



# **WBS 2.4 PVC and Extrusions**

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**Argonne National Laboratory**



# WBS 2.4 Deliverables

- Far Detector **16-cell** rigid PVC Extrusions: 15.55 m long
  - 14,440 for Horizontal Modules (3.3 mm walls and 2.3 mm webs)
  - 14,638 for Vertical Modules (4.8 mm walls and 3.3 mm webs)
- Near Detector **16-cell** rigid PVC Extrusions
  - 224 Horizontal, 2.66 m long
  - 164 Vertical, 3.98 m long
- The above totals include
  - 2% spares
  - 140 51-foot extrusions for “pallet bridges” (bottom supports for shipping)
- Duration: 4 years
  - 1<sup>st</sup> year: tool fabrication, setup and pre-production
  - 2<sup>nd</sup> year: slow startup (4.5 Far Detector blocks)
  - 3<sup>rd</sup> & 4<sup>th</sup> years: full speed production (remaining 33.5 FD blocks + near detector)
- All extruding will be done at one vendor location

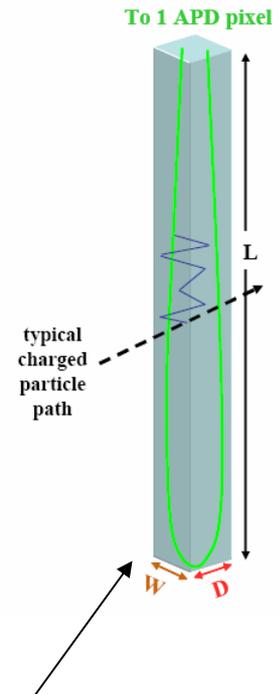
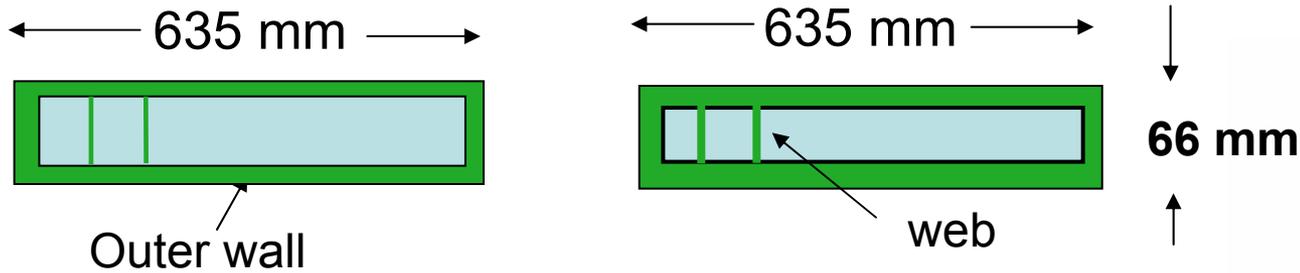
Note: All extrusions will be produced ~ 2” longer for trimming to precise lengths



# Horizontal and Vertical Extrusions

*Vertical Extrusions have thicker walls*

This Makes Assembled Blocks Stronger



- Horizontal Extrusions

- **W = 37 mm**
- **D = 59.4 mm**
- **3.3 mm** outer wall
- **2.3 mm** web
- **~ 325 lbs** for 15.5 m

- Vertical Extrusions

- **W = 36 mm**
- **D = 57.4 mm**
- **4.8 mm** outer wall
- **3.3 mm** web
- **~ 455 lbs** for 15.5 m

Hydrostatic pressure 19.2 psi



# PVC Extrusions: Functions

- **Detector Building Blocks**

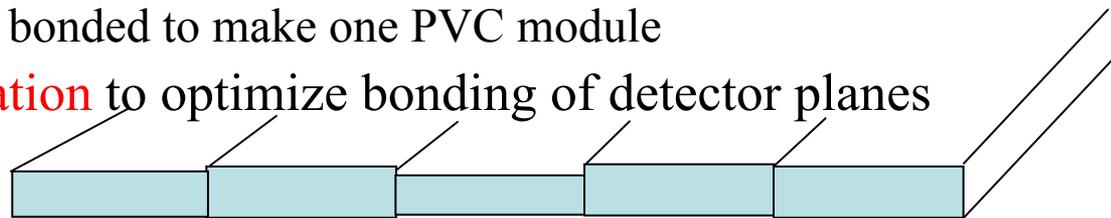
- **Mechanically strong**

- Rigid PVC
- Vertical extrusions have 50% thicker walls than horizontals

- Straight, to within a few mm over 51 foot length

- Two extrusions will be bonded to make one PVC module

- **Minimize thickness variation** to optimize bonding of detector planes



PVC extrusions with varying thickness: end view

- **Light Collectors**

- Highly reflective

- Scintillation photons bounce an average of 8 times before entering WLS fiber

- $(\text{reflectivity})^8 \rightarrow$  small changes in reflectivity have large impact

