Block Instrumentation for the Far Detector at Nova

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Outline

- Neutrinos and Nova
- Instrumentation of blocks
  - Measure distance and strain on blocks
- Displaying the parameter readings in Synoptic
- Results and conclusion

Neutrinos and their properties

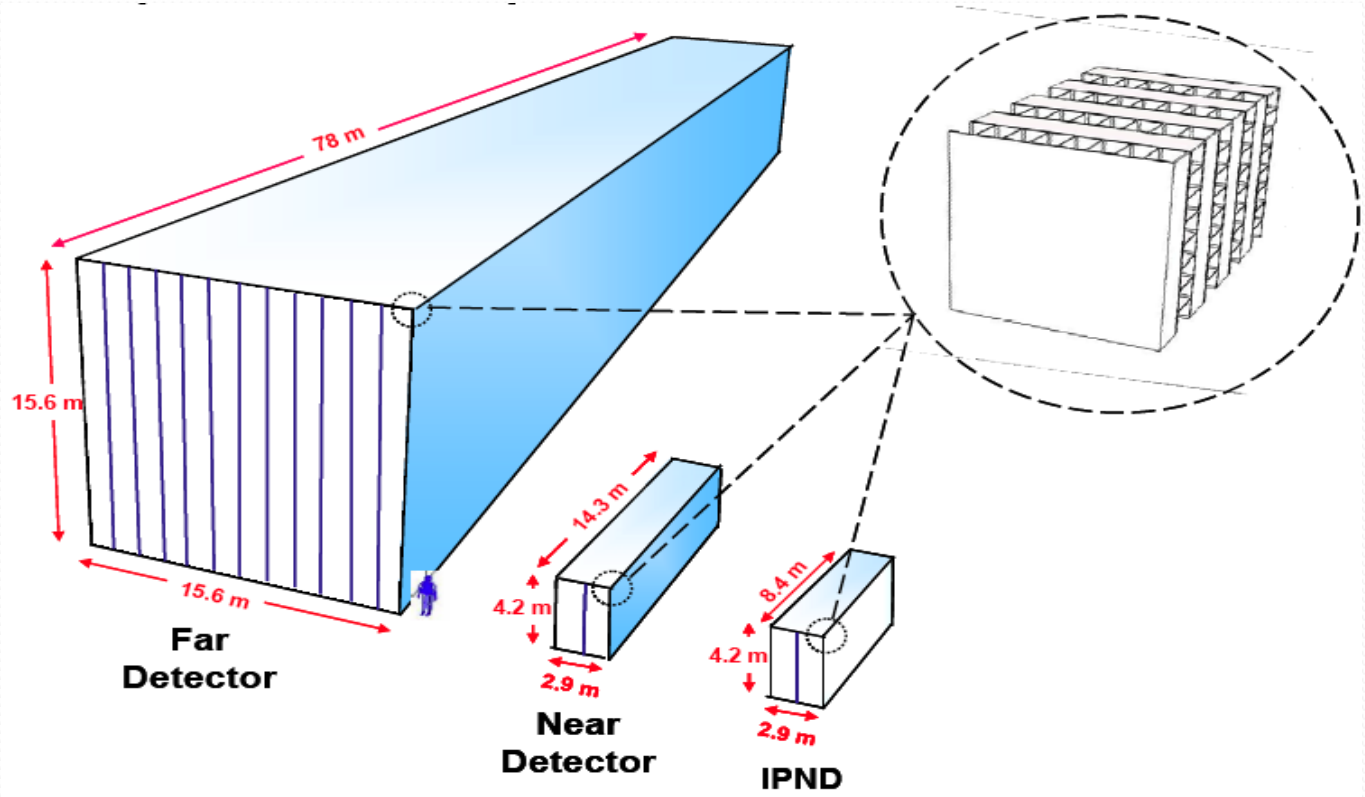
- Muon, tau, and electron neutrinos
- Have a mass, but very small
- Abundant particles, rare interaction with other particles
- Difficult to detect
- Need large detectors

Nova objectives

- Oscillation of *muon* neutrinos to *electron* neutrinos
- Ordering of the neutrino masses
- Symmetry between matter and antimatter

