LAYER 0 SENSOR SPECIFICATIONS

Layer 0 Sensor Production
Readiness Review
Jan 23, 2004

Marcel Demarteau
Bob McCarthy

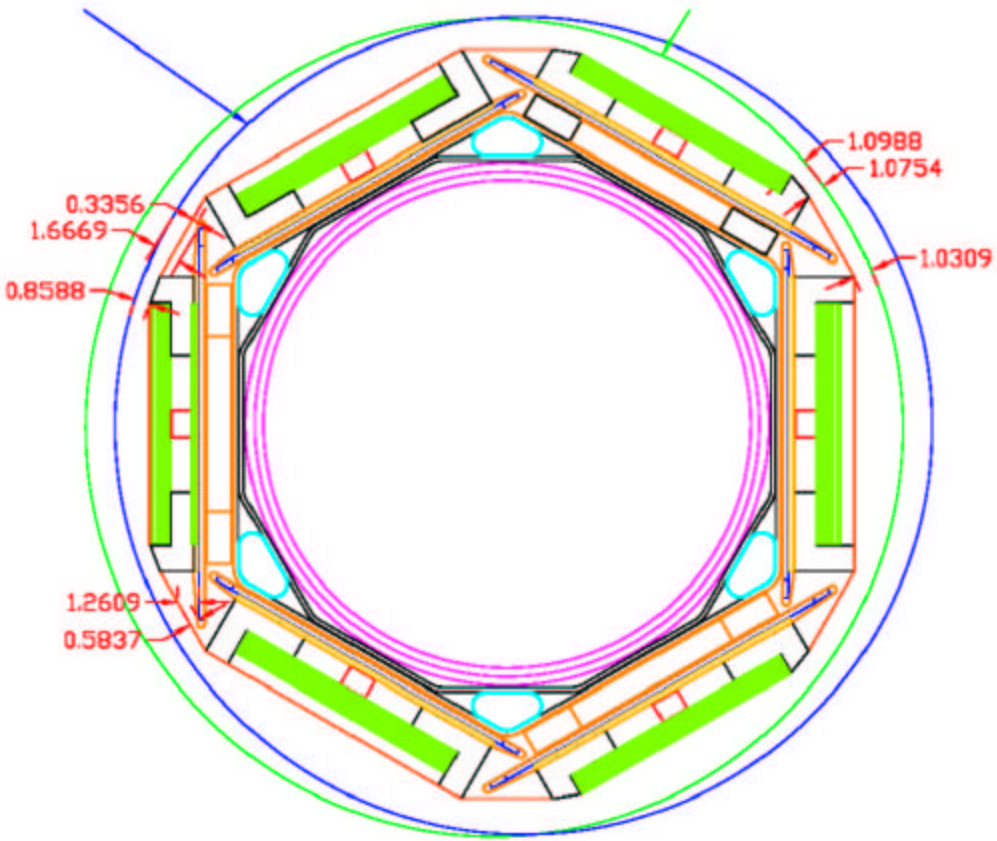
Outline

- Sensors
  - varieties and count
  - specifications
  - design
- Cost and schedule

- Strong reliance on our prototyping for Run2b
  - Received 13 Layer 1 prototype sensors
  - Submitted to rigorous quality control
  - PRR August 8, 2003
- Results shown based on Run2b results for Layer 1 sensors
  - D0notes 4309 and 4310
    M. Demarteau, R. Demina, S. Korjenevski, F. Lehner, R. Lipton, H.S. Mao, R. McCarthy, R. Smith
  - http://www.physik.unizh.ch/~lehnerf/dzero/prr/prr_l1.html

Layer 0 Design

- Six-fold crenellated design, driven by
  - space constraints
  - maximize azimuthal coverage
  - equalize capacitive load
- Two radial groups
  - Sublayer A:
    - R = 16.1 mm
    - 71 µm readout pitch
    - 256 traces
  - Sublayer B:
    - R = 17.6 mm
    - 81 µm readout pitch
    - 256 traces
  - Relative active azimuthal*z coverage: 98.4%



Layer 0 Design

- Equalize capacitive load
- Eight sensors in z (four per hemisphere) at each of six azimuthal positions
  - No ganging of sensors

Parameter	A	B	C	D
Detector length (cm)	7	7	12	12
Strip pitch (microns)	71	81	71	81
Active width (mm)	18.18	20.74	18.18	20.74
Radius (inner)	16.10	17.60	16.10	17.60
Max angle (radians)	0.51	0.53	0.51	0.53
L, effective (microns)	144.44	159.58	144.44	159.58
Analog cable length (cm)	36	34	27	20
Total capacitance (pF)	21	20.3	23.85	21.4
Total noise(electrons)	1445	1414	1573	1463
S/N (normal inc)	15.9	16.3	14.6	15.7
S/N (edge)	7.2	8.1	6.6	7.8

