Block Instrumentation for the Far Detector at Nova

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Outline

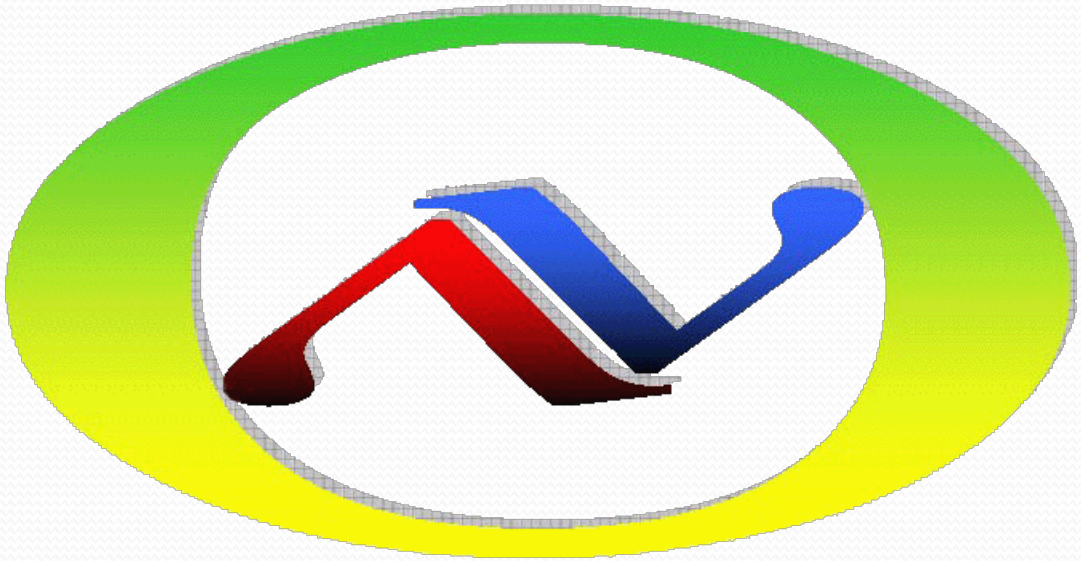
- Neutrinos and Nova
- Instrumentation of blocks
  - Measure distance and strain on blocks
- Displaying the parameter readings in Synoptic
- Results and conclusion

