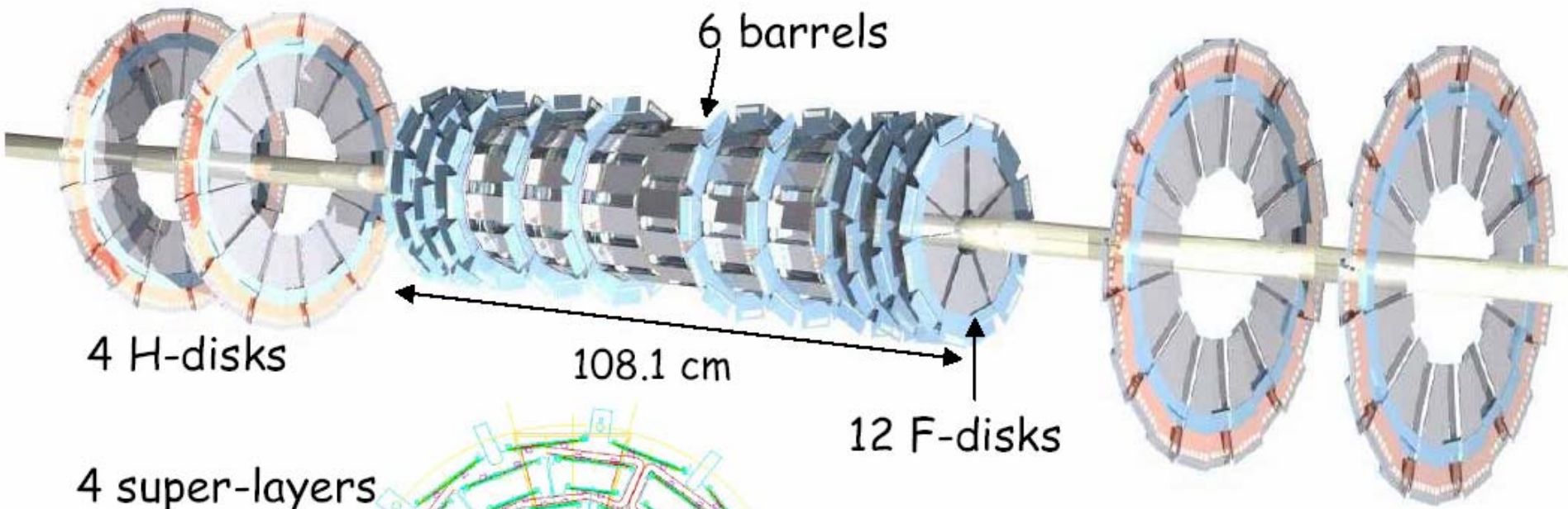
A New Inner-Layer Silicon Micro-Strip Detector for D0

Alice Bean for the D0 Collaboration

University of Kansas

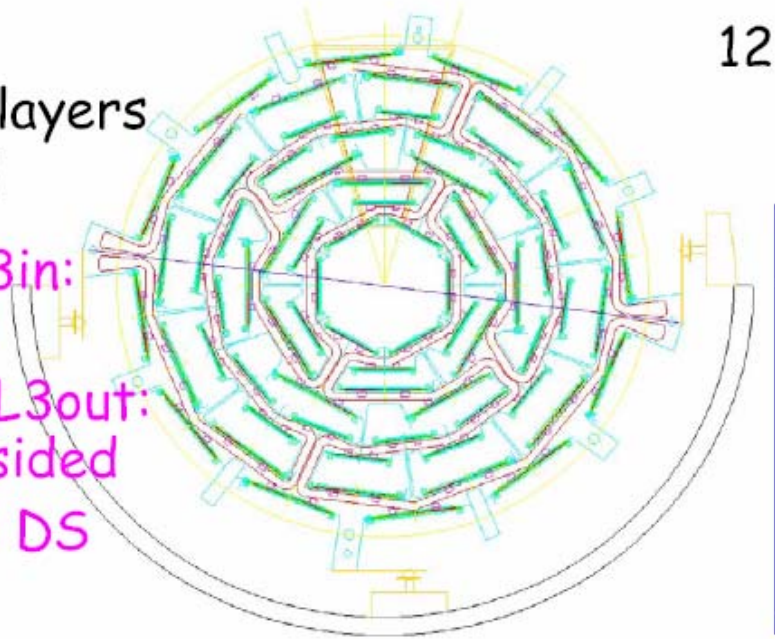
CIPANP 2006 @ Puerto Rico

D0 Silicon Microstrip Tracker



4 super-layers in barrel

- L1in, L3in: DSDM
- L1out, L3out: single sided
- L2, L4: DS



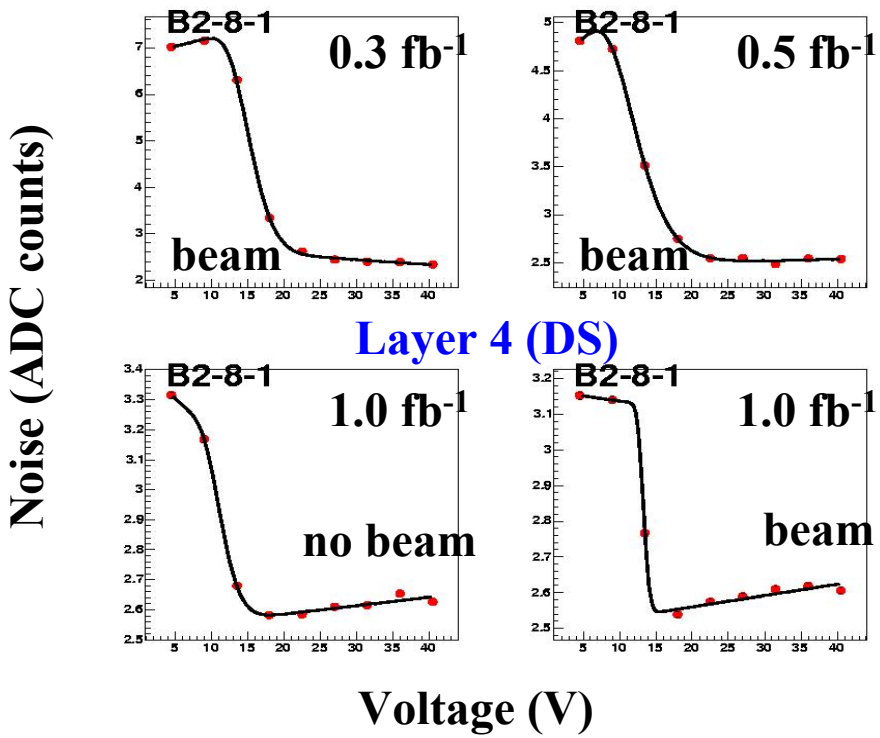
	Barrels	F-Disks	H-Disks
Channels	387072	258048	147456
Modules	432	144	96
Si Area	1.3 m^2	0.4 m^2	1.3 m^2
Inner R	2.7 cm	2.6 cm	9.5 cm
Outer R	9.4 cm	10.5 cm	26 cm

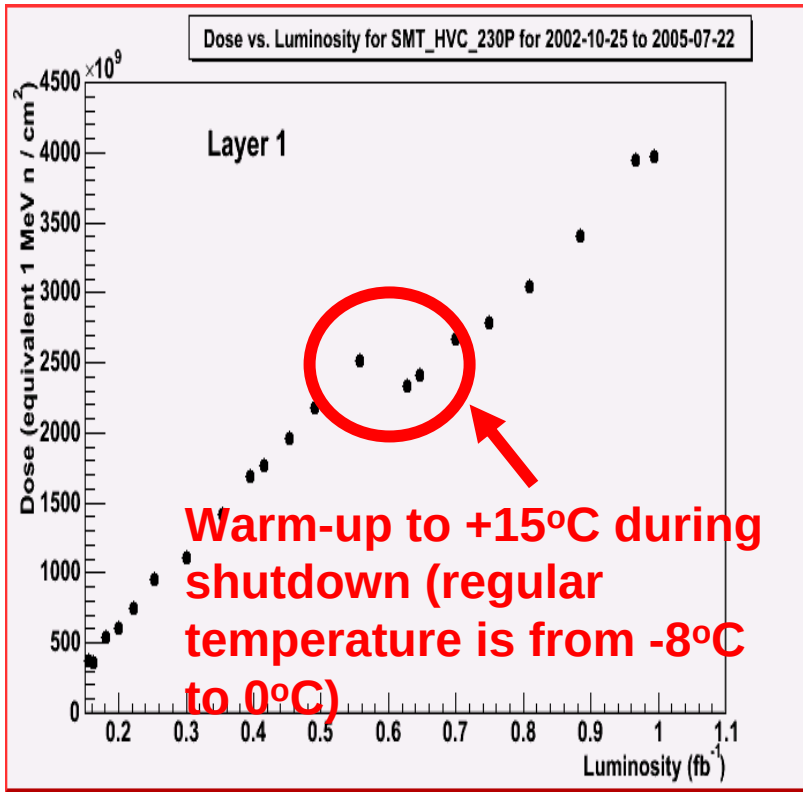
In use since 2001, designed for 2fb^{-1}

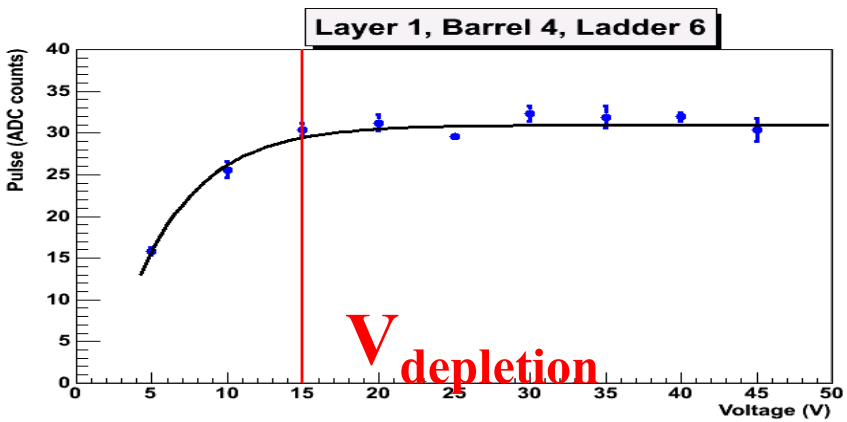
Radiation Damage after 1 fb^{-1} of data

