CDF Run II Silicon Detector

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On behalf of the CDF Run II Silicon Operations Group

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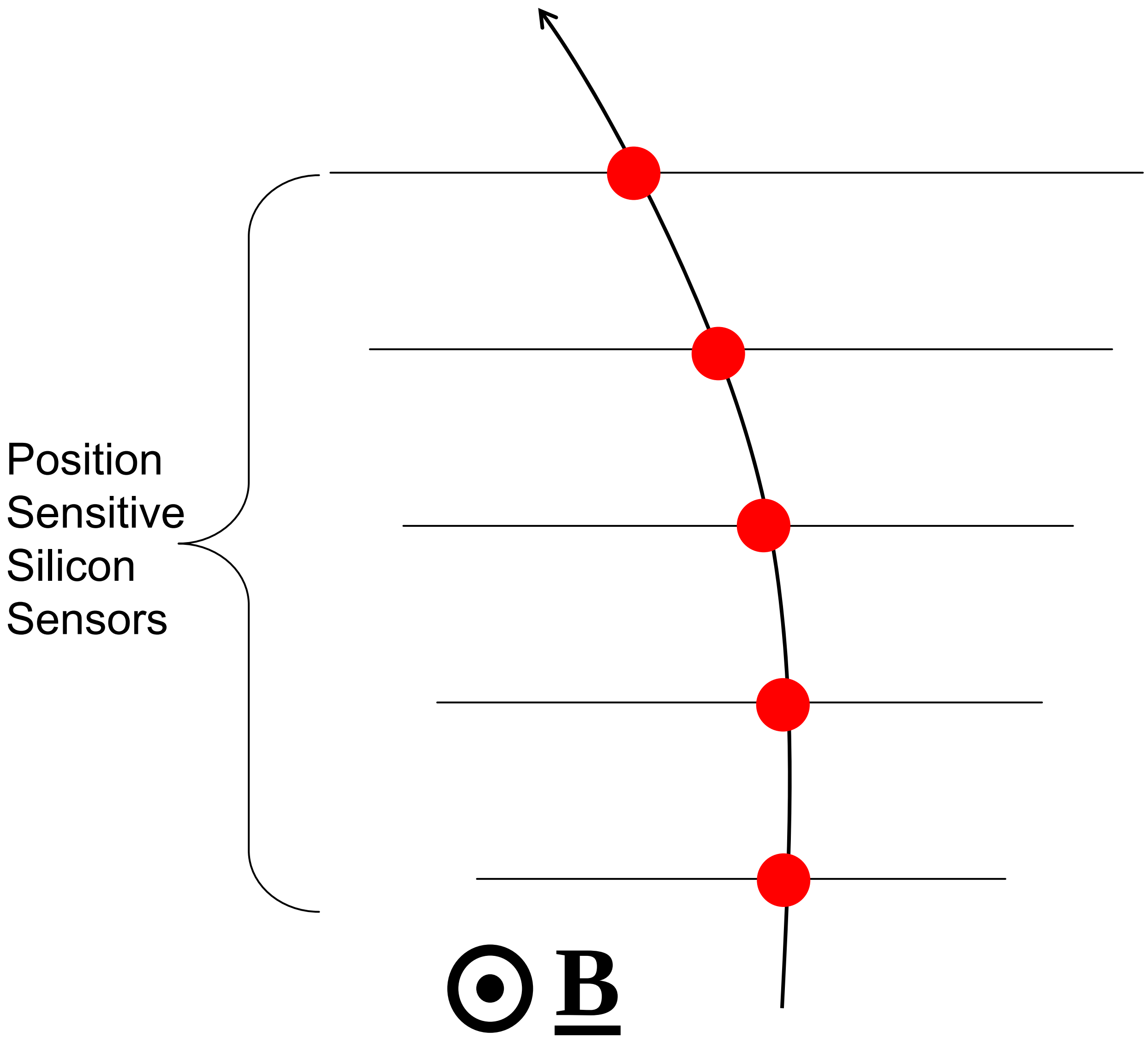
Order of Talk