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

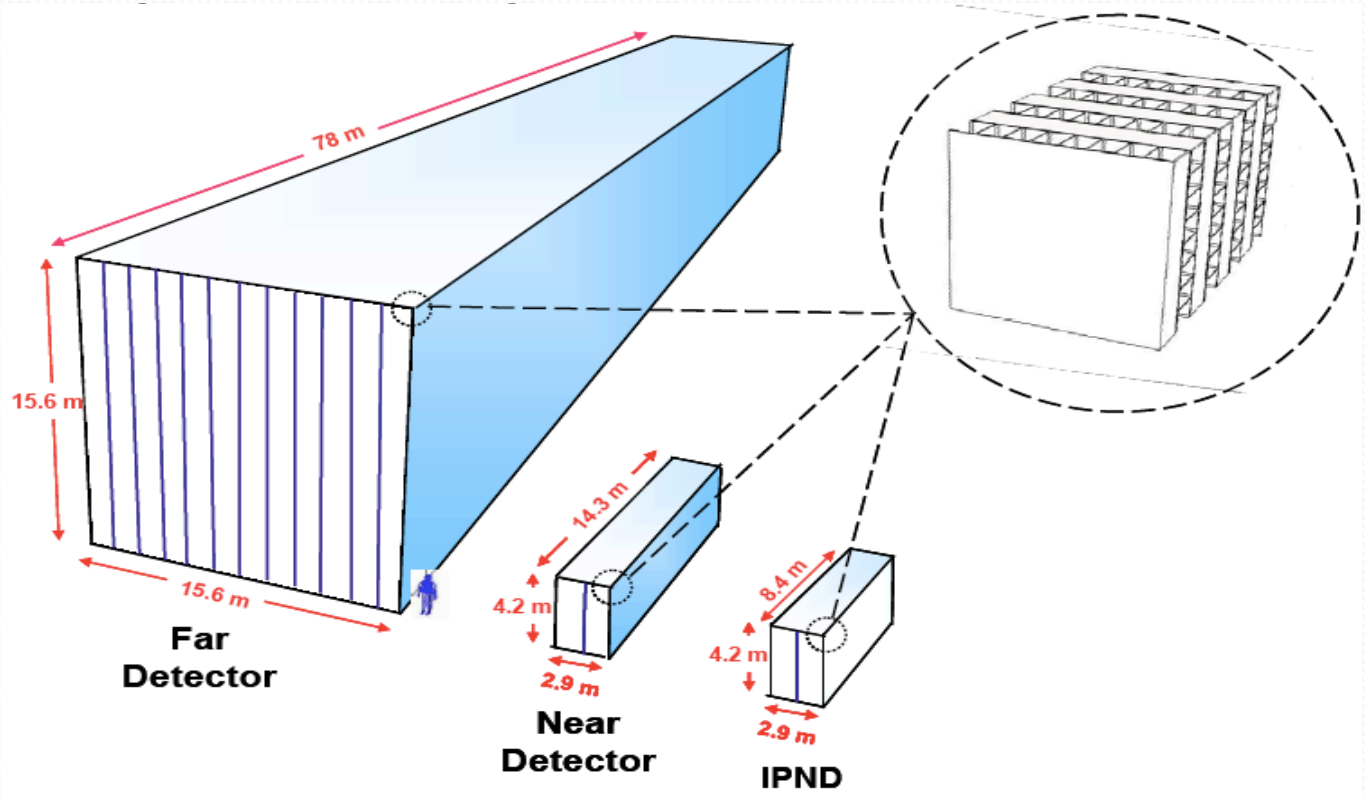
Nova objectives

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



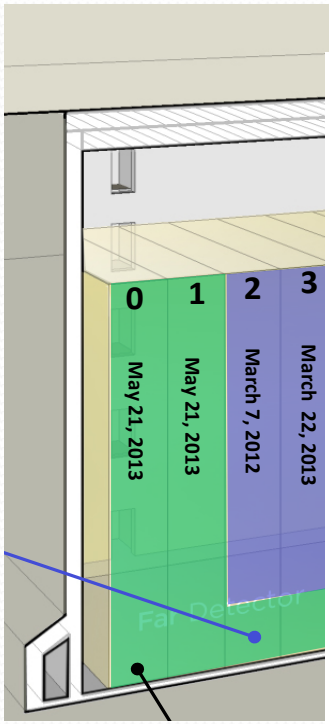
Nova

- 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



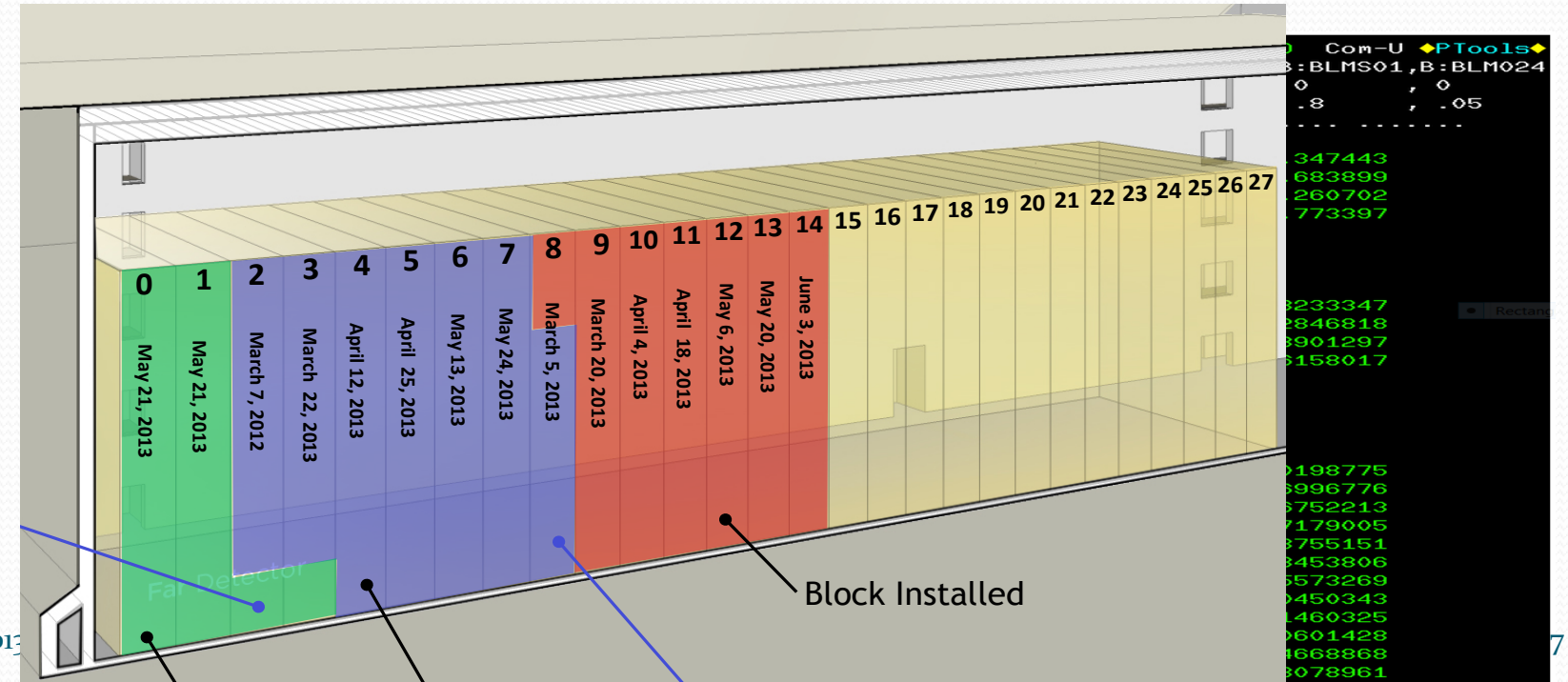
BlockGap.xml - Synoptic Builder

File Edit View Element Tools CVS Help

```
N7    Sensor Overview                    SET      D/A    A/D  Com-U ◆PTools◆
-<FTP>+ *SA◆ X-D/A   X=B:HL1T    Y=B:TORINJ,B:BLMINJ,B:BLMS01,B:BLM024
COMMAND ...X Eng-U   I=-12       I= 0       , 0       , 0       , 0
-< 1>+   One+ AUTO    F= 12       F= 1       , 2       , .8      , .05
ALL.... ....... ....... ....... ....... ....... ....... .......

 E:T0N11       Temperature B00 N11                    18.347443
 E:T1N11       Temperature B01 N11                    18.683899
 E:T2N11       Temperature B08 N11                    19.260702
 E:T3N11       Temperature B09 N11                    19.773397



 E:S0N111      Strain B00 N11-1                      -.18233347
 E:S1N111      Strain B01 N11-1                      -.22846818
 E:S2N111      Strain B08 N11-1                      -.53901297
 E:S3N111      Strain B09 N11-1                      -.76158017



 E:DSBN11      Distance SBE N11                       .10198775
 E:D00N11      Distance B00 N11                       .36996776
 E:D01N11      Distance B01 N11                       .06752213
 E:D02N11      Distance B02 N11                       .37179005
 E:D03N11      Distance B03 N11                       .03755151
 E:D04N11      Distance B04 N11                       .23453806
 E:D05N11      Distance B05 N11                       .25573269
 E:D06N11      Distance B06 N11                       .40450343
 E:D07N11      Distance B07 N11                       .21460325
 E:D08N11      Distance B08 N11                       .10601428
```

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.

