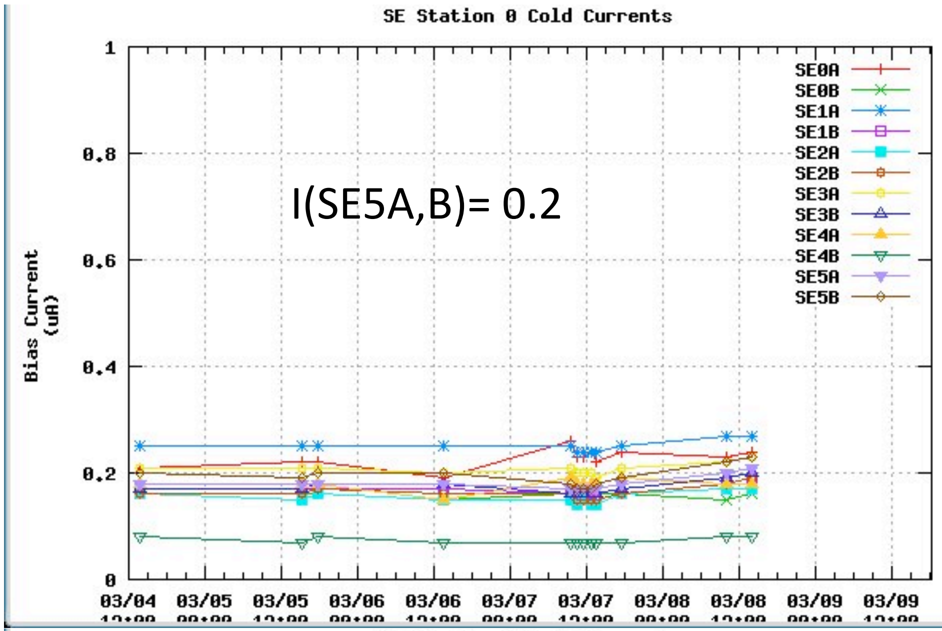
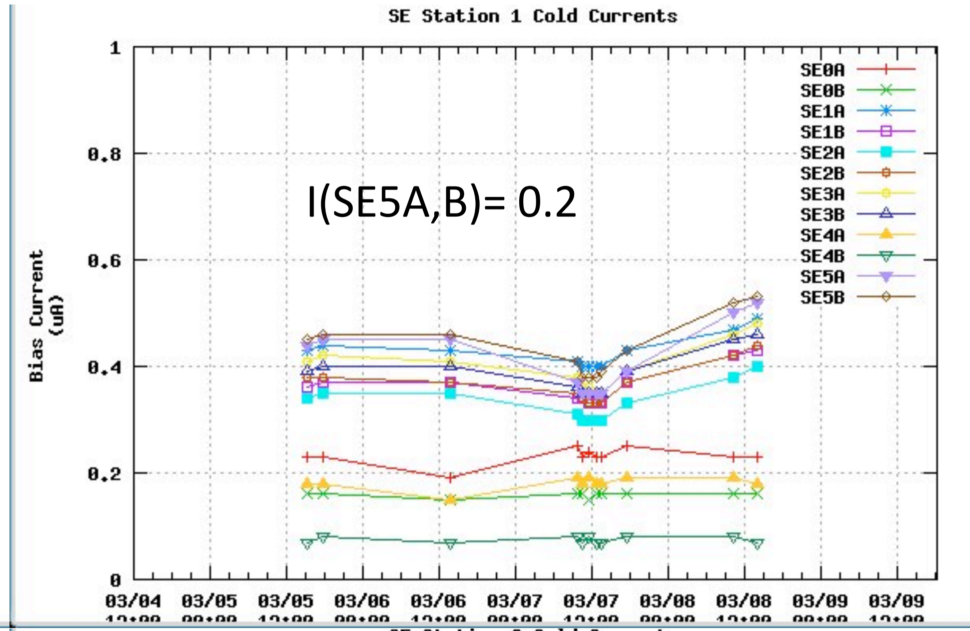
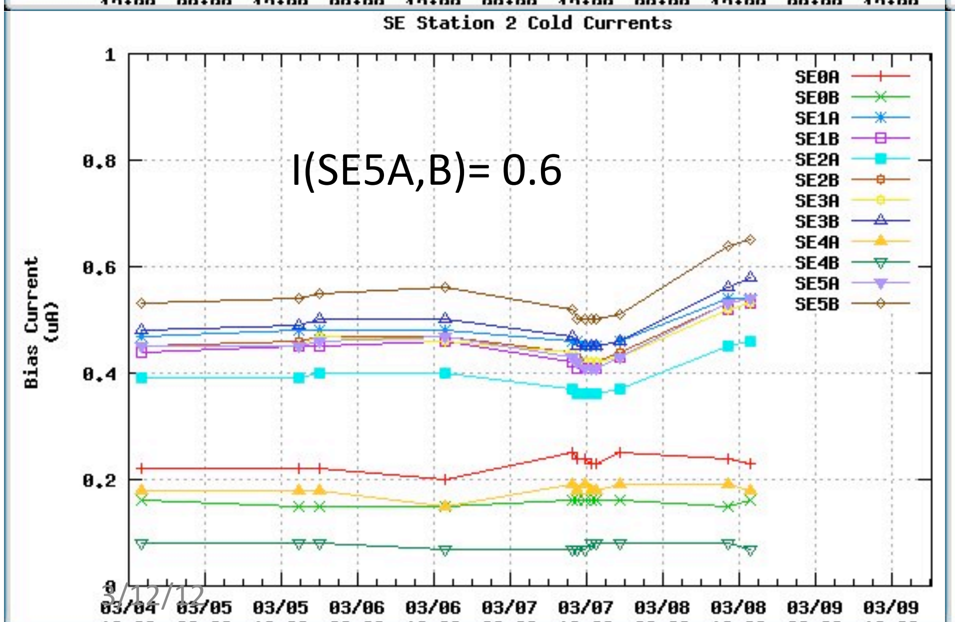
Bias Current Discussion 03/09/2012