- Longitudinal segmentation
  - Four sensors closest to z=0 are 70mm long
  - Four sensors furthest from z=0 are 120mm long
- Radial 'segmentation'
  - L0-A readout pitch of 71 μm
  - L0-B readout pitch of 81 μm
- All sensors
  - Single sided silicon
  - 256 traces (2-chip), AC coupled, Intermediate strips
  - Axial readout only

Sensor Types and Count

- Sensor + analogue cable forms a unit
- Four different lengths analogue cables; two sensor lengths, two pitches
  - 8 different module types
  - only 6 of each type for the full detector for a total of 6*8=48 modules

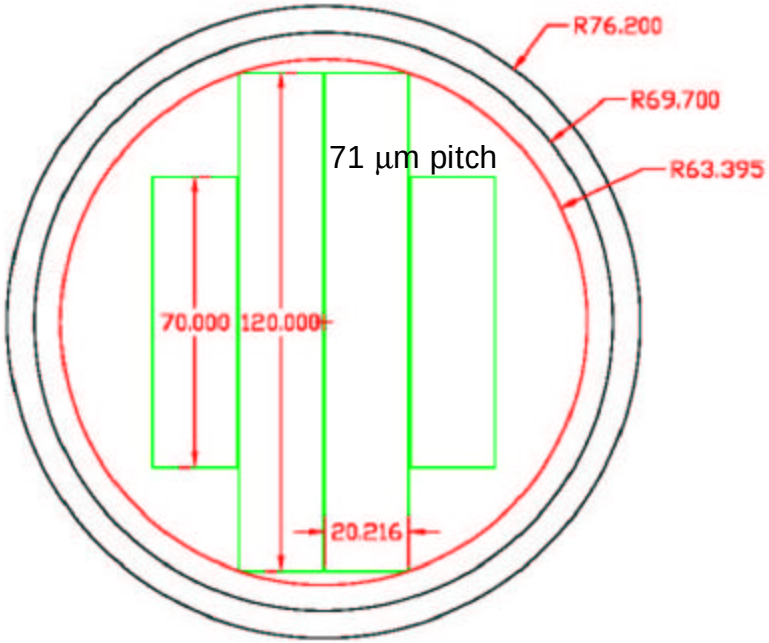
			# modules			# sensors	
	L (cm)	Cable type	71 mm	81 mm	# cables	71 mm	81 mm
z 1	7.0	analogue 1	6	6	12	12	12
z 2	7.0	analogue 2	6	6	12		
z 3	12.0	analogue 3	6	6	12	12	12
z 4	12.0	analogue 4	6	6	12		
Total			24	24	48	24	24

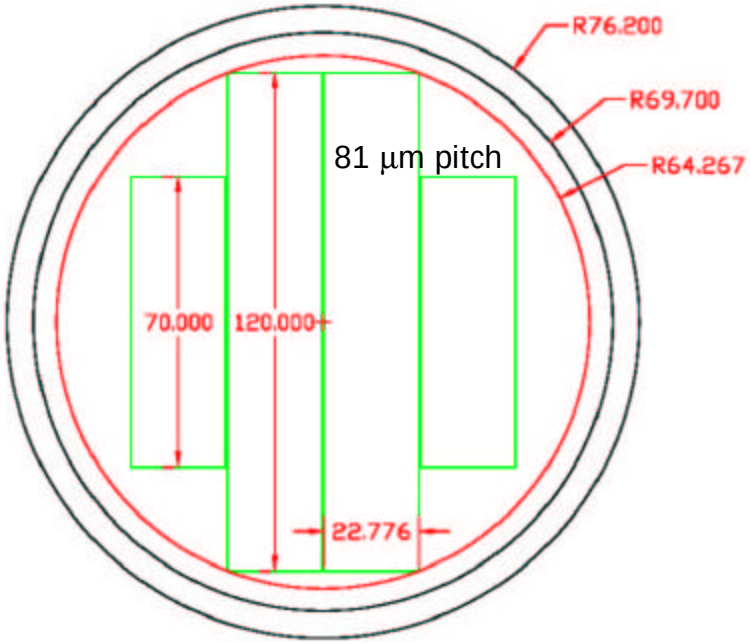
- Sensor and module count:
  - 3 prototypes for each module type (1.5 mechanical, 1.5 electrical)
  - assembly efficiency of 85%
  - 2 spare modules for each type
  - gives 13 modules to be built for each of the 8 types

- Order 30 sensors for each of the 4 types

Possible Wafer Layout

- To reduce cost, sensor parameters chosen so two sensor lengths would fit on one 6” wafer





- Additional test structures embedded in wafer
- 30 wafers; 120 sensors (48 needed for installation)