- Requires high reflectivity in range  $\sim 400\text{-}470$  nm





# PVC Extrusions Managers

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- L2 Managers

- Richard Talaga, ANL
  - WBS 2.4 Manager
- Anna Pla-Dalmau, FNAL
  - WBS 2.4 Alternate Manager

**PVC Extrusions**

**PVC Extrusions**

- L3 Managers

- Chuck Grozis, FNAL
  - WBS 2.4.1.1; 2.4.2; 2.4.3
- Anna Pla-Dalmau, FNAL
  - WBS 2.4.1.2, and portions of 2.4.2 and 2.4.3
- Jim Grudzinski, ANL
  - WBS 2.4.4
- Karen Kephart, FNAL
  - WBS 2.4.5

**Extrusion Production**

**Resin Procurement and Evaluation**

**Extrusion QA and Evaluation**

**Shipping and Handling**



# Technical Design Report: Chapter 12

- Requirements: 12.2
  - Strength, Shape and Reflectivity (→ Light Yield)
- PVC Extrusions 12.3
  - N-27 PVC resin
    - Formulation contains 15% TiO<sub>2</sub> (anatase)
    - Mixing TiO<sub>2</sub> with PVC and other ingredients (processing aids)
      - “Compounding”
  - Extruding Process
    - Extrusion Line: Extruder, Die, Vacuum Sizing & Cooling, Puller, Saw
    - Extrusion Parameters: ~ 12 Temperatures (Extruder, Die), Vacuum Strength, Puller Speed + many more
    - Quality Control: Straightness and Size (for all 16 Cells) at Vendor
      - Breakout talk by Chuck Grozis
  - Quality Assurance:
    - Statistical sampling of daily sample extrusions
      - Done at NOvA Institution
      - Mechanical properties; detailed reflectivity measurements
      - Evaluation of the database to look for trends
    - Breakout Talk by Jim Grudzinski