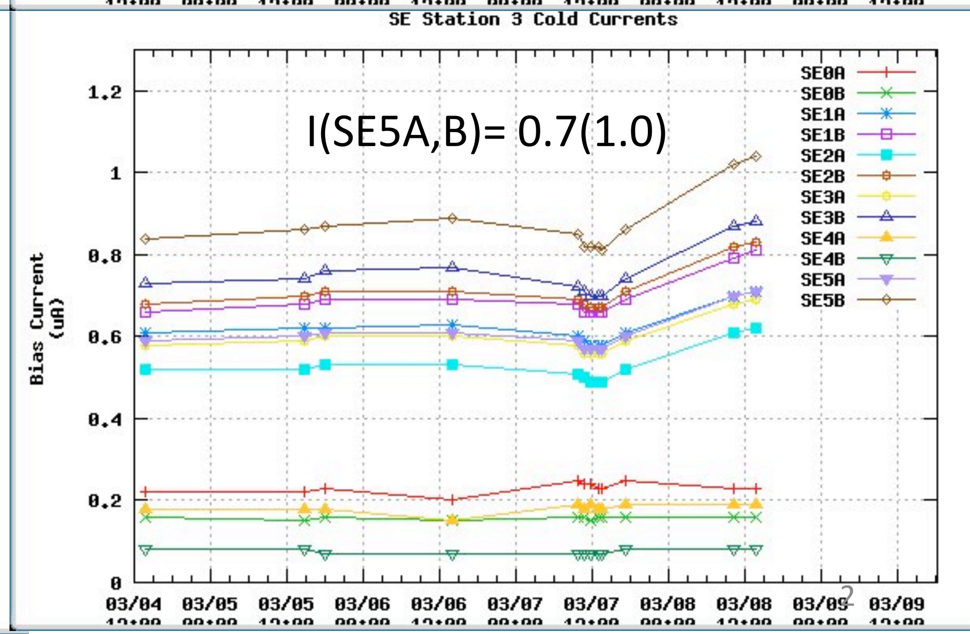
- Wedge Temp and high bias current
  - Cold vs hot
- Increasing cold bias current
  - Radiation damage
  - Surface contaminations