Bulk Damage Studied using

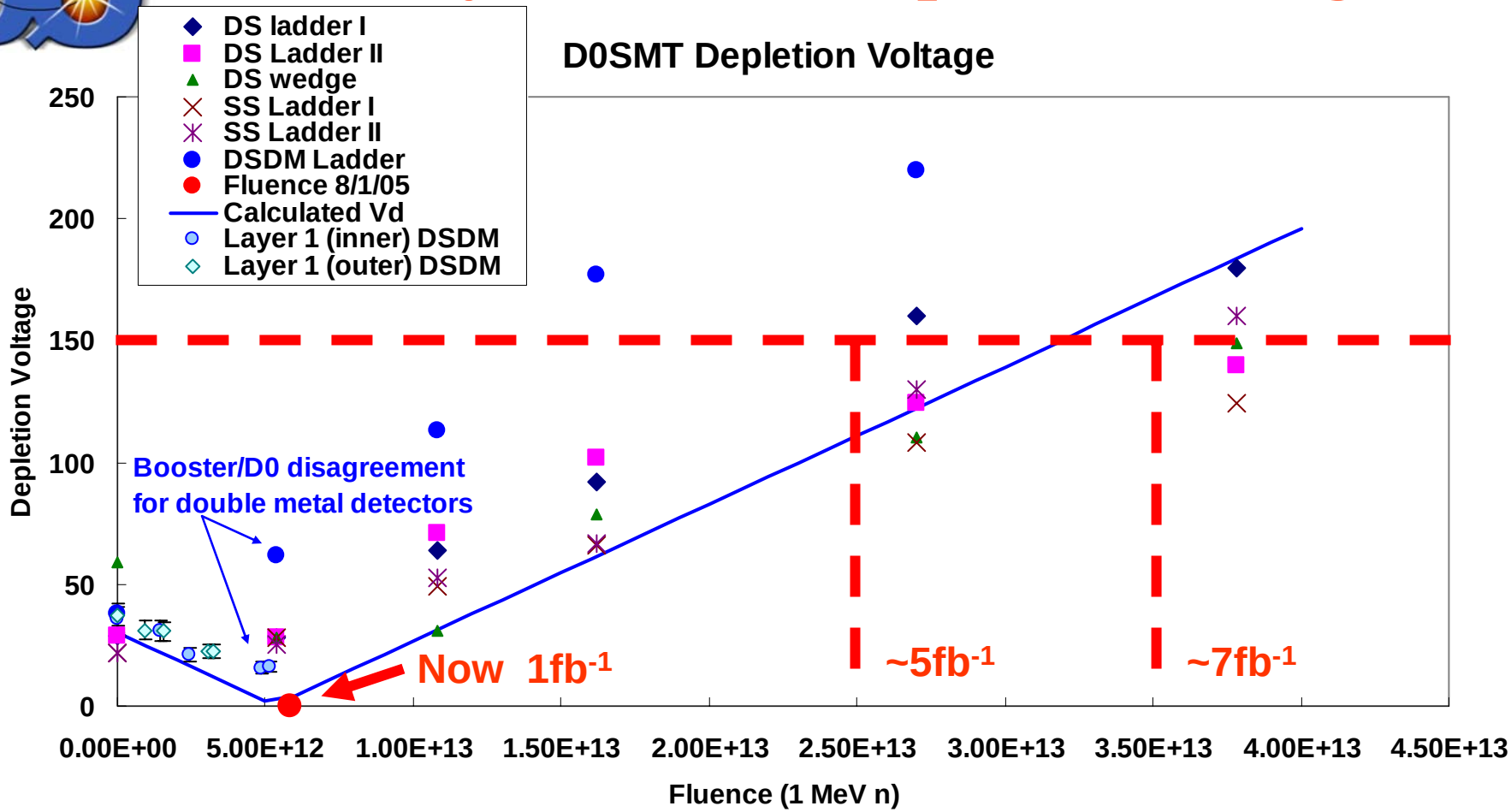
- Bias Current
- Depletion Voltage
  - ✓ Noise at n-side
  - ✓ Charge Collection Efficiency







Projections for Depletion Voltage

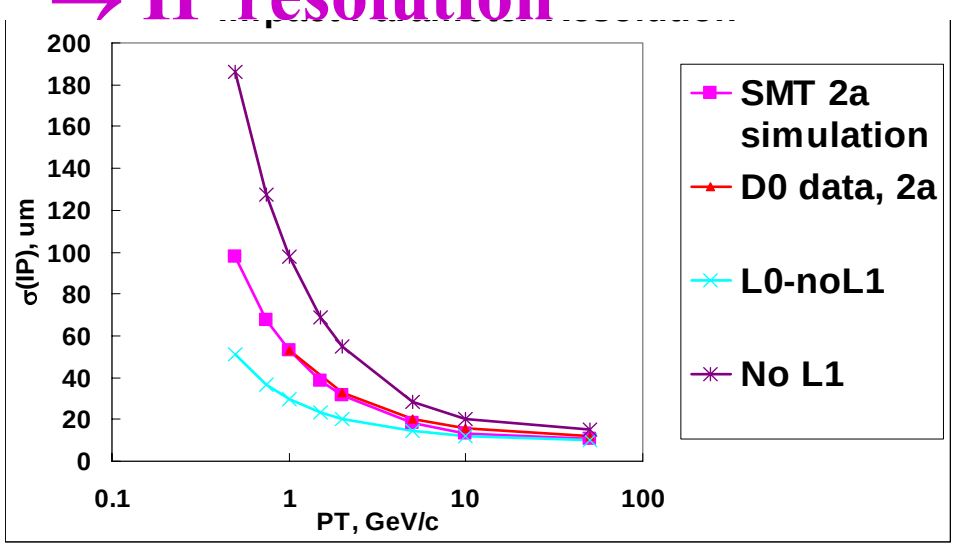


Behavior of depletion voltage for DSDM sensors agrees with the booster measurements of DS ladders → bulk damage is the same

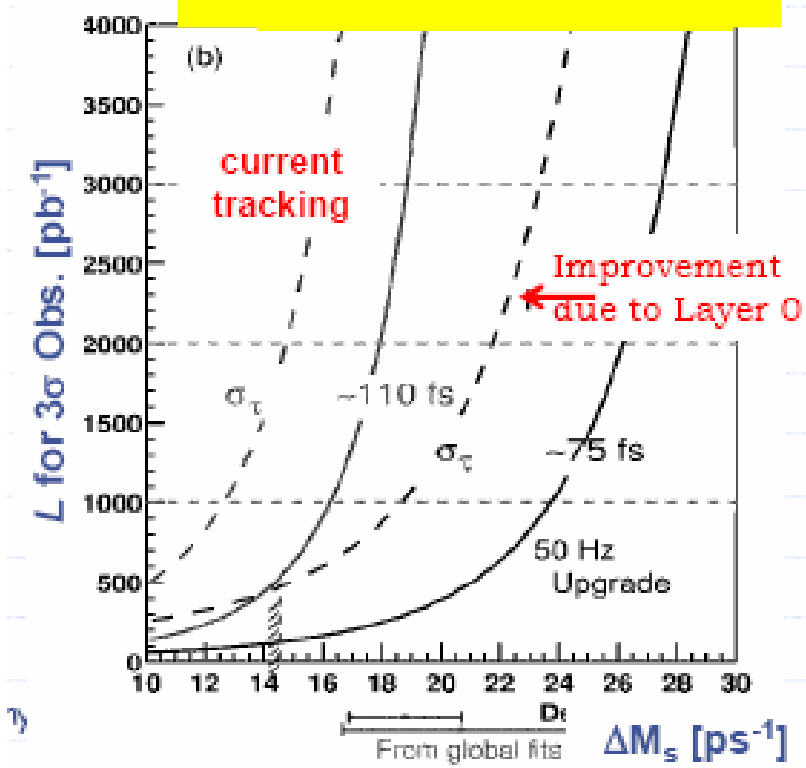
$V_{depletion} \sim V_{max} = 150V$ at delivered luminosity 5—7 fb^{-1}

A new inner layer – Layer 0

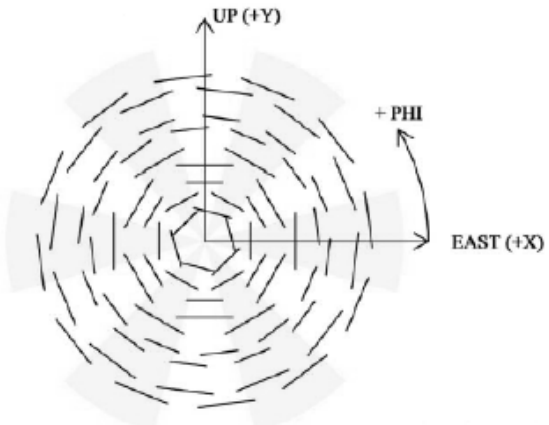
- Will mitigate degradation of performance for SMT inner layers after 3-4 fb-1
- Replacement tracker (RunIIb) cancelled
- Will improve
  - → Proper Time res. (→75fs)
  - → b-Tagging eff. (~15%)
  - → IP resolution