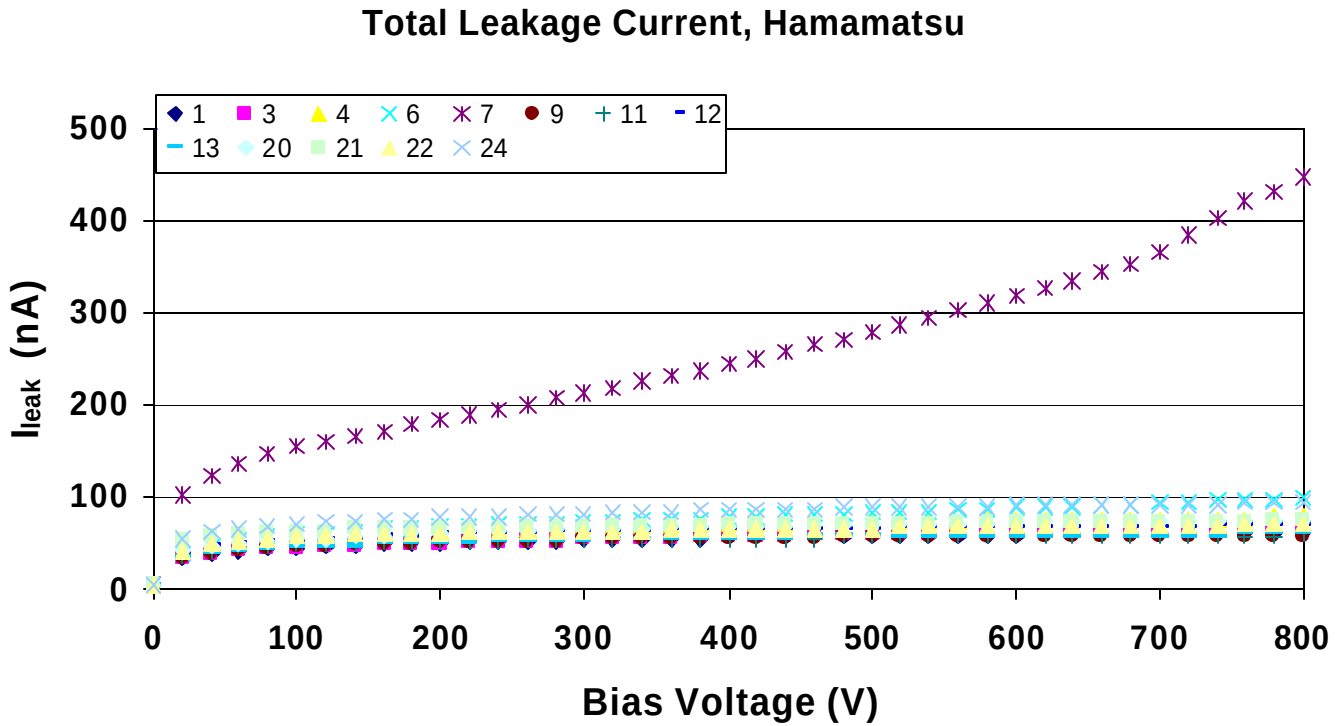
Sensor Specifications

- Sensor specifications adopted from Run2b
  - Breakdown voltage left at 700V
  - Wafer warp relaxed to 100 µm

Specification	L0-A	L0-B
Wafer	320±20mm,warp<100mm	320±20mm,warp<100mm
Depletion Voltage	40< Udep<300 V	40< Udep<300 V
Leakage Current	<100nA/cm2	<100nA/cm2
Junction Breakdown	>700V	>700V
Implant width	6 mm	6 mm
Aluminum resistance	< 30 W/cm	< 30 W/cm
Coupling Capacitance	>10 pF/cm	> 10 pF/cm
CC breakdown	>100 V	>100 V
Interstrip cap	<1.2 pF/cm	<1.2 pF/cm
R Polysilicon	0.8 ± 0.3 MW	0.8 ± 0.3 MW
Active length (mm)	67.960 / 117.960	67.960 / 117.960
Active width (mm)	18.176	20.736
Cut length (mm)	70.000 / 120.000	70.000 / 120.000
Cut width (mm)	20.216	22.776
R/O (strip) pitch (mm)	71	81
Defective strips	<1%	<1%