Bias current measurements: SE Cold, Mar 8, 2012

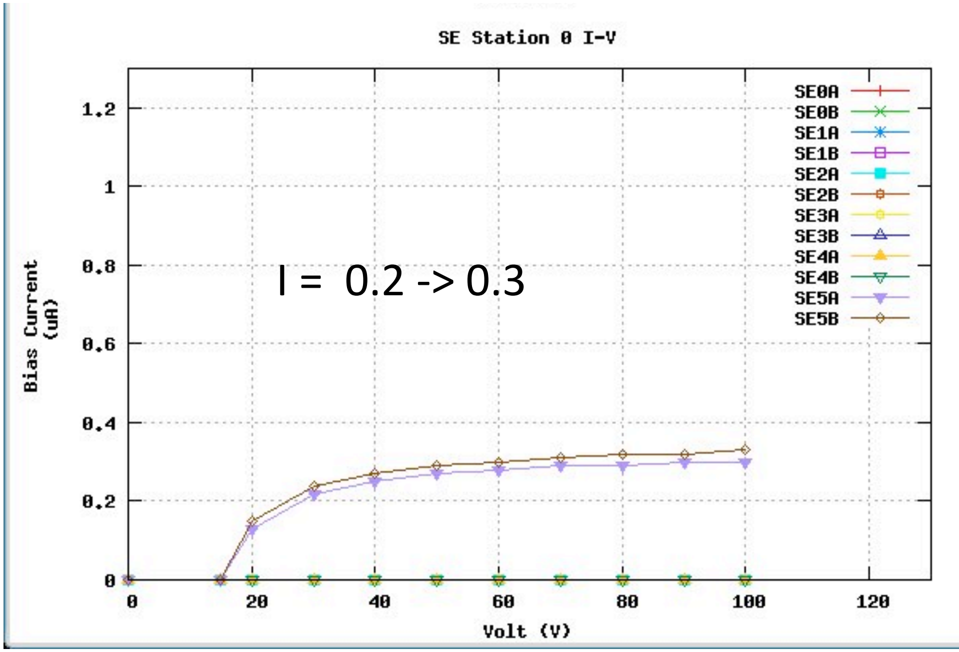


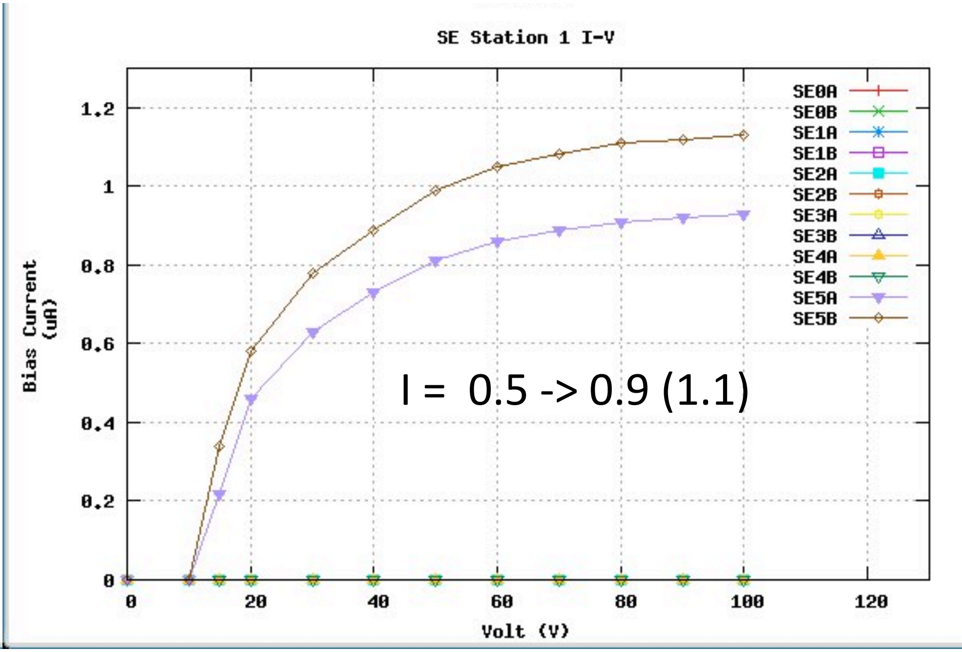


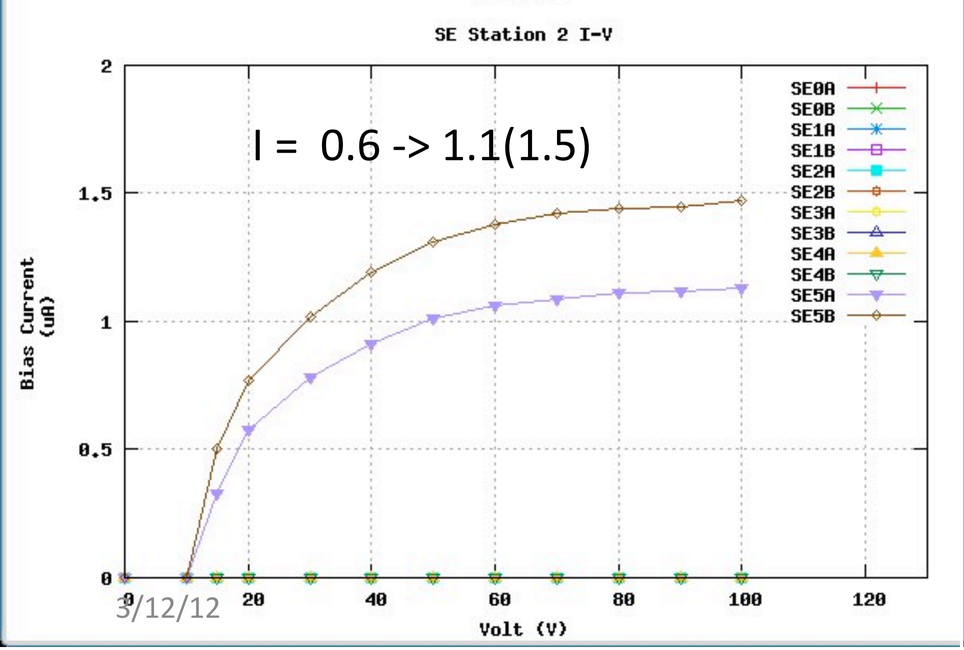


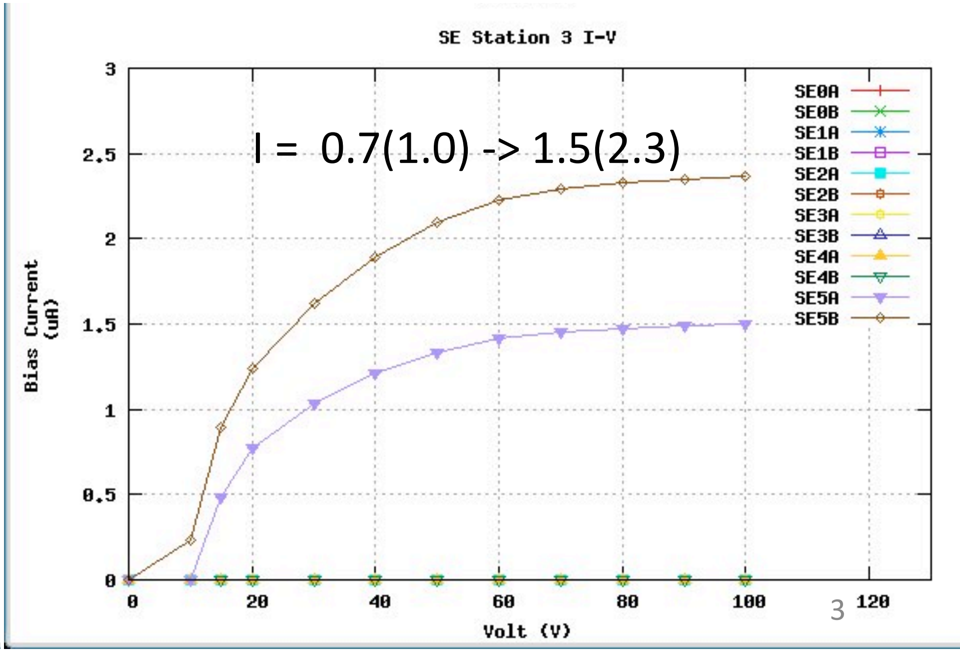


Bias current measurements: SE5-A(B) Hot, Mar 8, 2012









Temp. dep. of Bias Current

It seems FVTX sensors are operating at T = ~30 C

$$I = A \cdot T^2 \cdot e^{-\frac{1.15eV}{2k_B \cdot T}}$$