Bs Mixing Sensitivity

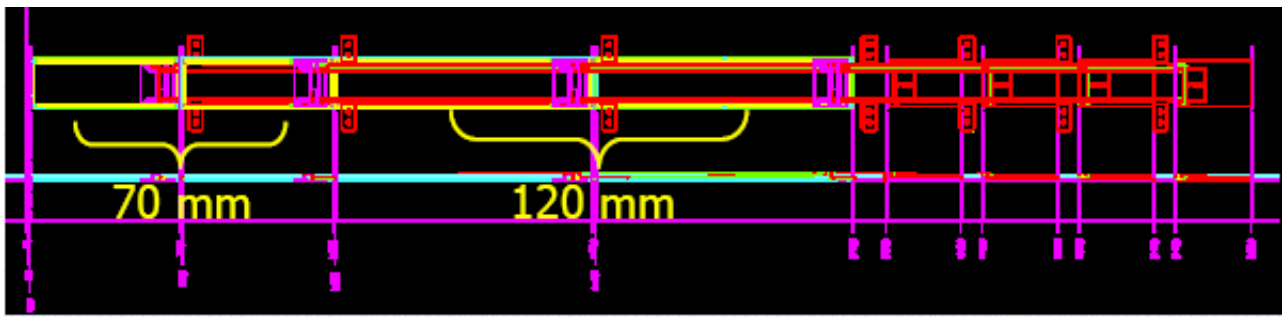


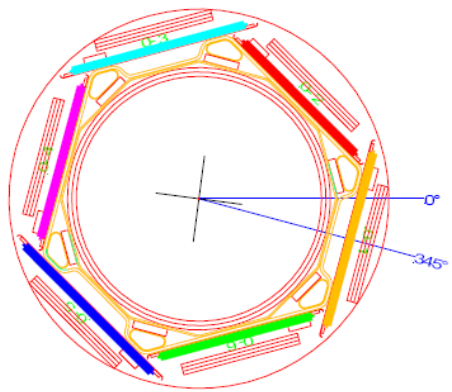
D0 Layer 0 Design



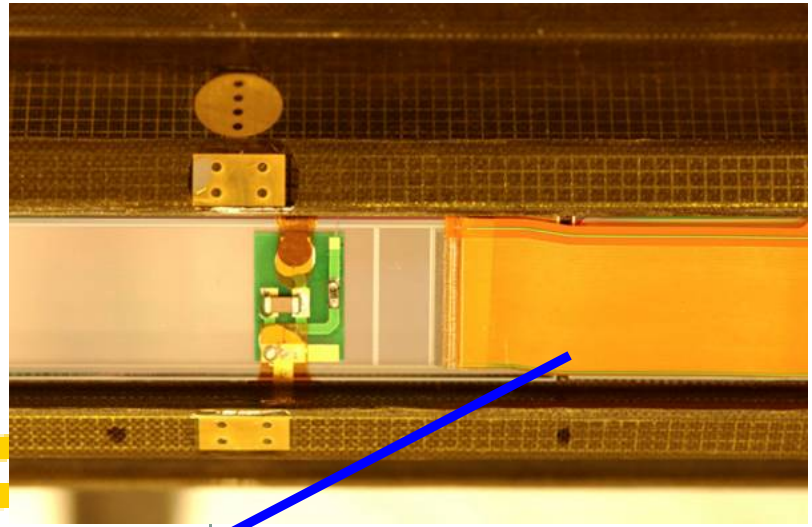
- Radius 1.6cm
- Tight clearance (15mm)
- Carbon Fiber support structure
- 48 modules (256 readout channels)

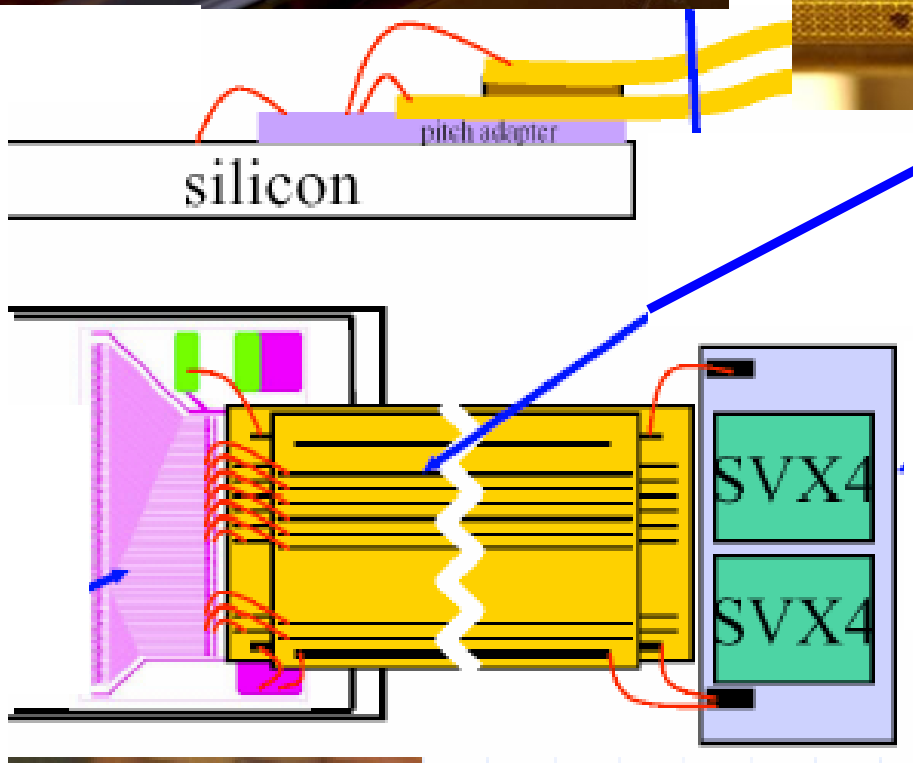
  6 ϕ-segments, 8 z-segments of 2 lengths (7cm and 12cm)
- Hybrids with SVX4 readout chip (0.25 μm) located outside interaction region necessitating low mass analog cables to bring signals from sensors