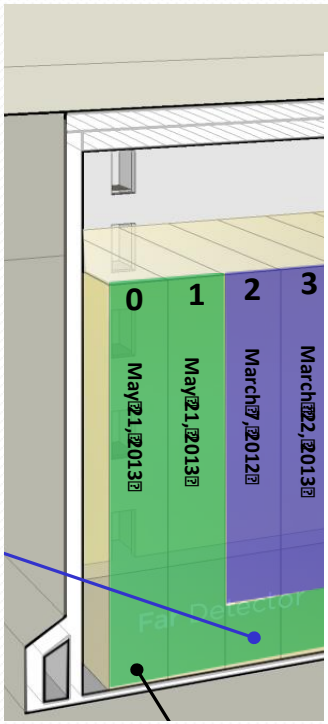
Nova

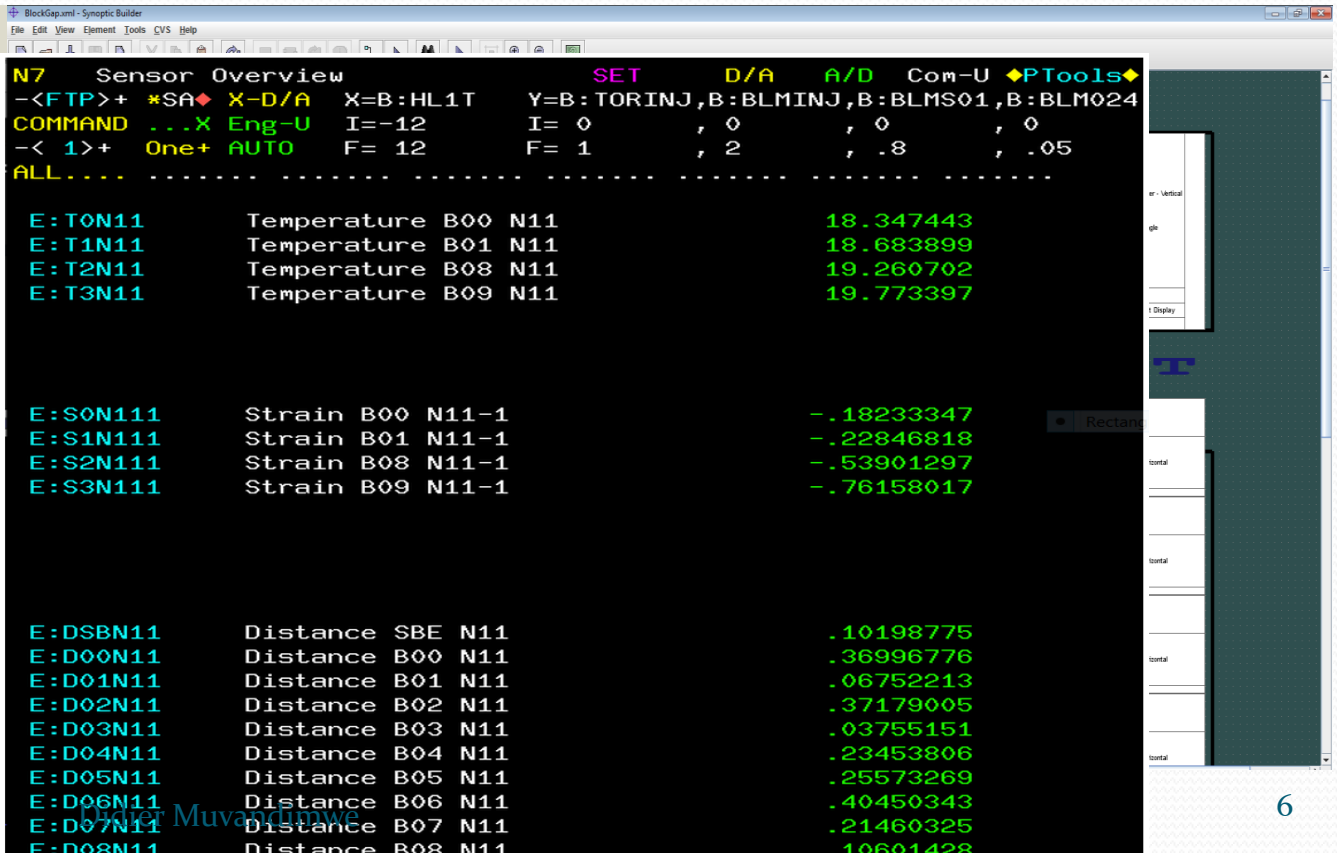
- Near detector and Far detector
  - ND: 222 tons, and FD: 14 ktons
  - Far Detector: 28 Blocks, Each block: 384 PVC modules