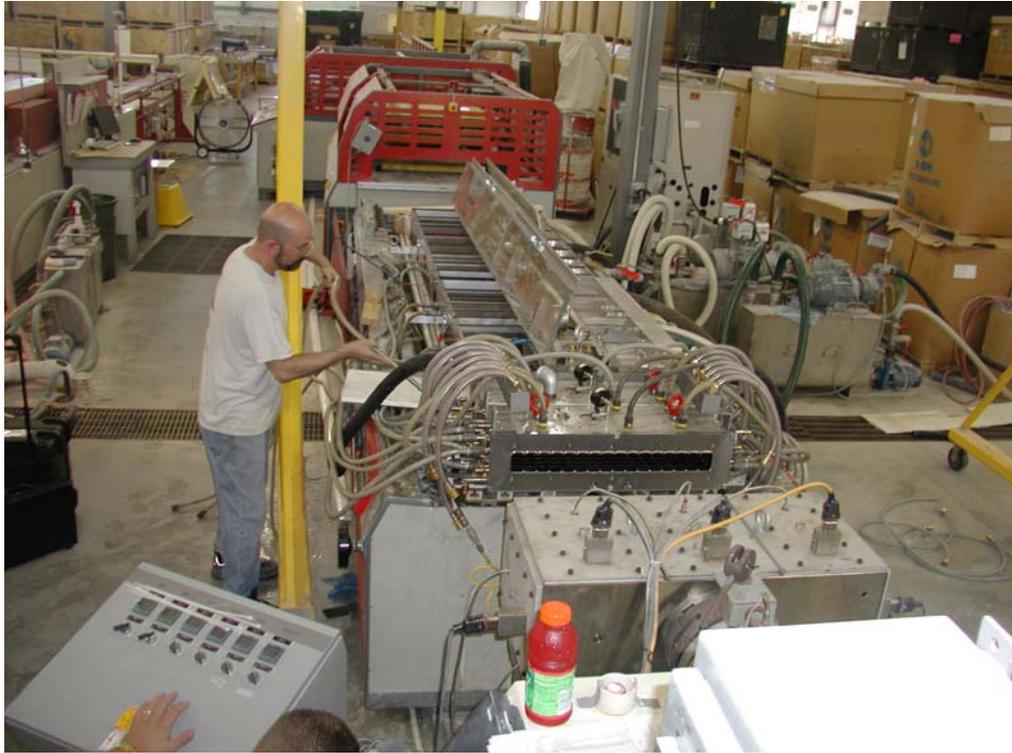


# PVC Resin Formula

<b>N-27 PVC Resin</b>			
<b>Ingredient</b>	<b>Commercial Brand Name</b>	<b>Parts per Hundre d</b>	<b>per cent</b>
PVC	Shintech SE950EG (high reflectivity)	<b>100</b>	<b>77.5%</b>
Tin stabilizer	Rohm & Haas Advastab TM-181 20% monomethyl tin	<b>2.5</b>	<b>1.9%</b>
Titanium dioxide anatase	Kronos 1000 anatase titanium dioxide	<b>19</b>	<b>14.7%</b>
Calcium stearate	Ferro 15F calcium stearate	<b>0.8</b>	<b>0.6%</b>
Paraffin wax	Ferro 165 paraffin wax	<b>1.1</b>	<b>0.9%</b>
Oxidized polyethylene	Ferro Petrac 215 oxidized polyethylene	<b>0.2</b>	<b>0.2%</b>
Glycerol monostearate	Rohm & Haas F1005 glycerol monostearate	<b>0.3</b>	<b>0.2%</b>
Acrylic impact modifier	Arkema Durastrength 200 Acrylic impact modifier	<b>4</b>	<b>3.1%</b>
Processing aid	Rohm & Haas Paraloid K120N processing aid	<b>1</b>	<b>0.8%</b>
<b>Total</b>		<b>129</b>	<b>100%</b>

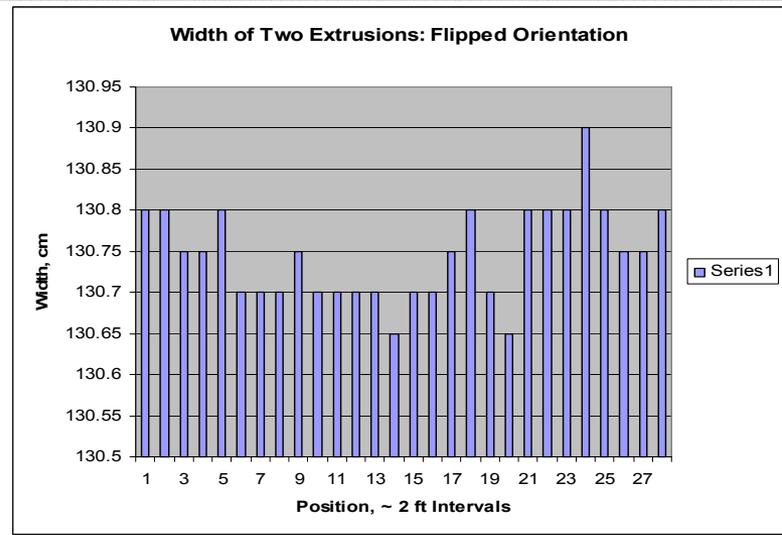
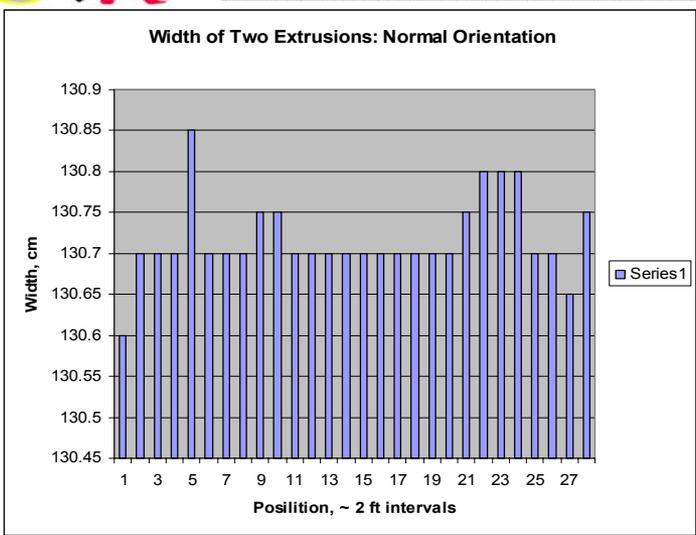