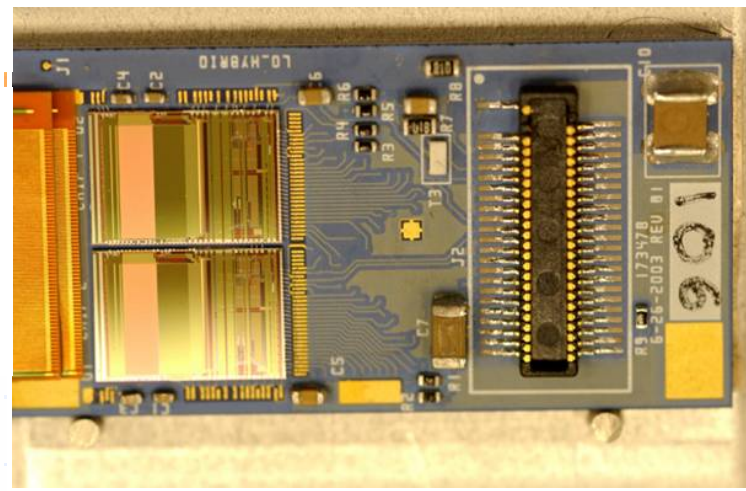




Module assembly

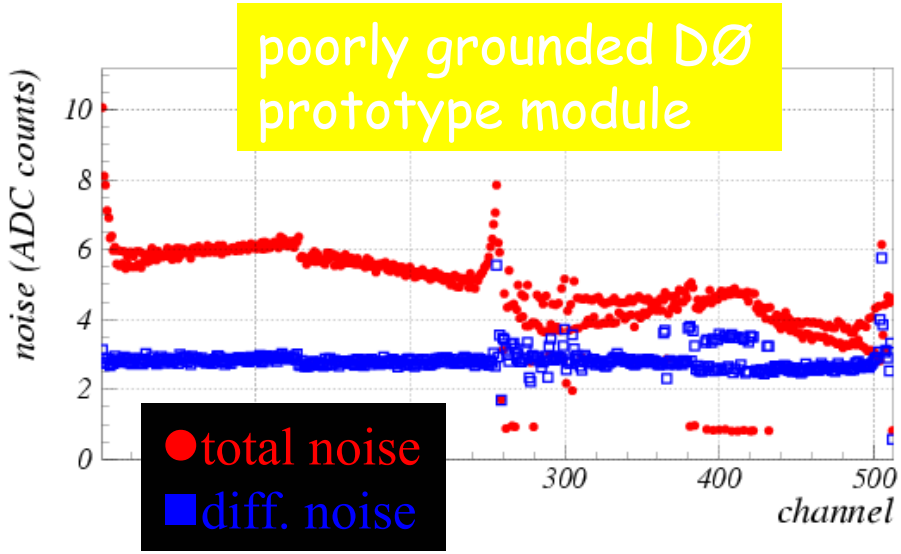


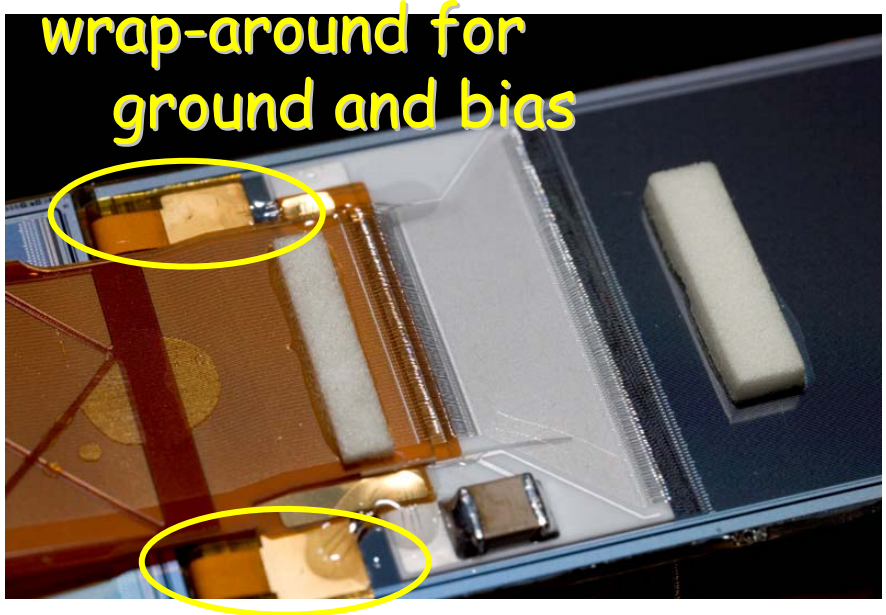


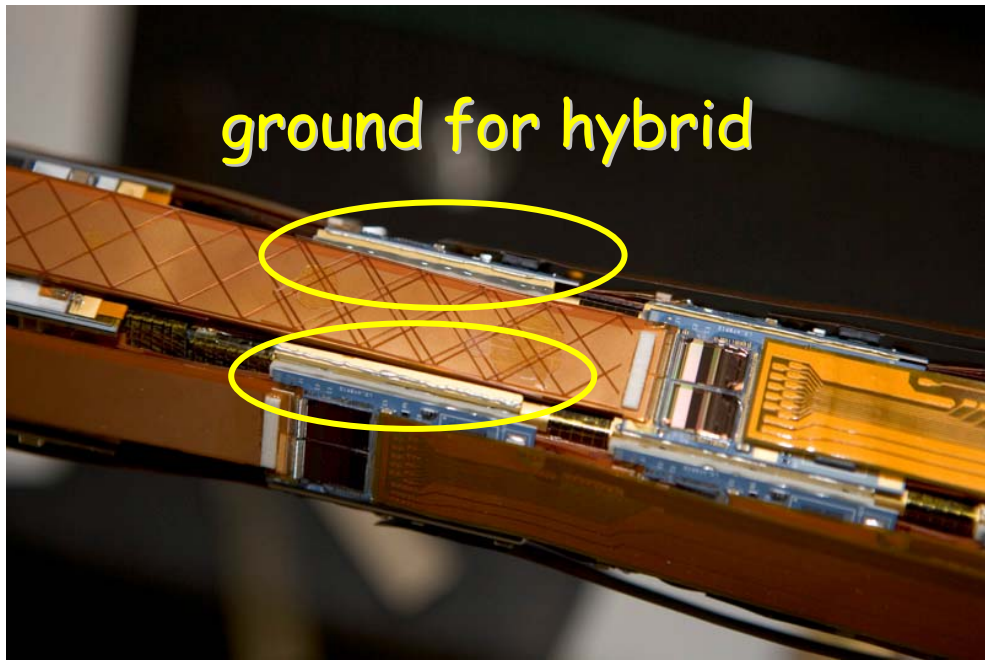


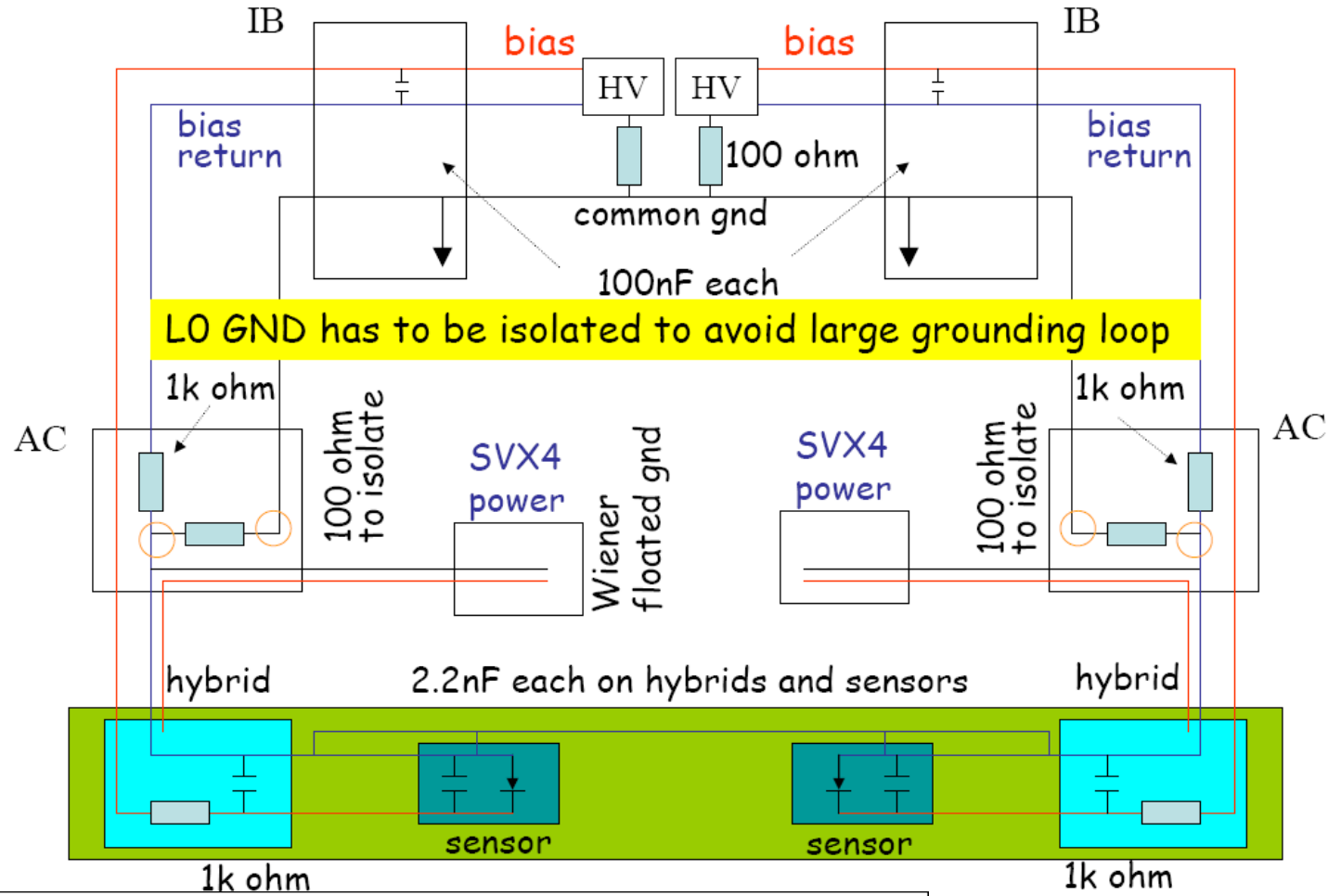
Big Challenge - NOISE

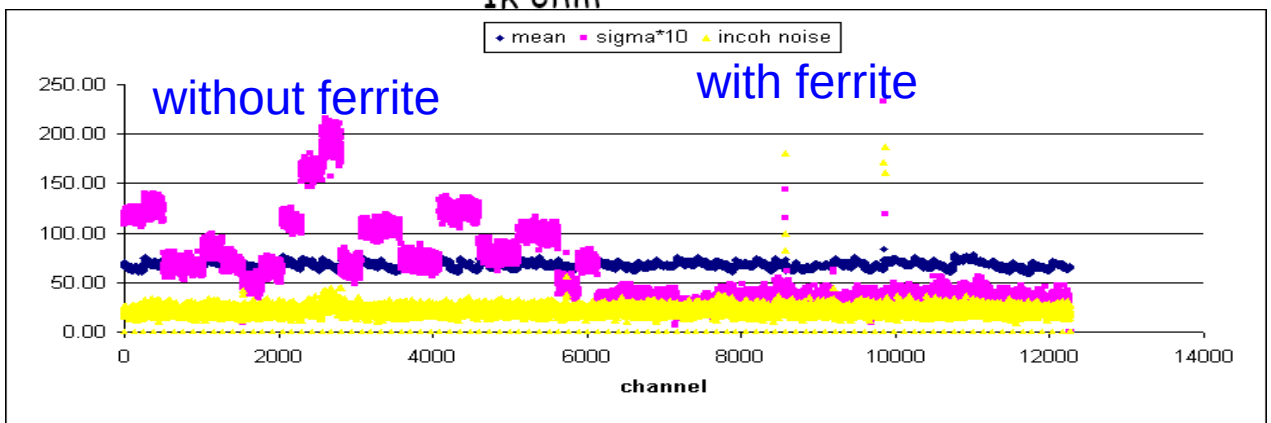
- Grounding scheme (Carbon fiber is conductor)
- Spacing between analog cables