Layer 1 Sensor Characteristics

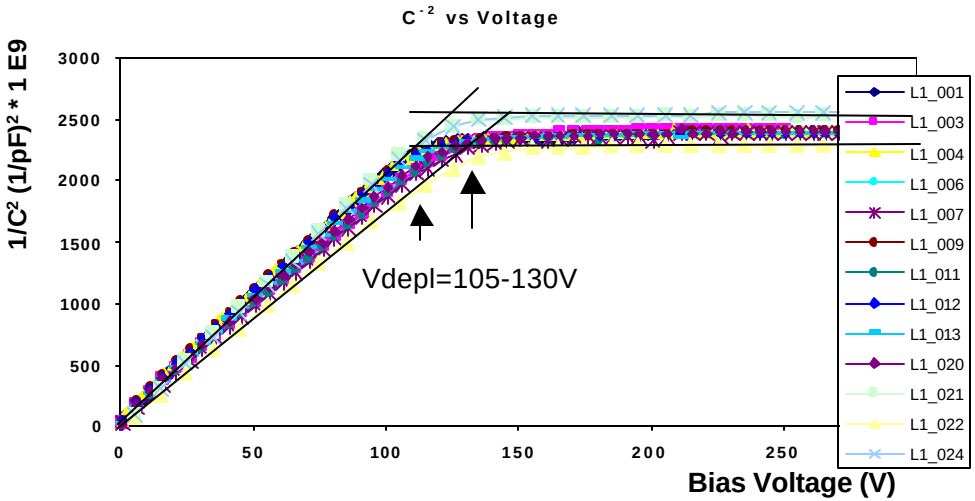
- IV curve for Layer 1 sensors

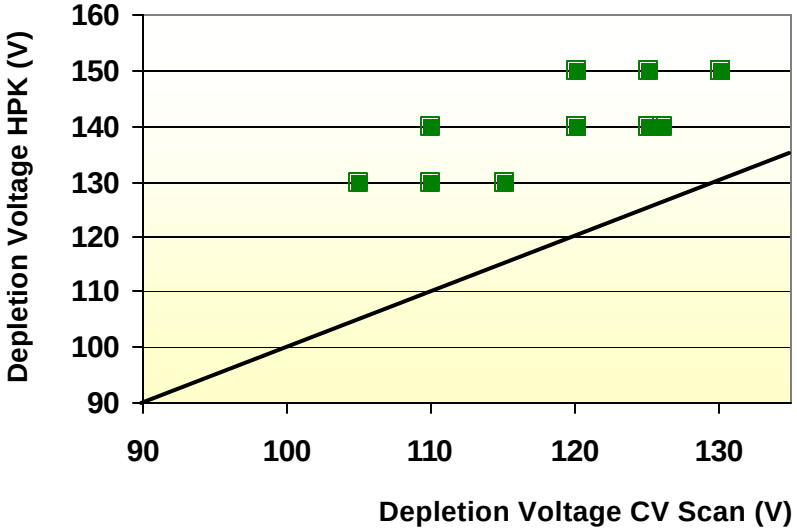


- All sensors (except one) have less than 100nA at U=800V
- sensors have very low current densities of ~0.5 nA/cm^2
- no sensor showed breakdown

Layer 1 Sensor Characteristics

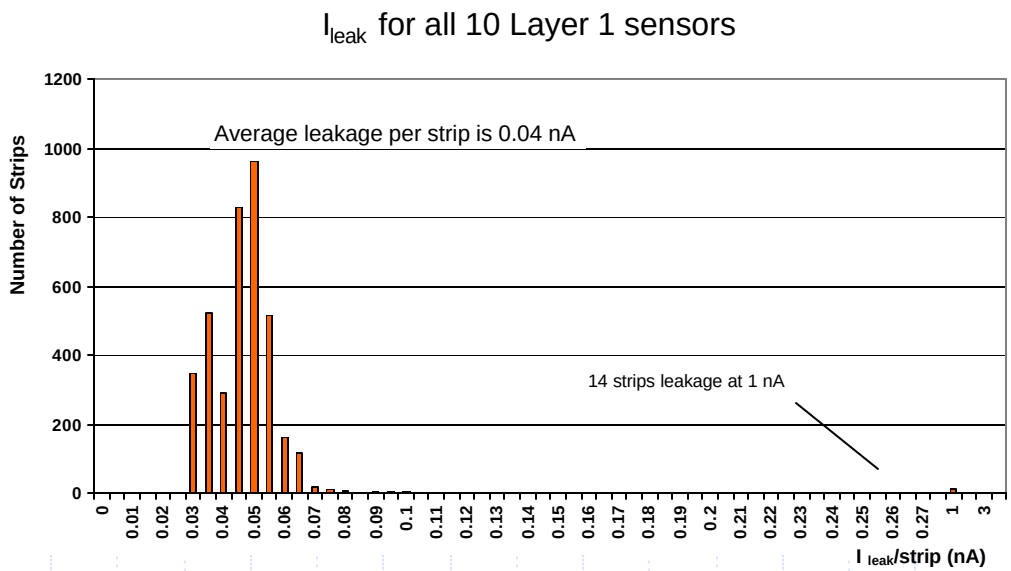
- FDV from $1/C^2$ vs bias
  - FDV is taken at intersection of two straight lines
- HPK used 2%-rule:
  - FDV is taken at the lowest voltage point where change in $1/C^2$ is less than 2%
- Adopted 2% rule at our probing sites
- Requested HPK to send us "raw capacitance" values to cross check our results





Layer 1 Sensor Characteristics

- DC scan on strips
  - average leakage current/strip is 40pA
  - no leaky strips (>10nA) observed
- Use DC scan to also measure poly resistors
  - "intermediate" strips give value for R_poly
  - R/O strips give series of R_poly and R_implant
  - both values are consistent with test structure measurements