$$k_B \cdot 1K = 8.6 \times 10^{-5} eV$$

$$\frac{I(30^0C)}{I(20^0C)} = 2.3 \quad 0.2\mu A \rightarrow 0.5\mu A$$

$$\frac{I(40^0C)}{I(20^0C)} = 4.9 \quad 0.2\mu A \rightarrow 1.0\mu A$$

$$\frac{I(50^0C)}{I(20^0C)} = 10.1 \quad 0.2\mu A \rightarrow 2.0\mu A$$

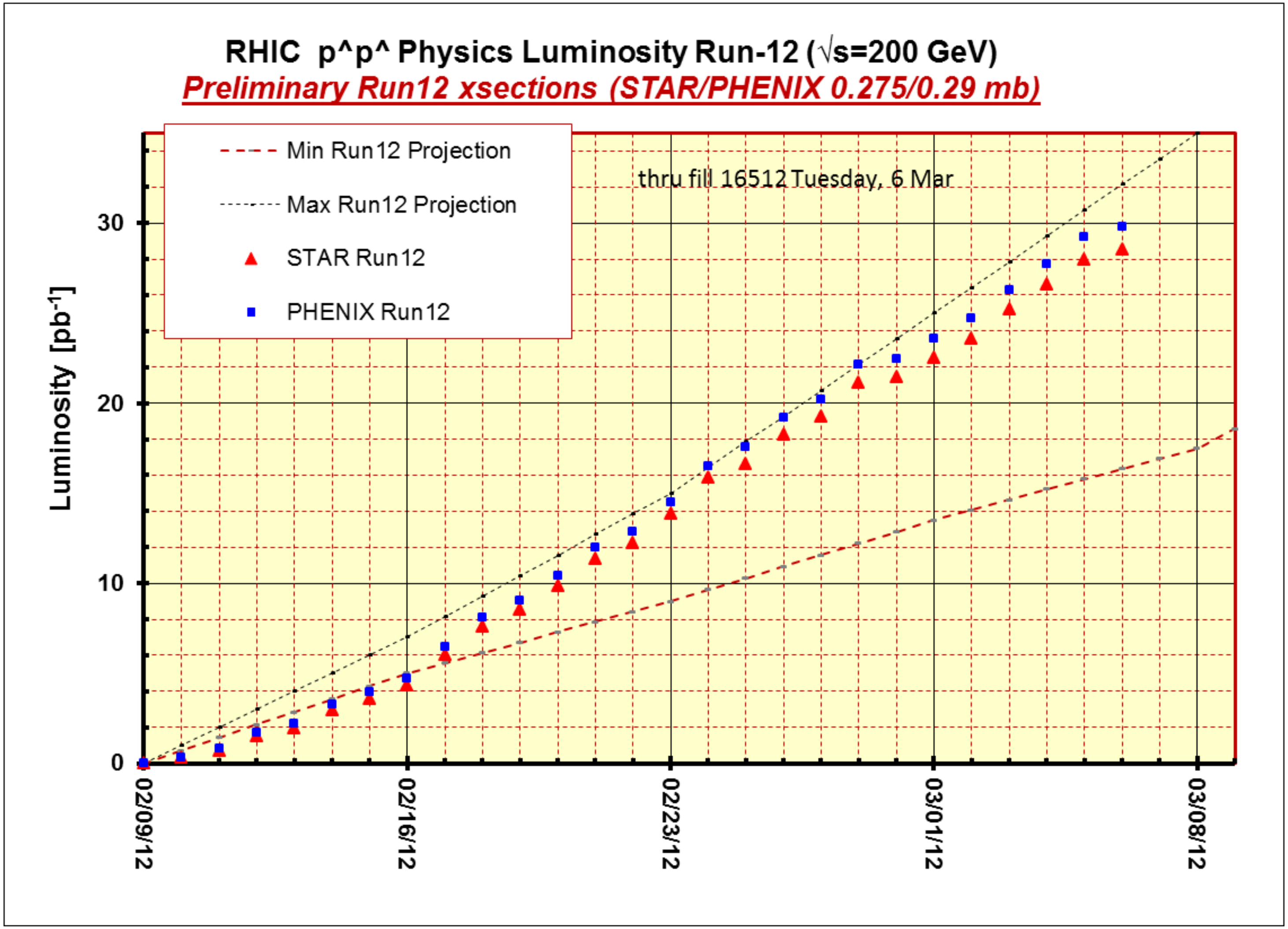
$$\frac{I(60^0C)}{I(20^0C)} = 20.0 \quad 0.2\mu A \rightarrow 4.0\mu A$$

