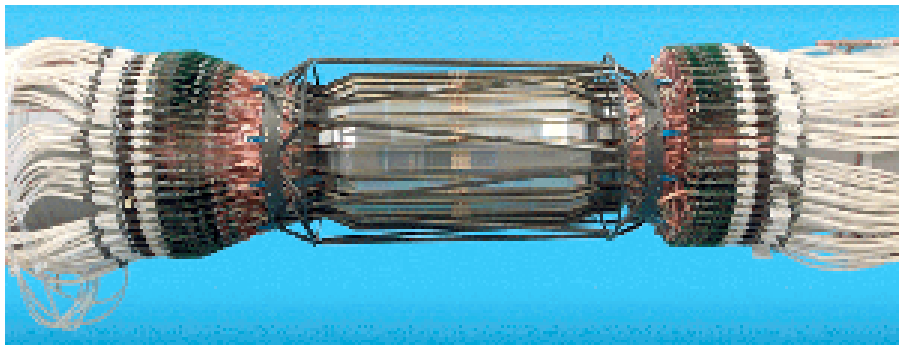
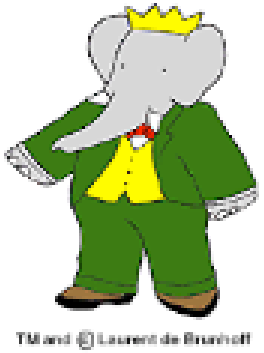
Status and future plans of the **BaBar Silicon Vertex Tracker**

Michael Wilson
University of California, Santa Cruz

Representing the BaBar SVT Group



The 11th International Workshop on Vertex Detectors
Kailua-Kona, Hawaii, USA
4 November 2002



Outline

- Description and Features
- Status, improvements, and future plans...
  - Radiation hardness, monitoring and protection
  - Internal alignment
  - Shutdown activities

Design Requirements

Physics Requirements

- σ_z resolution $<130\,\mu m$
- *single vertex* resolution $<80\,\mu m$
- stand-alone tracking for particles with low transverse momentum ($p_t < 120\,MeV/c$)

Much higher luminosity than originally planned!

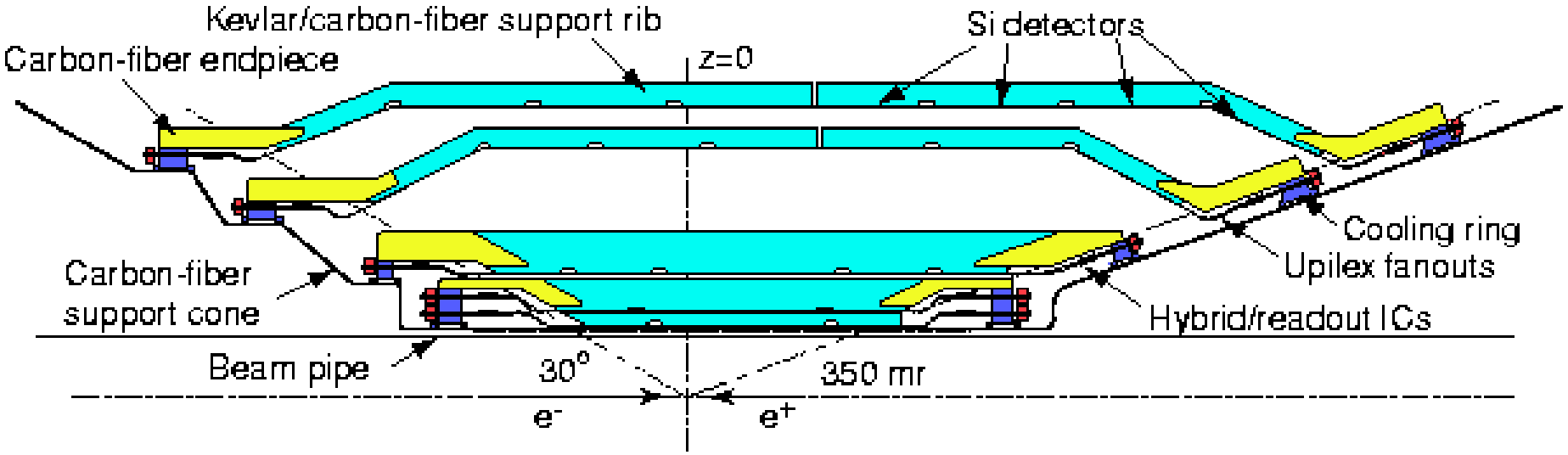
PEP II Contraints

- permanent dipole magnets $\pm 20\,cm$ from the IP
  - || polar angle $17.2° < \theta < 150°$
  - || SVT is mounted on the magnets
- bunch crossing $4.2\,ns$ ($\sim 238\,MHz$)
- radiation at inner layers (estimated)
  - average $33\,kRad/yr$
  - bend plane $240\,kRad/yr$

based on recent extrapolations

- average $250-400\,kRad/yr$
- bend plane $1000-2000\,kRad/yr$

The BaBar SVT



- **5 layers of double-sided, AC coupled silicon wafers**

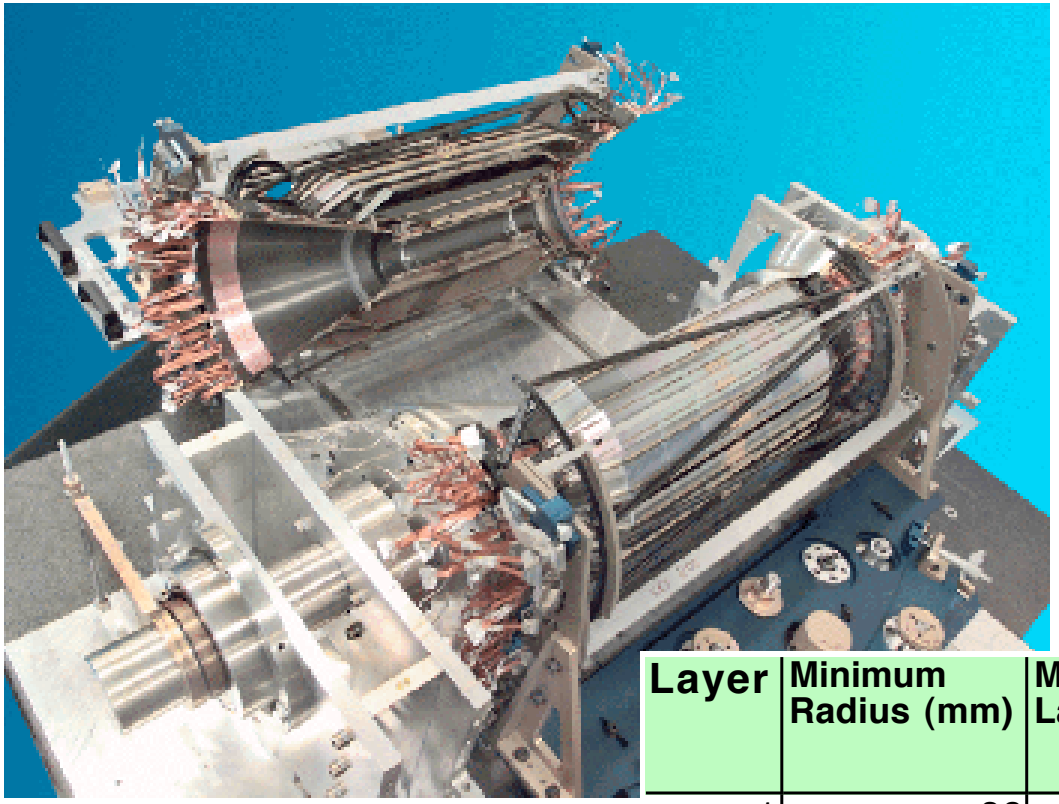
Inner layers (1-3)

- **vertexing** information (angle, impact parameter)
- hit resolution $10 \square 15 \square m$

Outer layers (4-5)

- **tracking** and pattern recognition
- hit resolution $30 \square 40 \square m$