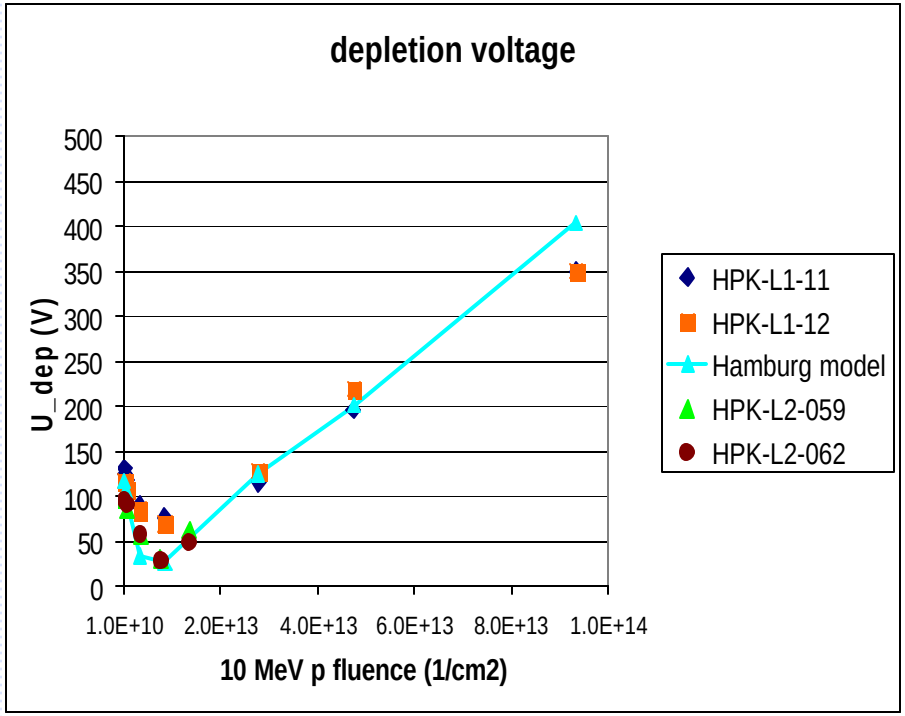
Strip leakage current for all strips of 10 L1 sensors

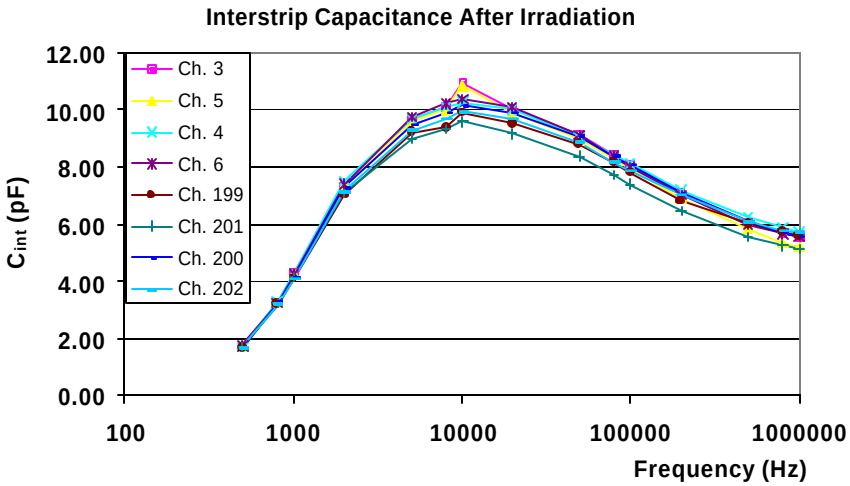
Layer 1 Sensor Characteristics

- Wafer warp relaxed to 100 μm
- Parametrization of wafer warp as quadratic function: $\Delta z = a * L^2$
  - Run 2b Outer Layers:
    - $a = 0.22\ 10^{-4}$ /mm (long axis)
    - $a = 0.28\ 10^{-4}$ / mm (short axis)
  - Run 2b Layer 1:
    - $a = 0.25\ 10^{-4}$ /mm (long axis)
    - $a = 0.28\ 10^{-4}$ / mm (short axis)
- So, expect for 120mm long sensors an average warp of 90 μm