- Bias currents almost doubled w/ LV ON
  - ST0 cooler than others
- Temp. change w/ LV on
  - Increase: ~10C
  - Wedge Temp ~ 30C
- Safe to operate?
  - S/N remains large
  - Temp not too high ~<50C

Radiation damage and Bias current

- Increasing "cold" bias current
  - PHENIX IR T increasing?
  - Radiation damage?
    - extra background from nose cone?

Delivered luminosity @PHENIX IR: 30 pb^-1   Tues. Mar 6, 2012



FVTX Radiation fluence @L=30 pb^-1

Ming's calculation: (FVTX-list, Mar 7, 2012)

Total p+p luminosity = 10 pb^-1
p+p cross section = 40mb

Total number of collisions = 40mb x 10 pb^-1 = 400 x 10^9

Particle multiplicity per collision = dN/dy ~ 3 for pp @200GeV

Total particle flux per unit of rapidity = 3 x 400 x 10^9 = 1200 x 10^9

FVTX coverage in rapidity = 1-2, area = pi*(R_2^2 – R_1^2) = 3.14 x (17^2 – 4.5^2) cm^2 = 840 cm^2

Radiation flux F = 1200 x 10^9/840 cm^2 = 1.4 x 10^9/cm^2

For 30pb^-1: F = 4.2 x 10^9/cm^2

Jon K's calculation: (fvtx-list Mar 7, 2012, corrected Mar 9)

The relationship is simple and linear. I(leakage) = alpha x F

I (leakage) is A/cmE3 alpha is a damage constant 2E-17 A/cm F is the fluence in N/cmE2

I use 700 nA as the increase in current for an entire detector.
I divide by the area of a large sensor (~21.7 cmE2) x the thickness (0.03 cm).
Then divide by alpha.

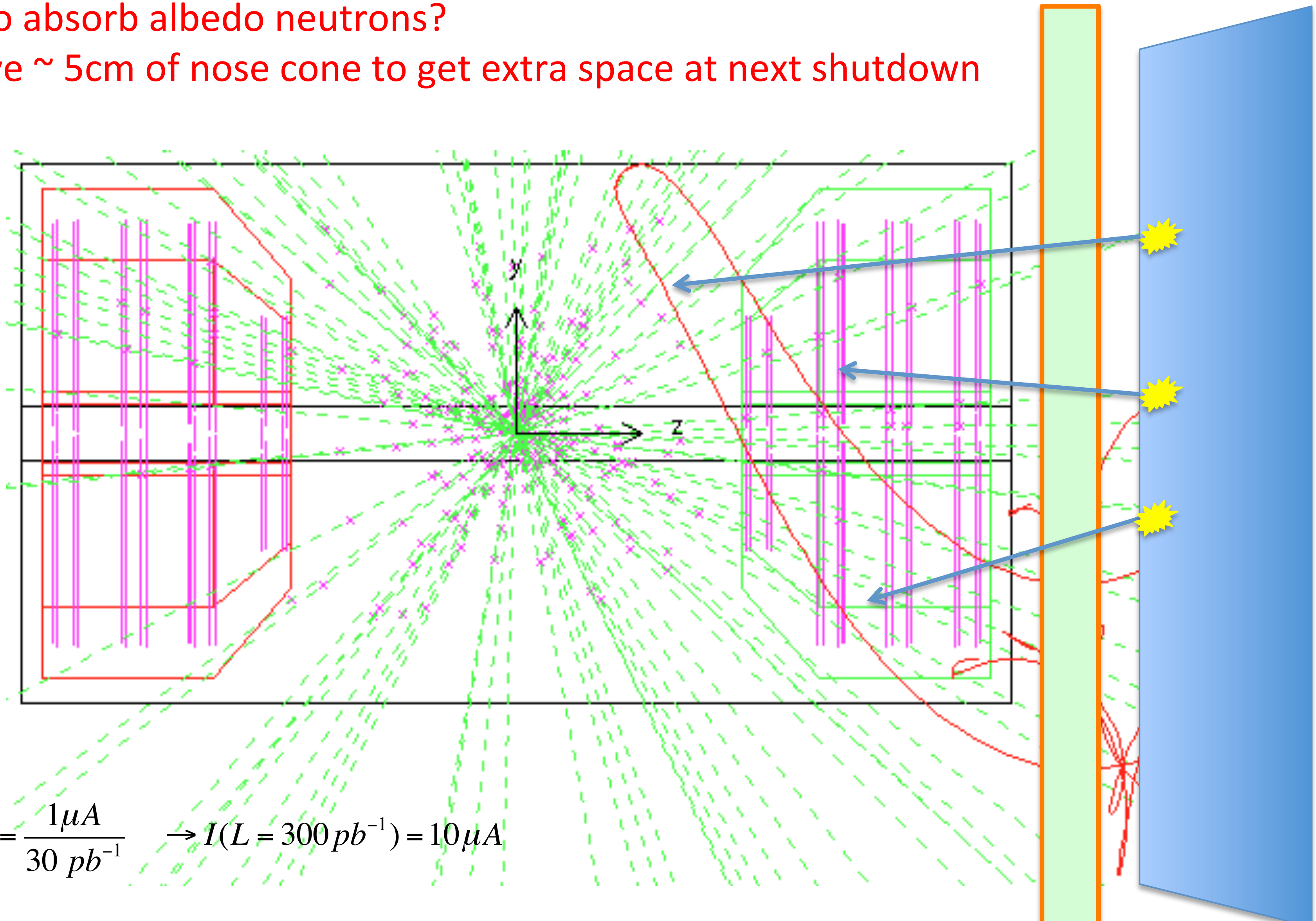
2x(5.4E-7 A/cmE3)/2E-17 A/cm) = 5.4E10 N/cmE2

