# BNL Stave Development

1. Stave-Barrel Interface
2. Mechanical Support Options/Studies
3. Stave Measuring Station
4. Stave Construction/Cooling
5. New Data Acquisition
6. Power Distribution
7. Sensors for Stave Prototypes

*D. Lynn for BNL. Santa Cruz Meeting, May 3, 2007*

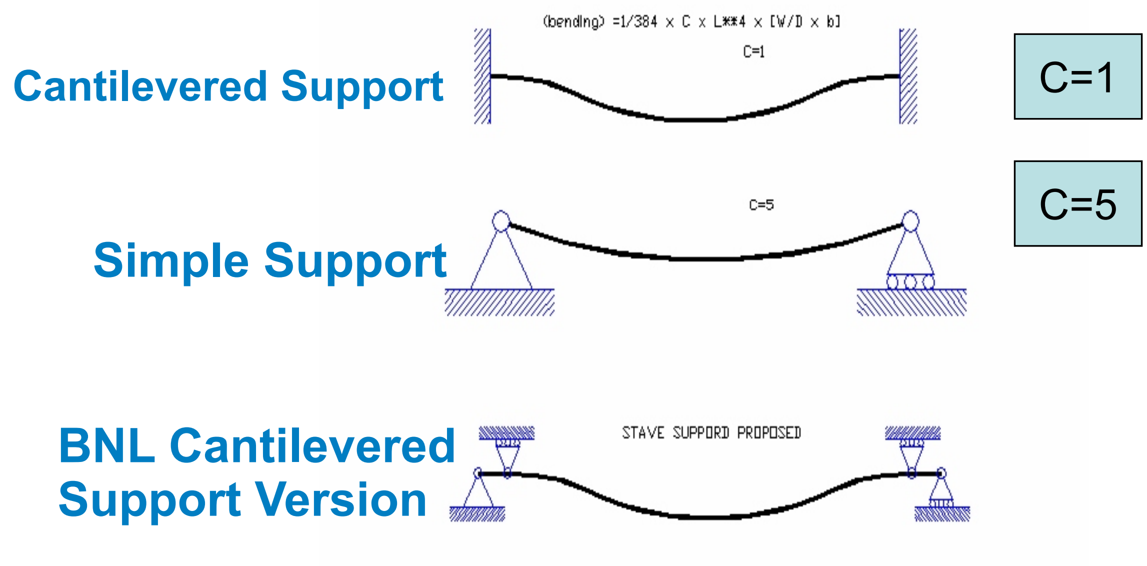
# Stave Barrel Interface

## *Why important?*

- Method of attachment depends upon stave and barrel design.
- Barrel design influences stave design and vice-versa
- All depend upon maximum permissible stave sag. Unfortunately, this number won't be known anytime soon (question of software alignment procedure or philosophy).
- Until now...we (LBNL, BNL) have been assuming stringent limit on sag less than ~60 um... requires stiff stave with cantilevered support

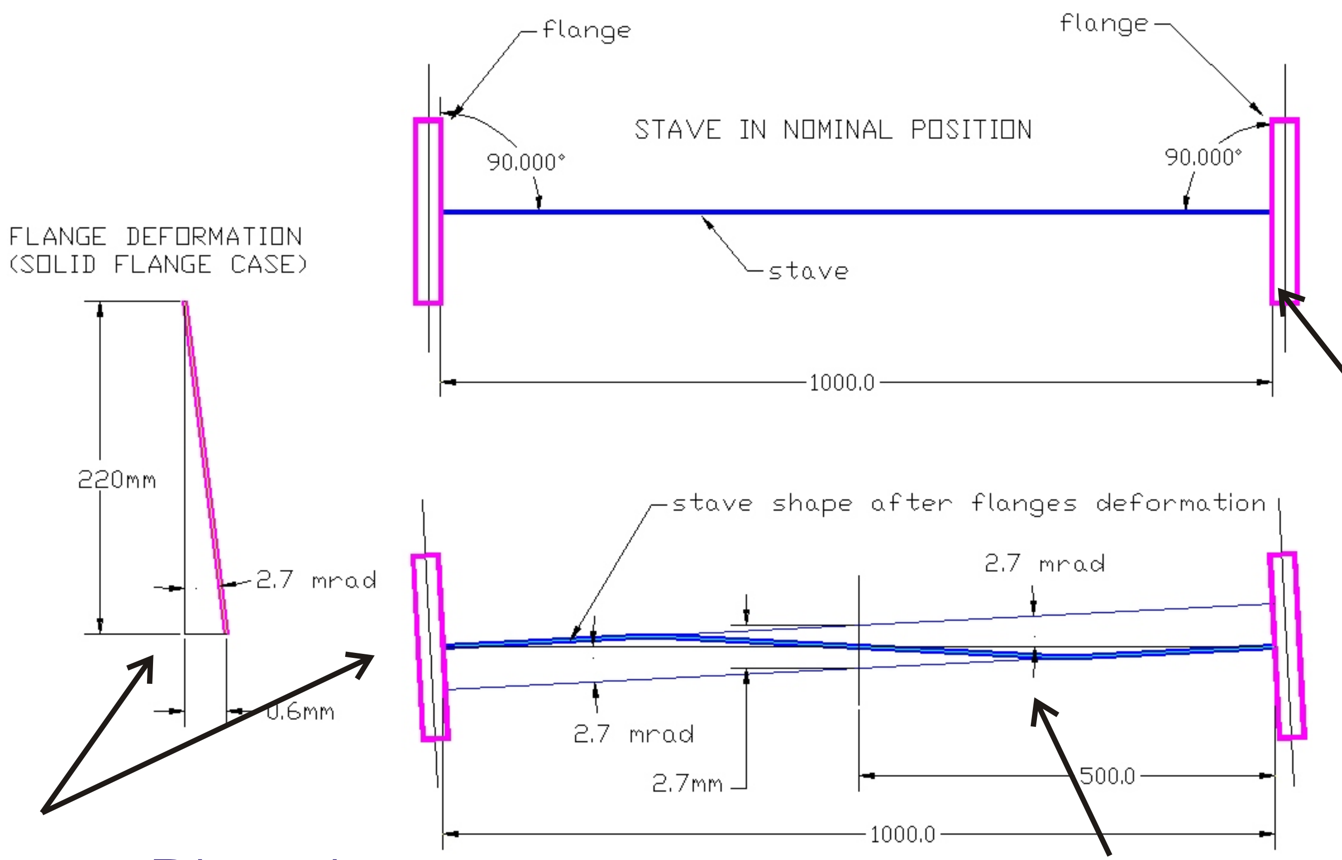
STAVE ATTACHMENT SCEMATIC

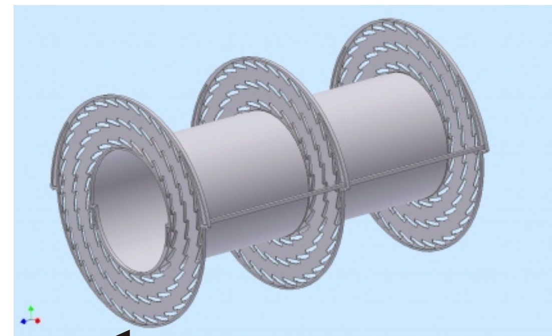
**BENDING=1/384 x C x L**4 * [ W/D x b }**



# Stave Barrel Interface

**Illustration of distortions in z direction coupling to stave distortion mounted with "cantilever" support**



Flange

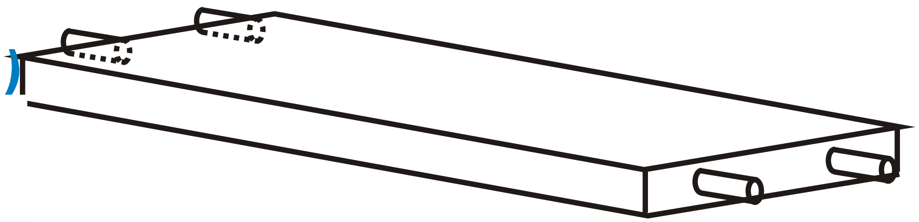
Flange Distortions to to forces in Z direction

Will lead to distortions in stave

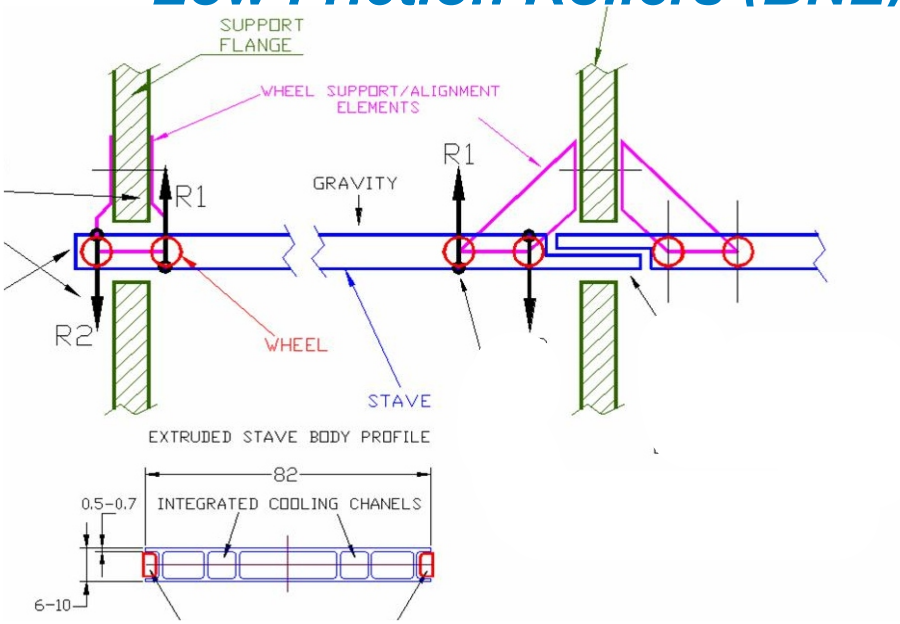
# Stave Barrel Interface FY06-07 Designs

- **Cantilever support at each end  to keep stave sag <60 um (if supported 1 m apart in space frame approaches)**
- **Fix z position at outer ( 2 meter) end, let slide in Z at inner end (permits thermal expansion)**
- **<u>Some Options</u>**

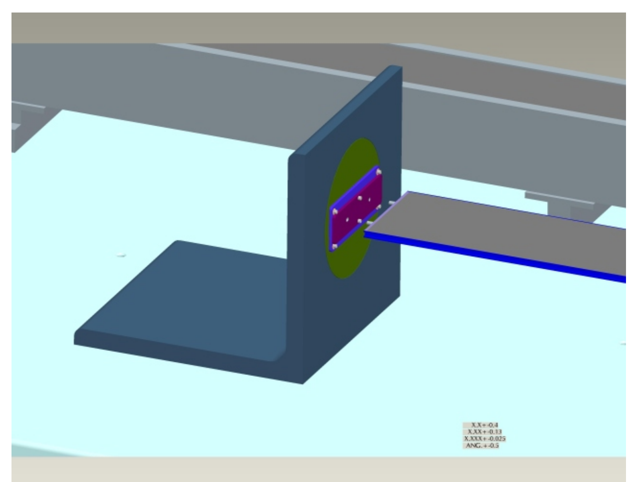
***Pin Option (LBNL)***



***Low Friction Rollers (BNL)***




***Test Interface Bracket Design***



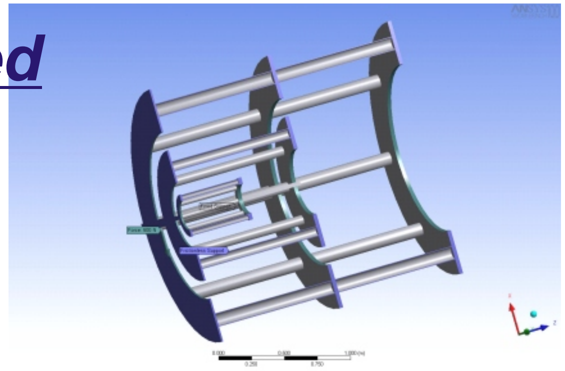
- **Currently building system to test mounting mechanisms at BNL and LBNL and to measure sag**