Layer 1 Sensor Characteristics

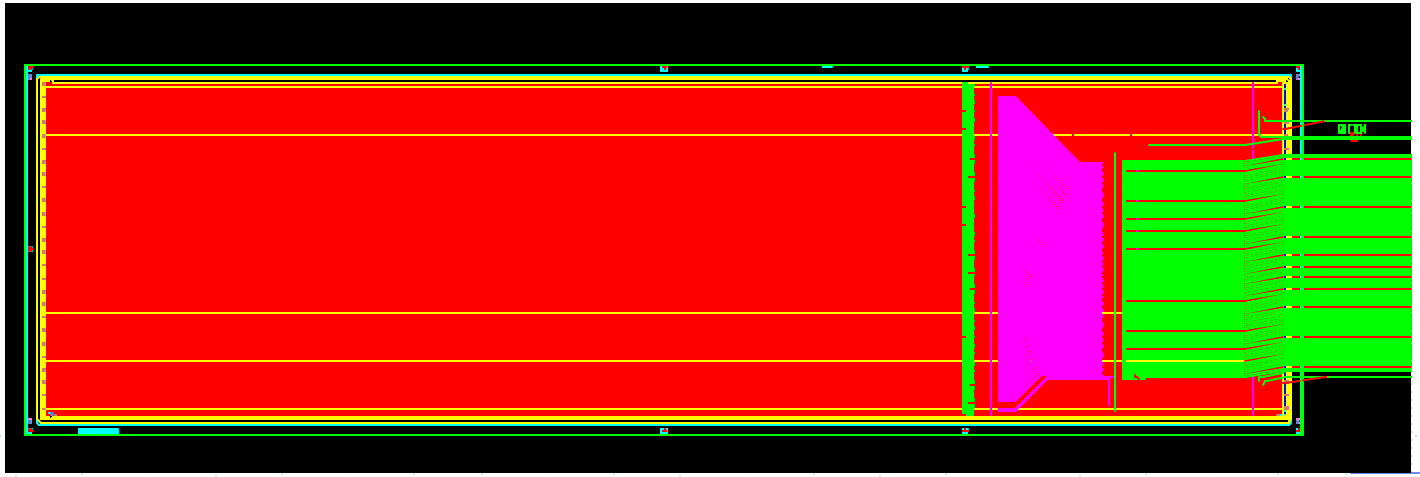
- Fluence of about 4 10^{13} 10 MeV p/cm^2 equivalent to 9 fb^{-1} at r=18 mm
  - Depletion voltage close to 200 V, Ileak < 1 mA
  - C_{int}(after Irradiation) = 2 * C_{int} = 6 pF