1. In my calculation, I only take into account particles from IP! No other sources.
2. There could be significant radiation dose from back splashed low energy neutrons and charged particles from nose cone!
3. In this case, ST3 is the worst, ST0 is the best

Back scattered particles from nose cone

- could significantly affect ST3
- add “soft neutron absorber” (5 cm borated polyethylene?) in front of nose cone to absorb albedo neutrons?

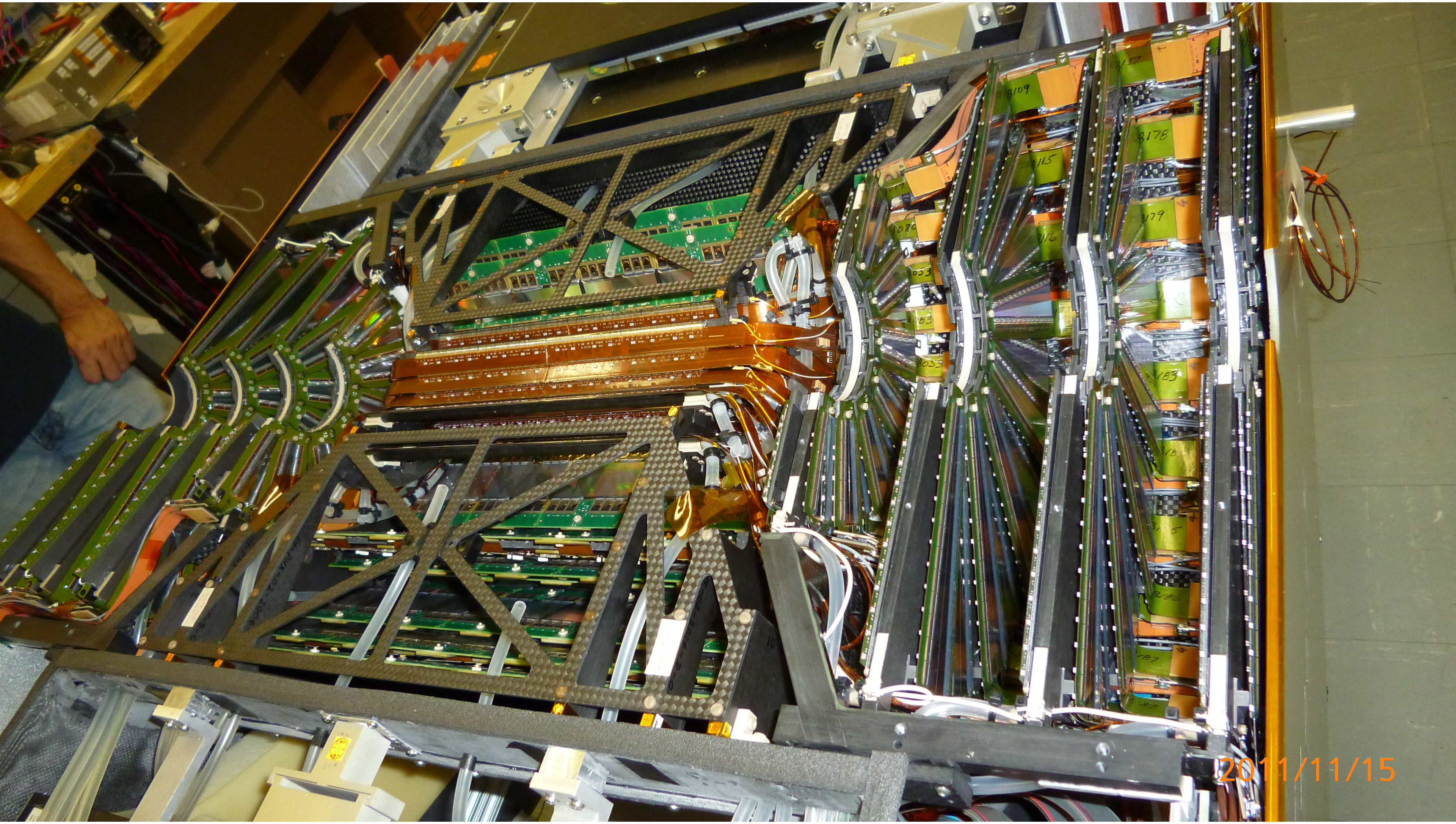
Remove ~ 5cm of nose cone to get extra space at next shutdown



$$\frac{\Delta I}{\Delta L} = \frac{1\mu A}{30\ pb^{-1}} \quad \rightarrow I(L = 300\,pb^{-1}) = 10\,\mu A$$

Add neutron absorber?