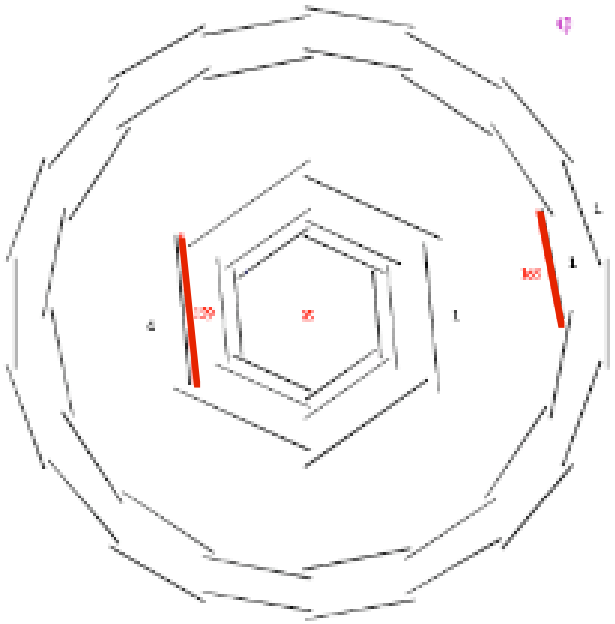
Specifications



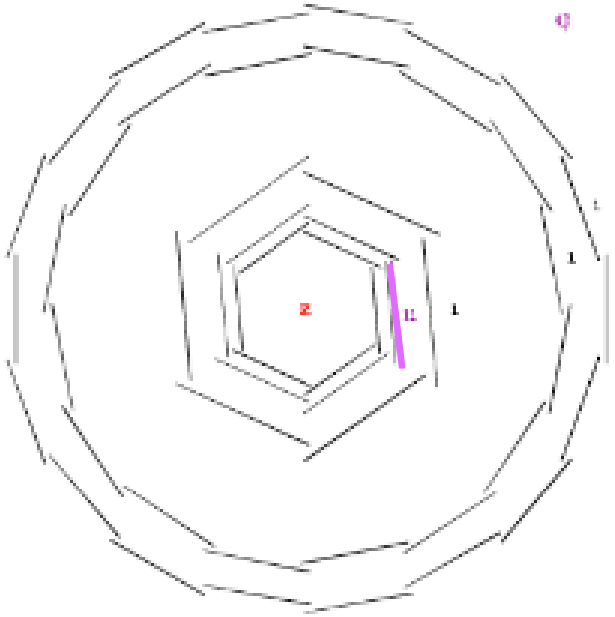
Layer	Minimum Radius (mm)	Modules/ Layer	Wafers/ Module	ϕ pitch (μm) (readout)	z pitch (μm) (readout)
1	32	6	4	50-100	100
2	40	6	4	55-110	100
3	54	6	6	110	100
4	124	16	7	100-82	210
5	140	18	8	100-82	210

Module Status

Forward



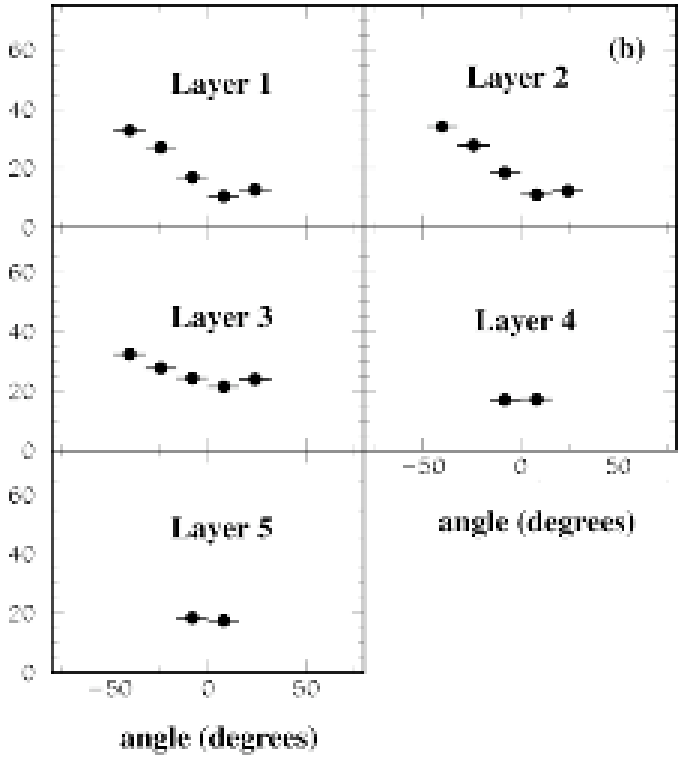
Backward



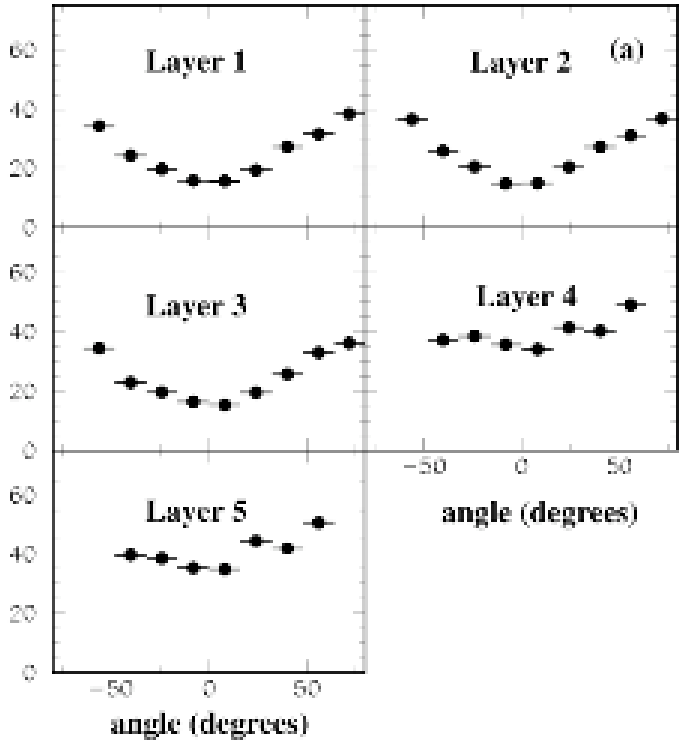
- 104 half-modules, 208 readout sections
- **only 3 sections are not read-out**
  (6 were fixed this summer, more later...)
- no sections lost to radiation damage

Resolution

ϕ Resolution (μm)



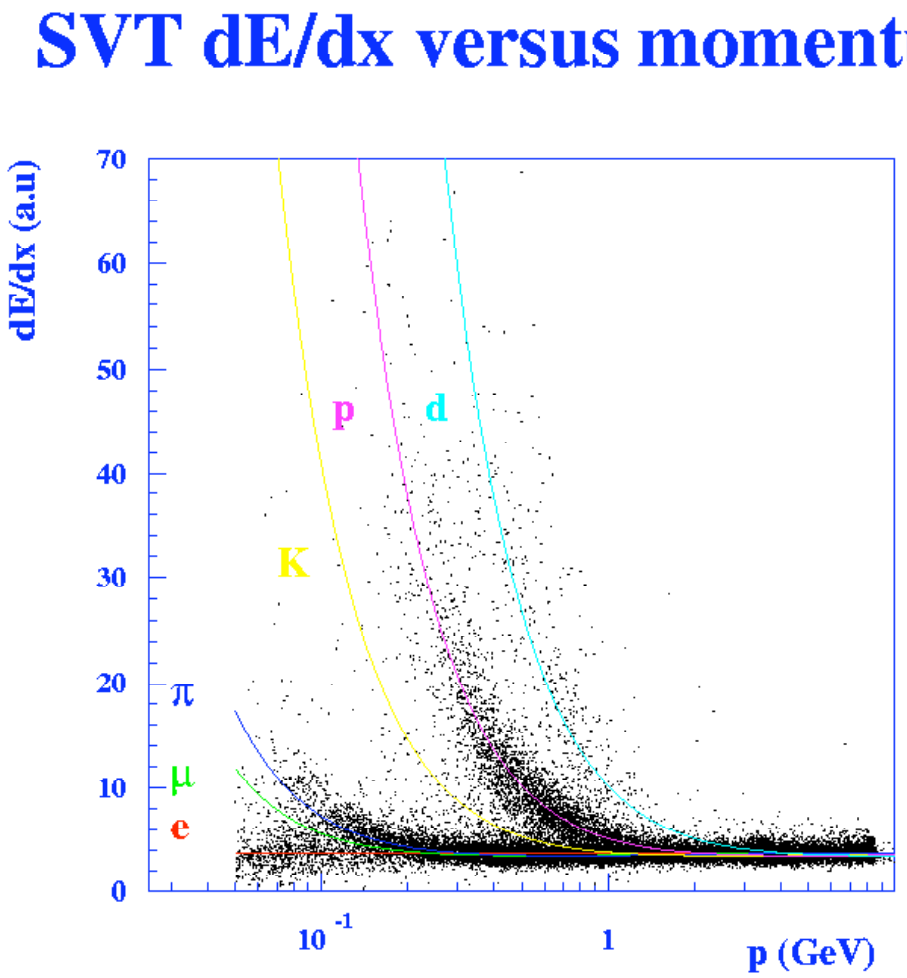
z Resolution (μm)