# Stave-Barrel Interface Plans FY08

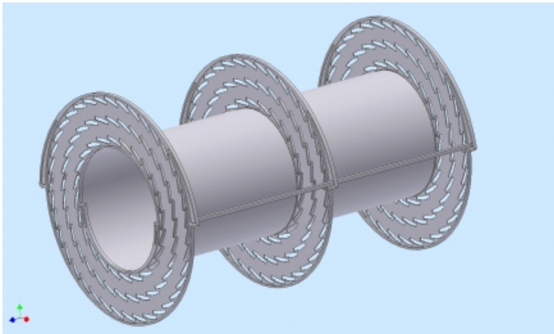
- Design several options
- Options will depend upon choice for barrel support baseline as seen in next slides
- Build prototypes and test

# Barrel Support Options

***Three Options Being Studied and Simulated***

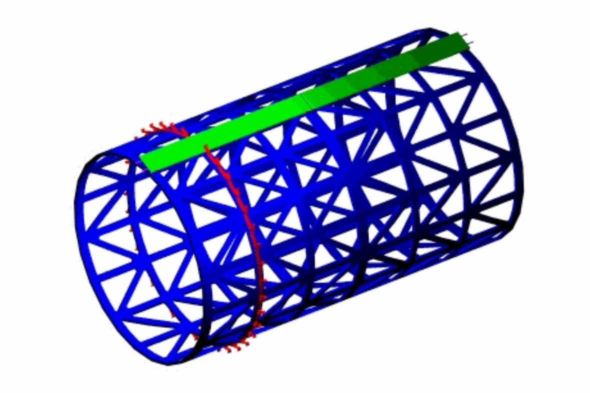


**1. "Open" Space Frame with Flanges (FY06)**



**2. "Closed" Space Frame with Flanges (FY07)**

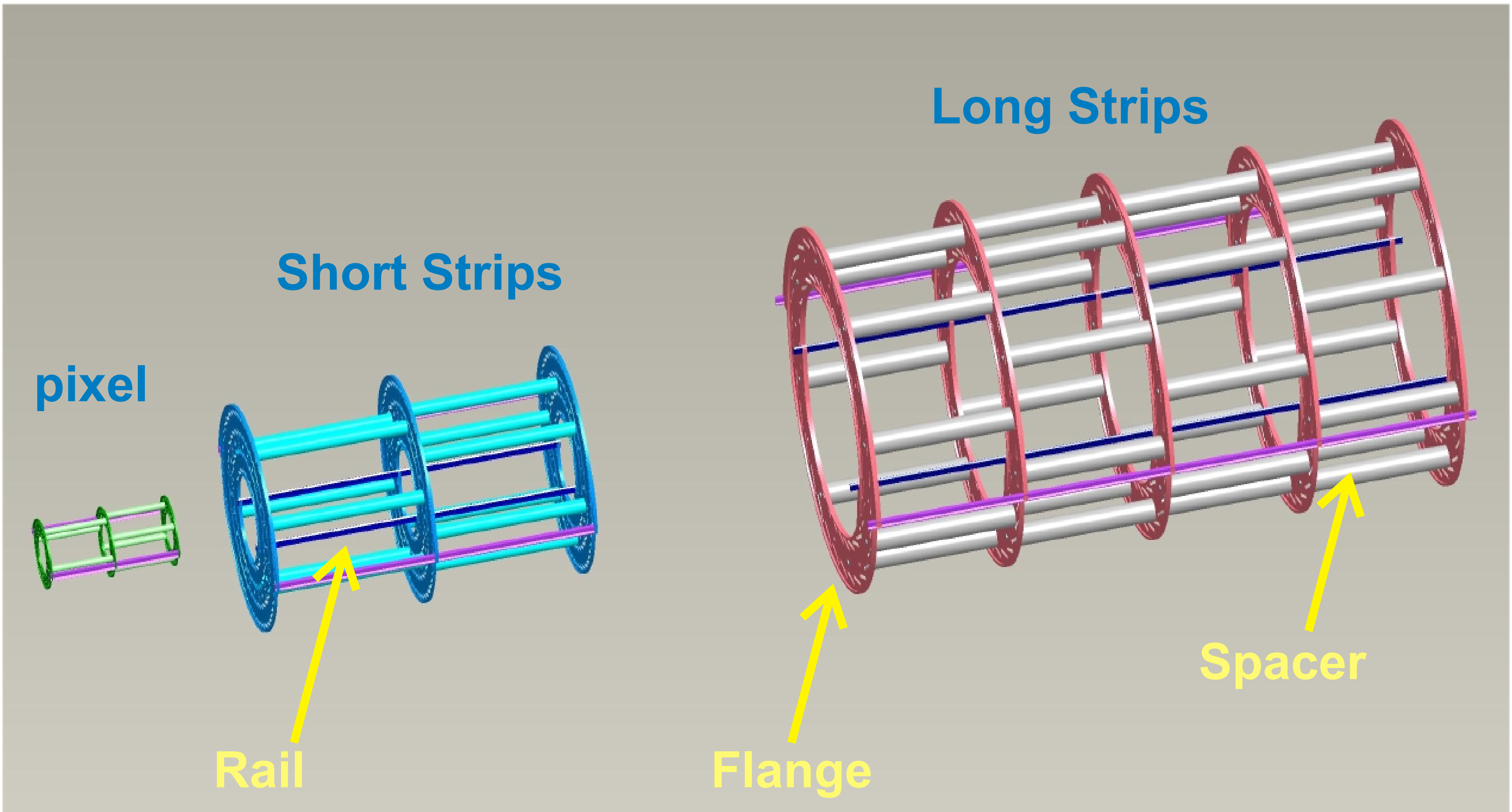
**3. Cylindrical Frames (Fy07)**



# “Open” Space Frame FY06

– Short strip and Long strip flanges spaced 1 meter apart

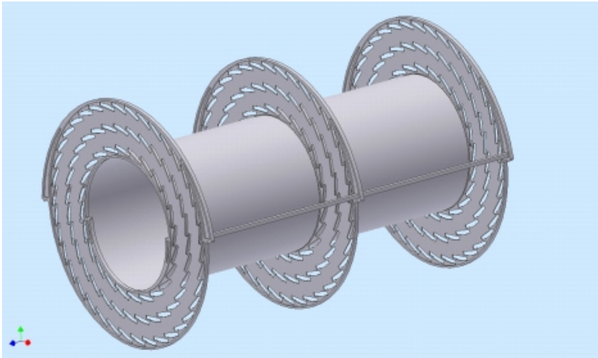
– Each sub-frame allows independent assembly of LS/SS/Pixel Barrels

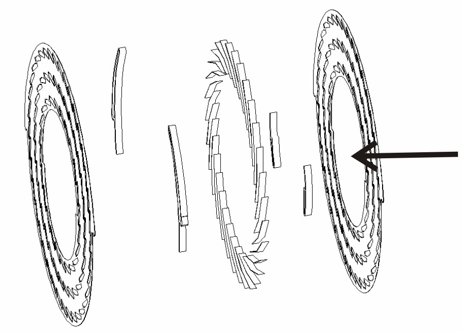


# “Closed” Space Frame FY07

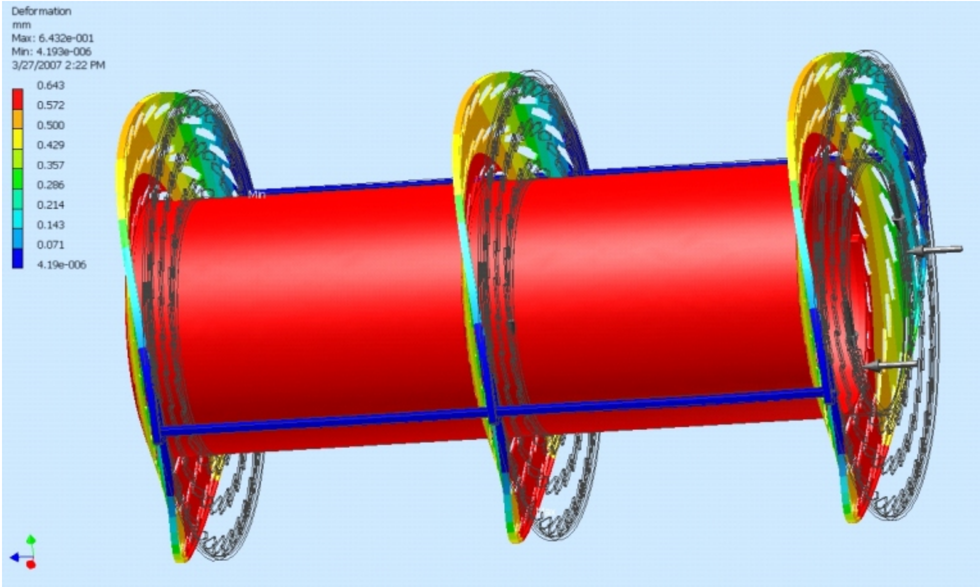
- Spacers of Open frame replaced with cylinder
- Cylinder provides high torsional stiffness

- Each sub-frame allows independent assembly of LS/SS/Pixel Barrels





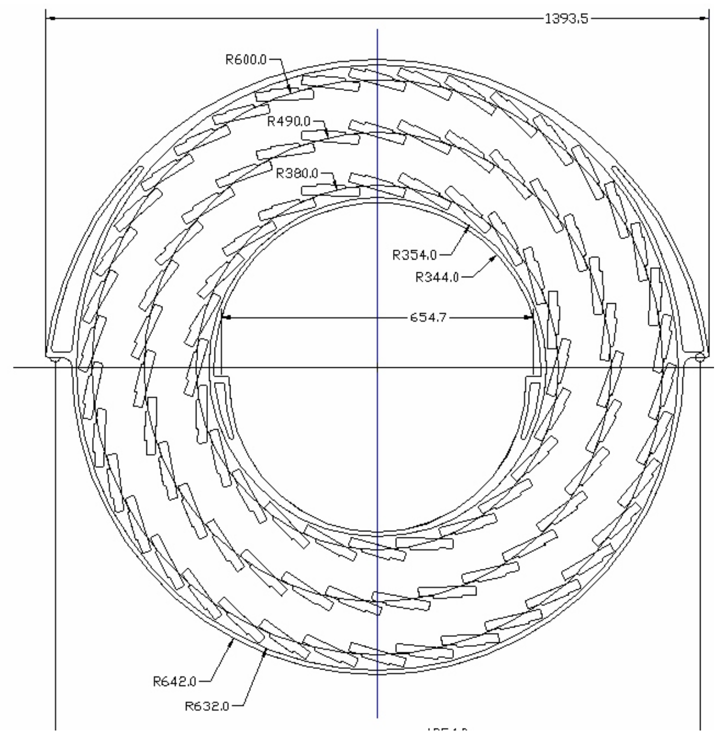
**Composite Flange to increase stiffnes in Z direction**



