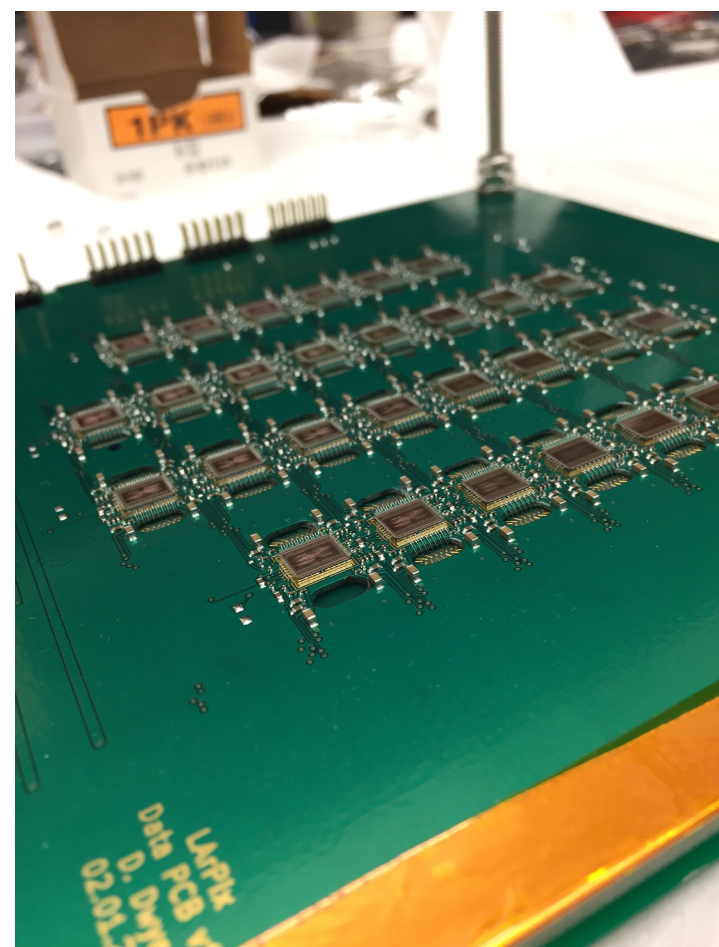
# Cost Model for LArPix

## Pixelated Charge Readout for LArTPCs

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Pixel LArTPC Autumn Workshop

Sep. 29, 2018





# Introduction

## **3D pixelated charge readout for large LArTPCs:**

- Considered to provide enhanced physics potential
- In development for DUNE Near Detector LArTPC
- Considered potential candidate for future far detector module

## **Not without concerns:**

### **Technical Feasibility:**

Is 3D readout viable in terms of noise, power, etc?

→ LArPix-v1 shows promise

### **Scalability:**

Can it be produced and meet specs at large scale?

→ Target of ongoing LArPix, ArgonCube R&D program

### **Cost:**

Can we afford it?

→ Target of this presentation

## Working concept for a detector-scale pixel readout system



- Ground
- Power (~1.8V)
- Clock (~2.5 to ~40 MHz)

Per tile:

- ~6 Digital I/O (~2.5 to ~40 MHz)
- Tile reset
- External trigger
- Analog monitor
- ADC test input
- ?

### *Preliminary Concept:*

Have designs for:

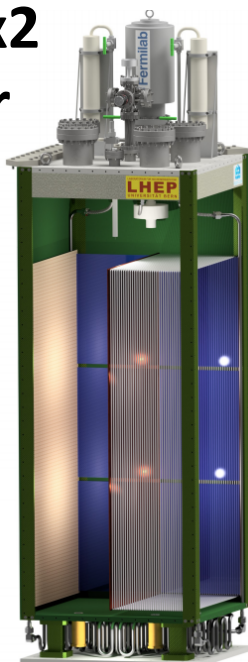
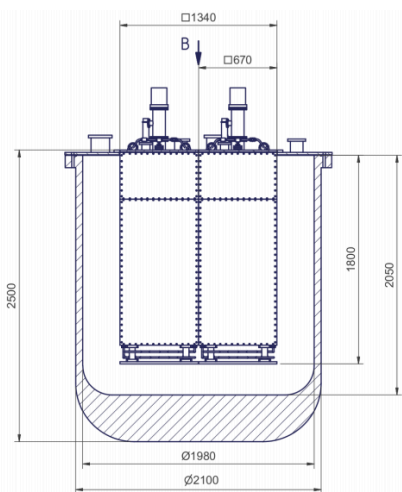
- LArPix ASIC
- Pixel Tile (partial)
- Control Electronics

Other components  
are currently fictional.

# Cost Model Targets

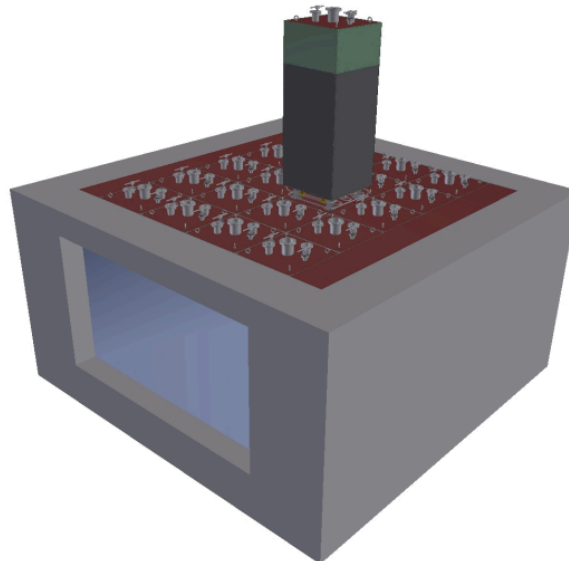
Estimate costs for three detector-scale systems:

## ArgonCube 2x2 Demonstrator



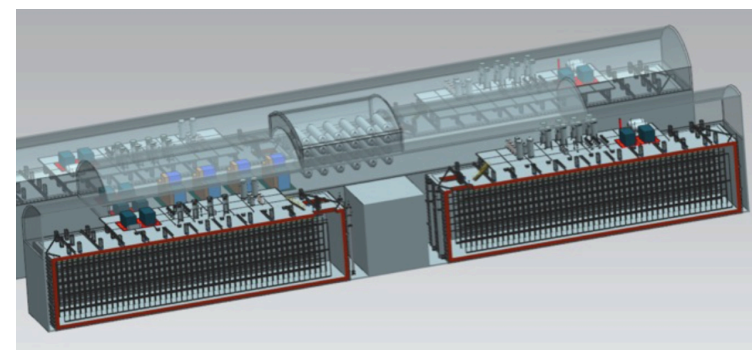
Readout area: 6.4 m<sup>2</sup>  
 # pixels: 400k  
 # ASICs: 6.3k  
 Target: Late 2019  
 → Will use pixels

## DUNE Near Detector



Readout area: 120 m<sup>2</sup>  
 # pixels: 7.5M  
 # ASICs: 120k  
 Target: 2026  
 → Pixels by default,  
 assuming R&D successful

## DUNE Far Detector (per 10 kton module)



Readout area: 3000 m<sup>2</sup>  
 # pixels: 180M  
 # ASICs: 3M  
 Target: 2024-2028  
 → Pixels possible for  
 4<sup>th</sup> module?

*Pixel, ASIC counts assume 4mm pixel spacing, 64 channels/chip*



# Cost Model Details

## Model Criteria:

Costs determined using actual quotes or similar recent purchases

## Model Includes:

**Complete production of sufficient pixel tiles for targeted system:**

ASIC Production, Preparation, and Packaging

PCB Tile Production, Components, and Assembly (w/ASICs)

**Spares:** 10% of all components

**Overheads:** +20% to all costs

## Not included:

*Pixel tile production  $\neq$  total system cost*

**System Design:** assumed to be included in current R&D effort

→ And assumes current R&D program continues to be successful!

**QA/QC, Testing program**

**Related systems:** anode frame, cabling, feedthroughs, etc. ( $\ll$  \$5000/m<sup>2</sup>)

**Contingency**



# Cost Model: Summary

## Current cost estimates for production of Pixel Tiles

	ArgonCube 2x2	Near Det.	Far Det.
Readout Area [m2]	6.4	120	2880
# Pixels (4mm pitch)	4.02E+05	7.50E+06	1.80E+08
# ASICs	6,282	117,188	2,812,500
# Tiles (32x32cm)	63	1,172	28,125
Cost, Wafer Production	\$100,780	\$280,807	\$4,660,018
Cost, Die Preparation	\$1,571	\$29,297	\$703,125
Cost, Packaging	\$6,910	\$128,907	\$3,093,750
Cost, PCB Production	\$3,735	\$52,806	\$1,267,200
Cost, PCB Components	\$2,073	\$38,672	\$928,125
Cost, PCB Assembly	\$1,176	\$15,690	\$376,509
Total Cost	\$116,245	\$546,178	\$11,028,727
Total Cost (+20% Ovhd)	\$139,494	\$655,414	\$13,234,473
Cost, per square meter	\$21,796	\$5,462	\$4,595

*Pixel tile production ≠ total system cost*

~\$2.9k @ 5mm

~\$8.2k @ 3mm

# Cost Model: Wafers

ASIC wafer production is single largest cost

	ArgonCube 2x2	Near Det.	Far Det.
Readout Area [m2]	6.4	120	2880
# Pixels (4mm pitch)	4.02E+05	7.50E+06	1.80E+08
# ASICs	6,282	117,188	2,812,500
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Cost, per square meter	\$21,796	\$5,462	\$4,595

## Details:

180nm CMOS  
 ~\$90k masks  
 ~\$700 / wafer  
 ~450 ASICs/wafer  
 (assuming 90% yield)

*Pixel tile production ≠ total system cost*

# Cost Model: Packaging

**ASIC packaging is second-largest cost**

	ArgonCube 2x2	Near Det.	Far Det.
Readout Area [m2]	6.4	120	2880
# Pixels (4mm pitch)	4.02E+05	7.50E+06	1.80E+08
# ASICs	6,282	117,188	2,812,500
# Tiles (32x32cm)	63	1,172	28,125
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Cost, per square meter	\$21,796	\$5,462	\$4,595

## Details:

QFP package  
100 pin  
~\$1 per ASIC

Also quoted:  
LQFP-144pin  
QFN-100pin  
→ Prices similar

Task:  
Must demonstrate  
LArPix functions in  
packaged format.

*Pixel tile production ≠ total system cost*



# Cost Model: Conclusions

## Pixel tile production costs (including tile assembly):

Current estimate:

~\$22k / m<sup>2</sup> for ArgonCube 2x2

~\$5k / m<sup>2</sup> for larger detectors

*Pixel tile production ≠  
total system cost*

Leverages industrial-scale electronics production and assembly

At large scales, cost scales with pixel density (or pitch<sup>-2</sup>)

## Comments:

- Assumes planned changes to ASIC and pixel tile design are successful, and no unforeseen obstacles to assembly
- Detailed tile requirements undefined, so costs cannot be certain
- Costs will rise as system design becomes more 'on-shell'
- Other M&S (cabling, control, etc) appear modest, but still undefined

## Conclusions:

Pixel tile costs seem reasonable compared with scale of DUNE project

Other potential benefits: physics, system robustness, testing, installation?