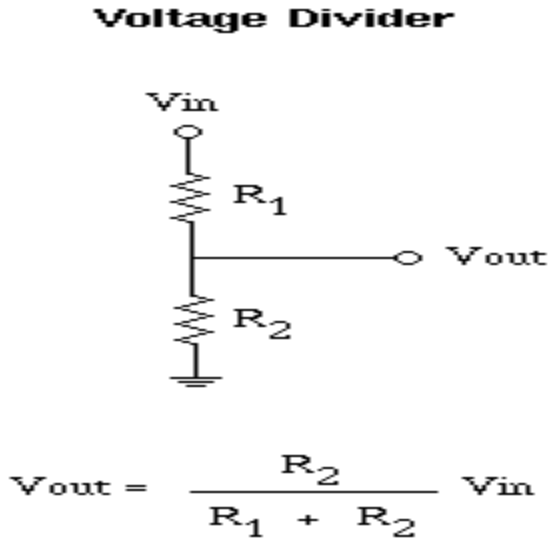
Digit	Block Number
0	B00
1	B01
2	B08
3	B09
4	B18
5	B19
6	B26
7	B27

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 $R↓vD$



- $V↓out = V↓in \cdot R↓VD / R$
- $V↓out / V↓in = R↓VD / R↓DIS + R↓VD$, $R↓DIS$ expressed as $(R↓DIS = mx + b)$

- $X = 1/V{\downarrow}out\ [1/m \cdot V{\downarrow}in \cdot R{\downarrow}VD\ ] - [1/m \cdot V{\downarrow}in \cdot R{\downarrow}VD\ ]$ (4)

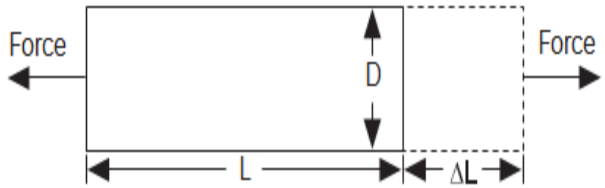
- Letting, $C = [1/m \cdot V{\downarrow}in \cdot R{\downarrow}VD\ ]$, and

  $D = [1/m \cdot V{\downarrow}in \cdot R{\downarrow}VD\ ]$

  Then, $X = 1/V{\downarrow}out\ [C] + [D]$ (5)