Meets TDR specifications for perpendicular tracks

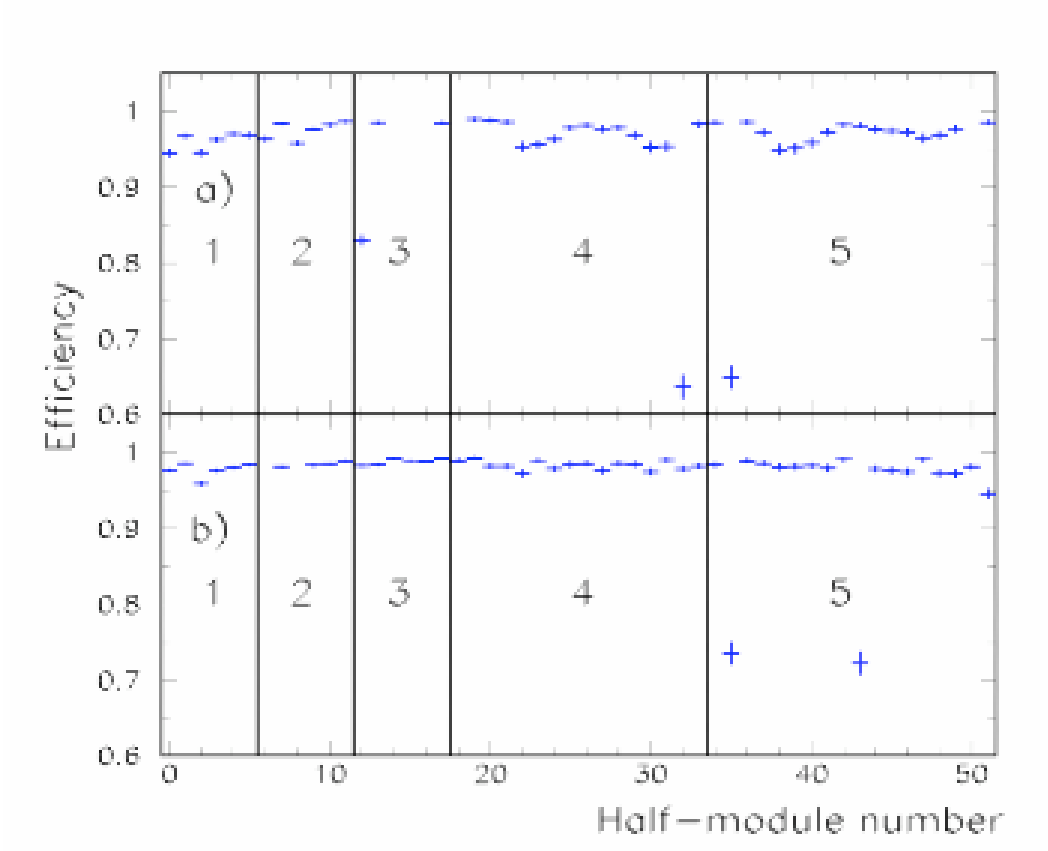
- layers 1-3 $10 \square 15 \mu m$
- layers 4-5 $30 \square 40 \mu m$

Particle ID



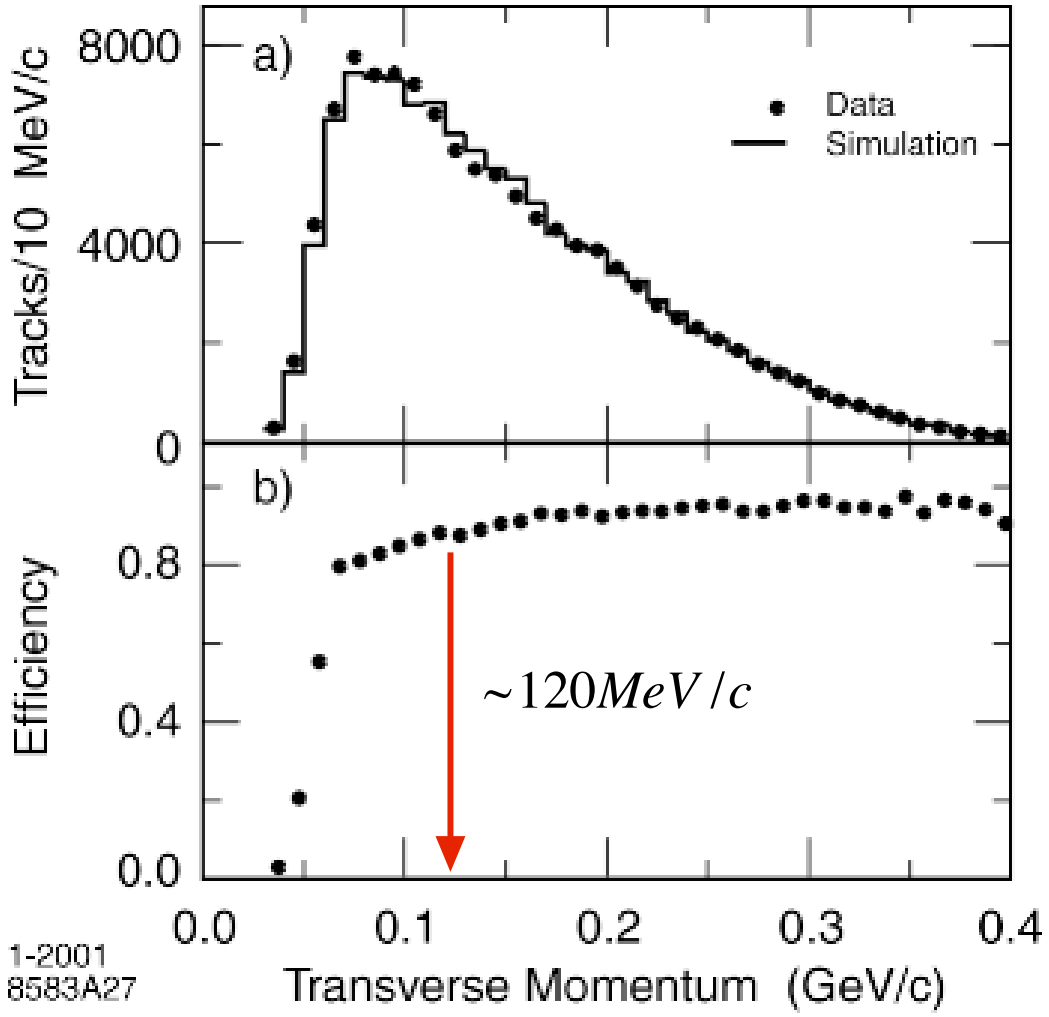
- Use pulse height measurement to determine ionization dE/dx
- 2/ separation between K and / / up to 500 MeV/c, K and protons up to 1GeV/c

Efficiency



- Hit reconstruction efficiency is typically > 98%

Tracking



- slow pion detection efficiency with both SVT and Drift Chamber
- SVT significantly extends charged particle detection down to ~50MeV/c
- Important for $D^{*+} \to D^0 \pi^+$

A Year Older...

Radiation Good News

- Tests indicate that **the SVT is Rad Hard up to 5Mrad**
- Our detector is more radiation hard than our background sensors!

A Reunion

- BaBar shutdown from July 1 -- Nov 15
- The SVT came out, but it was **not** disassembled. **We were able to restore 6 readout sections!** (only 3 remain unused)

Alignment Successes

- **Improved algorithms make SVT local alignment accurate and fast**
- Able to detect and correct for shift of layers 4 and 5 (why did they shift, you ask...)