Block instrumentation for the Far Detector

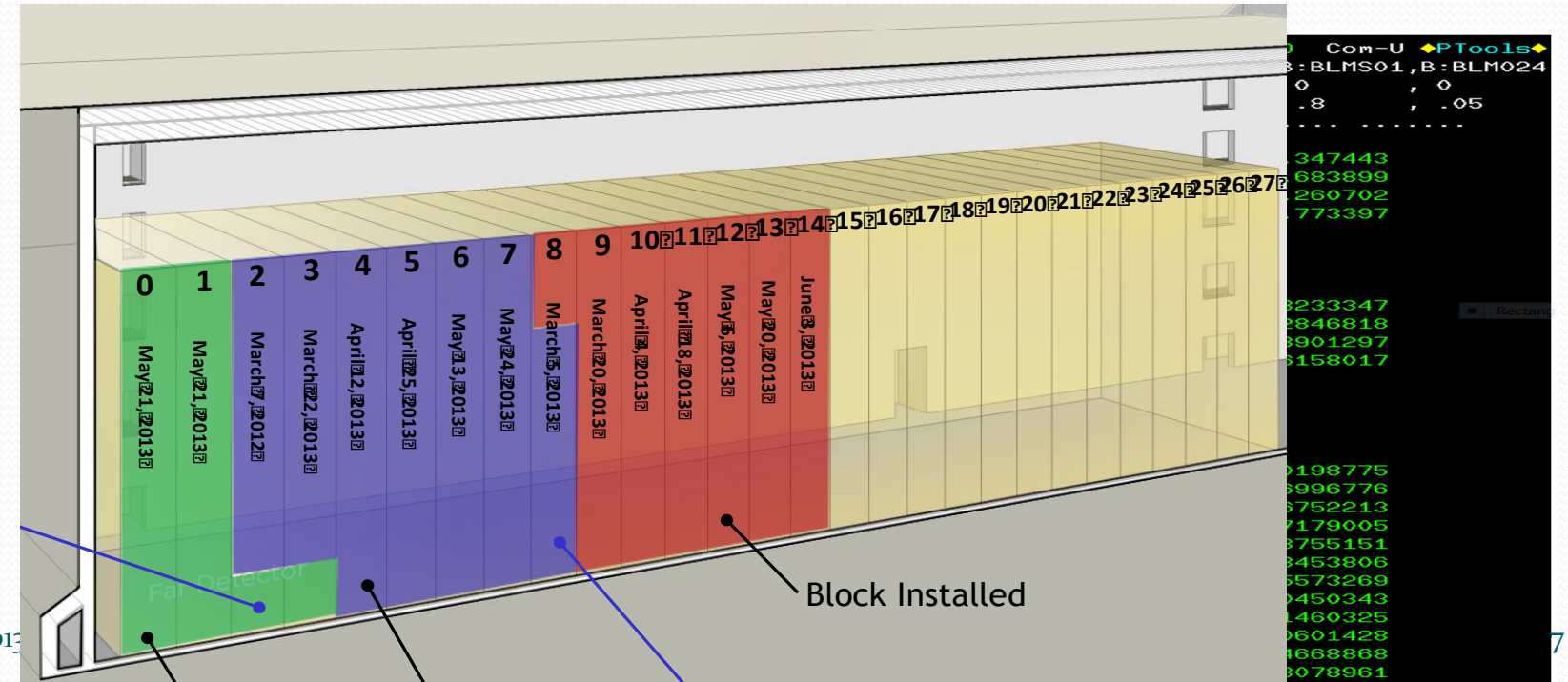
- Measuring ***distances*** between blocks and ***strain*** on some blocks
- Using Synoptic to build displays (GUIs)
- Monitoring these parameters in the Nova control room