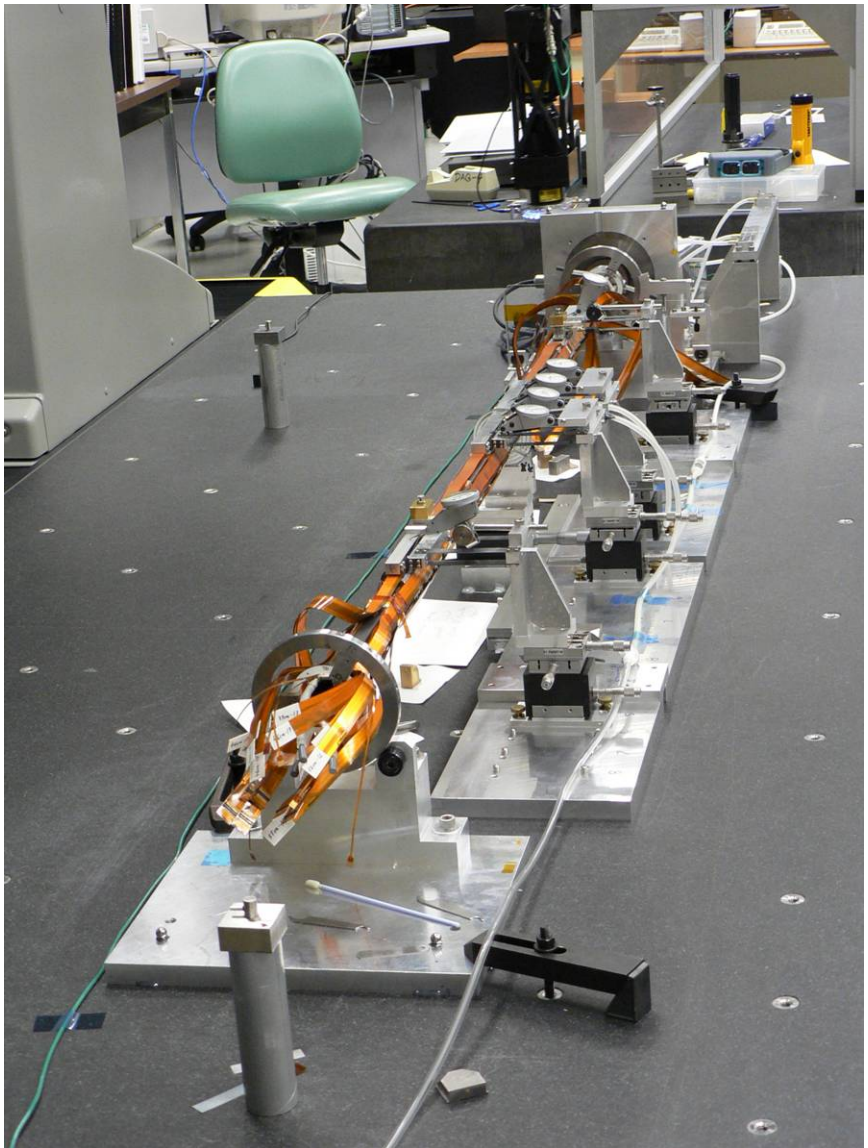


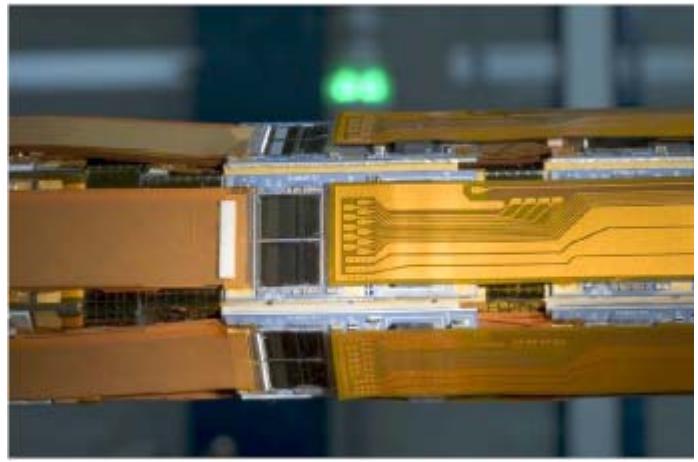


Filter power lines

- pedestal
- total noise ×10
- diff. noise ×10

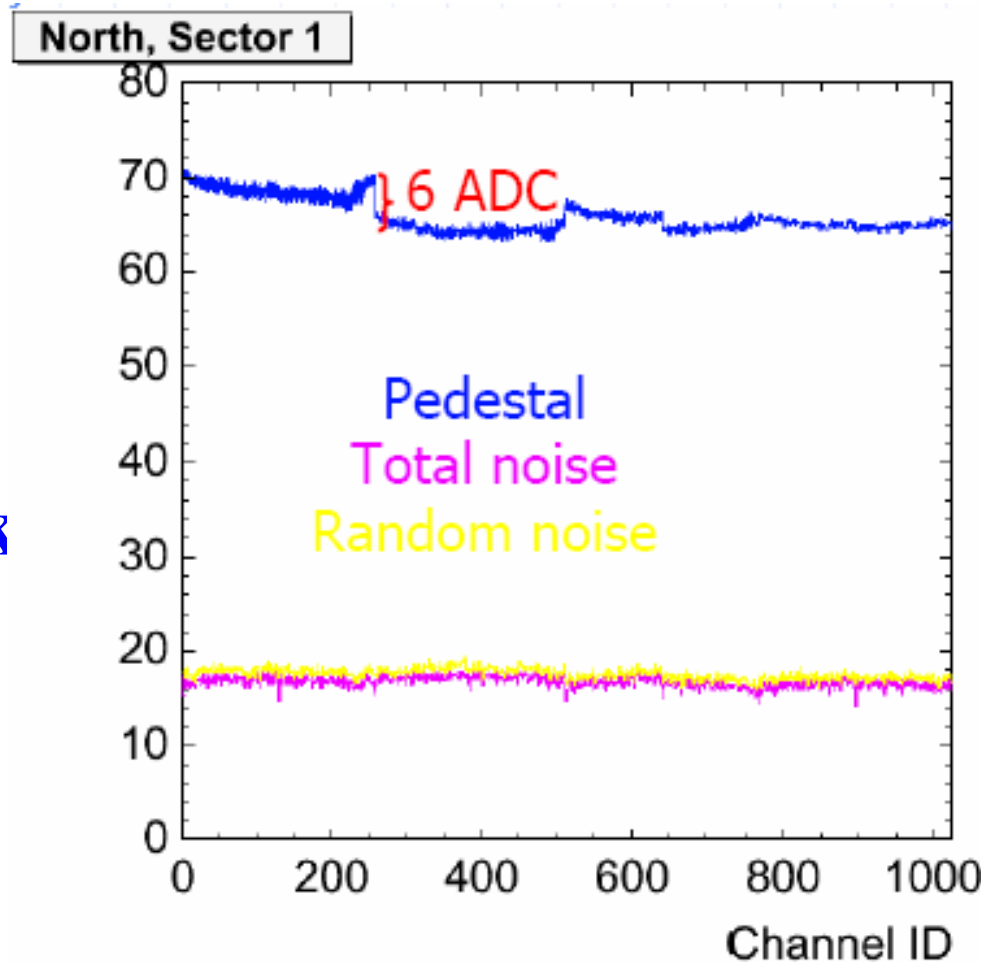
Layer 0 Detector is completed and installed into D0 in April 2006





Performance

- Outstanding noise performance
  - ~1.7 ADC
  - S/N ~ 18
- Pedestal peak-to-peak difference of 4-5 ADC counts acceptable
- Very few bad channels ~0.15%

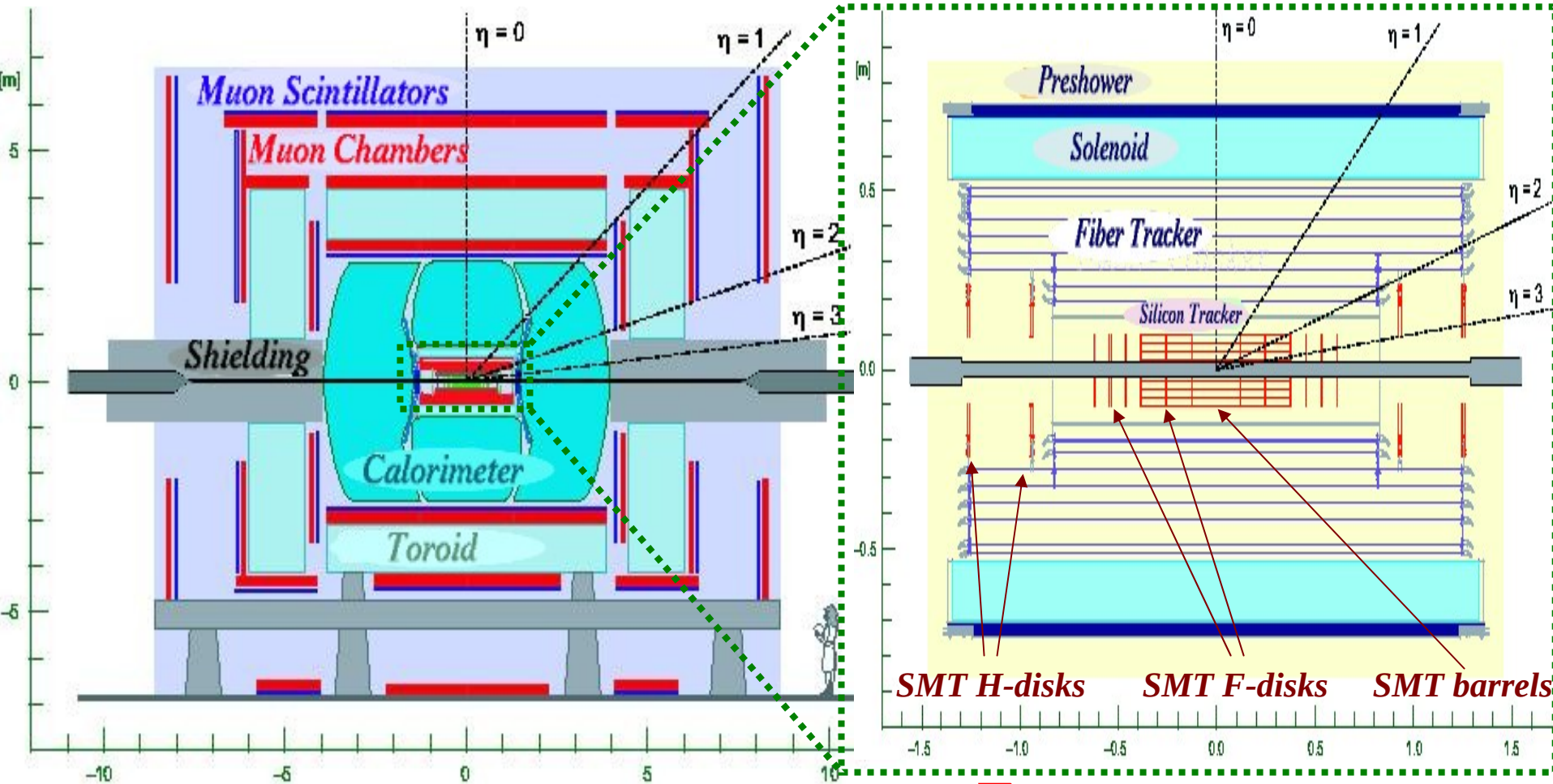


Conclusions

- Radiation Damage studies for SMT detector indicate it can be depleted up to 5-7 fb^{-1}
- Inner layer of Silicon called Layer 0 will improved tracking
- Layer 0 is built and installed
  - Excellent noise performance
  - Very few bad channels
  - Error free readout

Backup Slides

DZero Detector

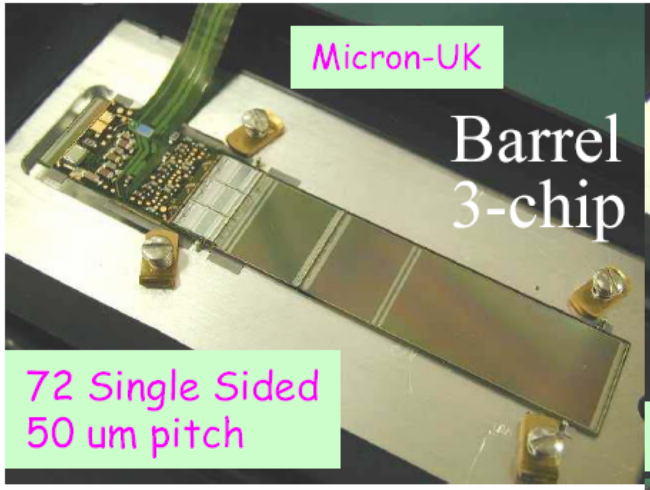


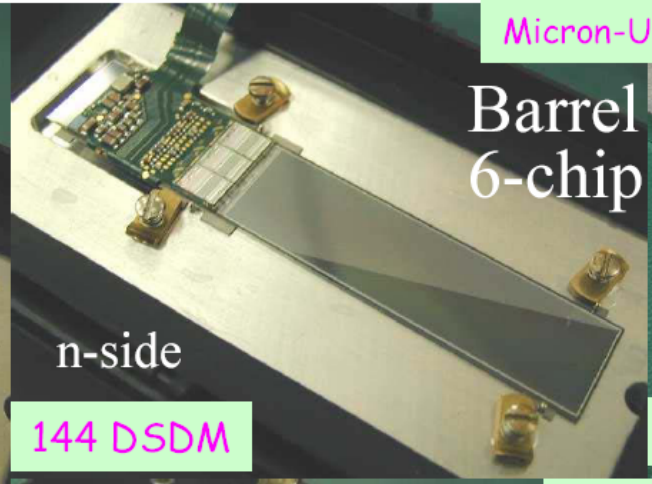
Muon system with coverage |η|<2 and good shielding

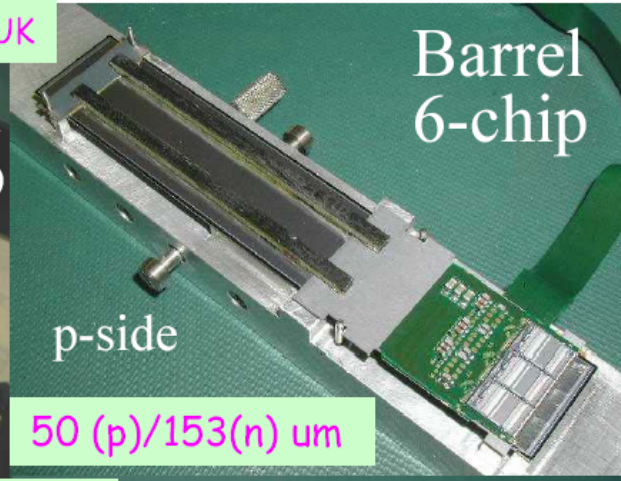
- **Trackers**
  - Silicon Tracker: |η|<3
  - Fiber Tracker: |η|<2
- **Magnetic field 2T**