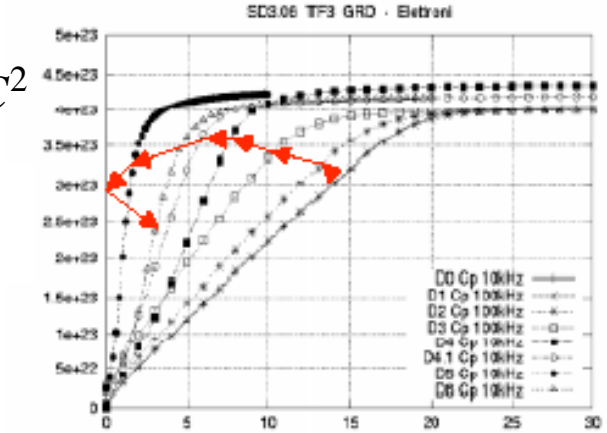
Radiation Tests

- *SVT originally designed for 2 MRad total* over the lifetime of the detector (~10 years)
- The inner layers in the bend plane will receive ~5 MRad by 2005
- Tests indicate that the **SVT is OK up to 5 Mrad**
  - silicon wafers OK (increased noise, type inversion)
  - front-end electronics (ATOM chips) OK (decreased gain, increased noise, no digital failures)
- Still need to do test of charge collection efficiency after type inversion (silicon + readout-chain)

Silicon Radiation Tests

electron beam

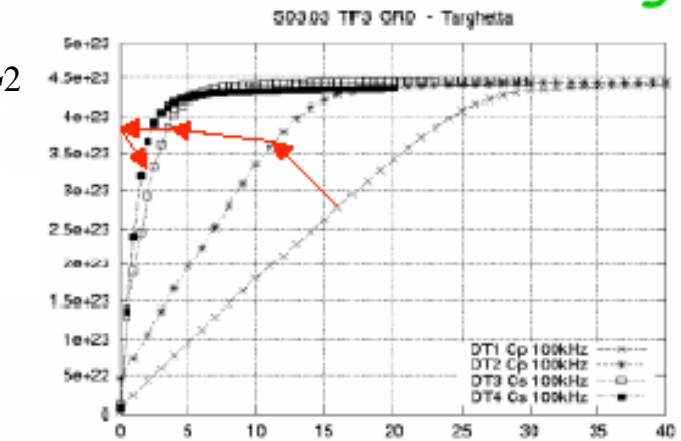
$1/C^2$



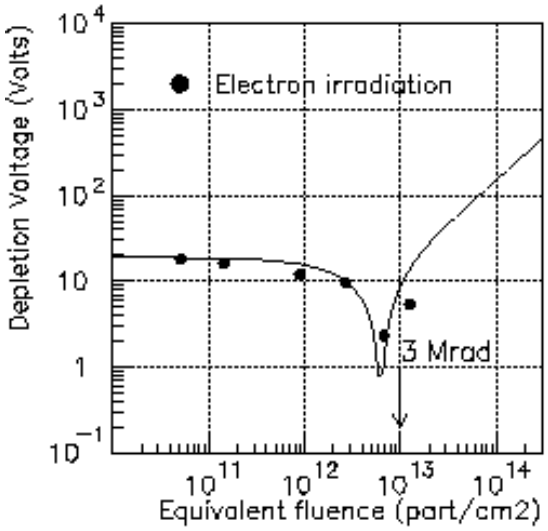
V

electron beam on Cu target

$1/C^2$

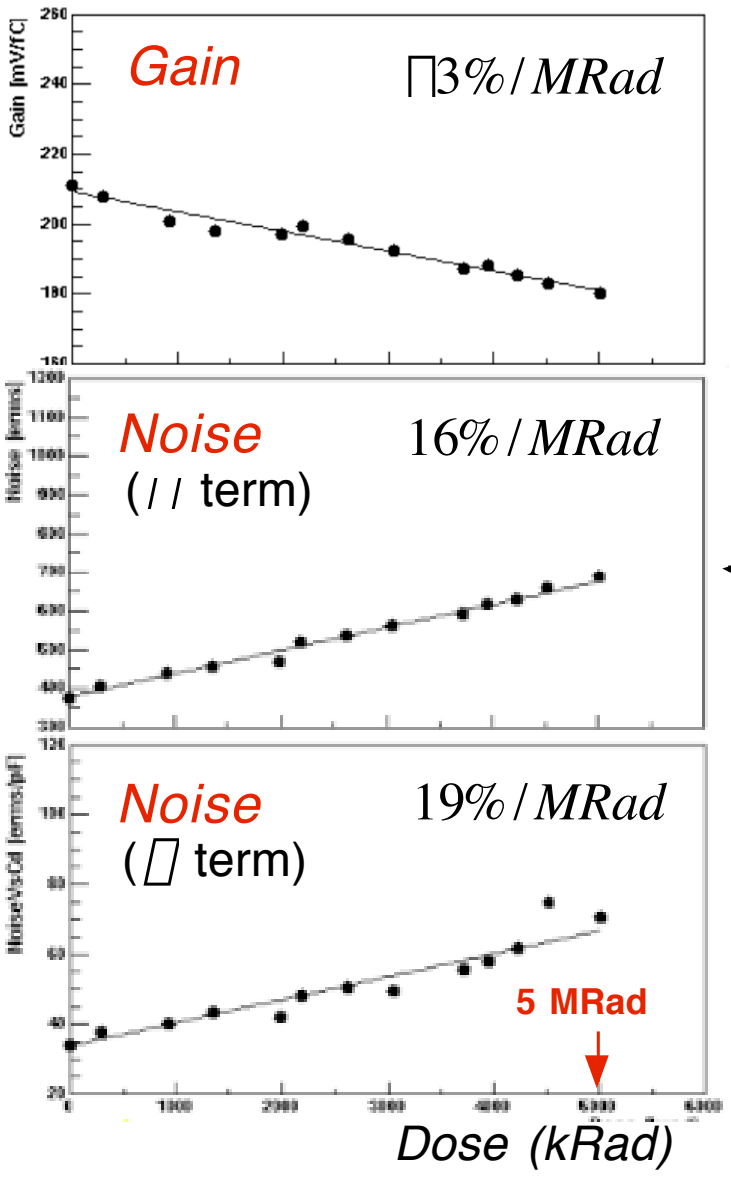


V



- shows type inversion $\sim 2 \square 3 MRad$
- results agree with NIEL hypothesis (not obvious or expected)
- leakage current increase $\sim 2 \square A / MRad \square cm^2$
- Agrees with in-situ meaurements

Front-end (ATOM) Radiation Tests

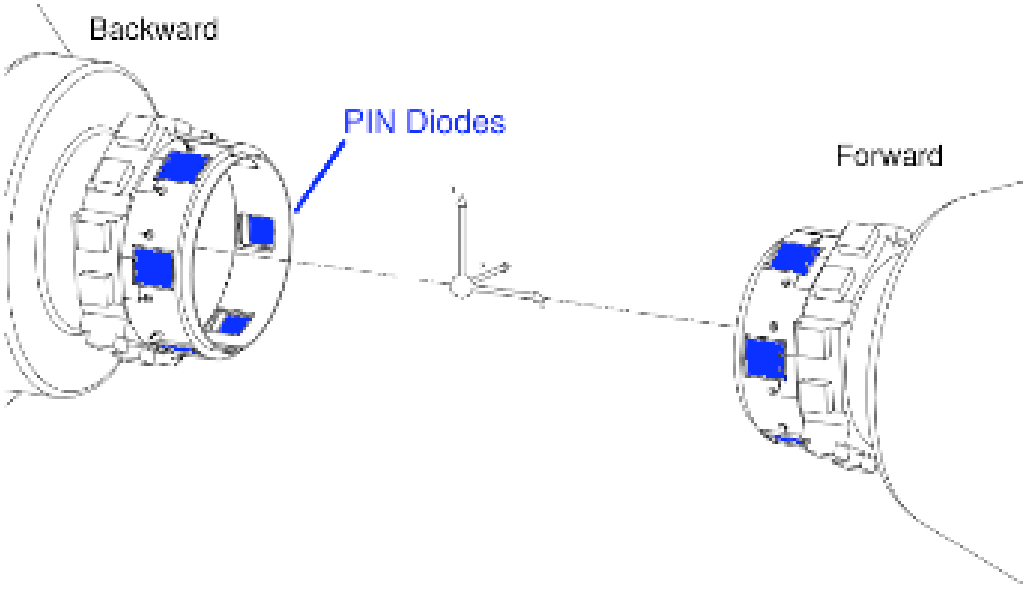


- Tests performed with Co^{60} source at LBL and SLAC
- Chips powered and running during irradiation
- No digital failures up to 5 MRad

$Noise = \square + \square\, C_{load}$

Significant decrease in performance of inner layers around 5MRad (S/N ~ 10)