Gap Distances

- 27 gaps (B00/B01 gap, B01/B02 gap,… B15/B16 gap,…….B26/B27 gap)
- Each Gap: 24 sensors: 18 north side and 6 south side.
- Each sensor has a name (sensor variable),
- Variable broadcasted through ACNET
- Variable imported from ACNET to display in Synoptic



Distance sensor Variables

- DIS- B# # - N/S XY
- B:[Block], ##: Block number, N or S: North or South side sensor, X or Y: horizontal and vertical position

	B01-S61	B01-S51	B01-S41	B01-S31	B01-S21	B01-S11	
B00-N19							B00-N29
B00-N18							B00-N28
B00-N17							B00-N27
B00-N16							B00-N26
B00-N15							B00-N25
B00-N14							B00-N24
B00-N13			Block 00/01 Gap				B00-N23
B00-N12							B00-N22
B00-N11							B00-N21

Strain sensor variables

- Sensor variables: *S-#-N/W-XY-1/2/3*.
- *S* : Strain, N/W: North or West, X/Y: Horizontal or vertical position, gauge number.

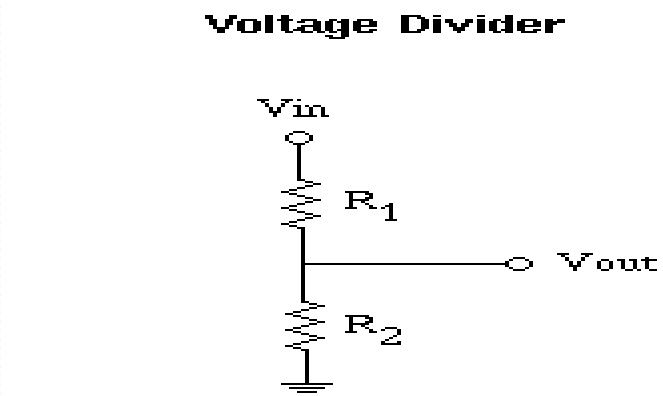
Digit	Block Number
0	B00
1	B01
2	B08
3	B09
4	B18
5	B19
6	B26
7	B27

S1N11	S1N21	S1N31	S1N41	S1N51	S1N61
S1N12	S1N22	S1N32	S1N42	S1N52	S1N62
S1N13	S1N23	S1N33	S1N43	S1N53	S1N63
S1N14	S1N24	S1N34	S1N44	S1N54	S1N64

S1W11	S1W21
S1W12	S1W22
S1W13	S1W23

How to measure the distances

- Changing resistor (R_{DIS}) and a known resistor(R_{vD}) of 20 KΩ
- Voltage divider across R_{DIS} and R_{vD}



$$Vout = \frac{R_2}{R_1 + R_2} Vin$$

- $\boldsymbol{V_{out} = V_{in} \cdot \frac{R_{VD}}{R_{DIS}+R_{VD}}}$ **(1)**
- $\frac{V_{out}}{V_{in}} = \frac{R_{VD}}{R_{DIS}+R_{VD}}$, R_{DIS} expressed as ($R_{DIS} = mx + b$)
- $\frac{V_{out}}{V_{in}} = \frac{R_{VD}}{(mx+b)+R_{VD}}$**(3)**

- $$X = \frac{1}{V_{out}}\left[\frac{1}{m}\cdot V_{in}\cdot R_{VD}\right] - \left[\frac{1}{m}\cdot V_{in}\cdot R_{VD}\right] (4)$$

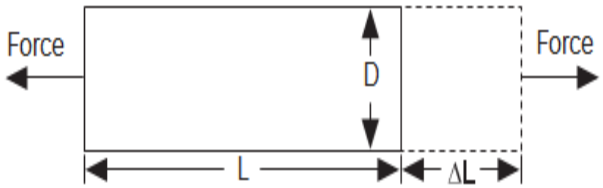
- Letting, $C = \left[\frac{1}{m}\cdot V_{in}\cdot R_{VD}\right]$, and