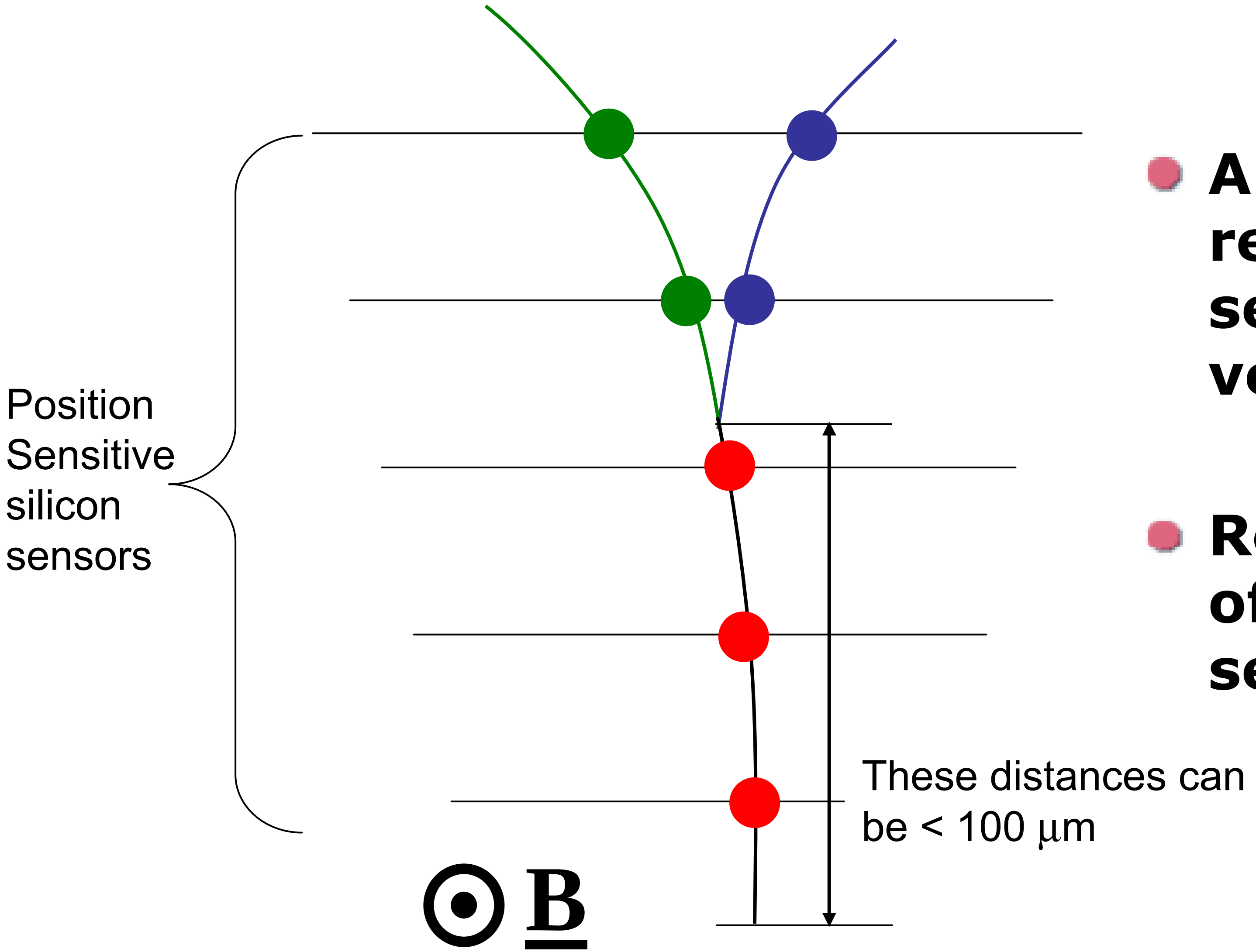
- **Introduction**
  - Tracking *for dummies*
- **Commissioning**
- **Detector Longevity**
- **Conclusions**