Radiation Sensors

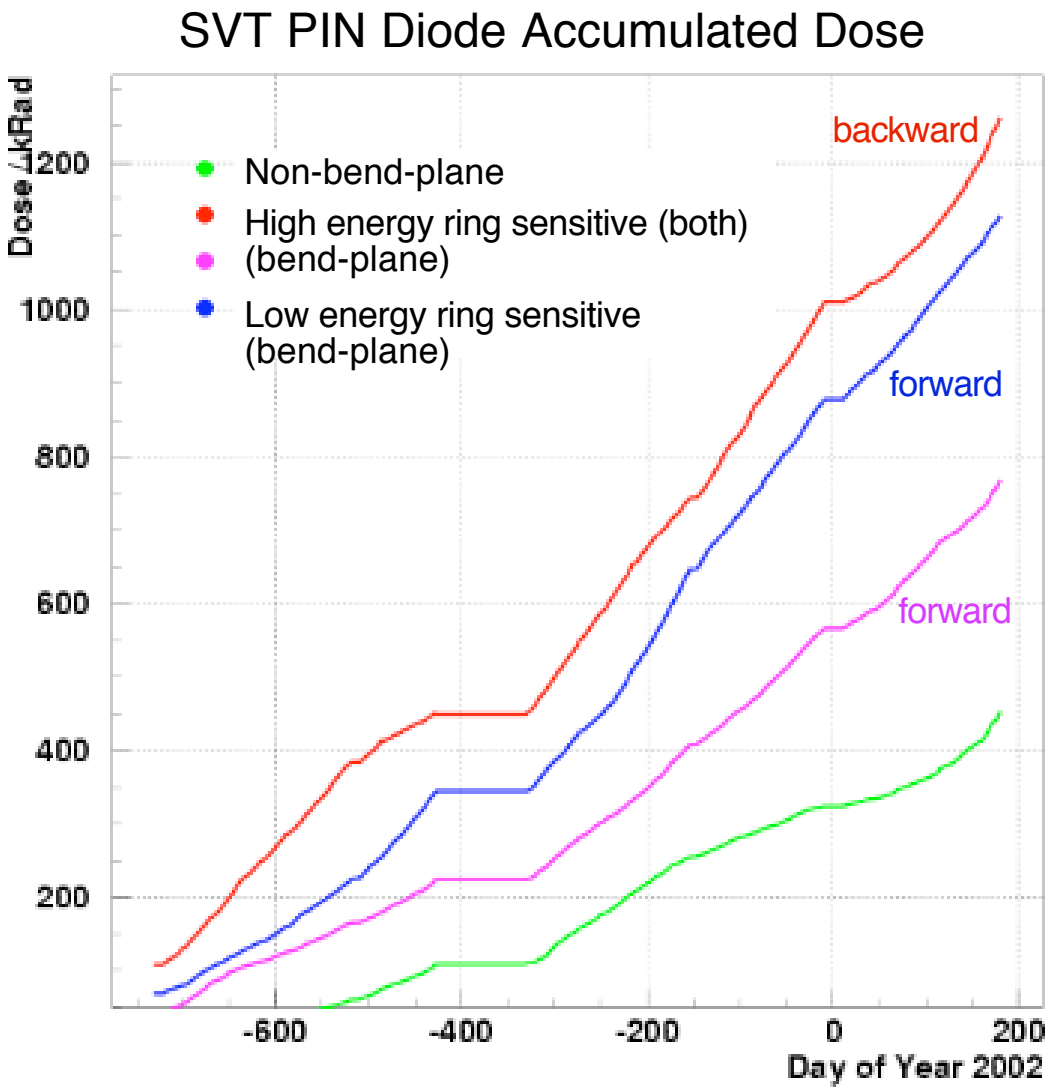


- 12 reversed-biased PIN diodes
- 1cm x 1cm x 0.03 cm active area per diode
- 1mRad ~ 200pC
- **Used for both monitoring and protection**

- Most irradiated diodes > 1MRad
- Leakage currents ~ 1000-2000nA
- Typical signals ~ 2-4nA
- Temperature correction ~ 10%/deg C

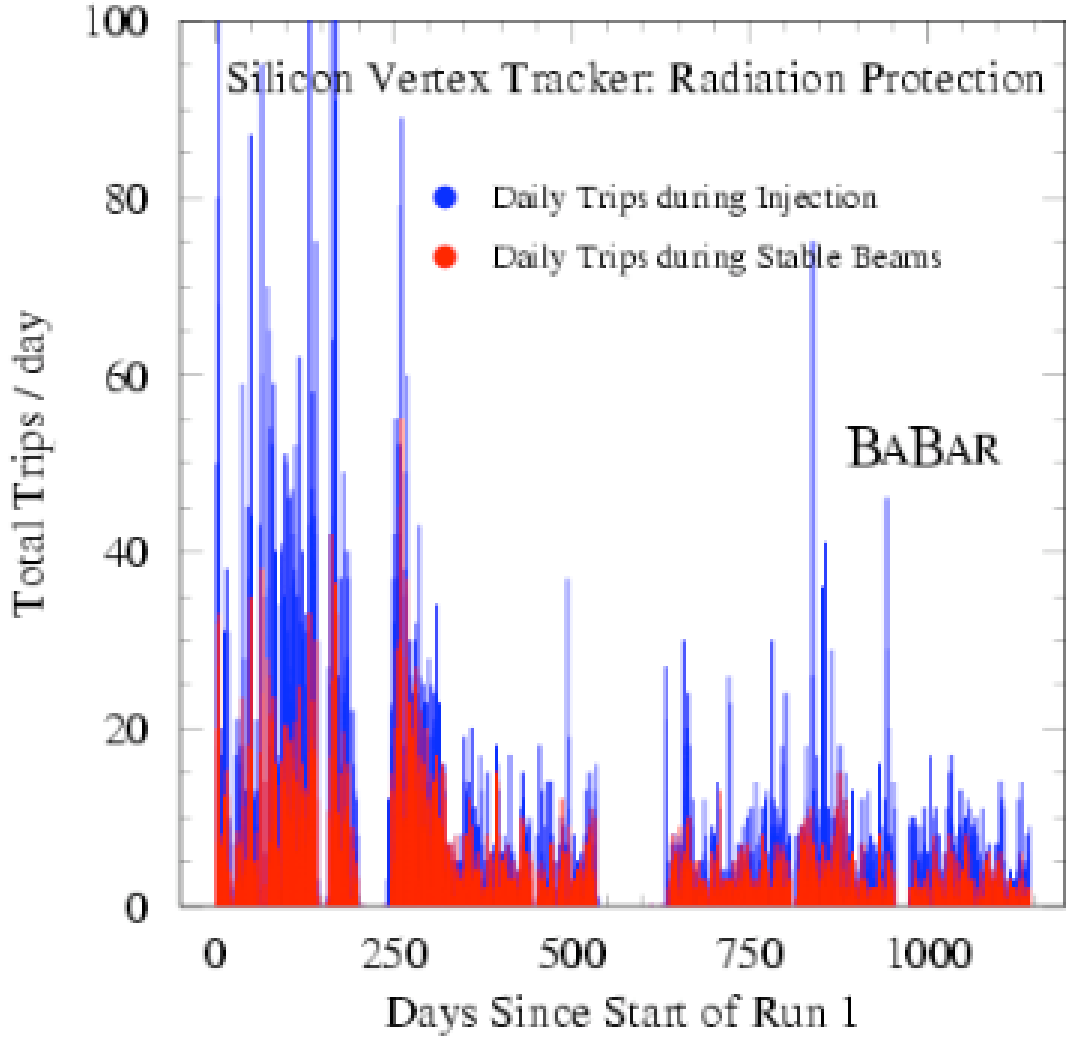
Increasingly difficult to measure background conditions accurately!

Radiation Monitoring



- Most damaged areas in the bend plane ~1.2MRad
- Typical “non-bend-plane” diode ~ 400kRad

Radiation Protection



- 4 bend plane (AKA “mid-plane”) diodes used in abort logic
- We have both a “fast abort” (hardware ~400us) and a “slow abort” (several minutes)
- dose rate thresholds ~1000mR/s (starting June 2002)
- **No major damage due to radiation since installation!**

Radiation Monitoring Upgrades

- *Cannot replace PIN diodes without removing the entire SVT*
- Use PIN diodes without bias? (short-term)
  - Response decreases significantly with increased accumulated dose
  - Probably makes dose estimates even worse
- Readout electronics upgrade (medium-term)
  - continuously measure the leakage current using the ion-clearing gap (~400ns every 7.3us)
- New sensors (long-term)
  - replace PIN diodes with diamond sensors
  - currently performing tests...