$$D = \left[\frac{1}{m}\cdot V_{in}\cdot R_{VD}\right]$$

Then, $X = \frac{1}{V_{out}}[C] + [D]\ (5)$

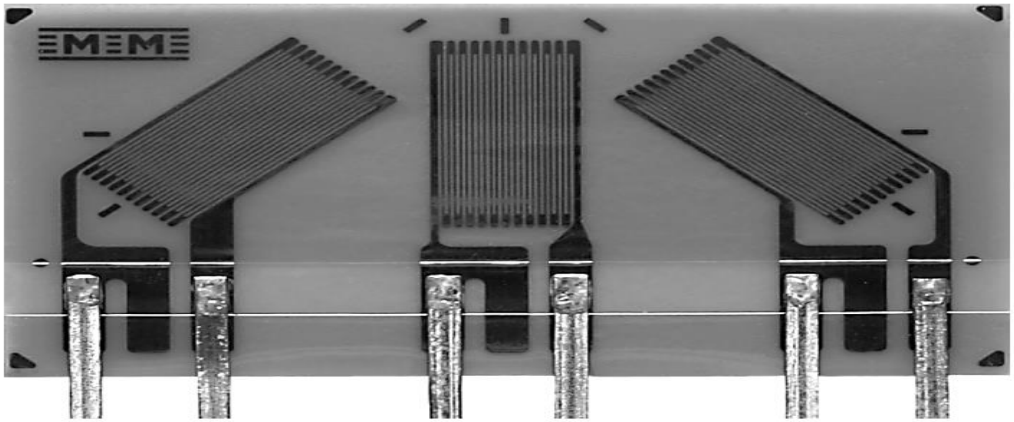
Strain and Strain gauge

- **Strain** is the amount of deformation of a body due to a force an applied force. Positive (tension) or negative (compressive)
- $\varepsilon = \frac{\Delta L}{L}$ (1), in micro-strain ($\mu\varepsilon$).
- Use of **Strain gauge to** measure strain**.**



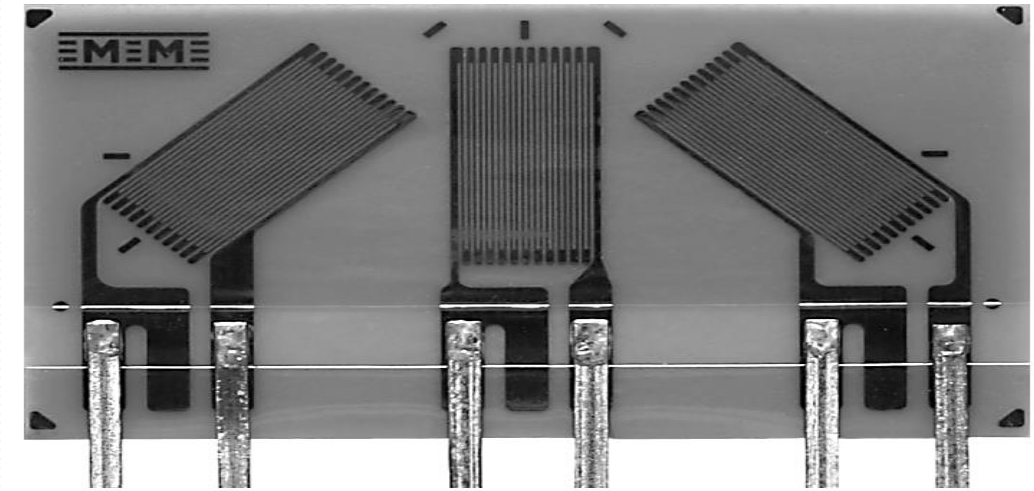
- Gauge Factor (GF): the fundamental parameter of the strain gauge.
- Measures the material *sensitivity to the strain. i.e. GF=2 for nova (metallic strain) gauges*

❖ $GF = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\varepsilon}$



How to measure strain

- 3 gauge strain sensor or rosette ($\varepsilon_1, \varepsilon_2, \varepsilon_3$)



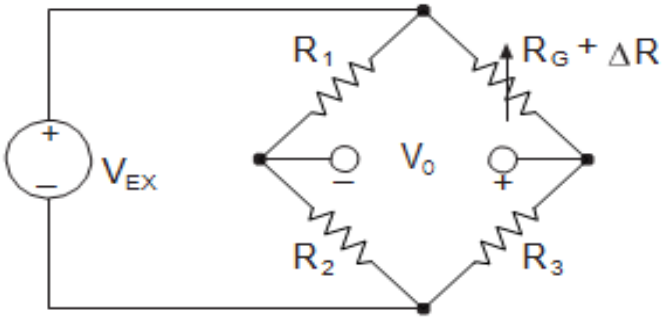
- Connecting a strain gauge to a modified *Wheatstone bridge*

- Slight modification to a quarter bridge circuit

- Setting $R_1 = R_2, R_3 = R_G$, and the GF equation, $\Delta R = R_G . GF . \varepsilon$.