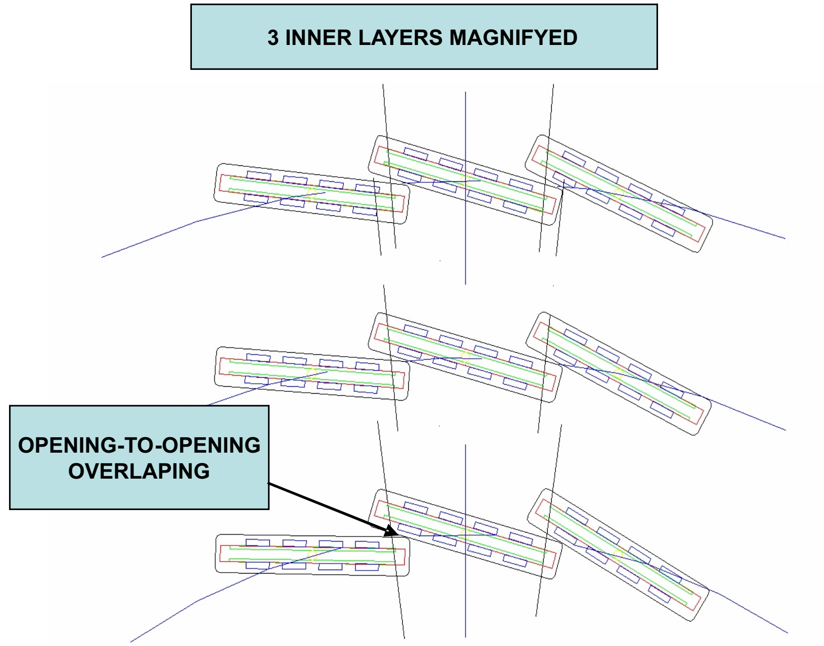

**Simulation of flange distortion due to 40kg of force applied to cylinder in Z direction**

# Flange - Detector Width Issue

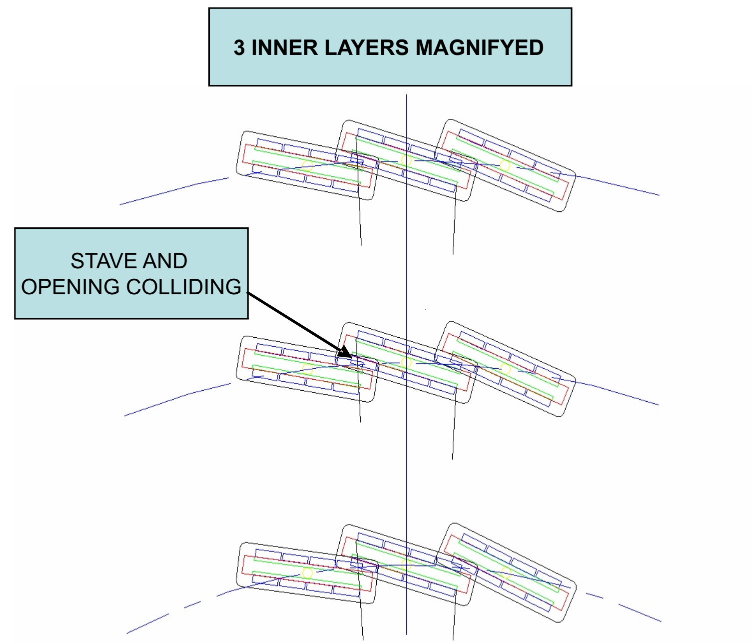
- Wider Staves/detectors easier to accomodate
- Dependent upon clearance cut-outs
- Loss of stiffness in Z direction




## ~10 cm wide staves

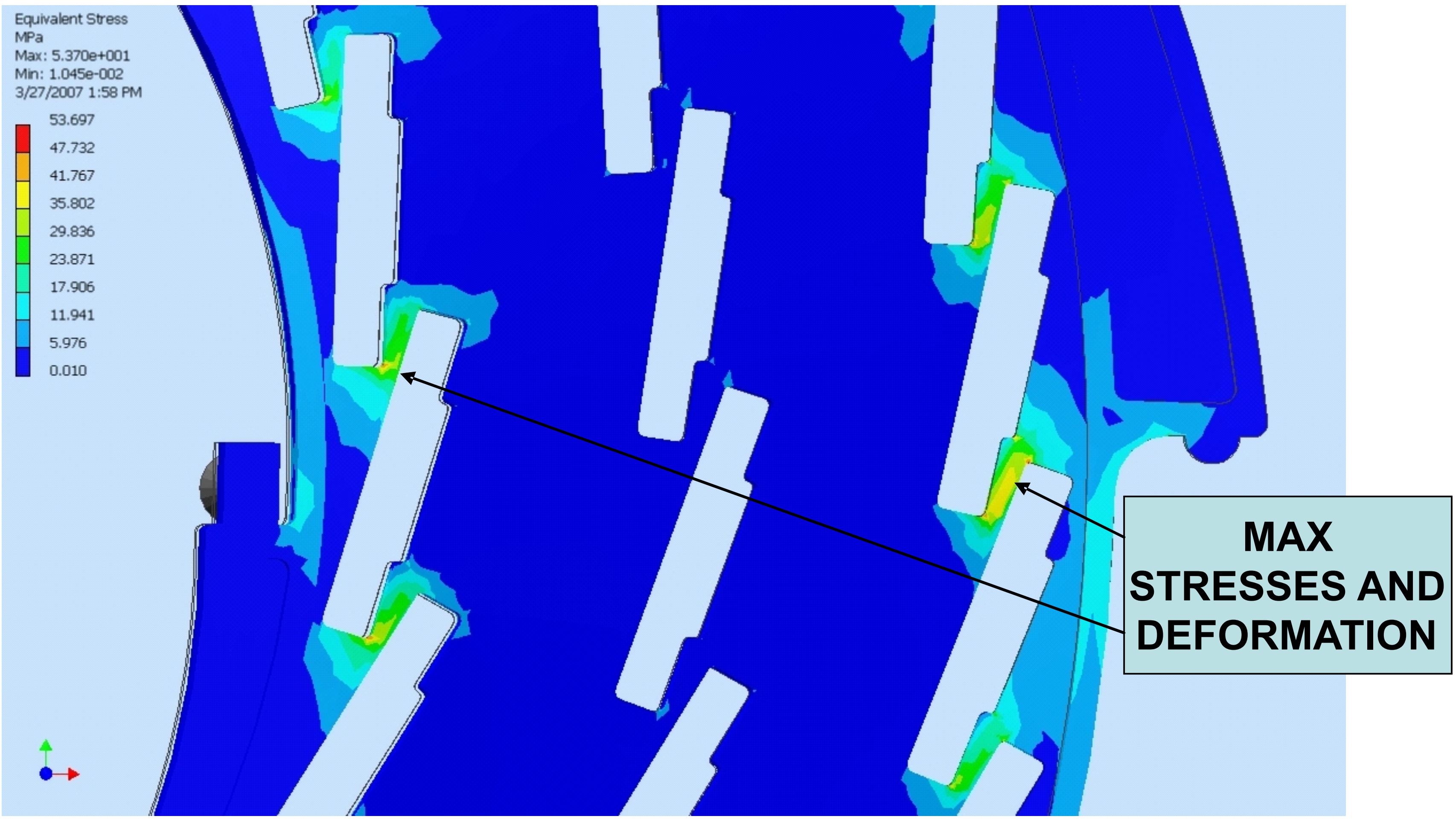



## ~6 cm wide staves



# Z Forces Simulation FY07

**FROM "Z" FORCES**
**MAX STRESES AND DEFORMATION LOCATED AT PLACES BETWEEN OPENING FOR STAVES**



# Weakness of Open or Closed Space Frame Approach in Z leads to consideration of Cylinders For Each Layer (very recent FY07)

**ALUMINUM CYLINDER WITH OPENINGS**
**2000mm LONG, SUPPORTED AT 4 POINTS ON THE ENDS**
**DEFORMATION FROM 40 kg "Z" FORCES**

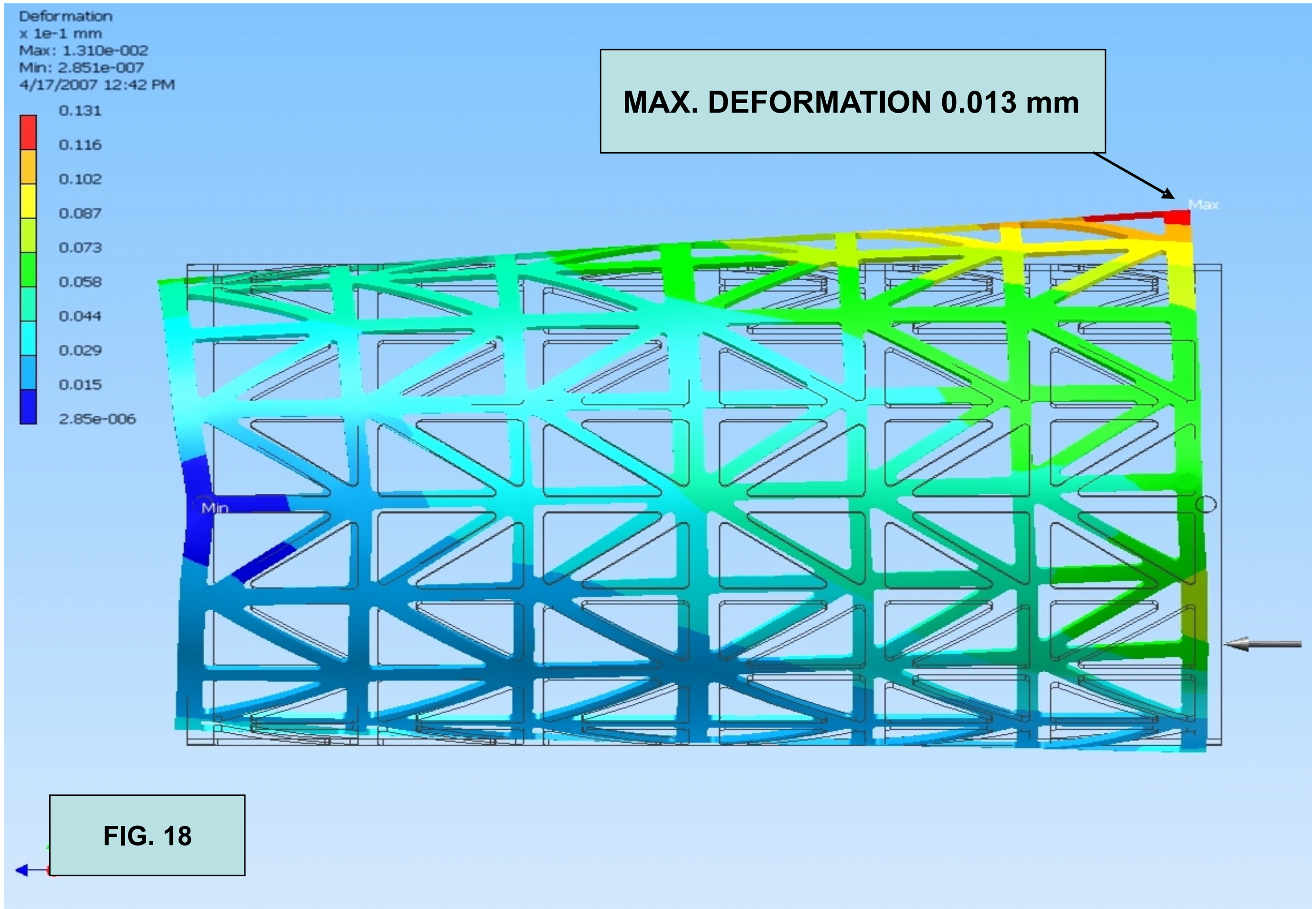
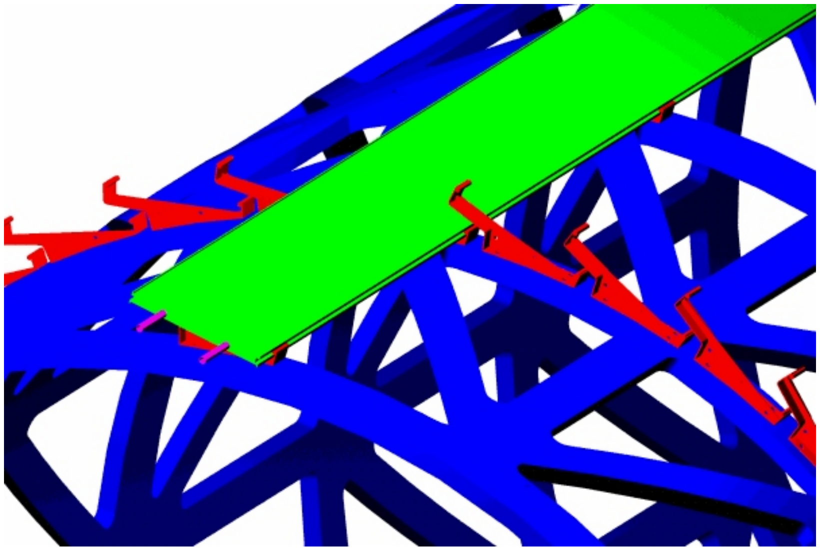