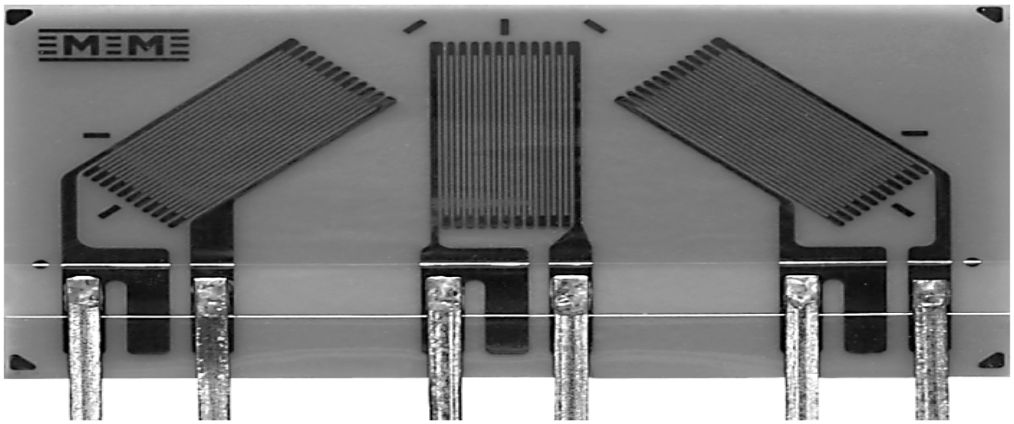
Strain and Strain gauge

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



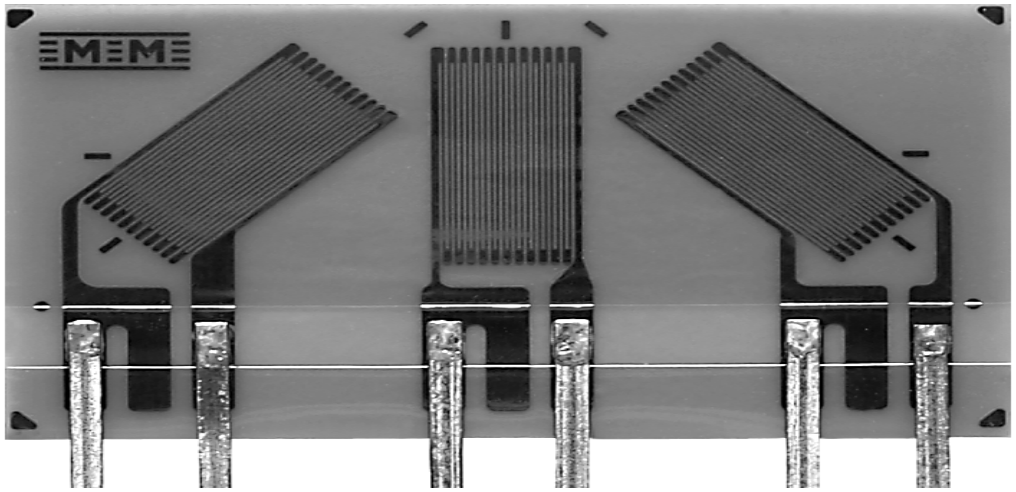
- Gauge Factor (GF): the fundamental parameter of the strain gauge.
- Measures the material *sensitivity to the strain. i.e. GF=2 for nova (metallic strain) gauges*

  - GF= $\Delta R/R\ /\Delta L/$

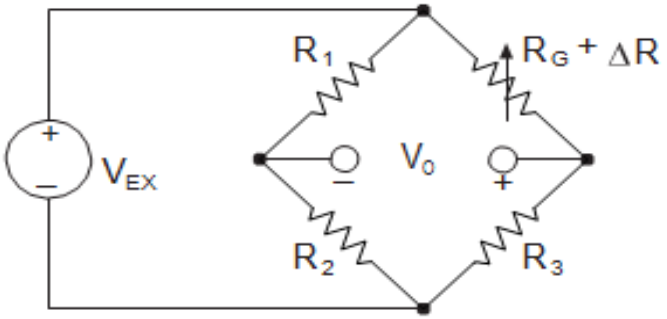


How to measure strain

- 3 gauge strain sensor or rosette (ε_1 , ε_2 , ε_3)



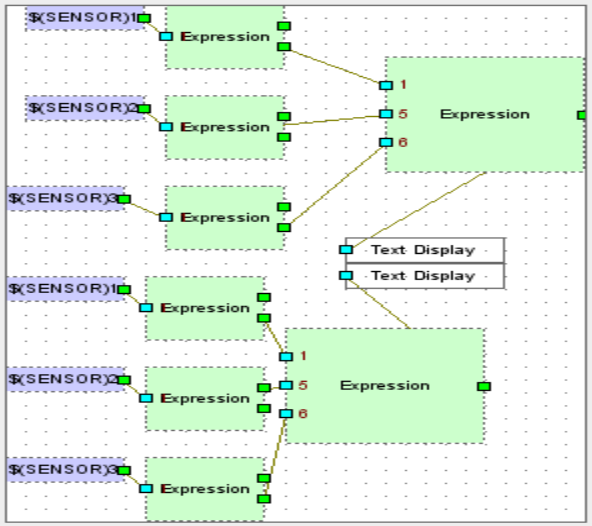
- Connecting a strain gauge to a modified *Wheatstone bridge*
- Slight modification to a quarter bridge circuit