# PVC Extrusion Line

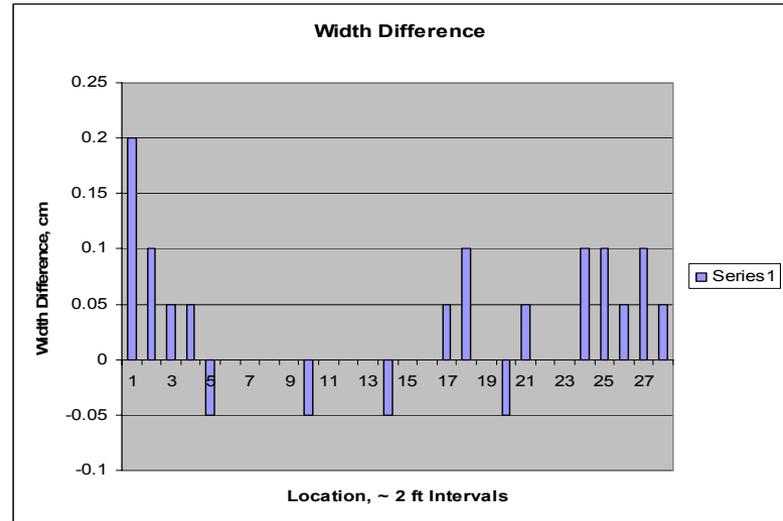




# Quality Control: Straightness



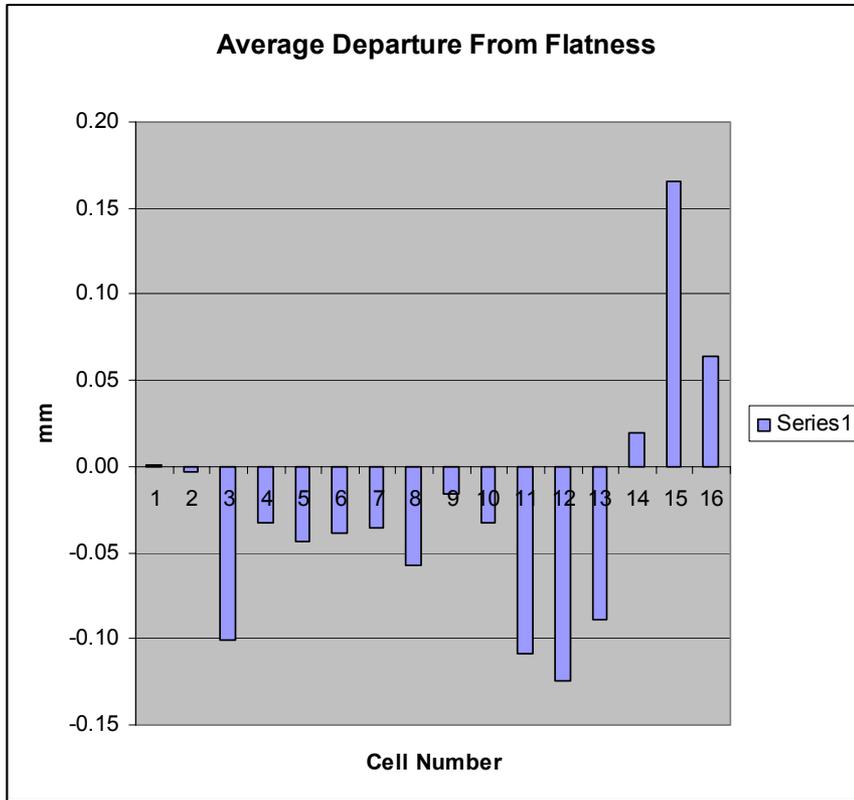
15.7 m (52 ft)



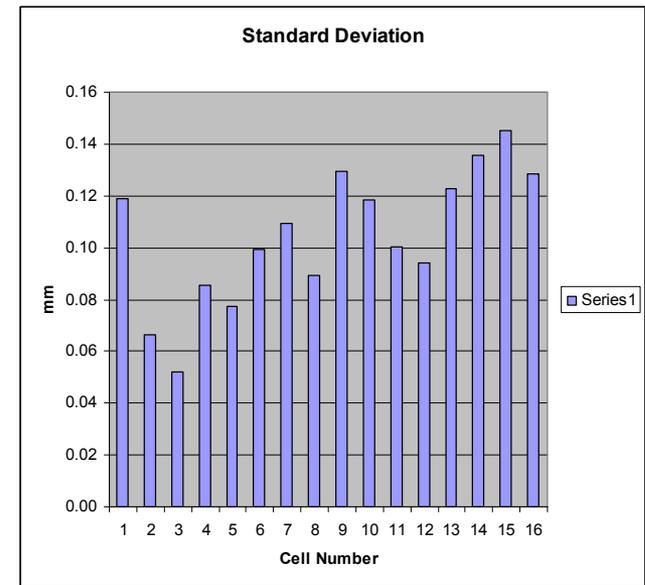
Specification: 0.1 cm per meter of length