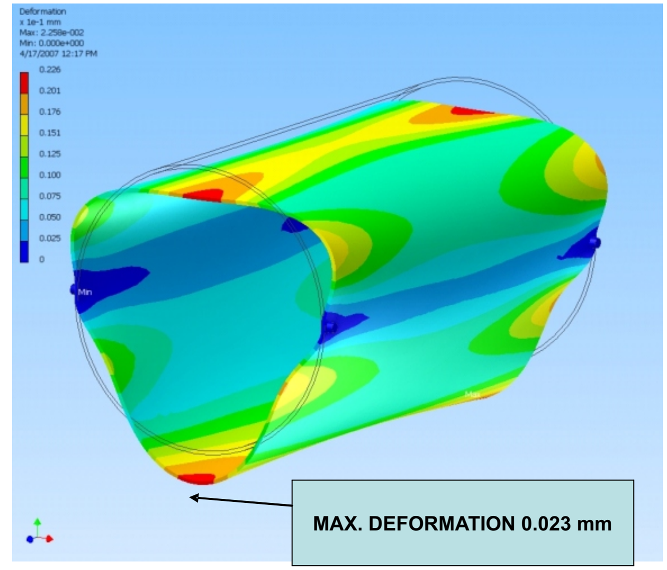

FIG. 18

# Cylinder Approach

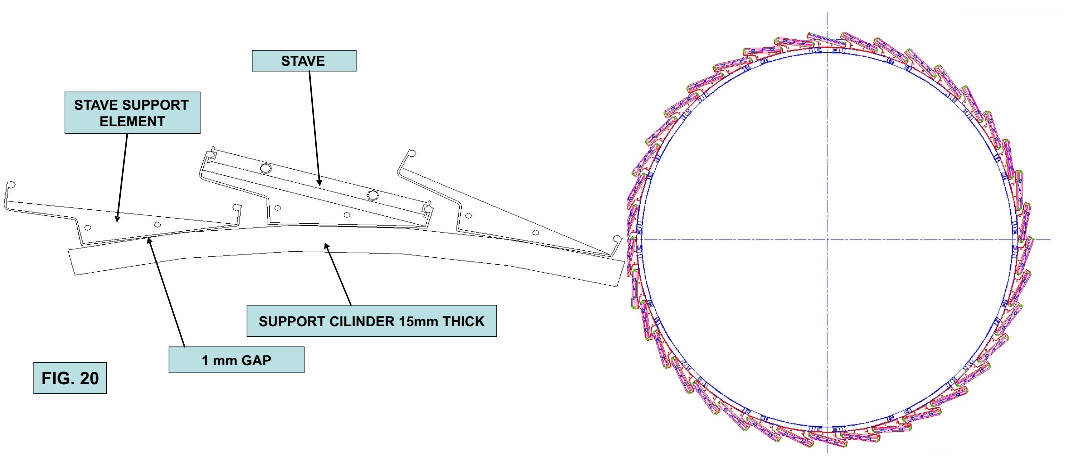
- One cylinder per barrel layer
- Staves permit cut-outs in cylinders

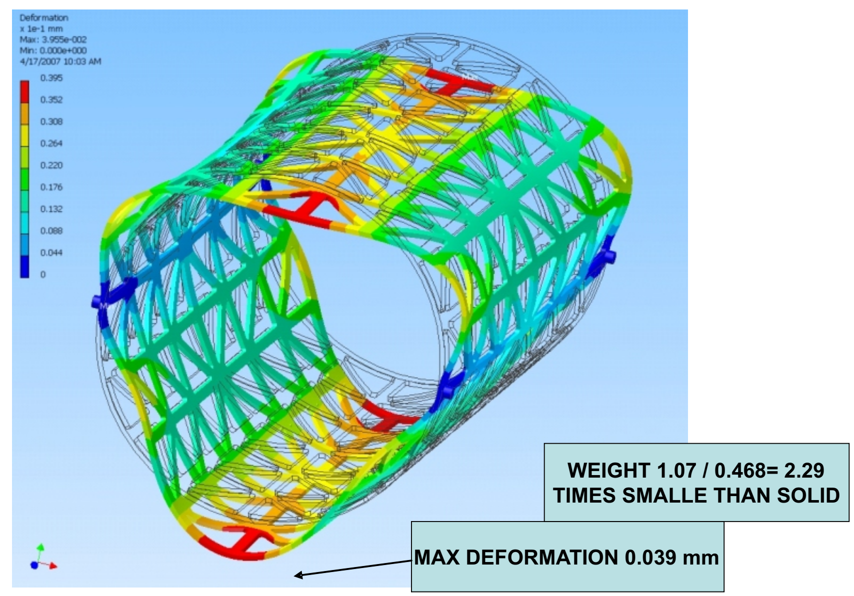


## Solid and Cut-out 2 meter long cylinder deformation simulation




STAVES SUPPORT ON THE TOP OF CILINDER DETAILS



# Comparison of Options

| | Vertical Stiffness | Torsional Stiffness | Stiff Stave Required? | Mass | Decoupling from unknowns* |
|---|---|---|---|---|---|
| Open | ✓ | | Yes | ? | |
| Closed | ✓ | ✓ | Yes | ? | |
| Cylinders | ✓ | ✓ | No | ? | ✓ |

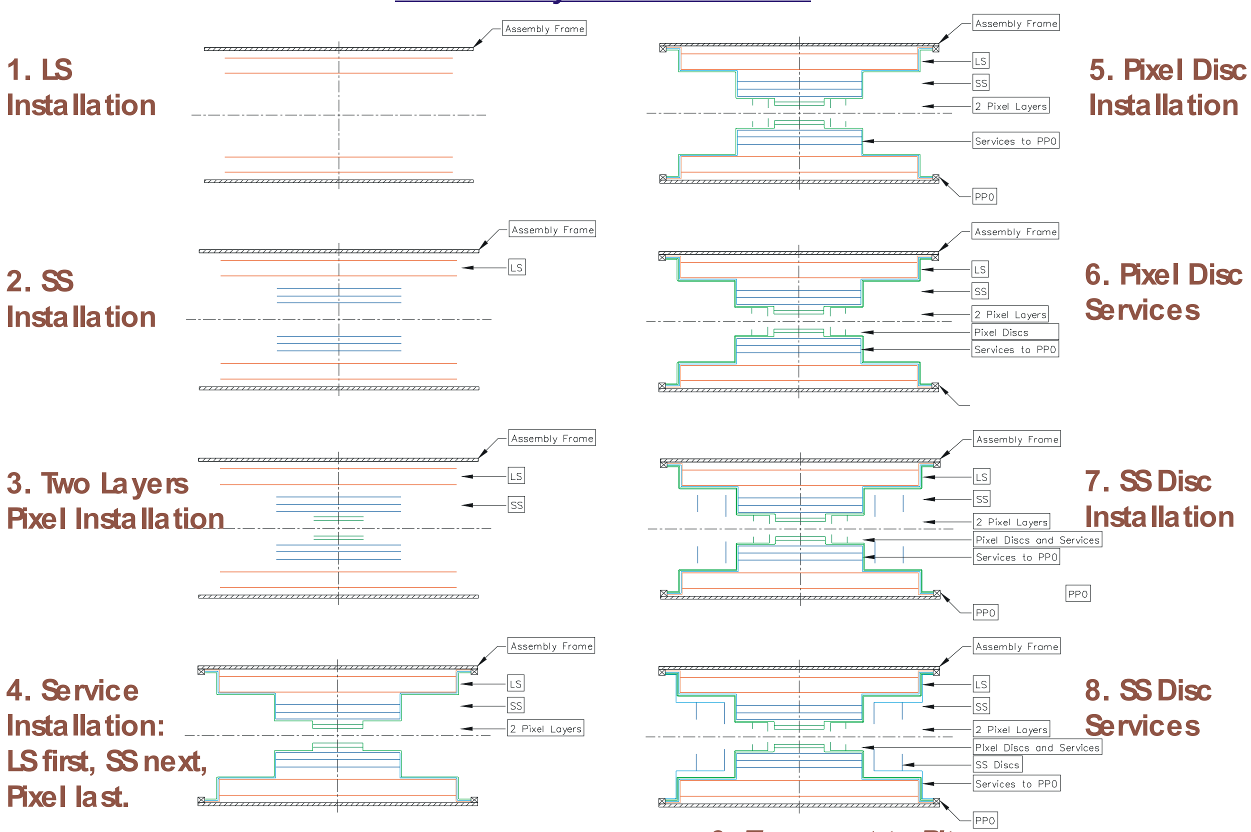
* Sag requirments, Magnitude of Z forces, Final Detector Width

# Assembly and Installation Studies

- Illustrates difficulties in service routing
- Patch panels will be required at ends of completed structure if assembly on surface

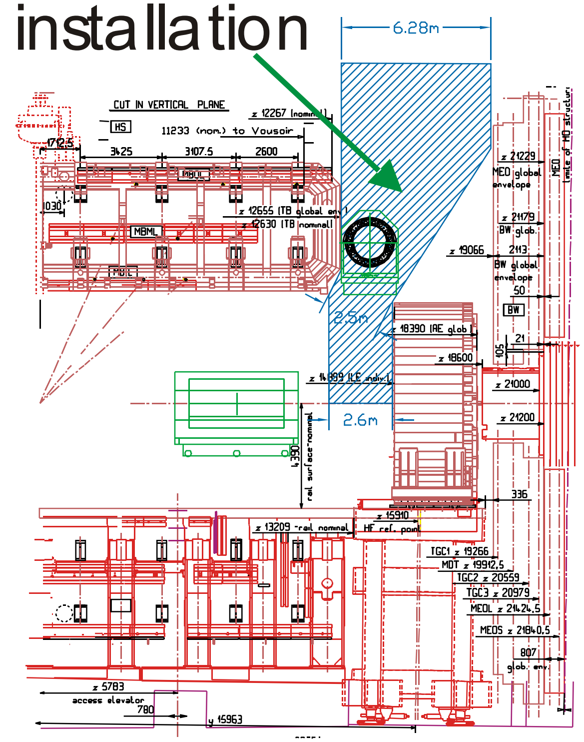
- Indicates need for guide rail system to allow ID to rotate to pass small clearance between Barrel Toroid and Extended Tile