- $\frac{V_0}{V_{EX}} = -\frac{GF.\varepsilon}{4}\left(\frac{1}{1+GF.\frac{\varepsilon}{2}}\right)$ (7)

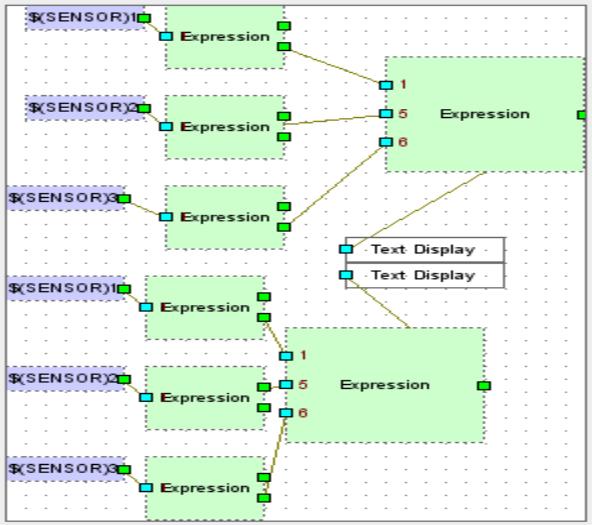
- From (7), letting $V_r = \frac{V_0}{V_{EX}}$, then



- $\varepsilon = \frac{-4 \cdot V_r}{GF(1+2V_r)}$ (8)

- Measuring and reading $(\varepsilon_1, \varepsilon_2, \varepsilon_3)$.
- However, displaying principal strain $(\varepsilon_p, \varepsilon_q)$
  - $\varepsilon_p = \frac{\varepsilon_1+\varepsilon_2}{2} + \frac{1}{\sqrt{2}}\sqrt{(\varepsilon_1-\varepsilon_2)^2+(\varepsilon_2-\varepsilon_3)^2}$
  - $\varepsilon_q = \frac{\varepsilon_1+\varepsilon_2}{2} - \frac{1}{\sqrt{2}}\sqrt{(\varepsilon_1-\varepsilon_2)^2+(\varepsilon_2-\varepsilon_3)^2}$