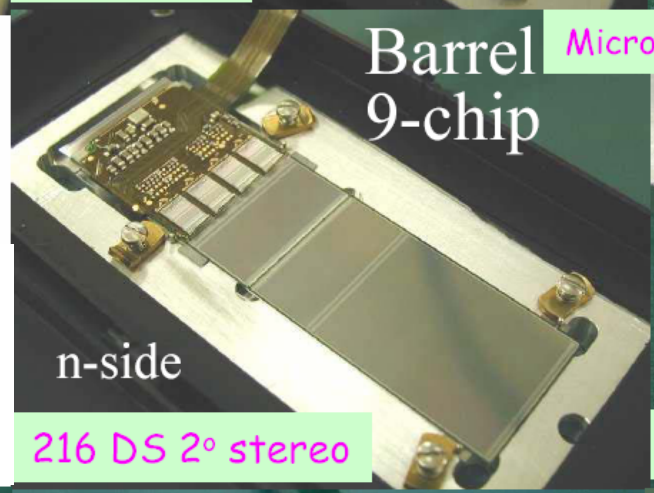
Various types of detectors

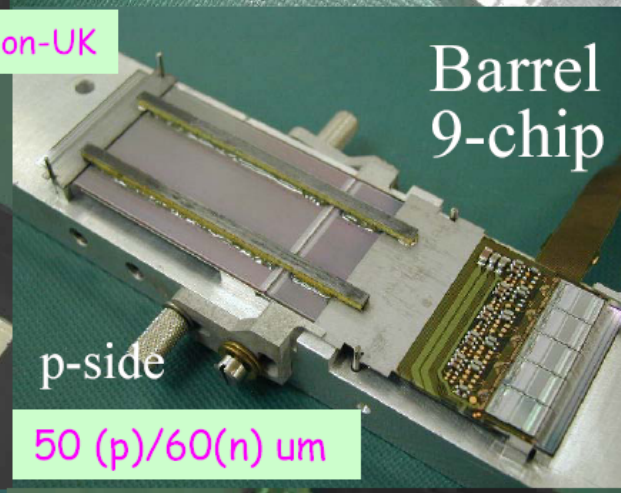
SVXIIe Readout

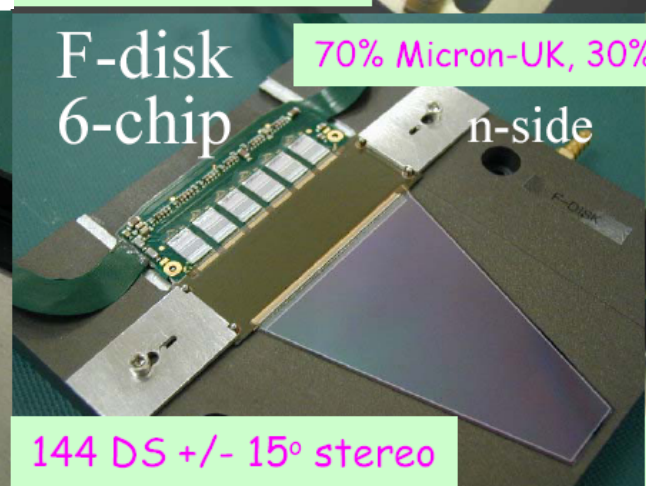


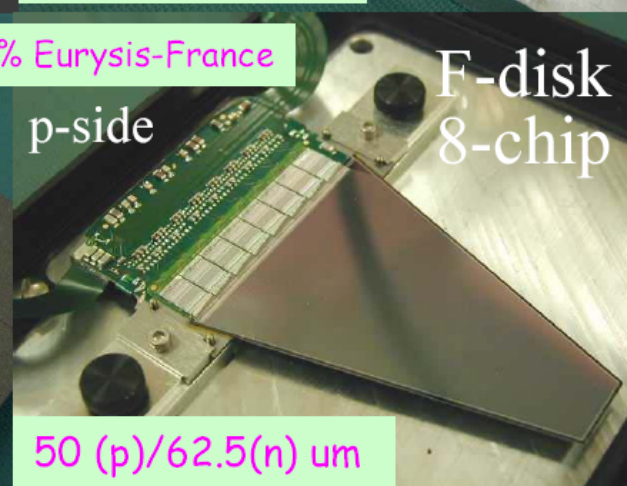




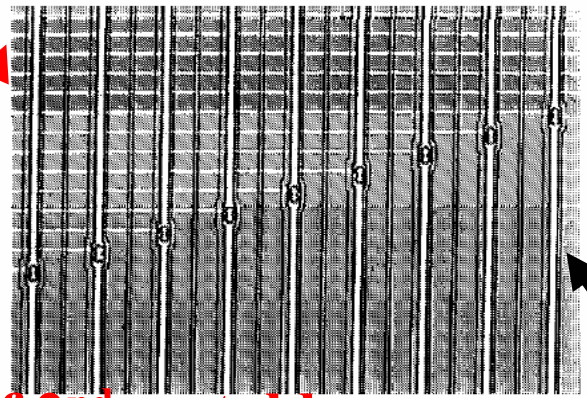


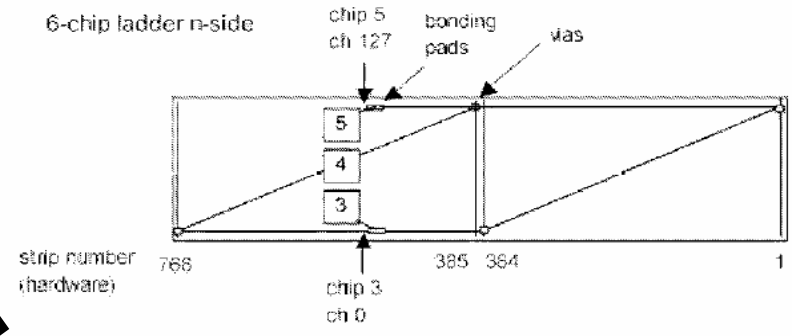






Why the DSDM detectors are special?





traces of 2nd metal layer

n^+-implant strips

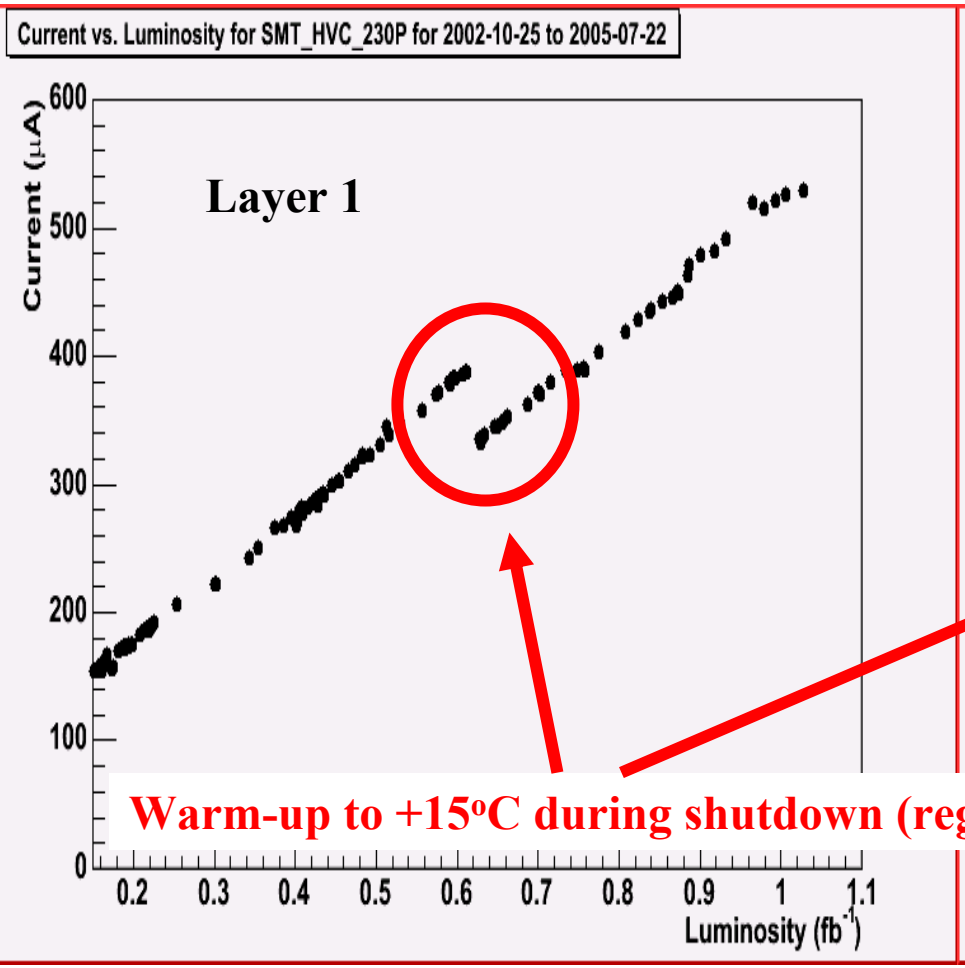
Figure 1: Left: Close-up of strips of the n-side of the 90°-sensor. Right: The sketch indicates the multiplexing schema on the n-side. The 1st ($2^{nd} \ldots 384th$) strip on the right end is connected to the 385th ($386th \ldots 768th$) strip through the double metal layer.