Tracking *for Dummies*



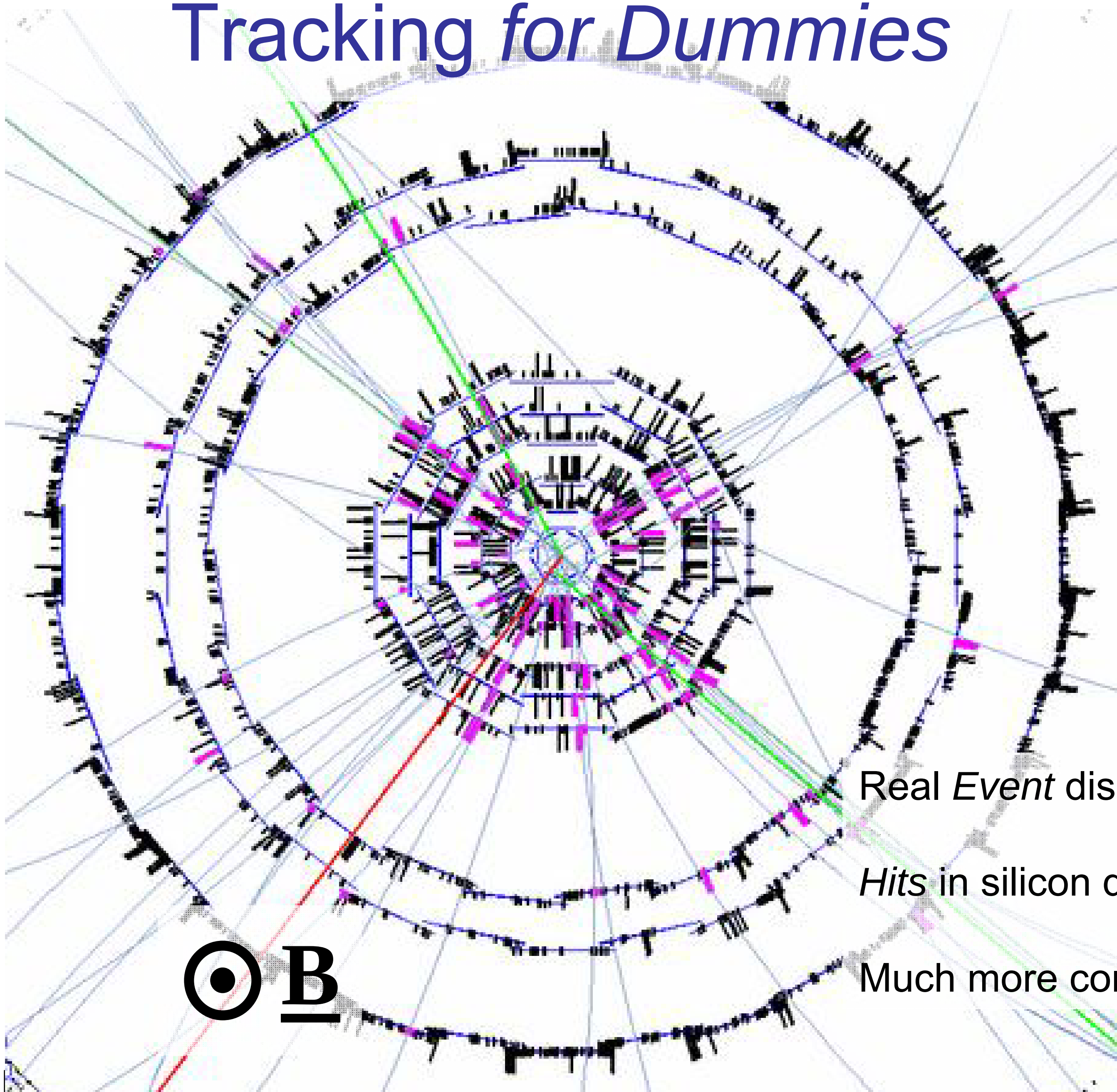
- **Use magnetic field to bend charged particle trajectory**
- **Amount of curvature depends on particle momentum**
- **Use position sensitive silicon sensors**
  - Reconstruct track
  - Measure momentum (& charge)