$(\varepsilon_p, \varepsilon_q)$ are displayed in Synoptic

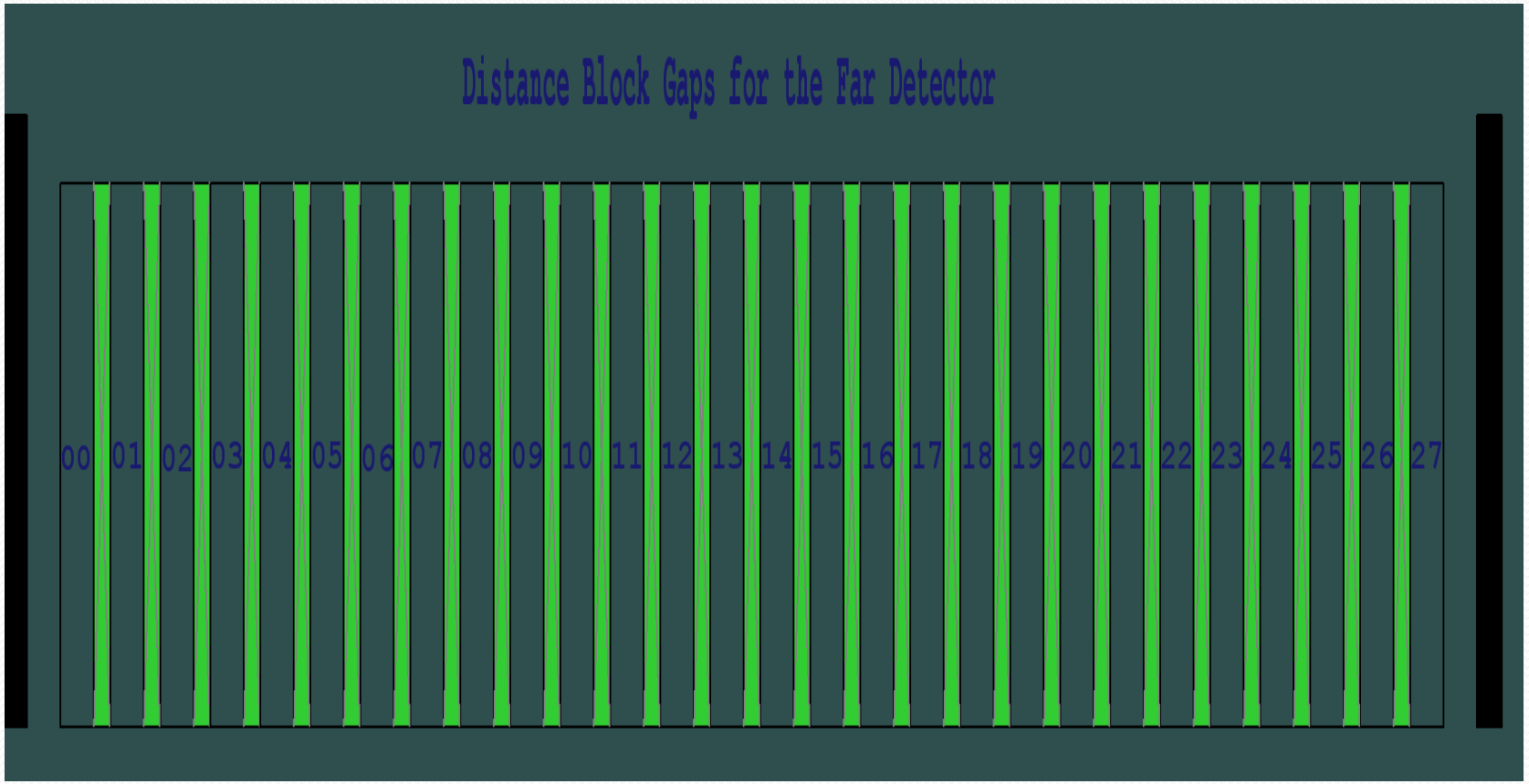


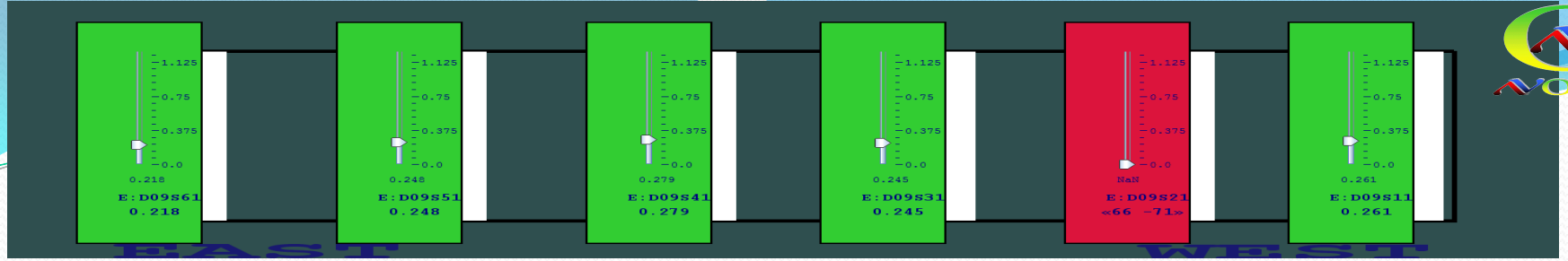
Epsilon P: 1069.708

Epsilon Q: 31.313

Results

- Distance readings with alarms
  - http://www-bd.fnal.gov/synoptic/display/Nova_Far/Displays/BlockGapOvervie