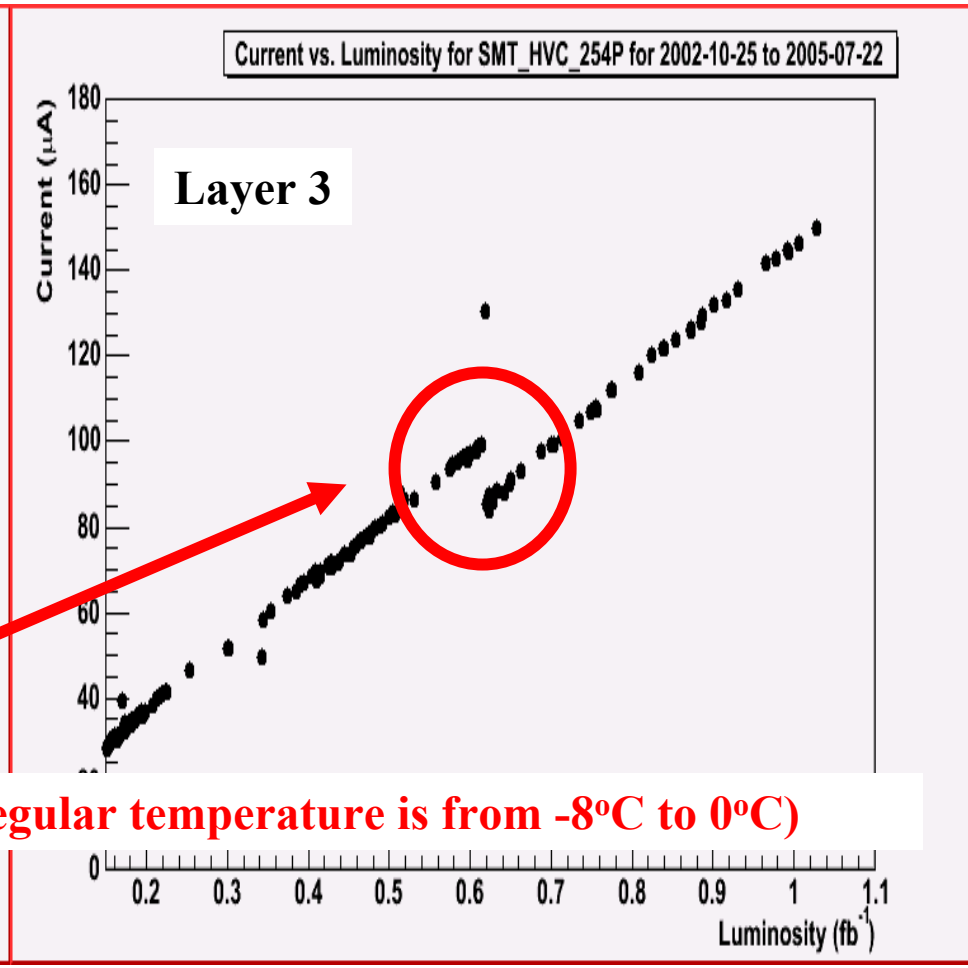
90° n-side

The 2nd metal layer is insulated from the 1st layer by a ~3μm thick layer of PECVD (Plasma Enhanced Chemical Vapor Deposition)

Expect the PECVD layer to be very sensitive to the radiation

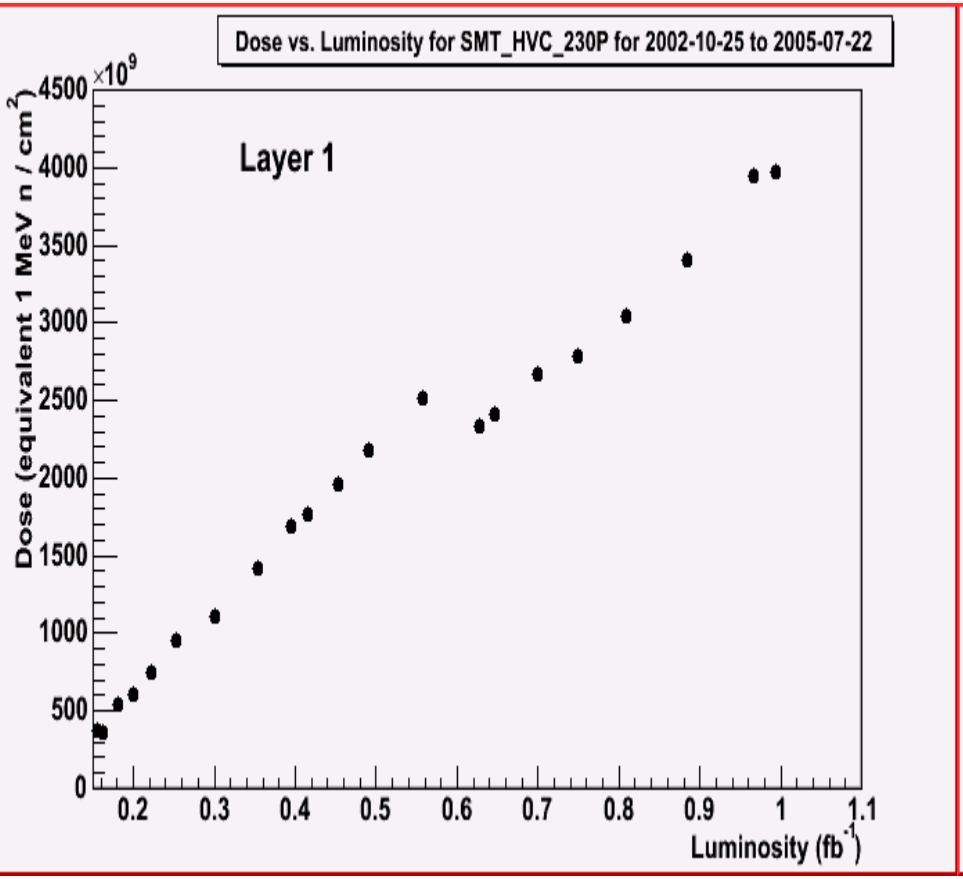
Dependence of Bias Current on Delivered Luminosity

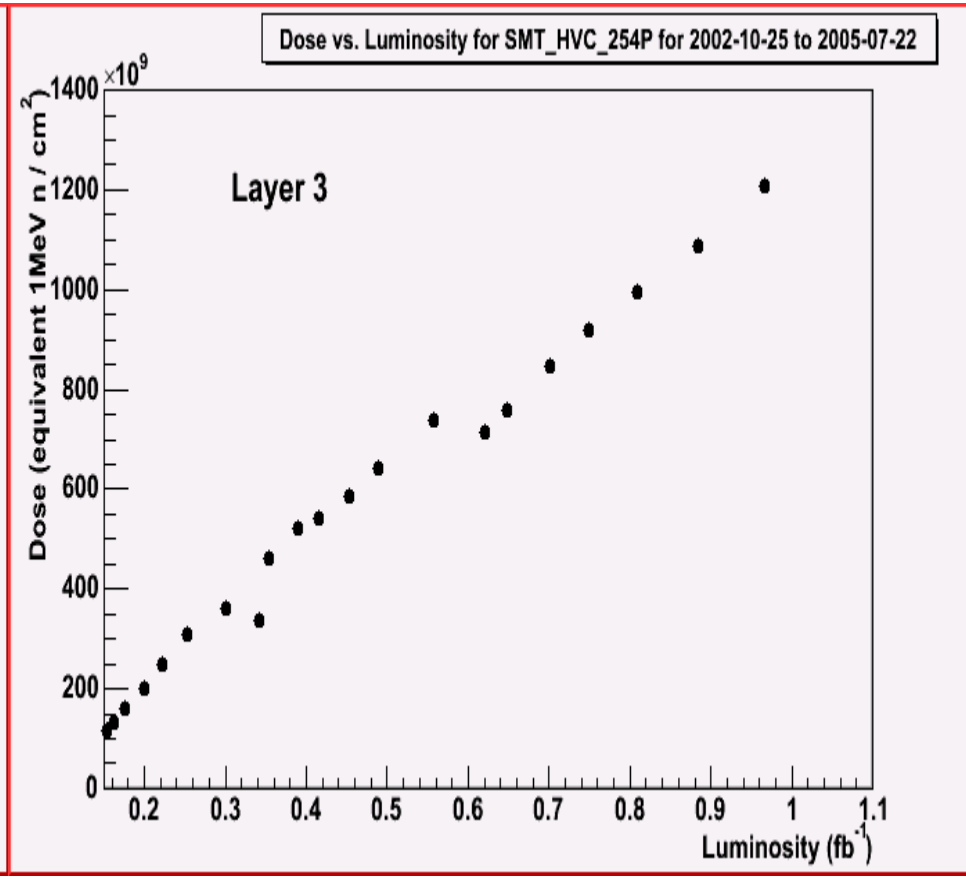




Warm-up to +15°C during shutdown (regular temperature is from -8°C to 0°C)

Estimate of the Radiation Dose





Description of annealing processes could be tuned using these data

Estimation of Damage Parameter

The evolution of α with time after irradiation

$$\alpha = \sum_i a_i e^{-\frac{t}{\tau_i}}$$

The τ_i depend on temperature

Scaling time with

$$\Theta(T) = \exp\left(\frac{E_I}{k_B}\left(\frac{1}{T_R} - \frac{1}{T}\right)\right)$$

E_I=1.09 eV and T_R=20°C

Finally

$$\alpha = \sum_i a_i e^{-\frac{\Theta(T)t}{\tau_i}}$$

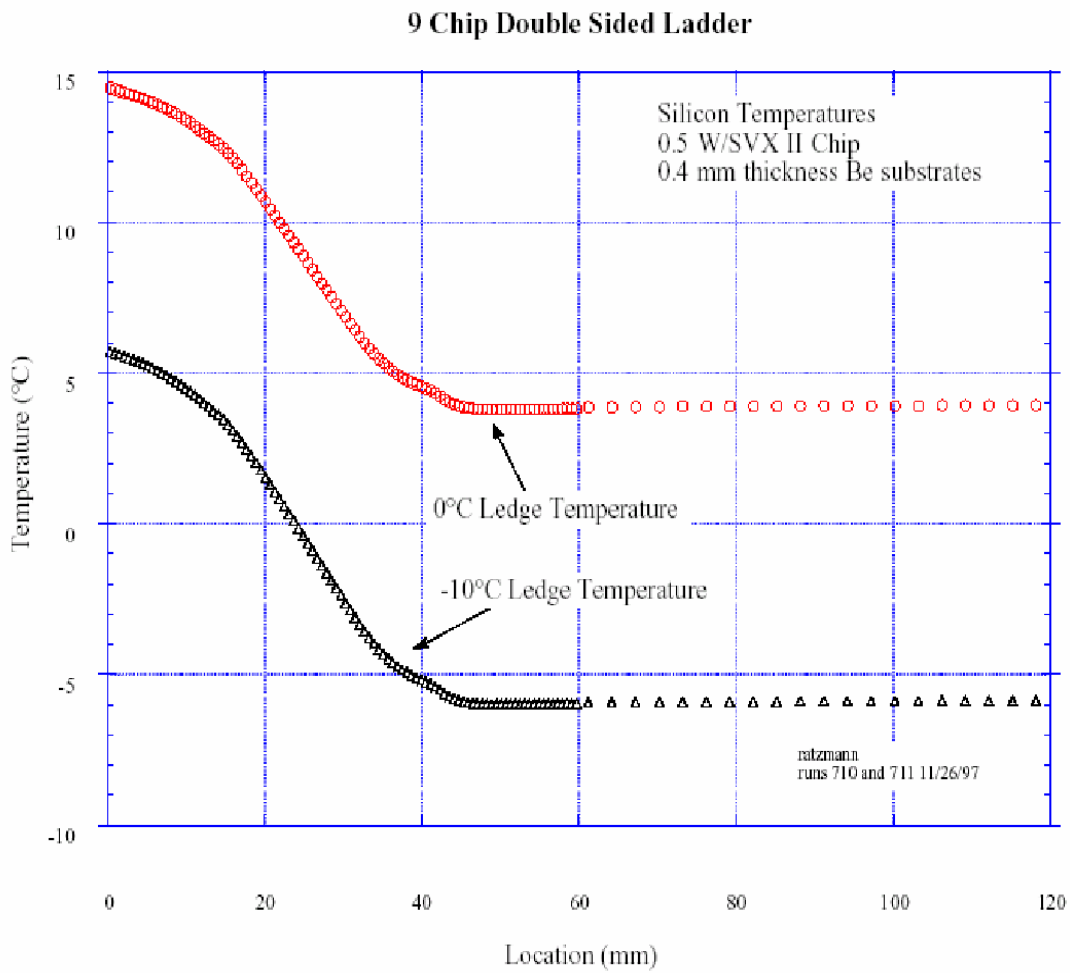
Table 1: Annealing parameter of the damage induced bulk generation current [1]