# Quality Control: Flatness of 26 Samples

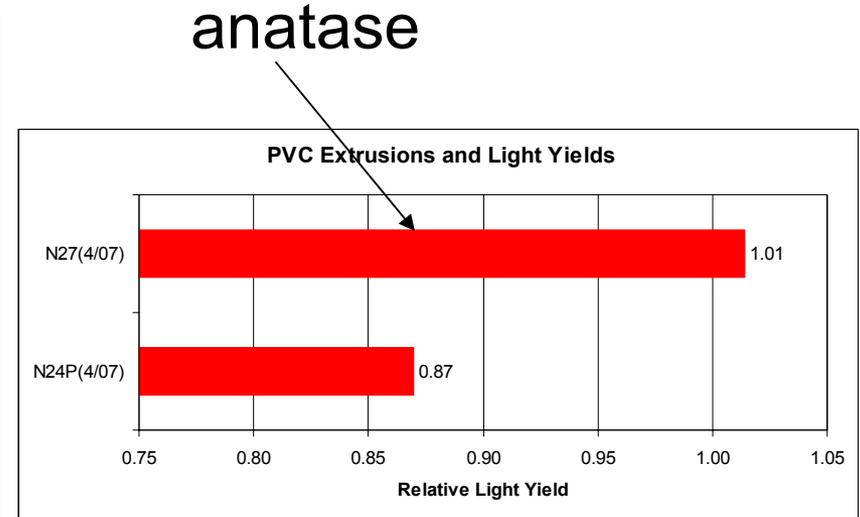
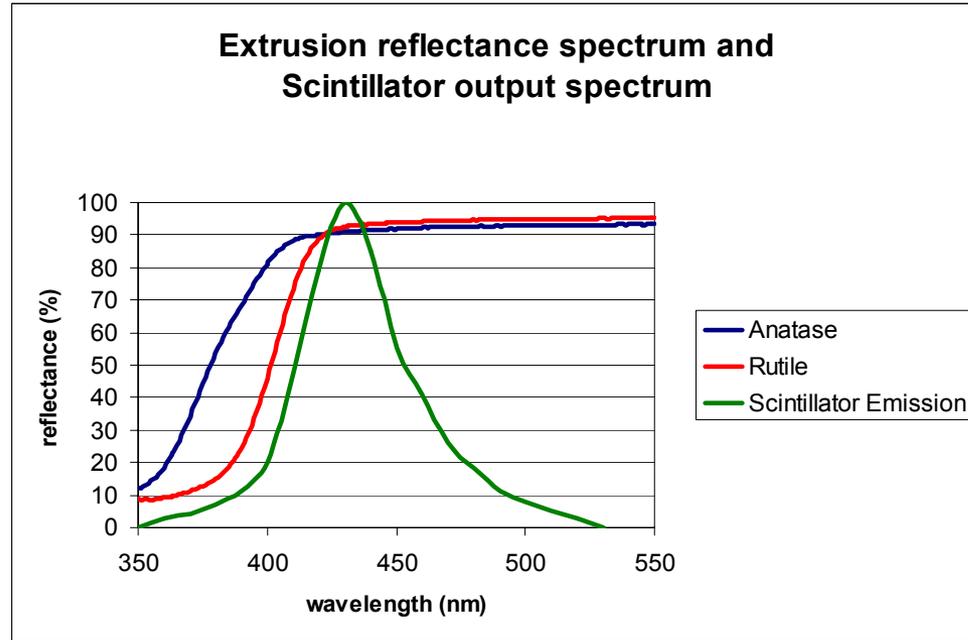