*All Assembly done on Surface*




9. Transport to Pit

Clearance of ID during installation



# Mechanical Support Plans FY07-FY08

## FY07

1. Need to decide FY07 which option to choose. The cylinder approach, having been just recently studied, needs more careful consideration (including assembly issues)

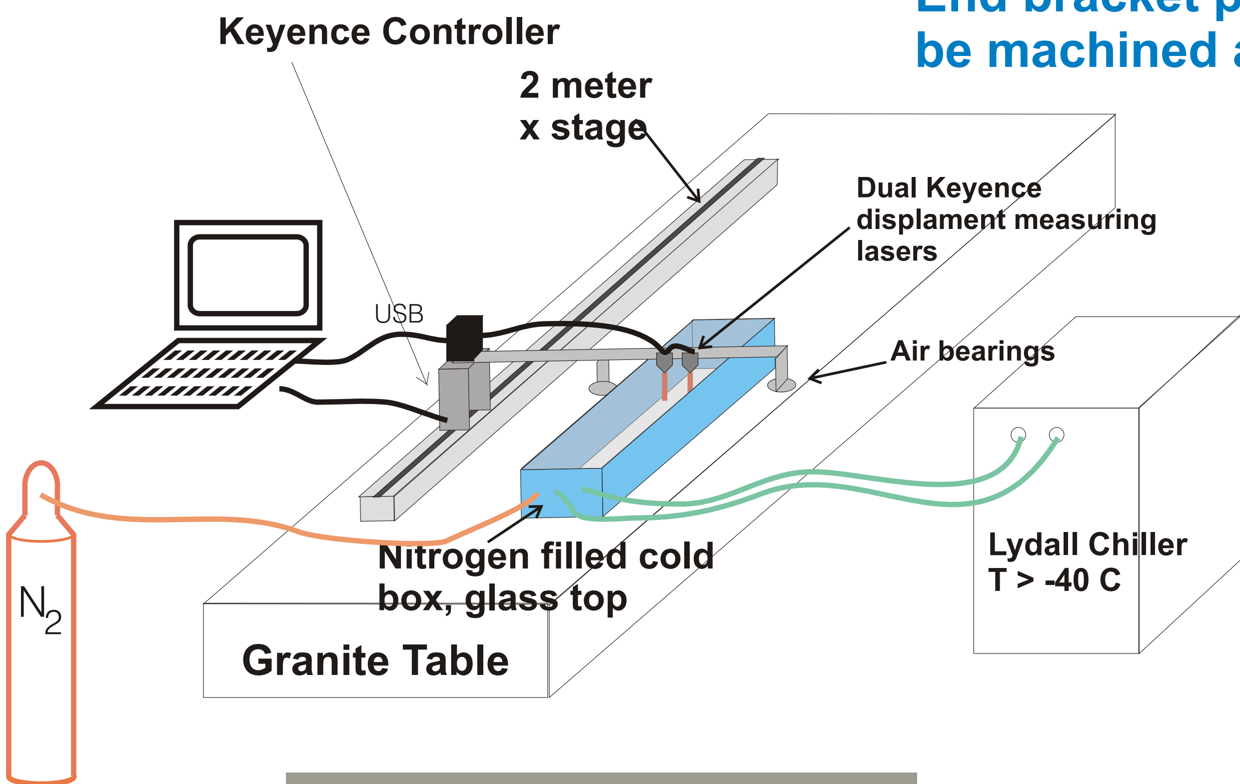
## FY08

1. Finalize Design of Baseline. Includes Barrel Design, Interface of Barrels to each other and to Cryostat, more detailed services and installation
2. Need to understand composite fabrication (have already discussed issues with AAR Corp., a composite manufacturer)
3. Plan to understand mechanical modeling of composites for input to simulation
4. Refine simulations based upon actual material properties
5. Make small section prototype of support structure

# BNL Stave Measuring System (FY07)

Mostly Complete

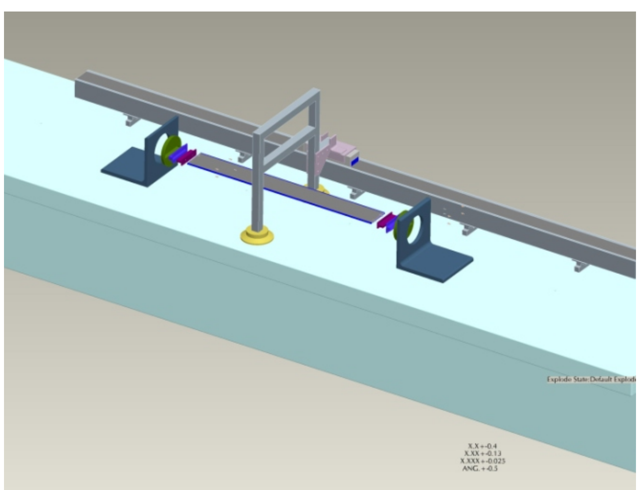
End bracket parts designed and will be machined at NYU