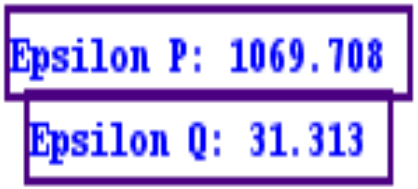
- Setting $R\downarrow 1 = R\downarrow 2 , R\downarrow 3 = R\downarrow$
the GF equation, $\Delta R = R\downarrow G \,.\, GF.\, \varepsilon$
- $V\downarrow 0 \,/ V\downarrow EX = -GF.\, \varepsilon/4$ (1
- From (7), letting $V\downarrow r = V\downarrow 0 \,/ V\downarrow EX$, then

$$\varepsilon = -4 \cdot V\downarrow r \,/ GF(1+2V\downarrow r) \quad (8)$$

- Measuring and reading ($\varepsilon\downarrow 1$, $\varepsilon\downarrow 2$, $\varepsilon\downarrow 3$).
- However, displaying principal strain ($\varepsilon\downarrow p$, $\varepsilon\downarrow q$)
  - $\varepsilon\downarrow p = \varepsilon\downarrow 1 + \varepsilon\downarrow 2 \ /2 + 1/\sqrt{2}\ \sqrt{(\varepsilon\downarrow 1 - \varepsilon\downarrow 2)\uparrow 2 + (\varepsilon\downarrow 2 - \varepsilon\downarrow 3)\uparrow 2}$
  - $\varepsilon\downarrow q = \varepsilon\downarrow 1 + \varepsilon\downarrow 2 \ /2 - 1/\sqrt{2}\ \sqrt{(\varepsilon\downarrow 1 - \varepsilon\downarrow 2)\uparrow 2 + (\varepsilon\downarrow 2 - \varepsilon\downarrow 3)\uparrow 2}$