Specification: +1.4 mm -0.6 mm





# TDR 12.4: Reflectivity and Light Yield



## Light Yield

Breakout Talks by Anna Pla-Dalmau and Chuck Bower

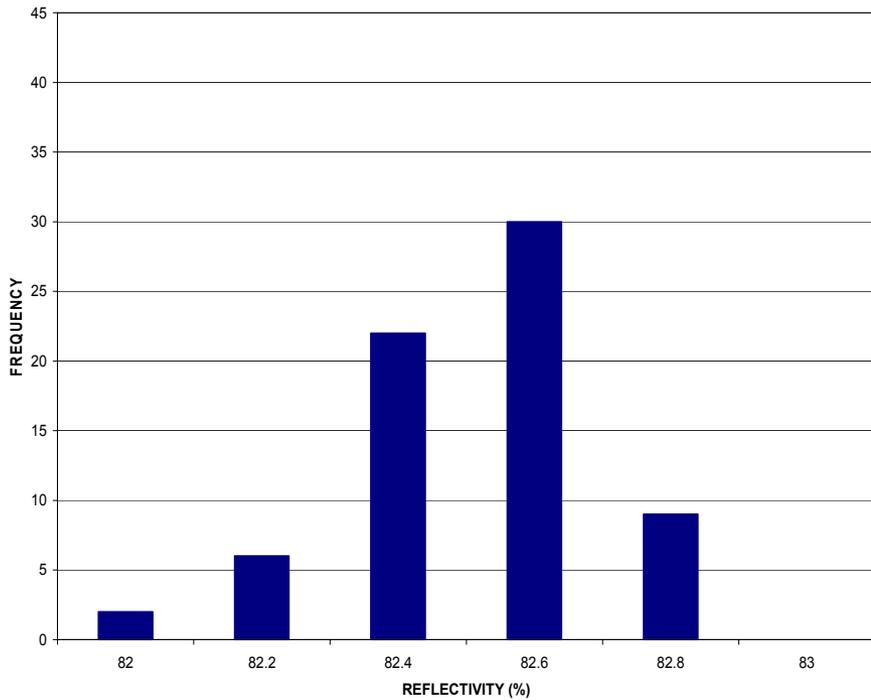


# Reflectivity Variation over 210 Feet of N-27

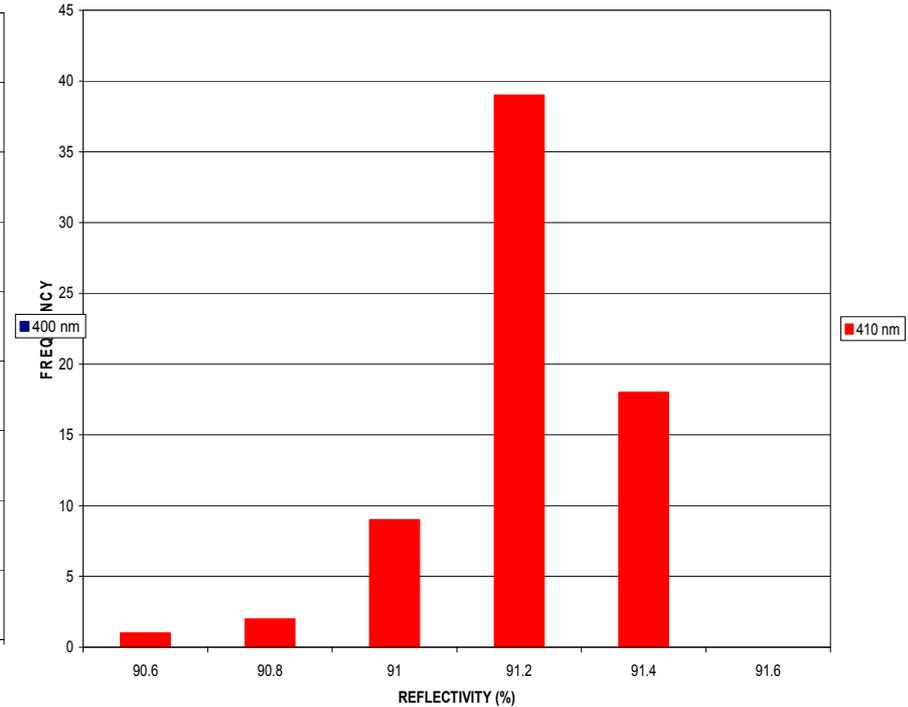


400 nm

410 nm



82.2%      82.6%      83.0%



90.8%      91.2%      91.6%



# TDR 12.5: Mechanical Strength and Creep

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- Comprehensive review is presented in Chapter 12 of the TDR
- In a Nutshell
  - PVC creeps; knowing the creep properties of N-27 PVC is of fundamental importance
  - Mechanical stiffness of PVC at 20 years must be understood
    - This can be predicted from “accelerated creep tests”
      - We are using several accelerated tests
    - Accelerated tests must be verified to agree with non-accelerated creep
      - We have been measuring creep in samples at room temperature for periods of several months
  - We have provided results as input to FEA calculations for the stability of the NOVA Structure (See talk by Dave Ayres)
  - Presentation on Mechanical Strength and Creep in the Breakout
    - Jim Grudzinski