**Measure Stave Sag**

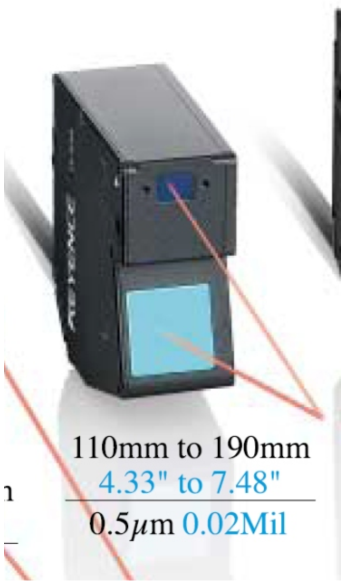
**Measure Thermal Distributions**

**Test Barrel Mounting Interfaces**

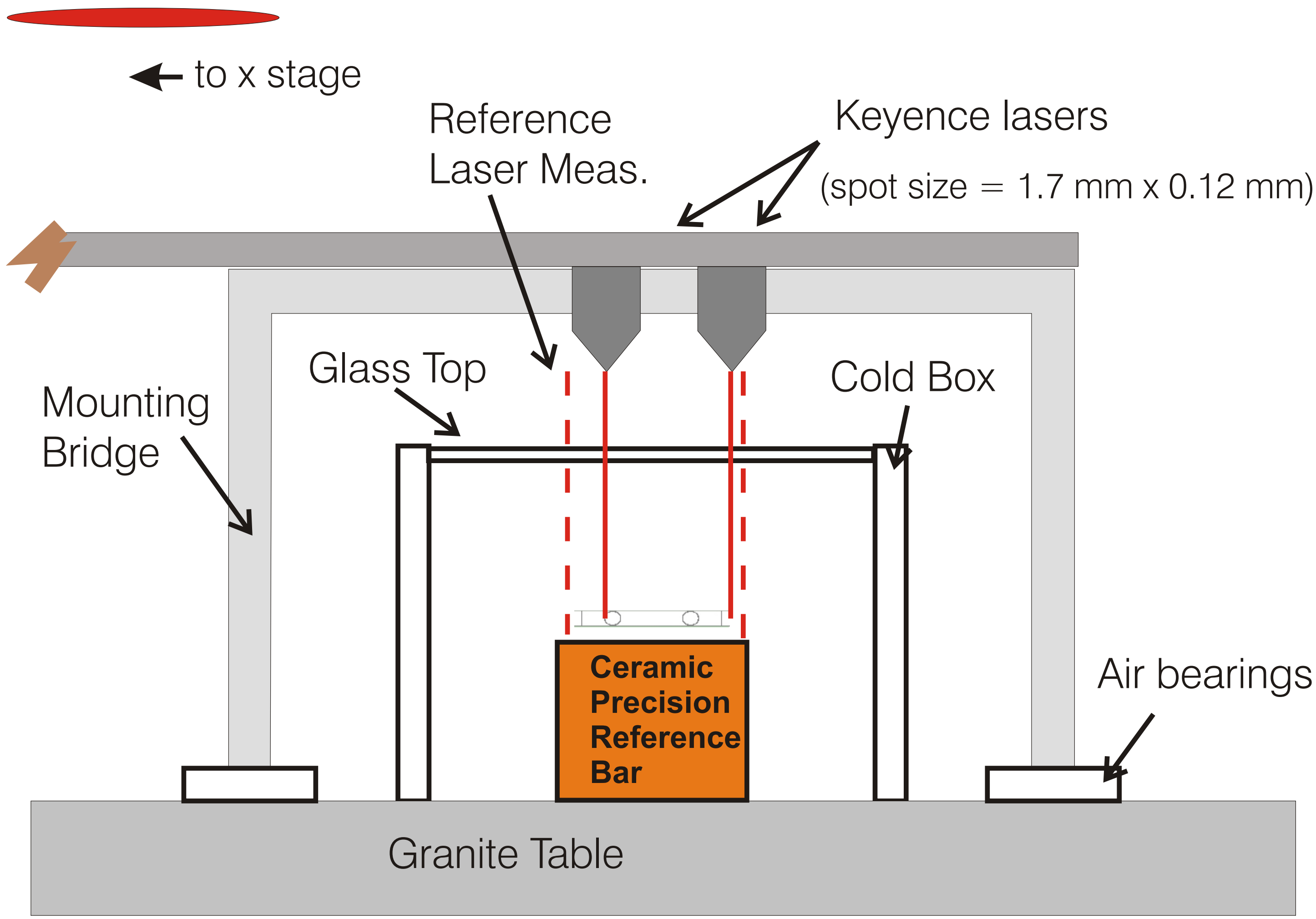


# BNL Stave Measuring System Conceptual Technique

**Keyence LK-G 157 Laser Displacment Sensor**

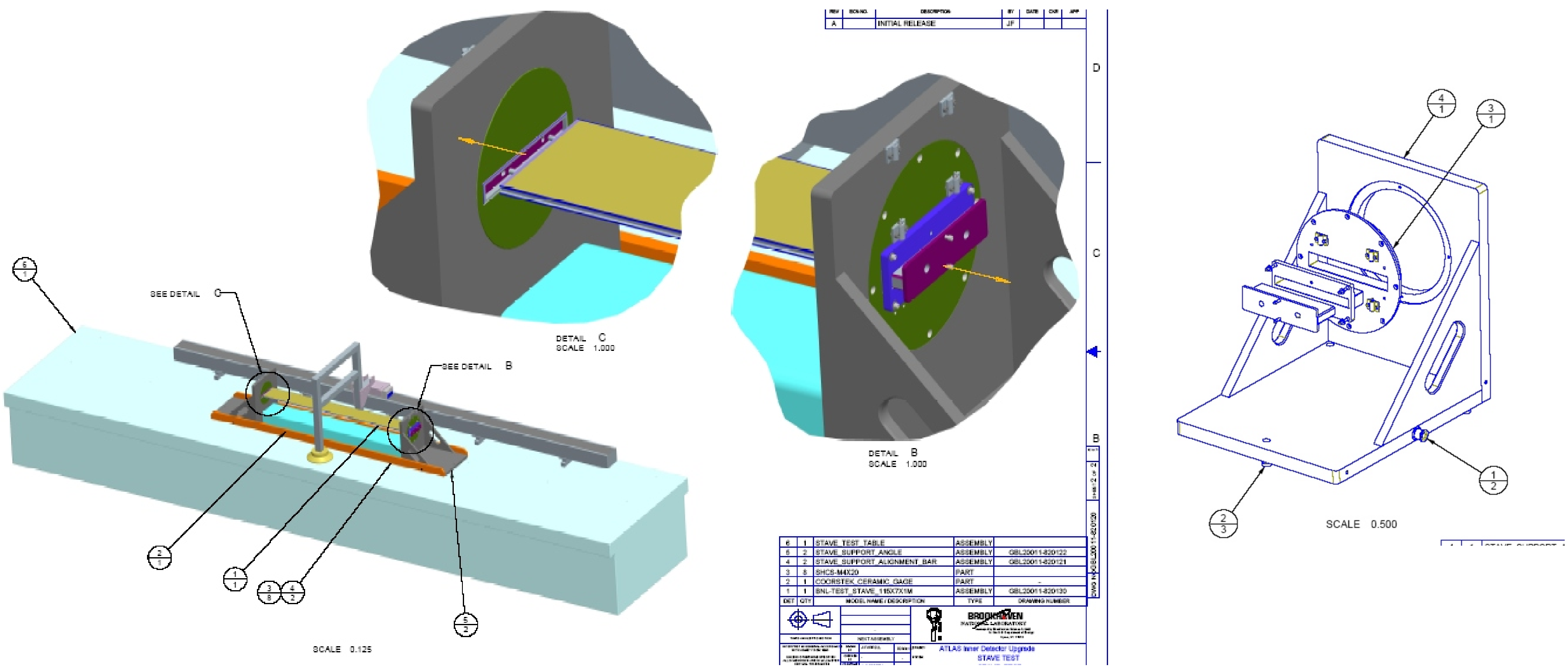



- **Large Measuring Range: 11 to 19 cm**
- **0.5 um accuracy**
- **Wide Laser Stop for averaging: 1.7 mm x 0.12 mm**



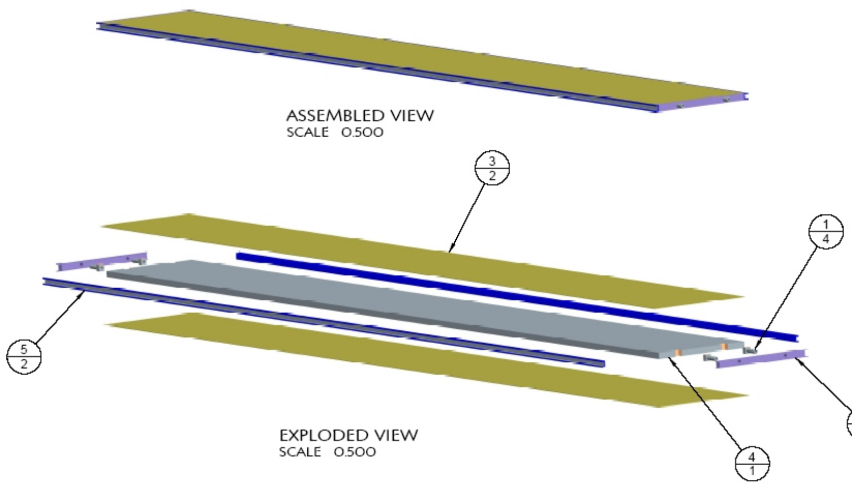
# Stave Measurent Station Plans FY07-FY08

- System close to completion
  - Upgrade computer, add multiplexer unit for thermal measurements, integrate Keyence into Labview via serial port (NYU) and write Labview control code (NYU), build cold box
  - Machine end bracket pieces for BNL and LBNL (NYU)
- FY08. Use system for characterizing stave protoypes from LBNL, and stave cores from BNL/LBNL



# Stave Construction Tests/Cooling

- Practice building stave core variants(flimsy stave?)
- Measure mechanical and thermal properties of variants




| DET | QTY | MODEL NAME / DESCRIPTION | TYPE | DRAWING NUMBER |
|---|---|---|---|---|
| 5 | 2 | STAVE-BNL-SIDE_RAIL_TST | PART | GBL20011-820131 |
| 4 | 1 | STAVE-BNL-HONEYCOMB_TST | PART | GBL20011-820135 |
| 3 | 2 | STAVE-BNL-FACESHEET_TST | PART | GBL20011-820134 |
| 2 | 2 | STAVE-BNL-END_TST | PART | GBL20011-820132 |
| 1 | 4 | STAVE-BNL-CLOSEOUT-PIN | PART | GBL20011-820133 |

BROOKHAVEN NATIONAL LABORATORY

Al -Honeycomb to mimic CF honeycomb in terms of density/shear modulus

## Hydrostatic Tests of Carbon Fiber Tubes

(one 6.8 mm diameter, 175 um +560 um Carbon Fiber wall survived to 260 Bar limit of pump)

# Plans FY07-FY08

- **FY07 – Build 1m FR4-nomex for FR4 Aluminum honeycomb stave cores in BNL Instrumenation Division using evacuated heat press with prepreg**

- **FY08 – Build 1m CF- Aluminum honeycomb for CF- CF honeycomb stave core**

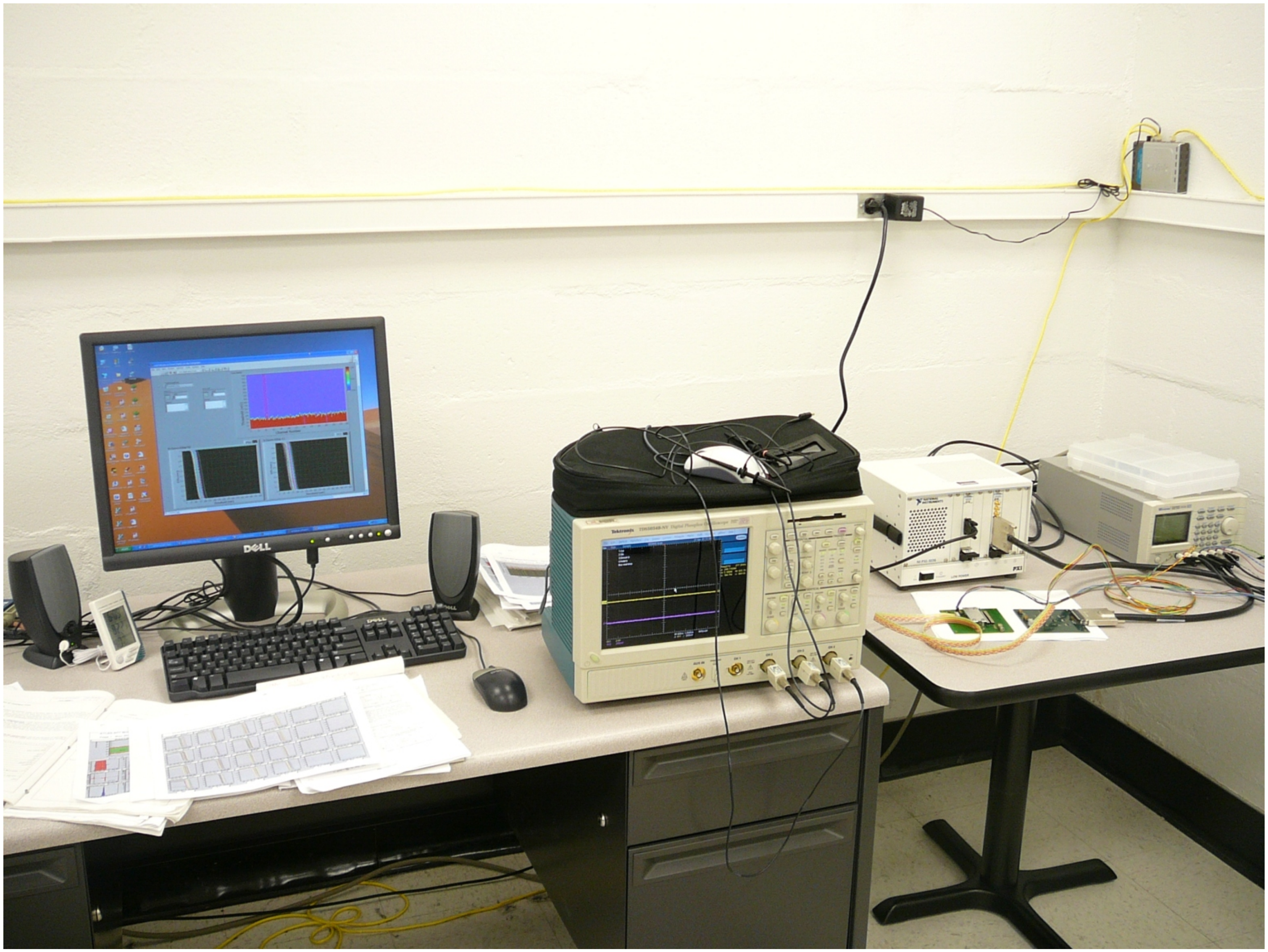
  - **Or move to building a flimsy stave**

  - **Measure and understand mechanical/thermal properties of staves**

  - **Cooling. Understand whether the are any advantages to Cu-NI (current SCT), Aluminum (current LBNL baseline), Titanium( recommendation of AAR Corp), or Carbon Fiber (BNL) tubes in terms of radiation length, fittings, thermal expansion matching. Investigate high pressure/low mass commercial fittings.**

# NewDaq Development FY06-07
### (in collaboration with LBNL and Yale)

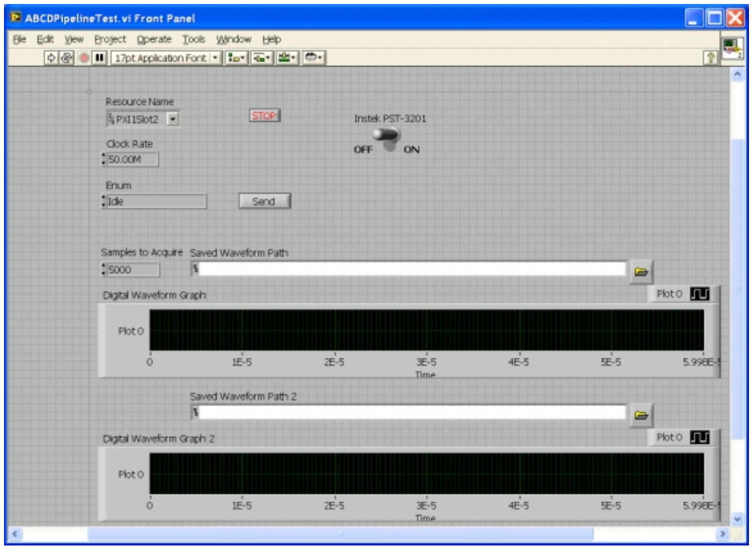
**BNL NewDaq Development Test Station**



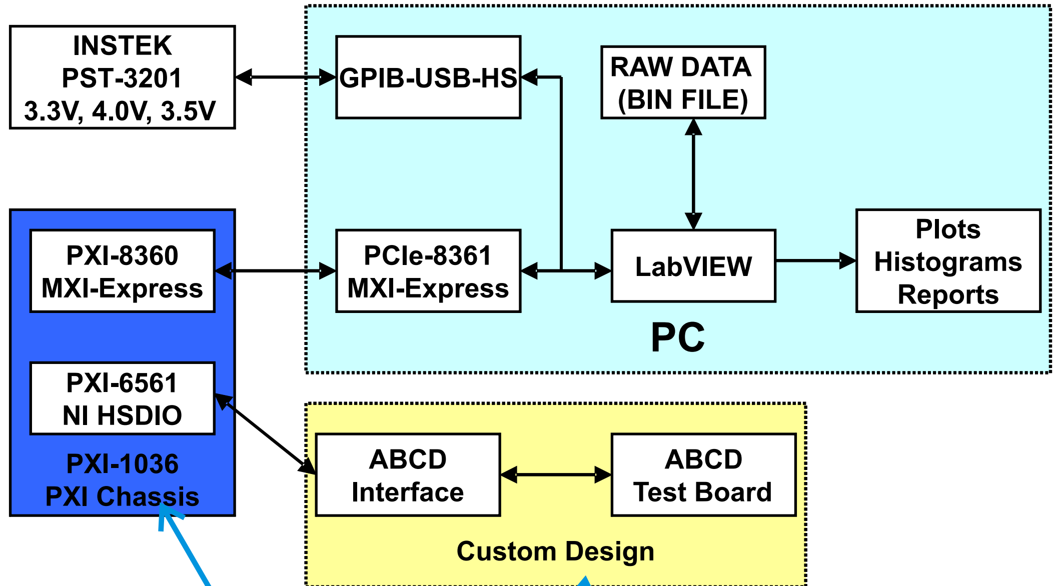
# NewDaq Development FY06-07

(National Instruments PXI-6561 Waveform Generator Based System)