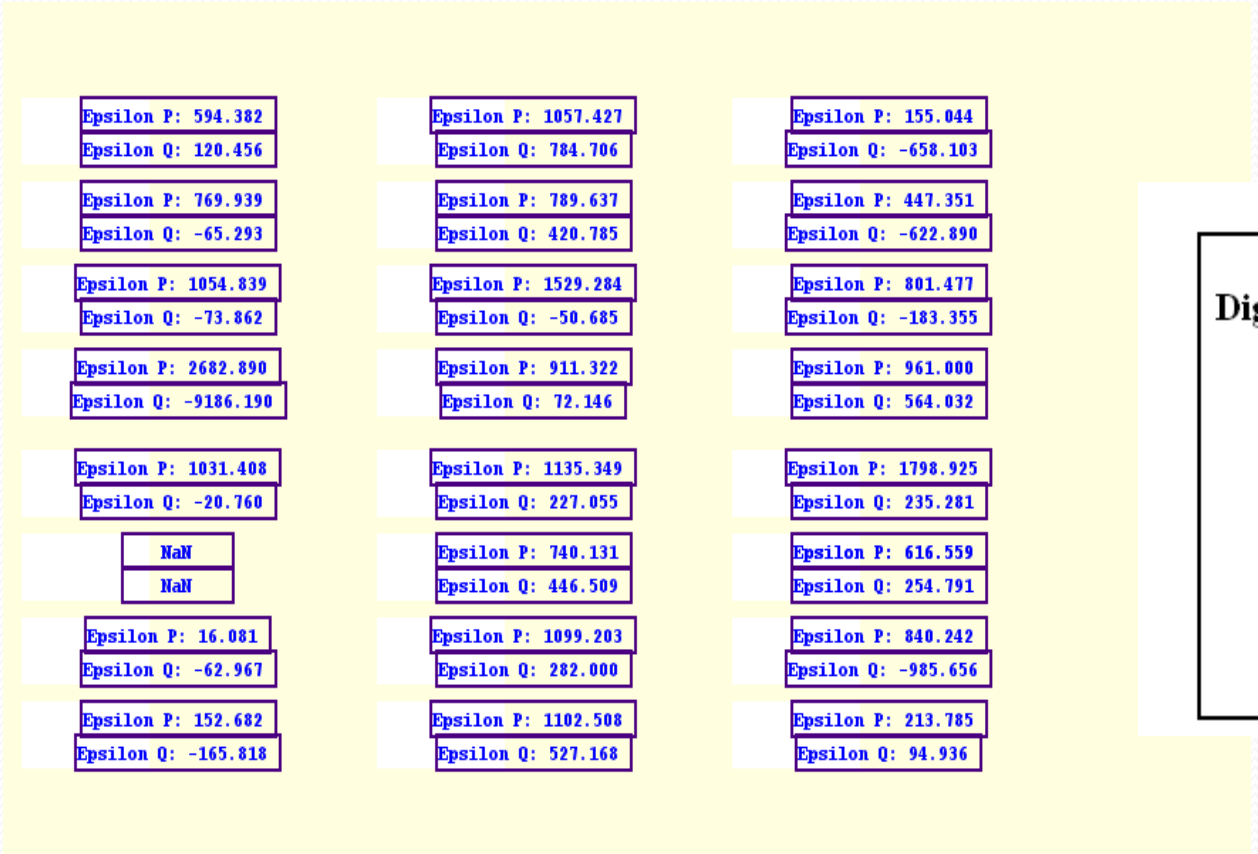




Distance Block Gap

Strain readings

- Rosette $(\varepsilon_1, \varepsilon_2, \varepsilon_3) \longrightarrow (\varepsilon_p, \varepsilon_q)$



Digit	Block Number
0	B00
1	B01
2	B08
3	B09
4	B18
5	B19
6	B28
7	B29

Conclusion and Future work

- Distance readings displays have been completed
  - Easy control and monitoring in Nova control room
    - Knowing broken sensors, detect any issues with the sensors
    - Recognizing out of range (abnormal) readings
- Strain displays are in progress and continue to work on them
  - Overview for all 8 blocks with strain sensors on them
  - Have all strain readings as it is for the distance display

Acknowledgements

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Questions ?