# TDR 12.6: Shipping and Handling

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- One truckload = 60 extrusions, 51 ft long
  - Two stacks of 30 extrusions supported by 8 equally-spaced pallets
  - Banded and wrapped for protection
  - Moved with an air-caster system
- 540 Truckloads for the project
  - From PVC extruder to Fermilab Assembly Factory
- 280 PVC extrusions are used as bottom support, bridging the 8 pallets
  - 200 additional “bridges” will be made to store extrusions/modules
- Pallets and PVC “bridges” are recycled
- Presentation on Shipping and Handling in the Breakout
  - Karen Kephart



# Cost and Schedule Plan

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- Requirements Documents
  - PVC Extrusions: NOvA DocDB 595
  - PVC Material: NOvA DocDB 537
  - Shipping and Handling: NOvA DocDB 539
- Engineering Reviews
  - Extrusion Contract to be Awarded
  - Resin Contract to be Awarded
  - Pre-production Extrusion to be Authorized
- Milestones
  - Pre-production extrusions authorized
  - One per completion of extrusions for each super-block
  - Completion of ND extrusions



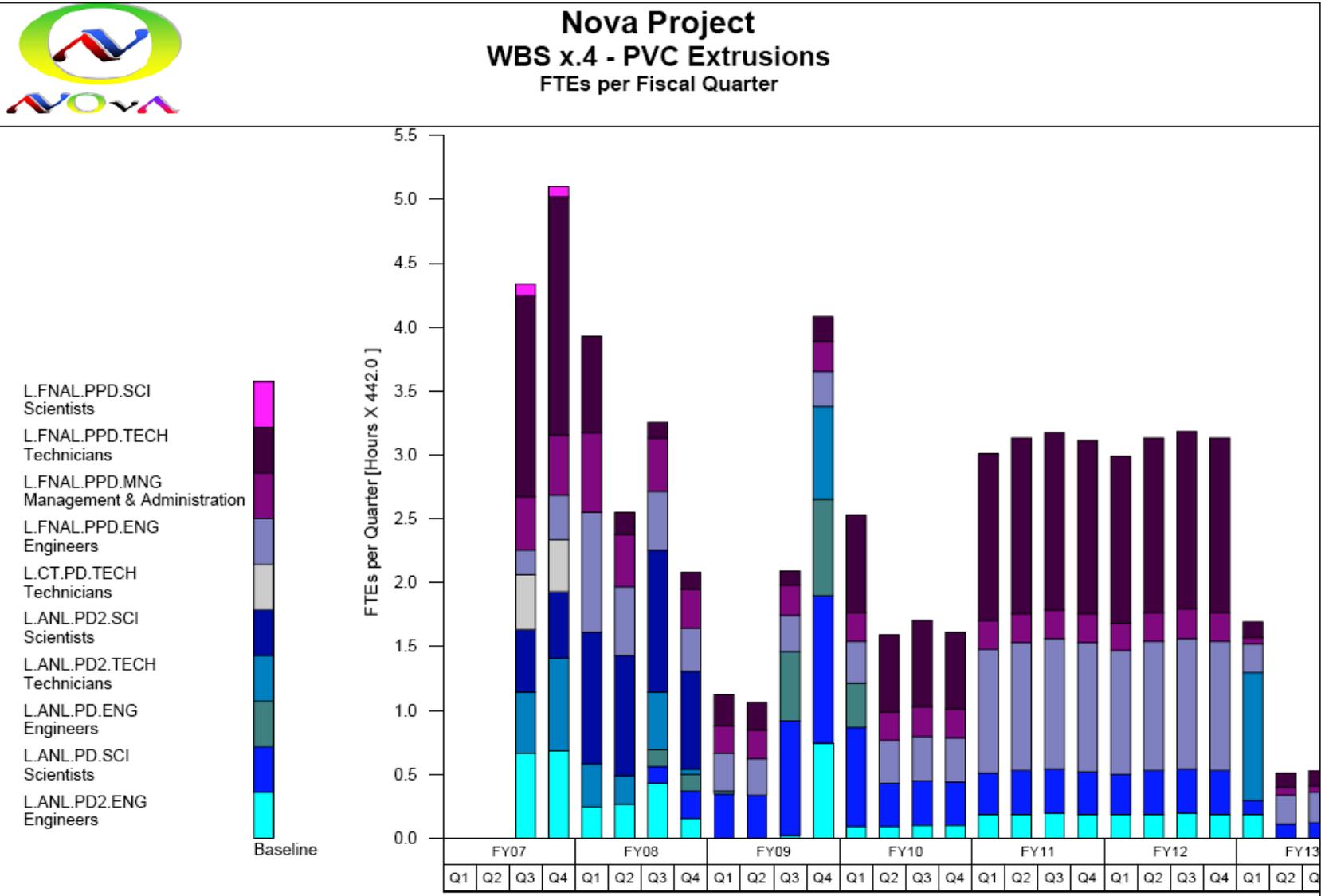
# Cost and Schedule Plan

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- 550 lines in C & S
  - 21 pages x ~25 lines/pg = 525 lines
  - Each FD block is one task
    - 38 Blocks → 38 tasks
- Production is done **periodically** in FY10
  - Production: ~ 1 week every 2 months
- Production is done **continuously** in FY11, 12 & 13\*
  - \* finish at end of 1<sup>st</sup> quarter FY 13