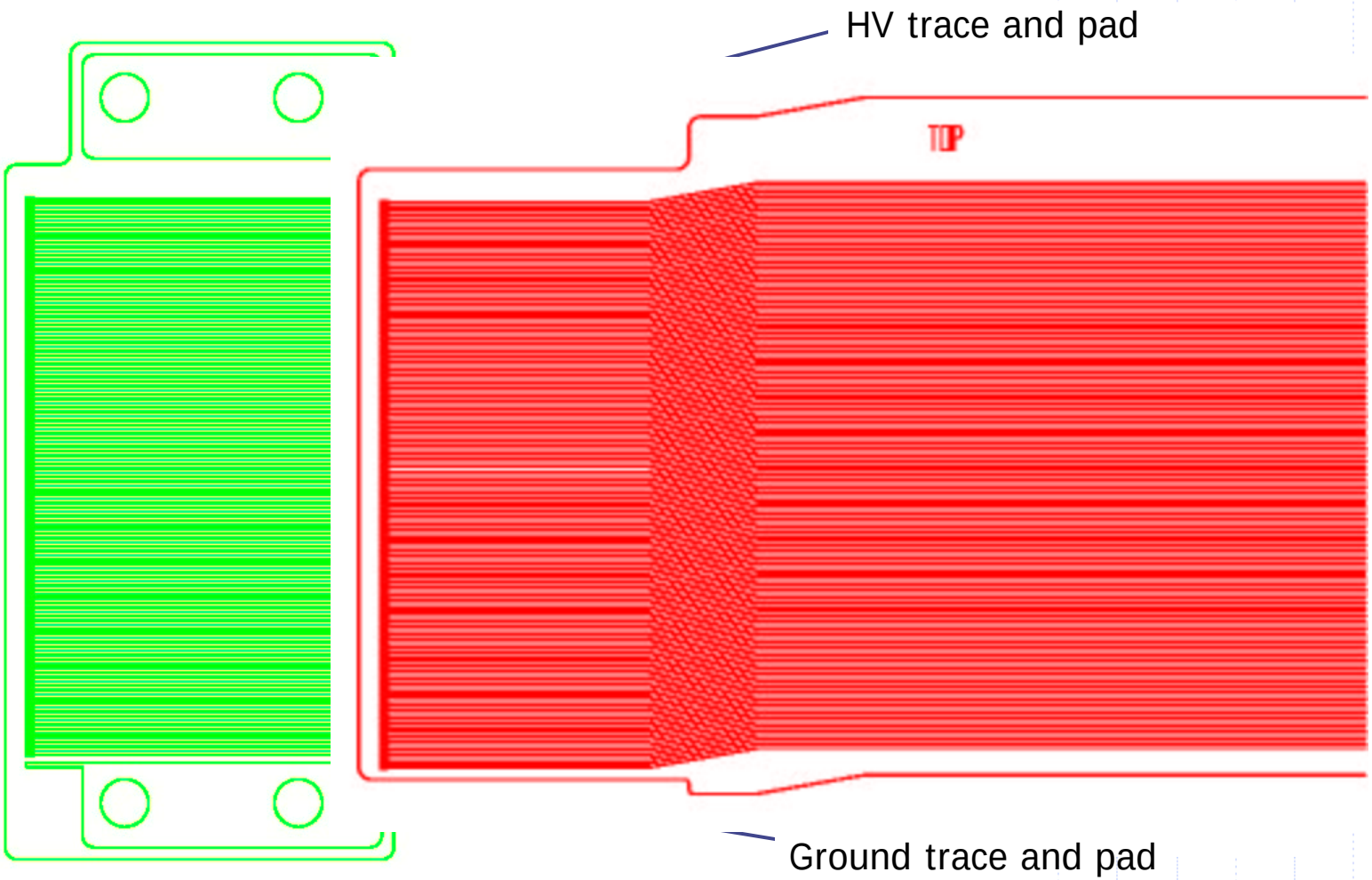
Sensor Design

- Strip and bond pad layout governed by mechanical constraints
- Notable differences from the Run2b Layer 0 detector:
  - Pitch Adapter
    - Strip pitch of 71 / 81 μm, compared with pitch of 48 μm of SVX4
    - Eliminates the need for a separate filter card.
    - Eliminates the need for a separate substrate for the first analog cable that is needed for microbonding.
    - Facilitates microbonding from the pitch adapter to the sensor
  - Bias and Ground connections to sensor
    - Bias to Sensor and ground for Carbon fiber support is provided through flexible Kapton layer circuit
      - » Run2b used filter card