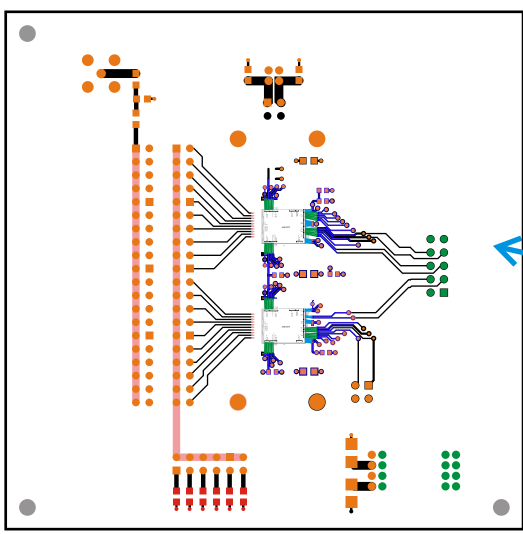
## PipeLine Test VI

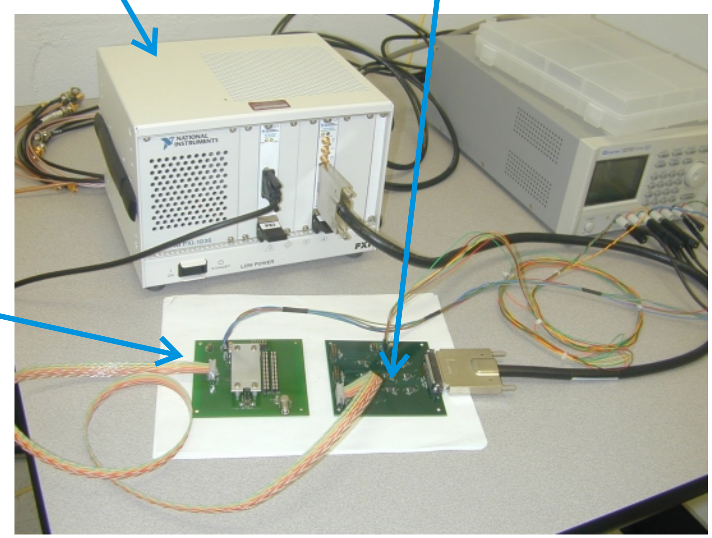



## Schematic of BNL Development Stand




## 2 ABCD Chip TestCard



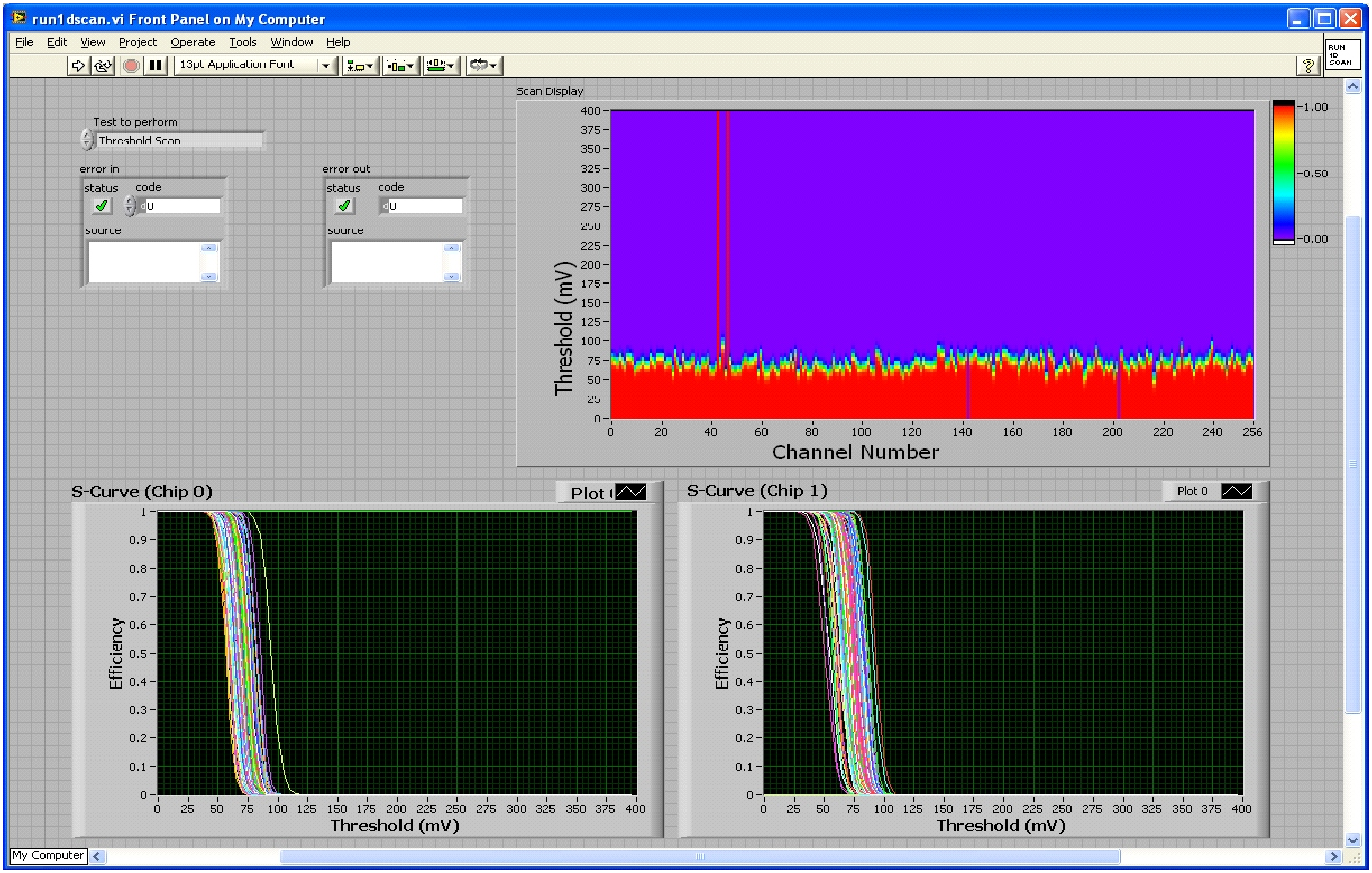


# Threshold Scan Test w S-Curve

**VI from LBNL**

## BNL Setup (2 ABCD Chips)

**~ 1 minute/80k events**



# NewDaq Development FY06-07

- Agreed with LBNL, RAL to pursue PXI-6561 based system
- Developed 2-chip ABCD boards and LVDS fanout to aid development for groups without current SCT modules (will provide to groups who wish to join development effort)
- will assemble 2 more boards for running three ABCD boards simultaneously
- will finish Peforce installation and evaluation (Source Code Control Software)
- will finish digital test code
- will perform test and evaluation of LBNL analog test code

# NewDaq Plans FY08

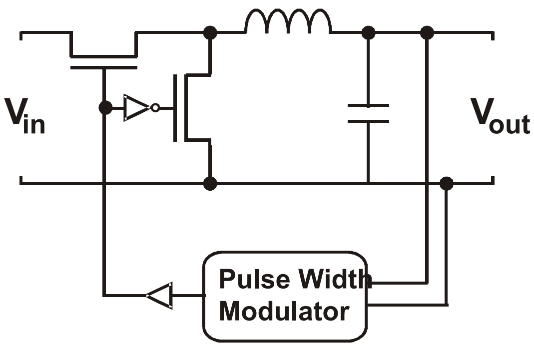
- Expand system to read 30 modules (speed tests of interest)
- Continue software development.
- Use system to study 6 cm wide 2-d stave (½ size) built by LBNL

# DC-DC Power Distribution FY07

- Have considered Buck Converters. Air-core inductors require high frequency (> 5 MHz) to minimize size.
- Collaborating with Yale (Satish Dhawan) on market solutions. Irradiate commercial 6-1(ran 3-1), 5MHz,6A, Buck regulator to 100 Mrad (gammas) with only small change in output.

## Buck Converter

- **Simple Buck Converter**
- **Magnetic field requires that we use air core inductors**
- **$V_{in}$ = 20 V, $V_{out}$ = 2V, $I_{peak}$= 1A**
  **$L_{min}$ = $(1.8/f_{switch})$ henries**
- **If $f_{switch}$ = 1MHz**
  **$L_{min}$ = $1.8 \times 10^{-6}$ henries**




$L_{min} = (V_{in} - V_{out})t_{on} / I_{peak}$

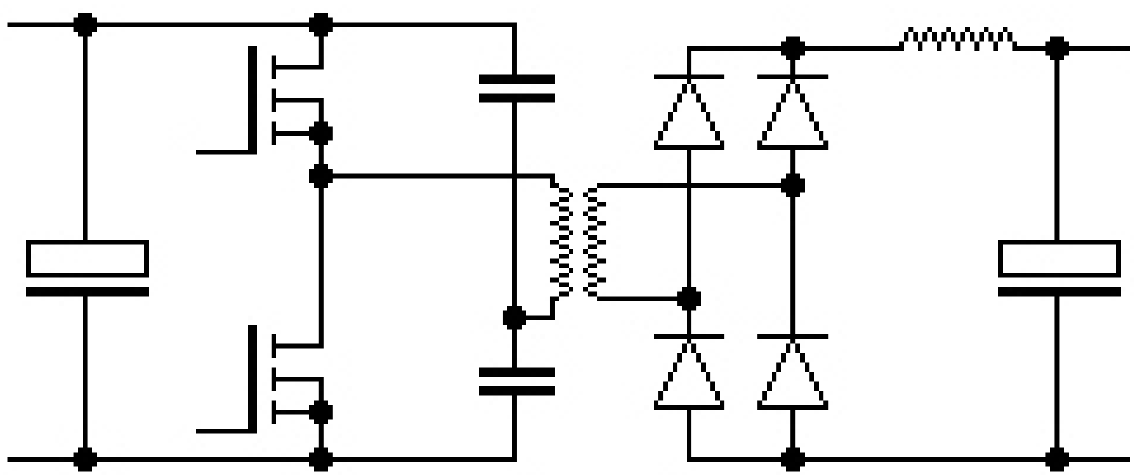
$t_{on} = V_{out} / (f_{switch} * V_{in})$