# “Manpower”





# Cost: WBS 2.4 PVC Extrusions

WBS x.4 PVC Extrusions	Estimated Cost (AY \$M)	Contingency Estimate (AY \$M)	Contingency (%)	Total Cost (AY \$M)
<b>Construction</b> w indirects				
<b>M&amp;S</b>	28.4	8.0	28%	36.4
<b>Labor<sup>1</sup></b>	1.7	0.6	35%	2.3
<b>Construction total:</b>	<b>30.1</b>	<b>8.6</b>	<b>28%</b>	<b>38.7</b>
<b>R&amp;D</b>				
<b>M&amp;S</b>	0.9	0.0	0%	0.9
<b>Labor<sup>1</sup></b>	0.4	0.0	0%	0.4
<b>R&amp;D total:</b>	<b>1.3</b>	<b>0.0</b>	<b>0%</b>	<b>1.3</b>

<sup>1</sup> Labor costs presented here include all project labor from Fermilab, other DOE facilities, and Universities.

- **Cost Drivers (unburdened)**
  - ~ \$11.9M for N-27 PVC resin
  - ~ \$10.9M for extruding process and hardware
  - ~ \$0.7M for shipping and handling



# Schedule: WBS 2.4

		 <b>Nova Project</b> WBS x.4- Nova_Milestones_PVC_Extrusions Milestone Gantt Chart																																
Activity ID	Milestone Description	Date	FY06				FY07				FY08				FY09				FY10				FY11				FY12				FY13			
			Q1	Q2	Q3	Q4																												
<b>2.4 -- PVC Extrusions</b>																																		
2.4.1.1.5	Release purchase orders - extrusion contract	01Oct08																																
2.4.1.2.5	Release purchase orders - raw material contract(s)	01Oct08																																
2.4.2.1.4	First horizontal extrusions available for evaluation	11May09																																
2.4.2.2.4	First vertical extrusions available for evaluation	09Jun09																																
2.4.2.1.13	Pre-production horizontal extrusions authorized	10Sep09																																
2.4.2.2.13	Pre-production vertical extrusions authorized	08Oct09																																
2.4.3.2.1.1.1	Production of horizontal extrusions authorized	08Oct09																																
2.4.3.2.1.2.1	Production of vertical extrusions authorized	08Oct09																																
2.4.3.2.4.1	Far detector extrusion production started	08Oct09																																
2.4.3.1.1.5	Near detector horizontal extrusions completed	11Nov09																																
2.4.3.1.2.5	Near detector vertical extrusions completed	11Dec09																																
2.4.3.2.4.2	Extrusions for superblock 1 produced	24Jan11																																
2.4.3.2.4.3	Extrusions for superblock 2 produced	04May11																																
2.4.3.2.4.4	Extrusions for superblock 3 produced	16Aug11																																
2.4.3.2.4.5	Extrusions for superblock 4 produced	29Nov11																																
2.4.3.2.4.6	Extrusions for superblock 5 produced	15Mar12																																
2.4.3.2.4.7	Extrusions for superblock 6 produced	26Jun12																																
2.4.3.2.4.8	Extrusions for superblock 7 produced	08Oct12																																
2.4.3.2.4.9	Extrusions for (partial) superblock 8 produced	11Dec12																																
2.4.3.2.4.10	Far Detector extrusion production completed	11Dec12																																



# Summary

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- Technical
  - PVC extrusions will meet NOvA mechanical and optical specs
  - Production is consistent with industry norms
- Cost: ~\$23.5M unburdened M&S
- Schedule
  - 1<sup>st</sup> year: tool fabrication, setup and pre-production FY 2009
  - 2<sup>nd</sup> year: slow startup (4.5 Far Detector blocks) FY 2010
  - 3<sup>rd</sup> & 4<sup>th</sup> years: full speed production FY 2011-12\*
    - remaining 33.5 FD blocks
- No CD-3a items in this WBS

\*completed 1<sup>st</sup> quarter FY 2013