Time constant τ_i [min]	Relative amplitude a_i
$(1.78 \pm 0.17) \cdot 10^1$	0.156 ± 0.038
$(1.19 \pm 0.03) \cdot 10^2$	0.116 ± 0.003
$(1.09 \pm 0.01) \cdot 10^3$	0.131 ± 0.002
$(1.48 \pm 0.01) \cdot 10^4$	0.201 ± 0.002
$(8.92 \pm 0.59) \cdot 10^4$	0.093 ± 0.007
∞	0.303 ± 0.006

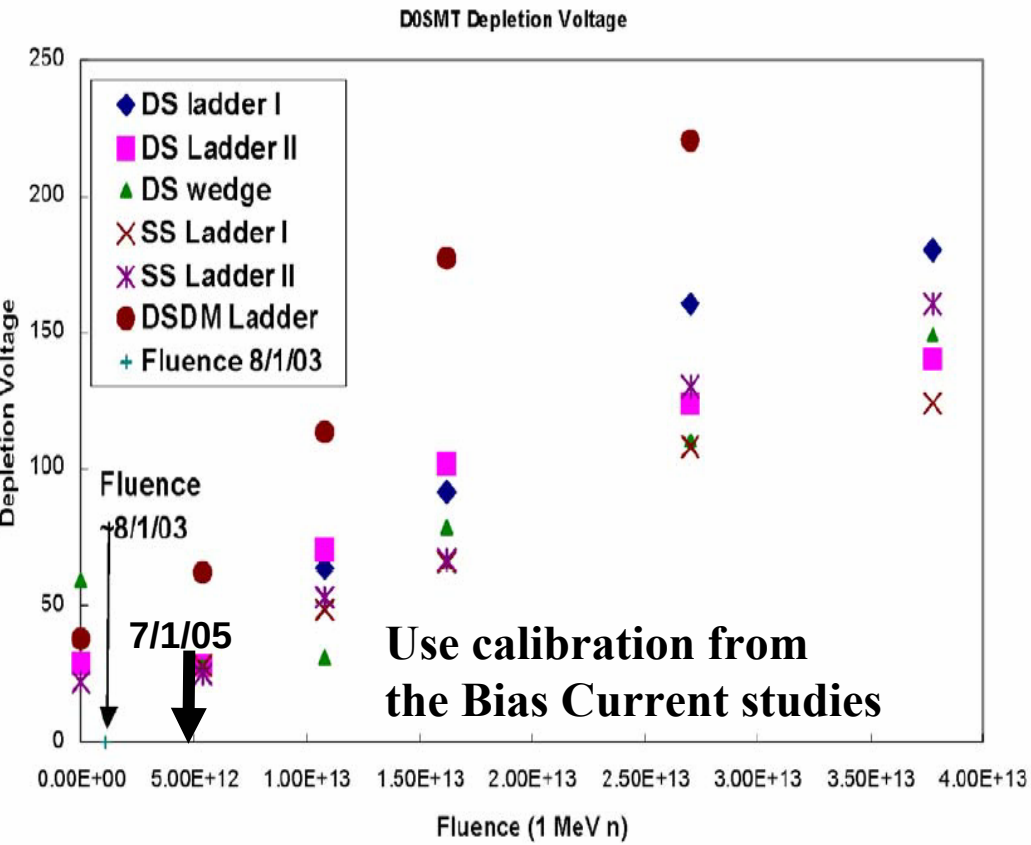
R. Wunstorf

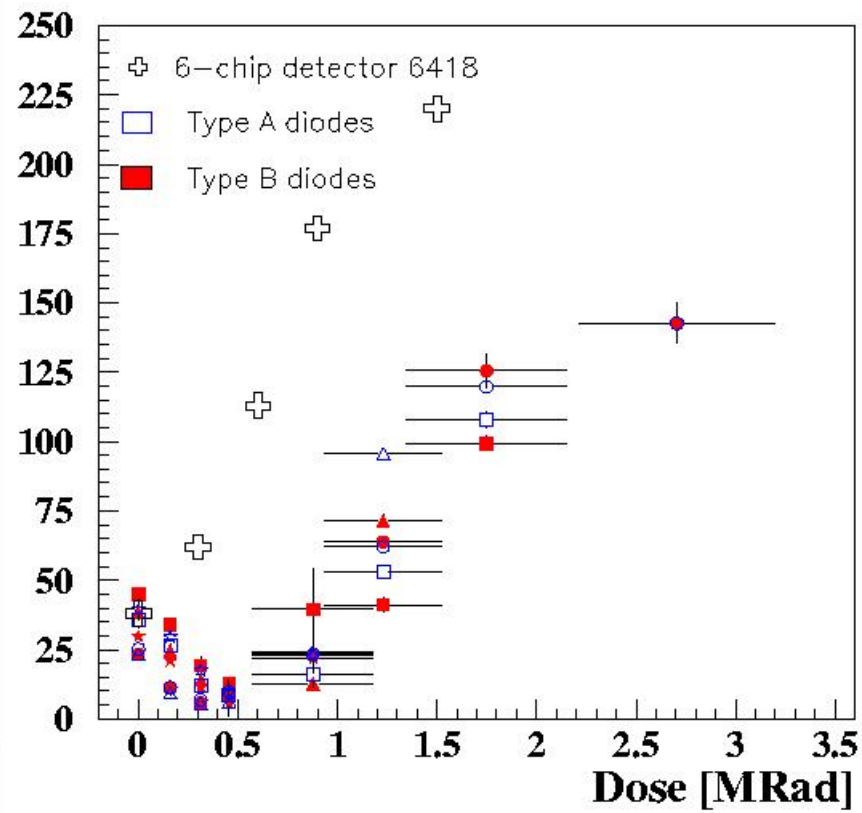
Temperature Corrections

- Temperature profile is complicated
  - HDIs warm-up during read-out
- Interesting solution proposed by summer student John Omotani
  - Include the profile into the temperature dependence instead of finding an average temperature



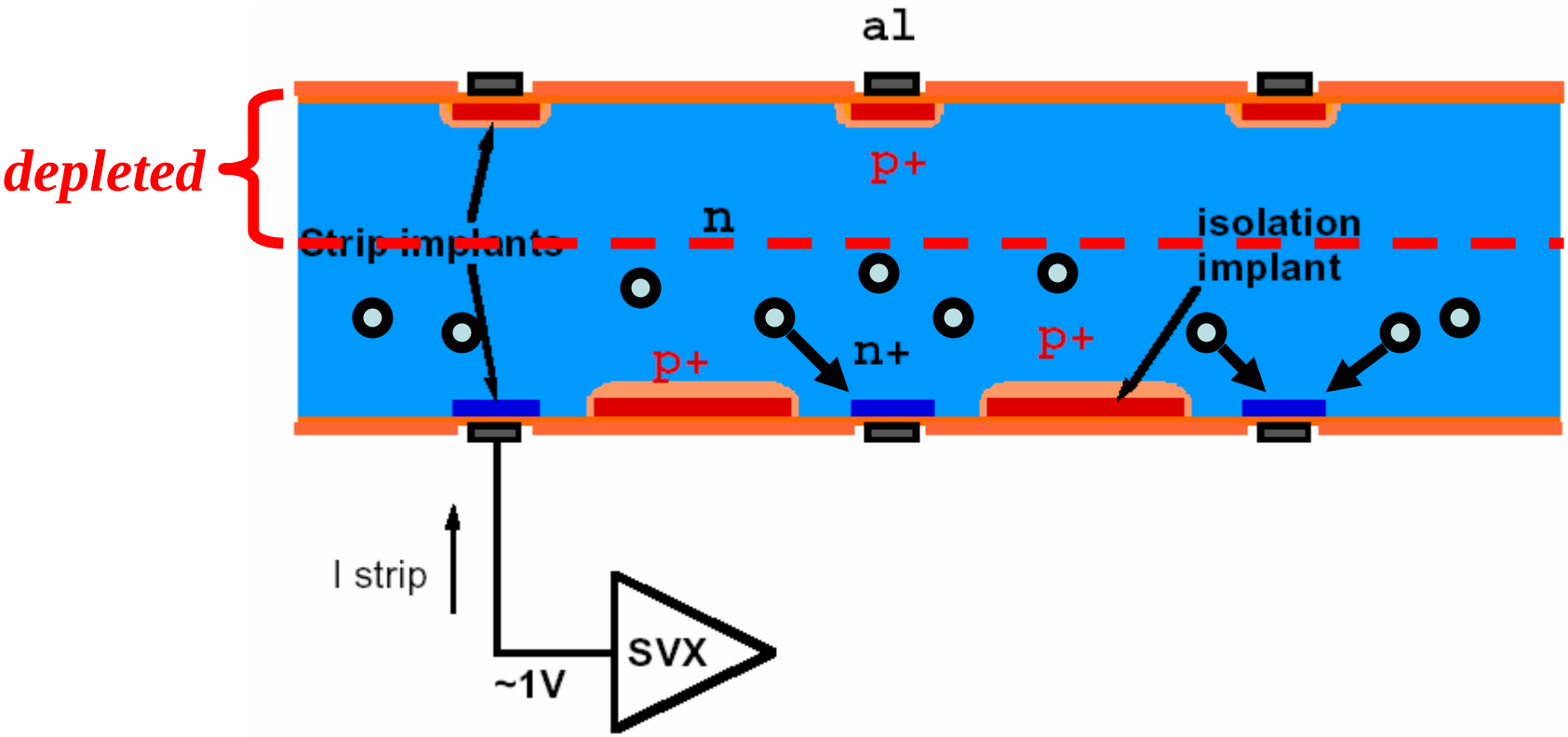
Dependence of Depletion Voltage from Dose Measured at Booster





The depletion voltages decrease for diodes from the same wafer as the 6-chip detector

Depletion Voltage: Noise at n-side



Thermal noise from free charge carriers

- removed by bias voltage
- strongly decreases at n-side when the Si volume is fully depleted