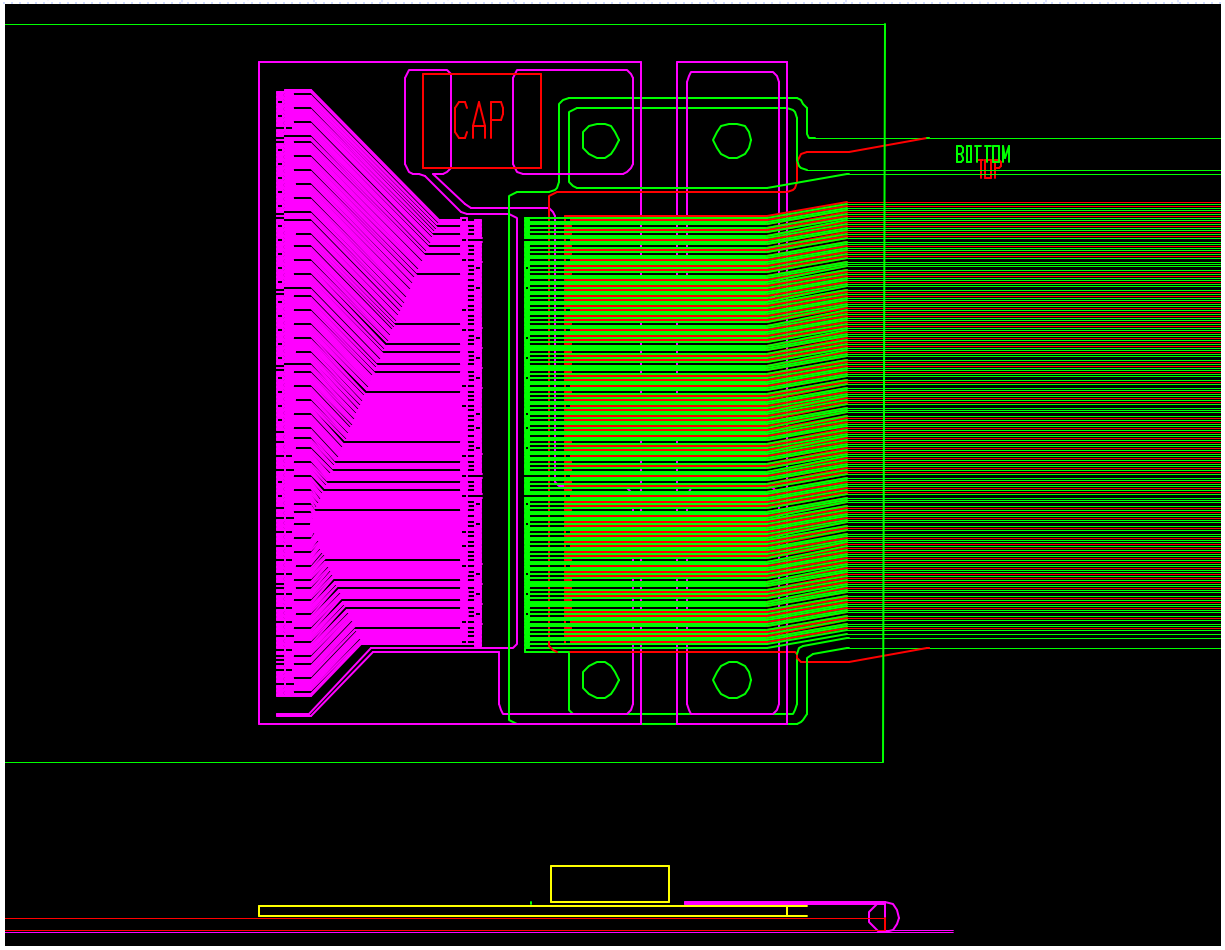


Analogue Cable

- Ground and Bias traces on analogue cable



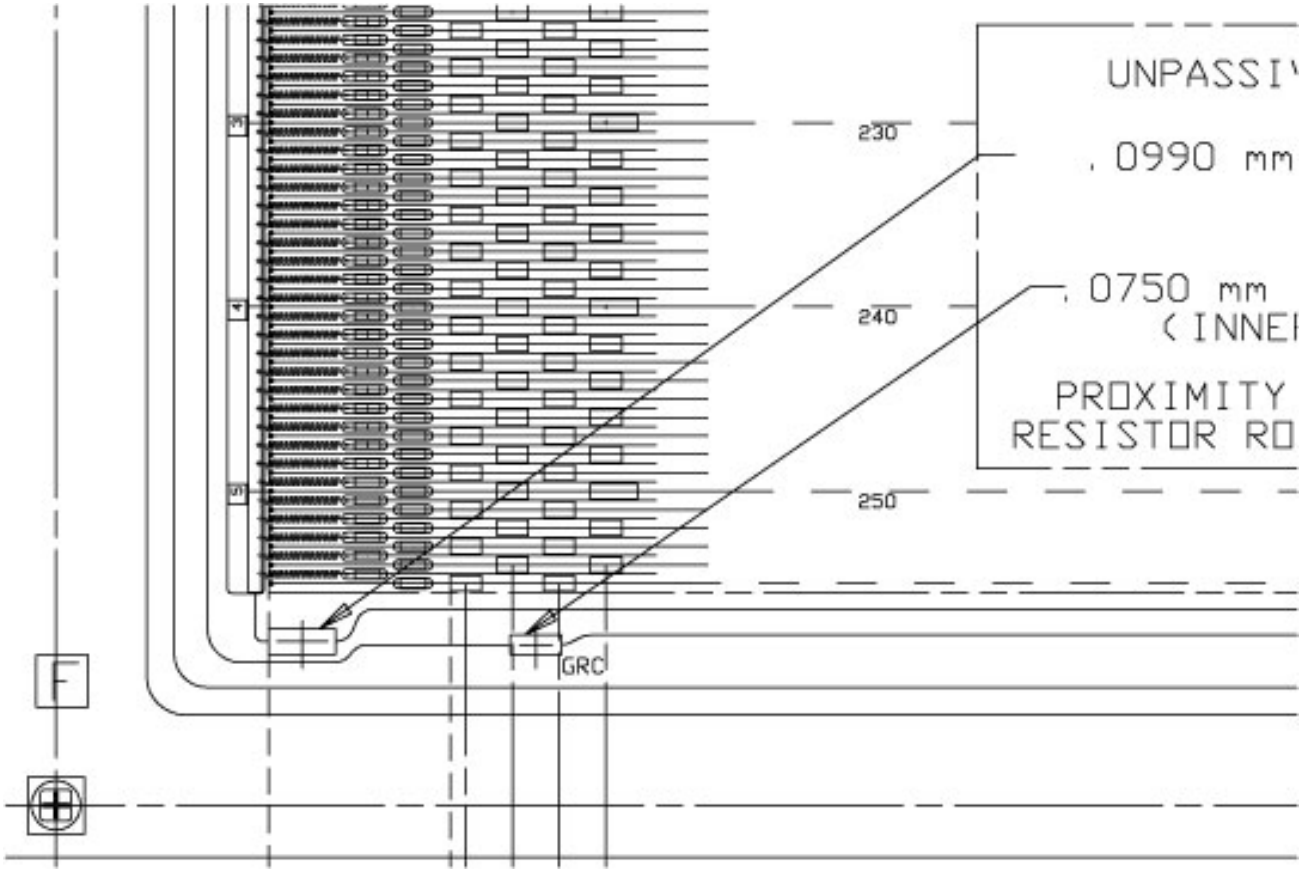
Pitch Adapter



- Bypassing for bias
- Provides connection for bias and ground under analogue cable

Sensor Design

- Sensor design completed



- Four drawings: 3823.210-ME-434043 / -434045 / -434055 / -434056

Vendor, Cost and Procurement

- Only one vendor approached: ? ?
- Initial quote from ? ?
  - two sensor lengths and two pitches
    - 4,800,000 ¥ = NRE
    - 40,000 ¥ = sensor a piece
  - Total anticipated cost about $96,000
  - All money provided from MRI through Stony Brook
    - Currently ~ $98,000 available at Stony Brook
- Sensors will be ordered in one batch; no prototyping foreseen
  - Expect high quality sensors from ? ?
    - Defect level for Layer 1 sensors was at the the 1‰ level !
  - Time scale of project does not allow for multiple rounds of prototyping

Conclusions

- Sensor design complete
- Sensor specifications complete
  - Sensor specifications all met for Layer 1 prototype sensors
- We're ready to place the order