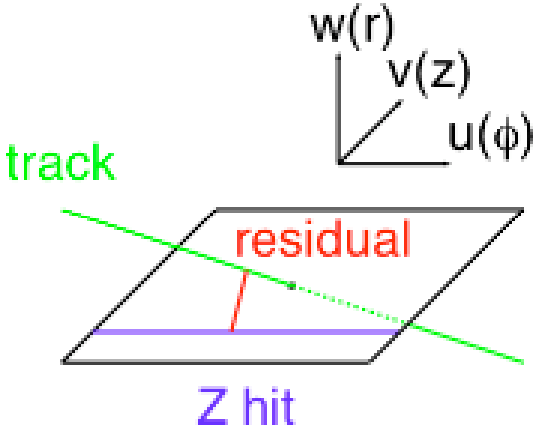
SVT Alignment

Two types of alignment: **global** (SVT with respect to BaBar) and **local** (internal alignment)

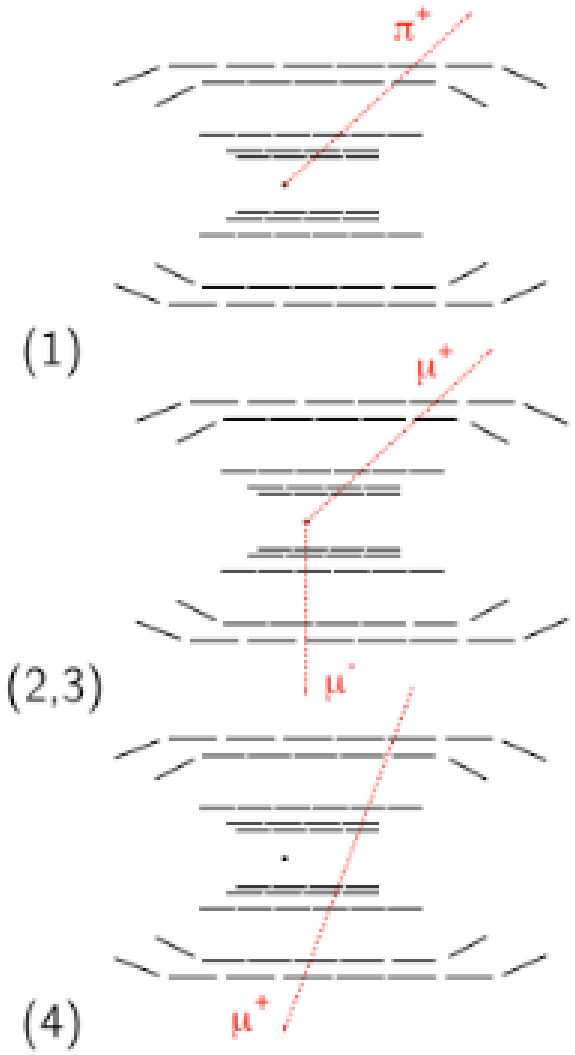
- Global alignment (SVT with Drift Chamber) is done run-to-run (has worked well for years)
- Local alignment has been improving each year
  Many new improvements in the last year!

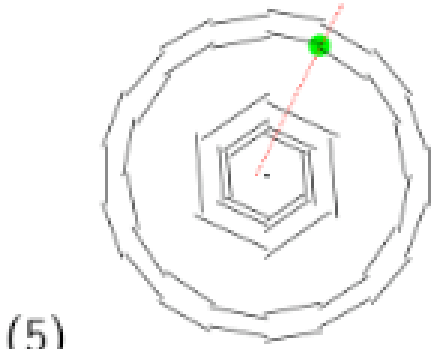
SVT Local Alignment

- Each of 340 wafers described by 6 parameters + *curvature*
- Calculate residuals, minimize χ^2



Track/Hit Selection





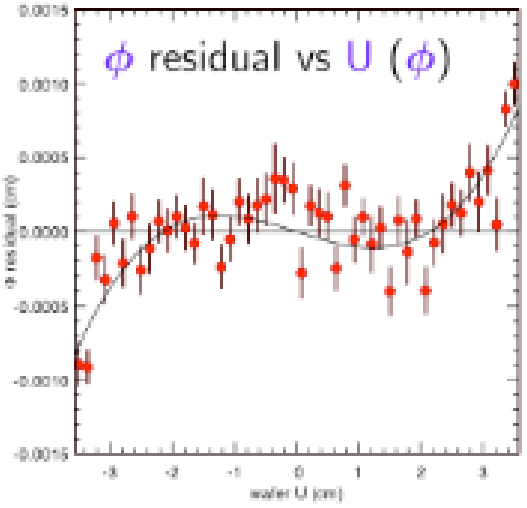
categories of tracks used

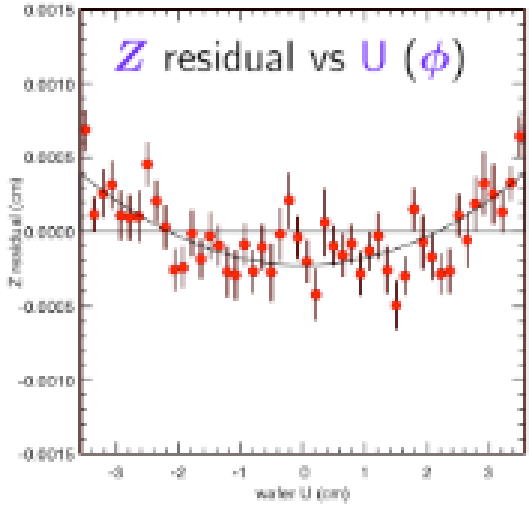
1. "normal"
2. $\pi^+\pi^-$
3. e^+e^-
4. cosmics
5. tracks with overlap hits

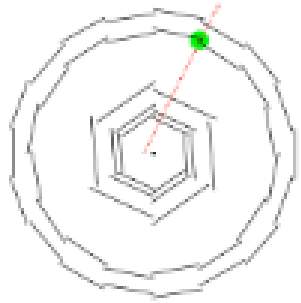
- choose tracks distributed uniformly over detector, categories
- select ~50,000 tracks, use ~3-4 hits/track

Latest Improvements

- New database format-- the “mini”
  - Used to use raw data to get individual SVT hits
  - The process would take weeks; now it takes about a day!
- Re-written algorithm, more flexible (allowing new track categories to be added easily...)
- Allows individual wafer curvature