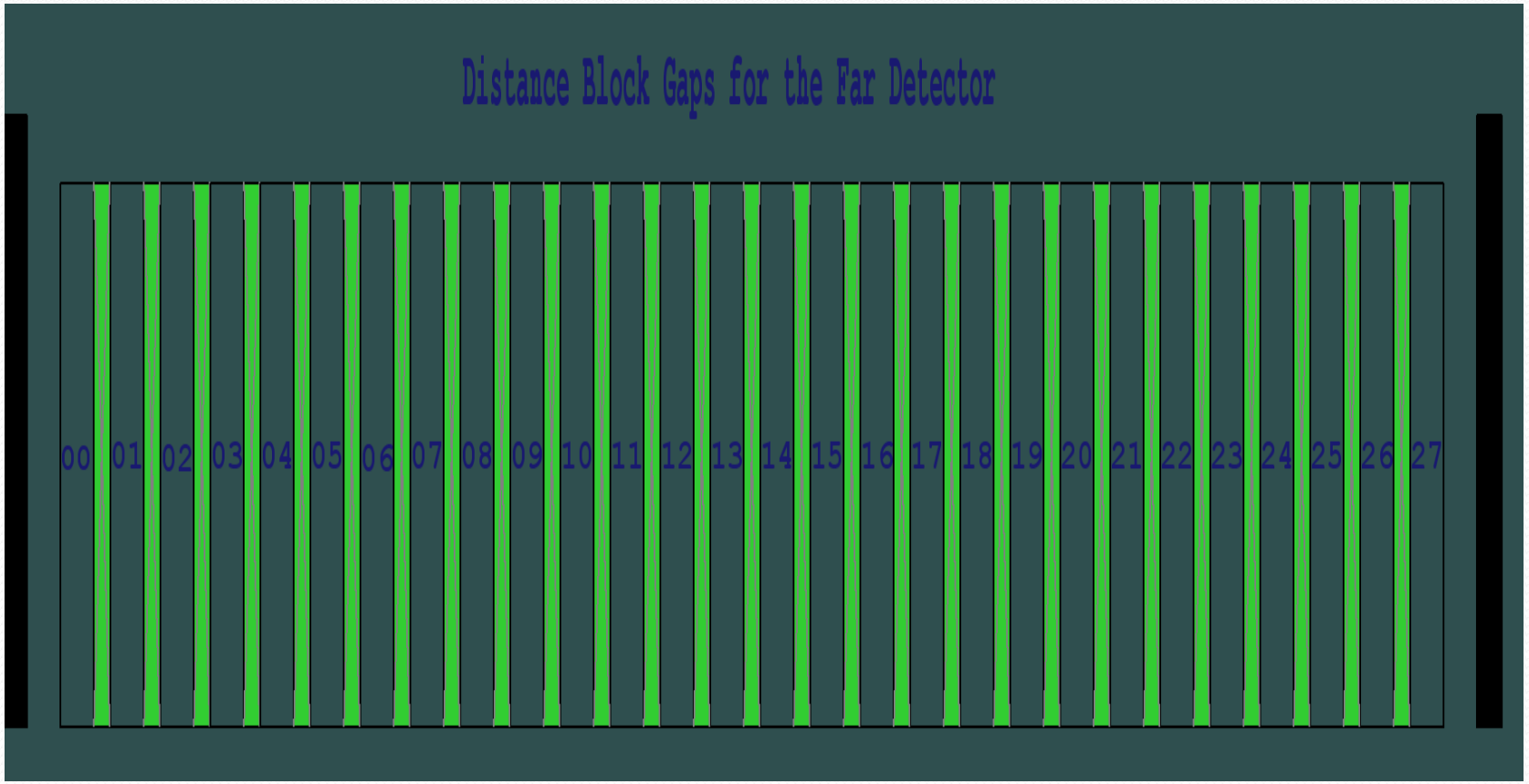


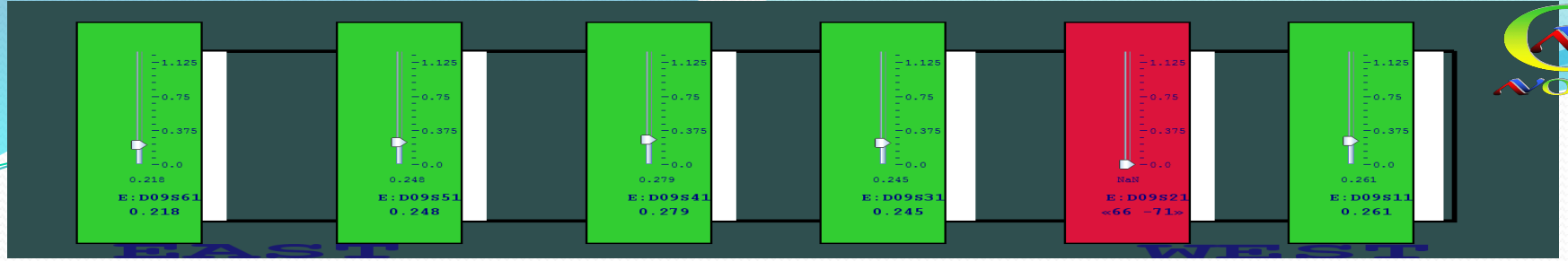
Synopti



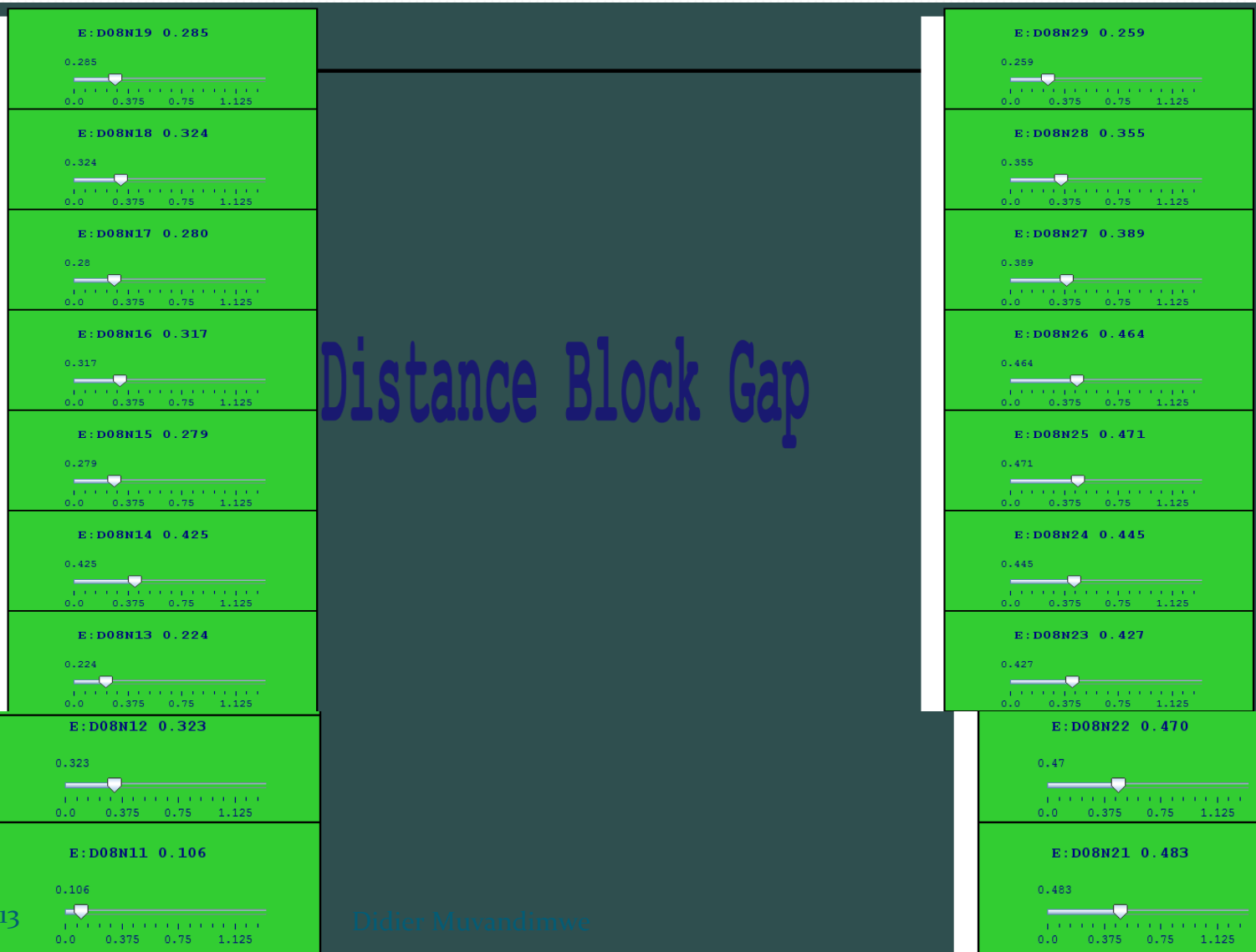
Results

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





Distance Block Gap



Strain readings

- Rosette (ε_1, ε_2, ~~ε_3~~) ⟶ (ε_p, ε_q)

Epsilon P: 594.382 Epsilon Q: 120.456	Epsilon P: 1057.427 Epsilon Q: 784.706	Epsilon P: 155.044 Epsilon Q: -658.103
Epsilon P: 769.939 Epsilon Q: -65.293	Epsilon P: 789.637 Epsilon Q: 420.785	Epsilon P: 447.351 Epsilon Q: -622.890
Epsilon P: 1054.839 Epsilon Q: -73.862	Epsilon P: 1529.284 Epsilon Q: -50.685	Epsilon P: 801.477 Epsilon Q: -183.355
Epsilon P: 2682.890 Epsilon Q: -9186.190	Epsilon P: 911.322 Epsilon Q: 72.146	Epsilon P: 961.000 Epsilon Q: 564.032
Epsilon P: 1031.408 Epsilon Q: -20.760	Epsilon P: 1135.349 Epsilon Q: 227.055	Epsilon P: 1798.925 Epsilon Q: 235.281
NaN NaN	Epsilon P: 740.131 Epsilon Q: 446.509	Epsilon P: 616.559 Epsilon Q: 254.791
Epsilon P: 16.081 Epsilon Q: -62.967	Epsilon P: 1099.203 Epsilon Q: 282.000	Epsilon P: 840.242 Epsilon Q: -985.656
Epsilon P: 152.682 Epsilon Q: -165.818	Epsilon P: 1102.508 Epsilon Q: 527.168	Epsilon P: 213.785 Epsilon Q: 94.936

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

- Supervisor: Martin Frank
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Questions ?