Radiation Damage in ST3 FVTX wedges:
Low energy (~ 1MeV) albedo neutrons from Al big wheel and nose cone ? …



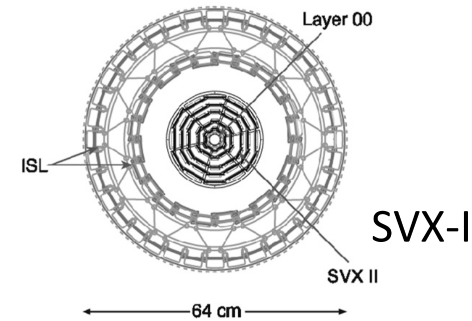
Radiation Damages: CDF/D0

- Two effects:
  - Bulk current (dominant)
  - Surface current
- Flux @inner most SVX-II, R = 2.5cm

  10.4 +/- 5.1 x 10^12/cm^2/fb^-1

  (=10.4 +/- x 10^9/cm^2/pb^-1)
- Compared with Ming's estimate for FVTX

  1.4 x 10^8/cm^2/pb^-1



SVX-II

Fig. 1. Endview of the CDF Silicon detector with ISL, SVX-II and L00.

$$\frac{\Delta I}{\Delta L} = \frac{6\mu A}{90\,pb^{-1}} = \frac{2\mu A}{30\,pb^{-1}} \sim \frac{1\mu A}{30\,pb^{-1}}(FVTX)$$

NIM A 582 (2007) 819-823

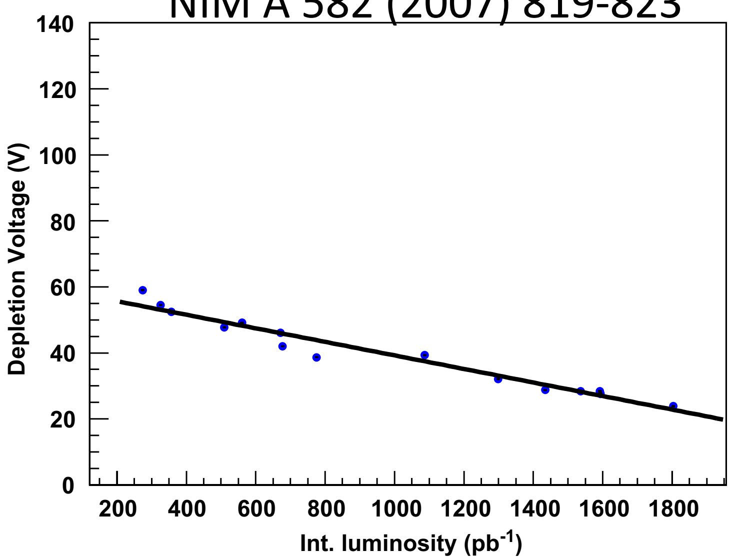


Fig. 3. CDF: Depletion voltage versus luminosity for one module in SVX-II layer 0. This plot includes data up to a delivered luminosity of 1.8 fb^{-1}.

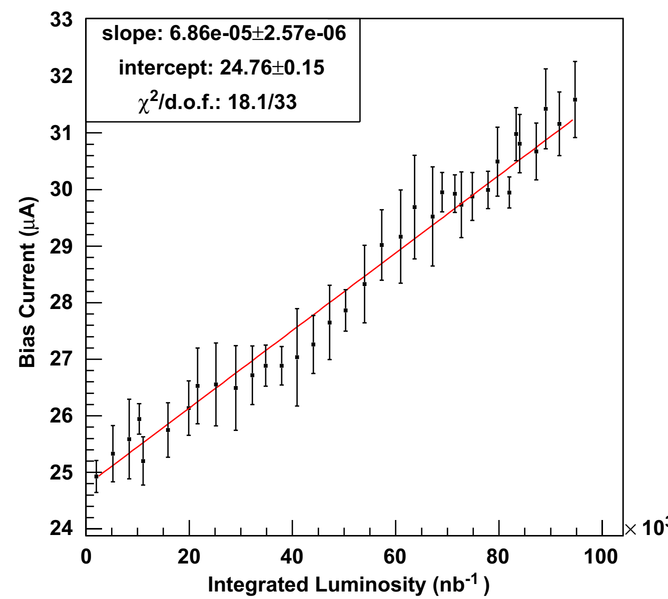


Fig. 5. CDF: The linear dependence of measured bias current with integrated luminosity for the 95 pb^{-1} used in the bias current measurement for a sample ladder.