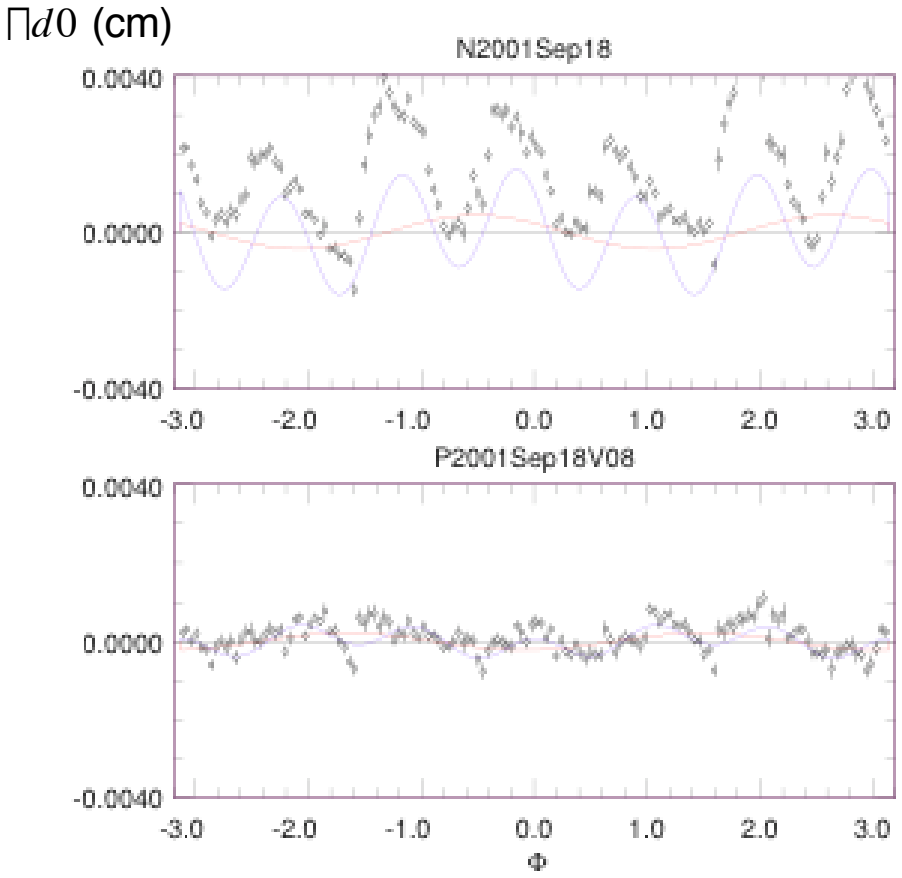






Mu-pair misdistance

distance between $\mu^+\mu^-$ tracks produced at the IP
as a function of ϕ



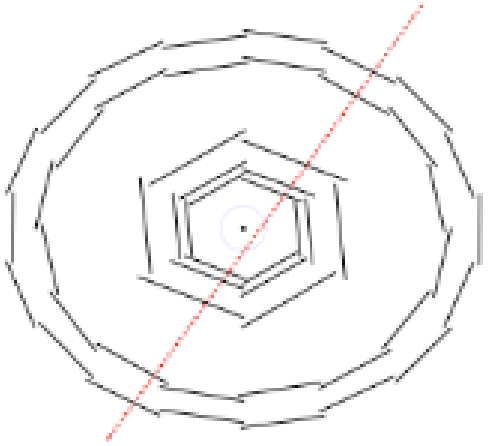
← *old alignment*

← *new alignment!*

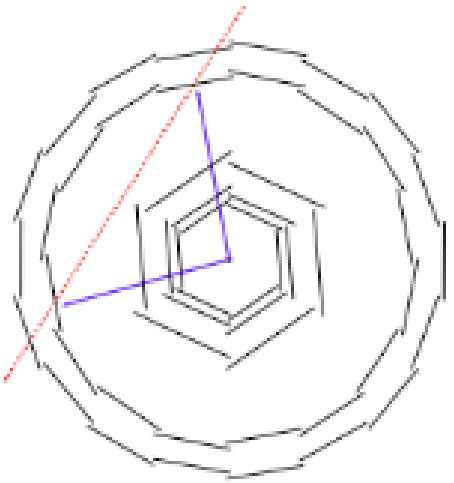
Further Improvements

- Currently, there is only a weak constraint on *elliptical bias*
- Present trigger only keeps tracks near IP
- Need tracks connecting wafers at $\Pi/2$
- Trigger changed sometime soon...

Present L3 Cosmics

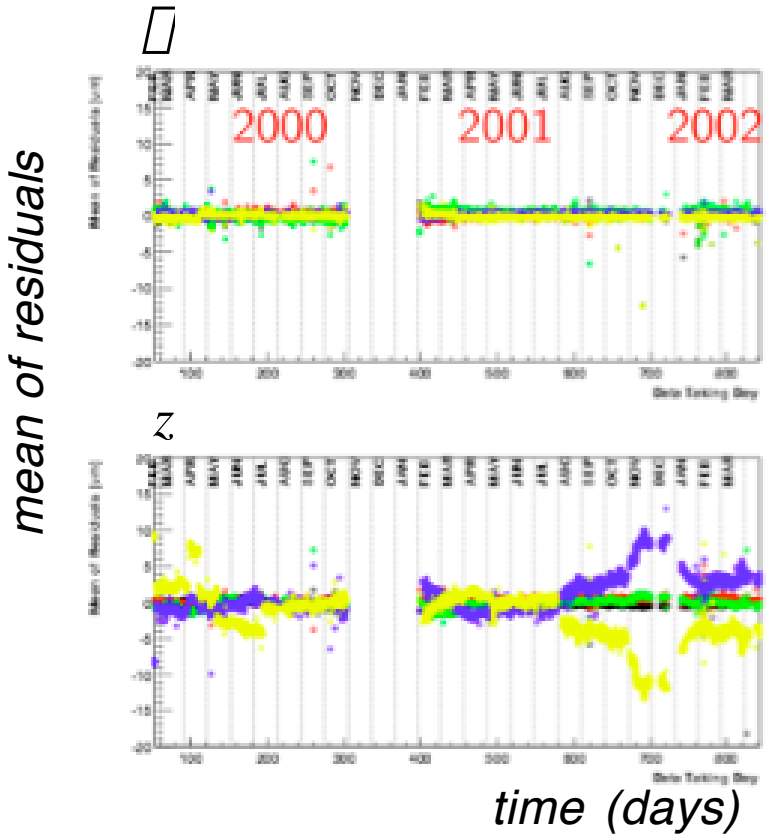


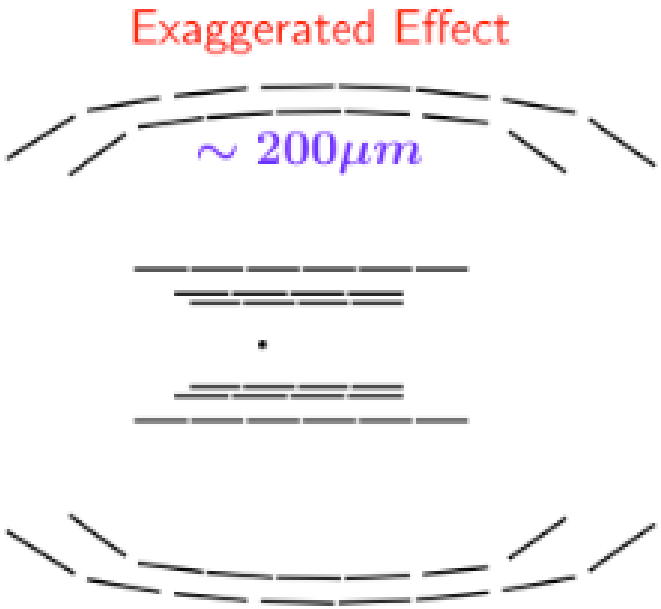
Cosmics we need



Alignment Monitoring

- Change in relative humidity near SVT caused slight expansion of layers 4 and 5
- Noticed change in mean and width of residual distributions, calculated new alignment parameters

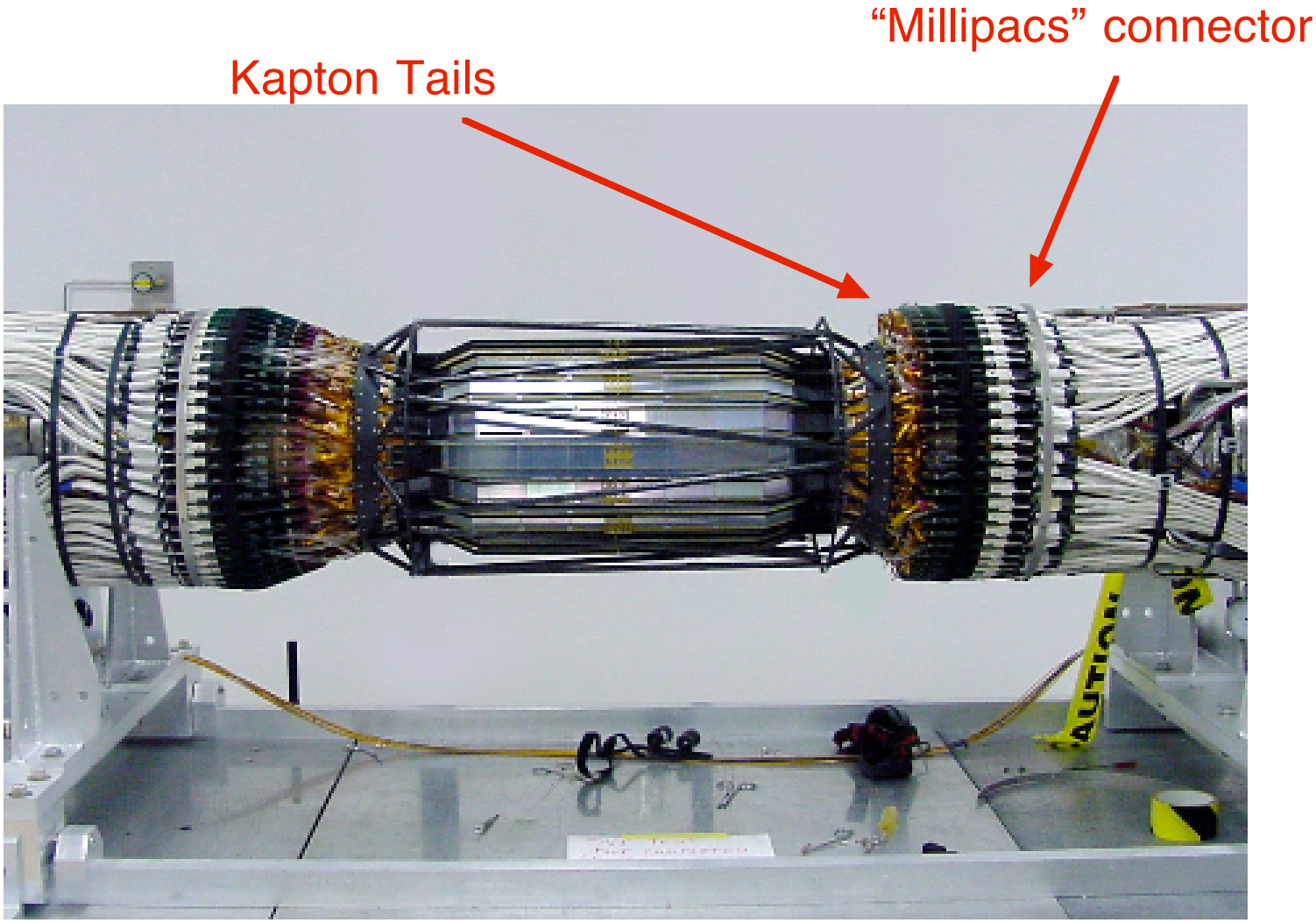




Summer Shutdown

- BaBar shutdown July 1 -- Nov 15, 2002
  - Upgraded/repaired muon detector
  - Installed more cooling to bellows near IP to allow higher luminosity
    - Removed the SVT!
- Restored 6 readout sections!
  - 1 half-module (2 readout sections) could not hold bias fixed itself!
  - 4 readout sections were not connected properly!
- No major work done on SVT (would require another 1.5 months)
- Tried not to break anything