$f_{switch}$ = switching frequency

# DC-DC Power Distribution FY08

- Will consider alternative topologies to Buck Converter (has limitations on gain/efficiency due to duty cycle.)
- Plan to make design plug-in power boards to mate with ABCD test board. Will study noise, efficiency. Will fabricate air-core inductors/transformers
- HV switches a problem (rad hardness); will look for solutions/collaborators
- Will continue irradiation studies of commercial components (regulators, switches)

Half-Bridge Push-Pull Converter



# 100 Atlas-Z Detectors for Stave Prototypes

– Fabricated by Hamamatsu

– Detector is a “Short” SCT-Like Design

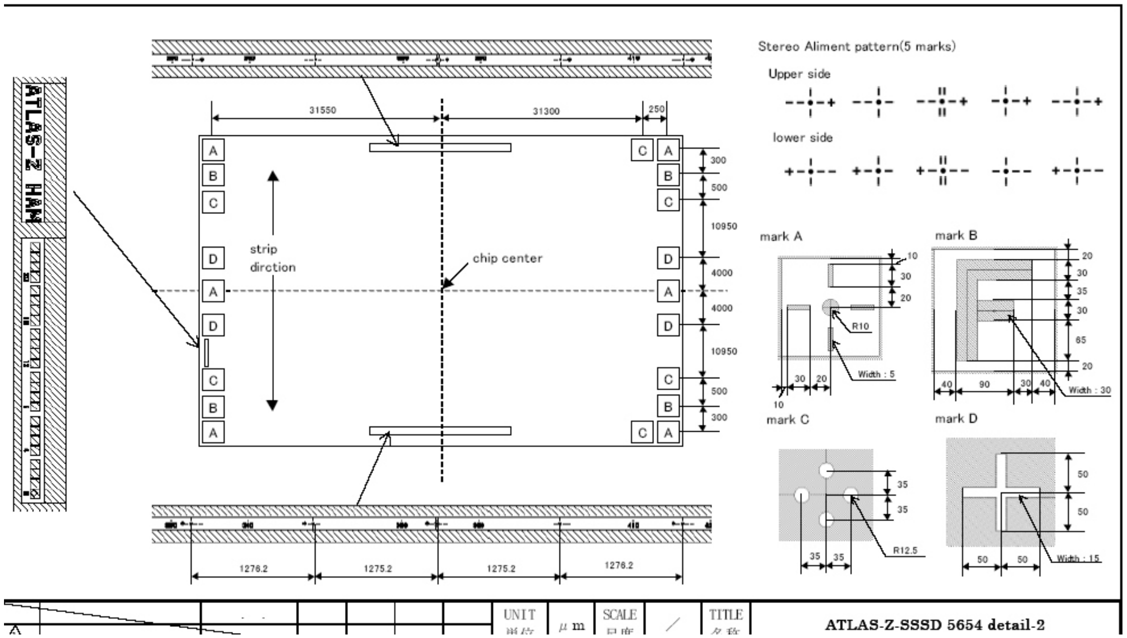
– Layout FY06, Delivery & Test FY07

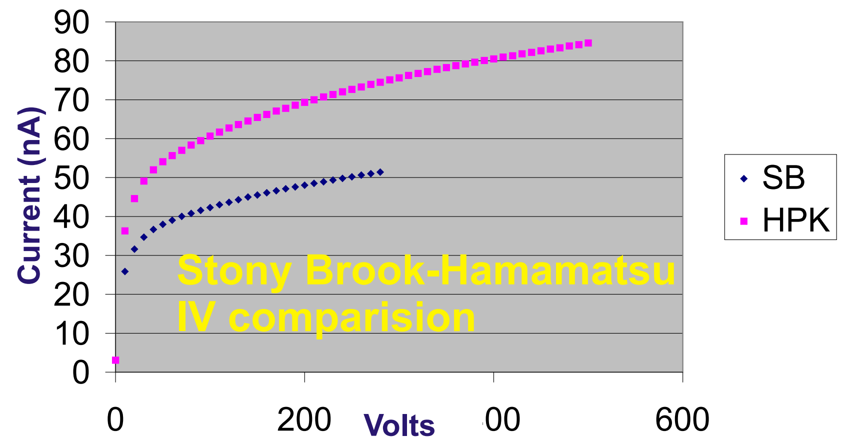
~ 6 cm wide x 3 cm strips

< 100 nA @ 500 Volts typical

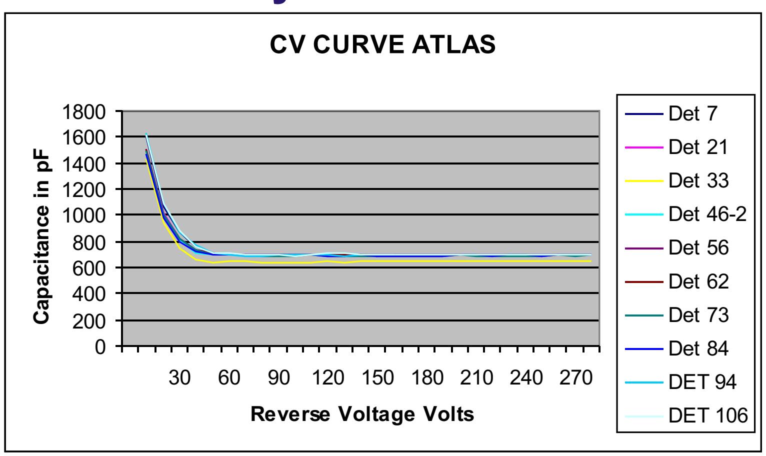
< Very uniform C-V , IV Curves

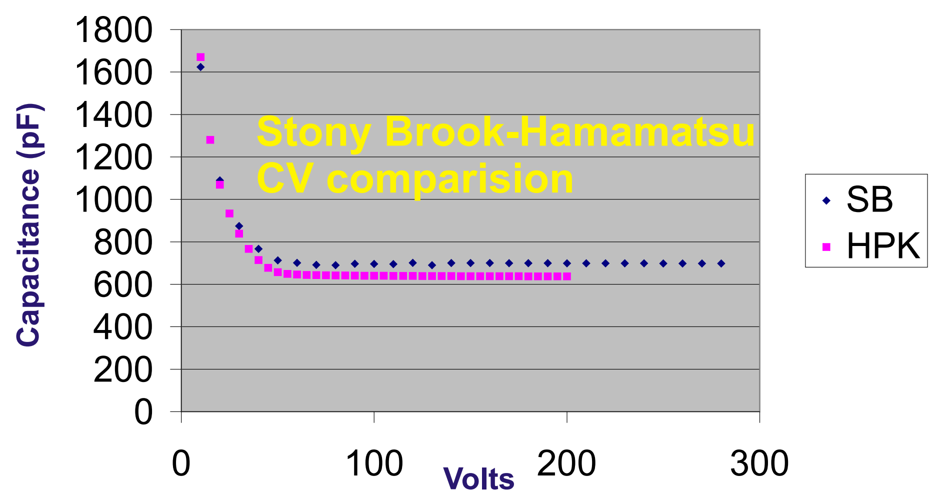
10 Dets retested at Stony Brook (McCarthy, Rijssenbeek). Confirmed Hamamatsu Results




## Uniformity of CV Characteristics



# Sensor FY08

- Participate in Procurement of new 10 cm x 10 cm p-type wafers

- Need ~ 100 detectors for US stave prototyping. Will arrange for testing of sample of ~10 detectors at Stony Brook

# Fy08 Budget Plan

| | item | num | materials | total | hours | labor-cost |
|---|---|---|---|---|---|---|
| | | | | | | |
| **1** | **Barrel-Stave Interface** | | | | | |
| 1.1 | Interface Studies | | | | 180 | $18,720.00 |
| 1.2 | Interface Design | | | | 160 | $15,360.00 |
| 1.3 | Raw materials | 1 | $1,500.00 | $1,500 | | |
| 1.4 | Machining | | | | 80 | $6,960.00 |
| 1.5 | Tests | | | | 120 | $10,440.00 |
| | | | | | | |
| **2** | **Mechanical Barrel Support** | | | | | |
| 2.1 | Optimization of Baseline | | | | 540 | $56,160.00 |
| 2.2 | Assembly/Services Studies | | | | 120 | $11,520.00 |
| 2.3 | Carbon Composite Studies | | | | 120 | $12,480.00 |
| 2.4 | Sectional Mockup | 1 | $20,000.00 | $20,000 | | |
| **2.5** | Design Mockup | | | | 130 | $12,480.00 |
| | | | | | | |
| | | | | | | |
| **3** | **Mech/Thermal Studies** | | | | | |
| 3.1 | Silicon Wafers (dummy) | 40 | $15.00 | $600 | | |
| 3.2 | Silcon wafers Cutting | | | | 40 | $3,480 |
| 3.3 | Thermal Simulations | | | | 180 | $15,660 |
| 0.4 | Temp sensors | 1 | $500.00 | $500 | | |
| 3.4 | Mechanical Testing | | | | 200 | $17,400 |
| 3.5 | Thermal Testing | | | | 320 | $27,840 |
| | | | | | | |
| | | | | | | |
| **4** | **Construction Techniques** | | | | | |
| 4.1 | Carbon Fiber | 1 | $5,000.00 | $5,000 | | |
| 4.2 | K-Foam | 1 | $1,200.00 | $1,200 | | |
| 4.3 | Honeycomb machining | | | | 60 | $5,220 |
| 4.4 | evacuated press experimentation | | | | 160 | $13,920 |
| 4.5 | Tooling Design | | | | 160 | $13,920 |
| 4.6 | Tooling Materials | 1 | $2,000.00 | $2,000 | | |
| 4.7 | Cooling Tube materials | | | | | |
| 4.8 | Commerical tube materials | | | | 80 | $6,960 |
| 4.9 | Commercial Fittings | | | | 100 | $8,700 |
| 4.10 | Hydrostatic Tests | | | | 80 | $6,960 |
| 4.11 | Corrosion Studies | | | | 30 | $2,610 |
| | | | | | | |
| | | | | | | |
| **5** | **NewDaq/Elect. Stave Test** | | | | | |
| 5.1 | Software Development | | | | 320 | $33,280 |
| 5.2 | Electrical Stave Testing | | | | 220 | $22,880 |
| 5.3 | PXI Daq Module | 1 | $5,000.00 | $5,000 | | |
| | | | | | | |
| | | | | | | |
| **6** | **Power Distribution** | | | | | |
| 6.1 | DC-DC Converter Design | | | | 250 | $26,000 |
| 6.2 | DC-DC Circuit Boards | 2 | $1,200.00 | $2,400 | | |
| 6.3 | CAD | | | | 40 | $3,840 |
| 6.4 | Circuit test and evaluation | | | | 100 | $10,400 |
| 6.5 | Rad Test Commer. Components | | | | 120 | $12,480 |
| 6.6 | Data Acquisition | 1 | $3,000.00 | $3,000 | | |
| | | | | | | |
| **7** | **Sensors** | | | | | |
| 7.1 | 10 x 10 cm**2 Sensors | 100 | $1,000.00 | $100,000 | | |
| | | | | | | |
| | | | | | | |
| **Subtotals** | | | | **$141,200** | | **$375,670** |
| | | | | | | |
| **Totals** | | | | | | **$516,870** |

| Task | Material | Labor |
|---|---|---|
| Barrel-Stave Interface | 1.5 | 51.5 |
| Mechanical Support | 20. | 92.6 |
| Mechanical/Thermal Stiudes | 1.1 | 64.4 |
| Construction Techniques | 8.2 | 58.3 |
| NewDaq/Elect. Stave Test | 5. | 56.2 |
| Power Distribution | 5.4 | 51.5 |
| Sensors | 100* | 0 |
| Subtotal | 141 | 375 |
| Total | | 517 |