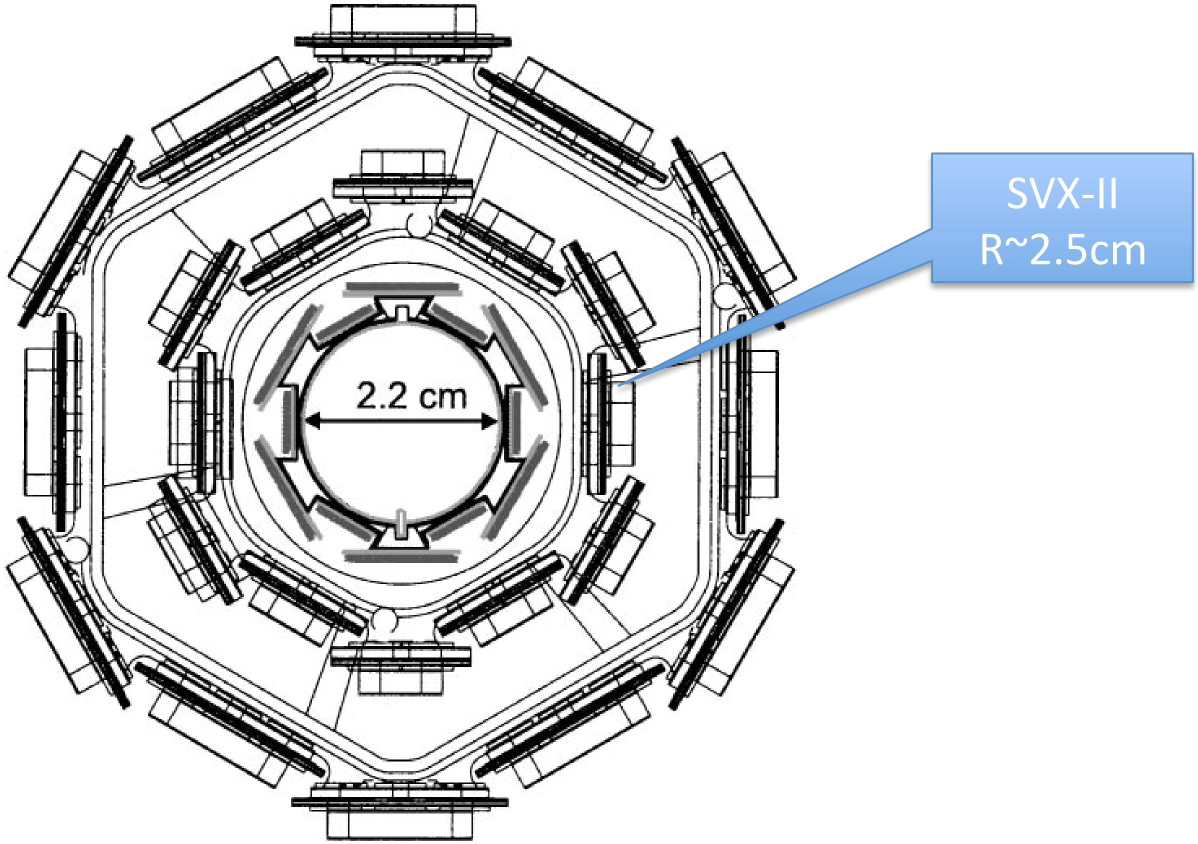


Fig. 5. End view of the innermost three layers of the CDF Run II silicon system, showing Layer 00 along with the first two layers of the SVX II region. The Layer 00 electronics (not shown) are mounted beyond the active volume for vertexing. The SVX II electronics are shown just outside and just inside of each of the layers drawn.

Radiation Damage

Two basic radiation damage mechanisms:

- Displacement Damage

  Incident radiation displaces silicon atoms from lattice sites. Also referred to as bulk damage.

- Ionization Damage

  Energy absorbed by electronic ionization in insulating layers, typically SiO_2, liberates charge, which drifts or diffuses and is eventually trapped either in the insulator layer at interfaces. Also referred to as surface damage.

Both types of damage occur both in detectors and transistors/ICs.

Impact of Bulk damages

1. Increase in bias current

The bias current after irradiation has been shown to be

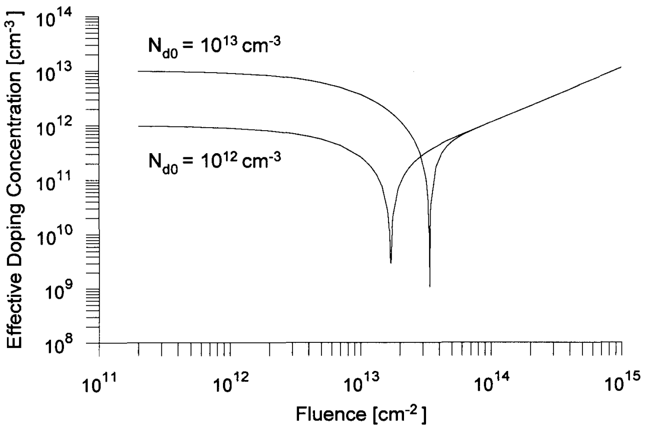
$$I_R = I_0 + \alpha \cdot \Phi \cdot Ad$$

where I_0 is the bias current before irradiation, α is a damage coefficient dependent on particle type and fluence, Φ is the particle fluence, and the product of detector area and thickness Ad is the detector volume.

For 650 MeV protons $\alpha \approx 3 \cdot 10^{-17}$ A/cm

1 MeV neutrons $\alpha \approx 2 \cdot 10^{-17}$ A/cm.
(characteristic of the albedo emanating from a calorimeter)

2. Change in doping: ~< 10^13/cm^2



3. Charge loss due to trapping

Relative displacement damage for various particles and energies:

Particle	proton	proton	neutron	electron	electron
Energy	1 GeV	50 MeV	1 MeV	1 MeV	1 GeV
Relative Damage	1	2	2	0.01	0.1