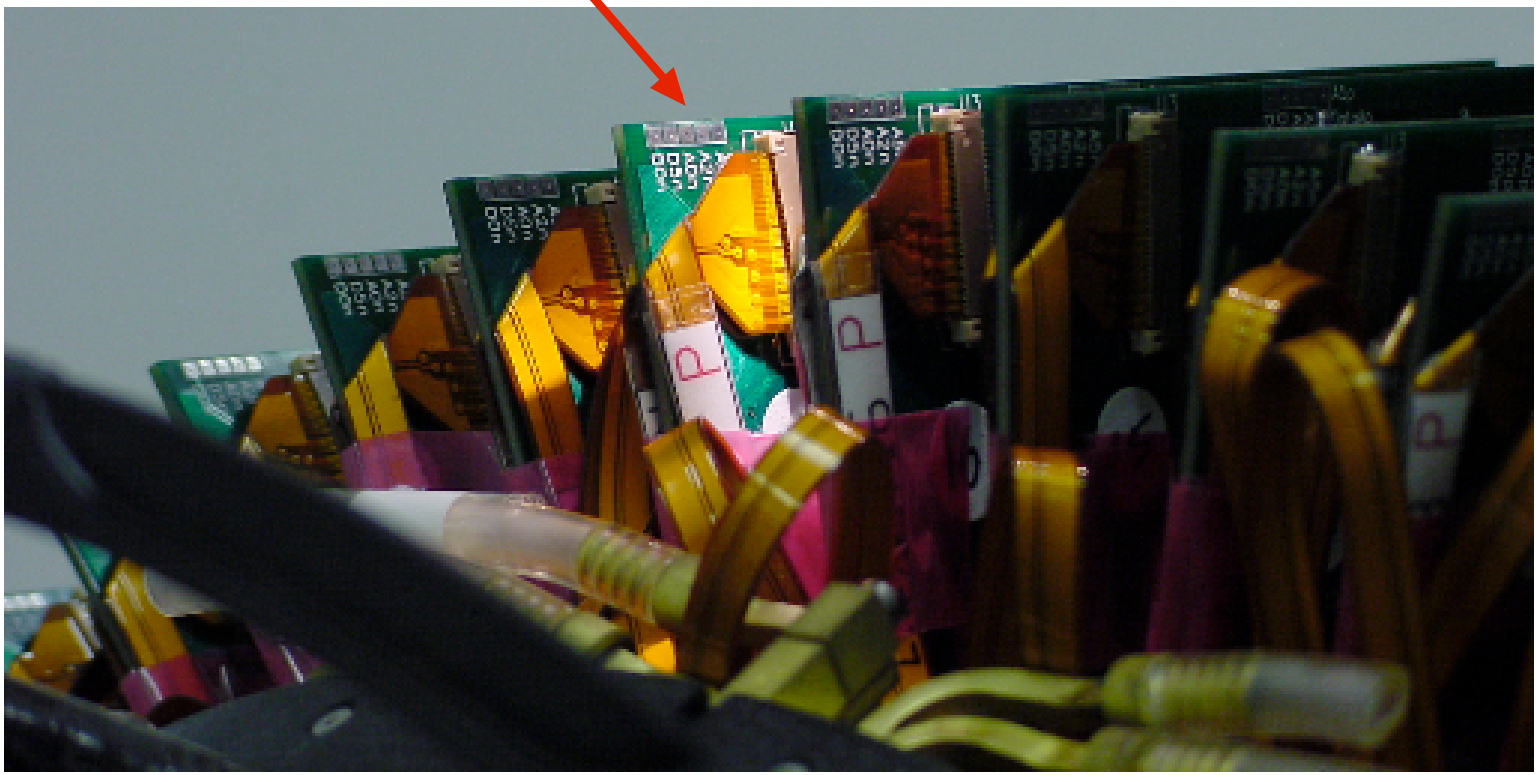
SVT in Clean Room



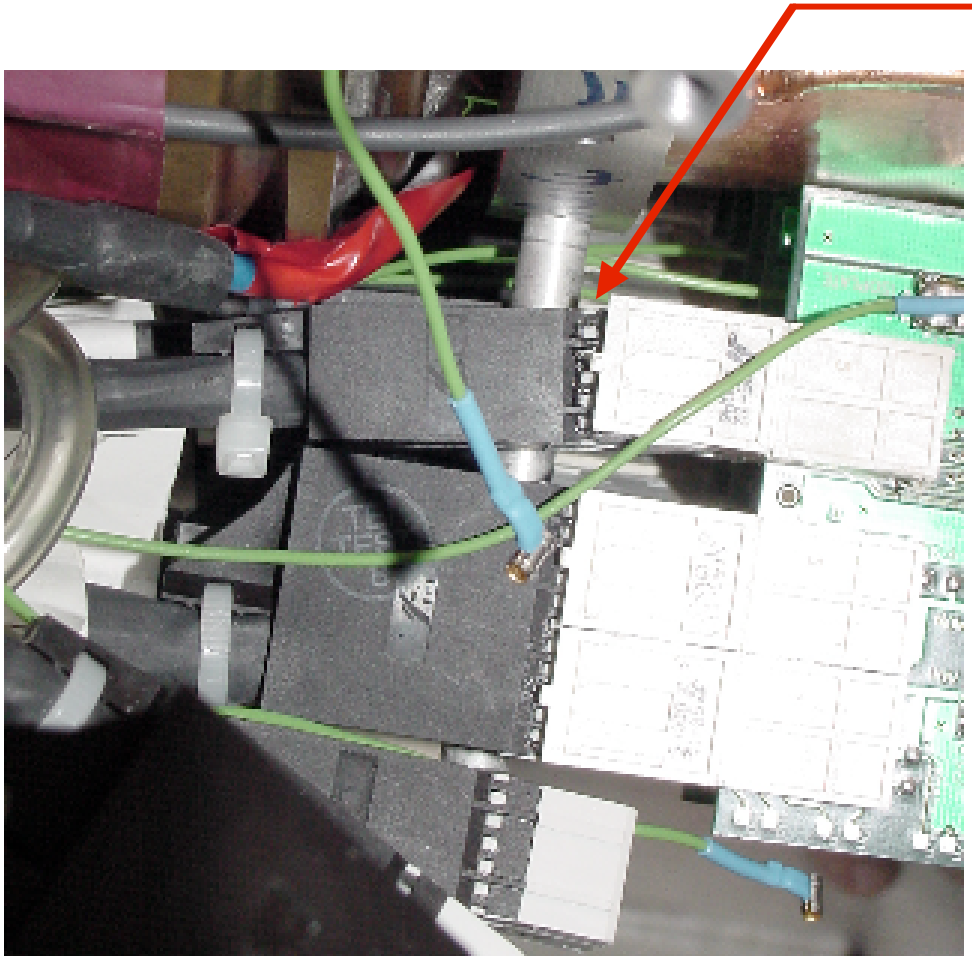
Slipped Kapton Tails

(fixed two readout sections by re-inserting tails)

Rotated just a little bit...



Connector came out...



Connector slipped out...

(fixed 1 half-module =
2 readout sections)

Moral of this story...

Redundancy is critical, and try to have good connectors!

Summary

- **The SVT works reliably as designed**
- It is more radiation hard than designed, so we can take more data
- The internal alignment is much better, taking many subtle features into account
- We recovered 6 readout sections during the shutdown this summer
- Ready for more data! (next week...)