Tracking *for Dummies*



- **Ability to resolve secondary vertices**
- **Real power of Silicon sensors**

Tracking *for Dummies*

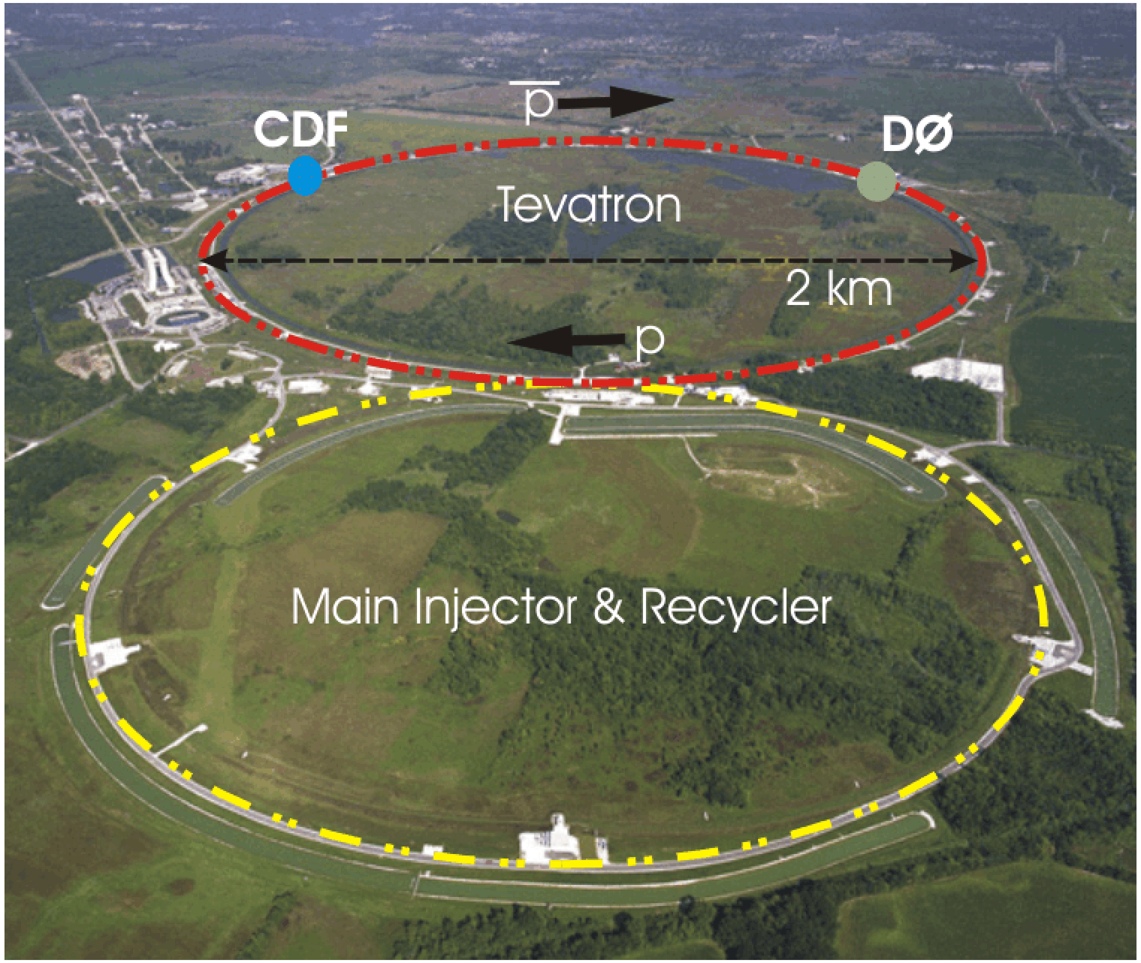


Real *Event* display

Hits in silicon detector

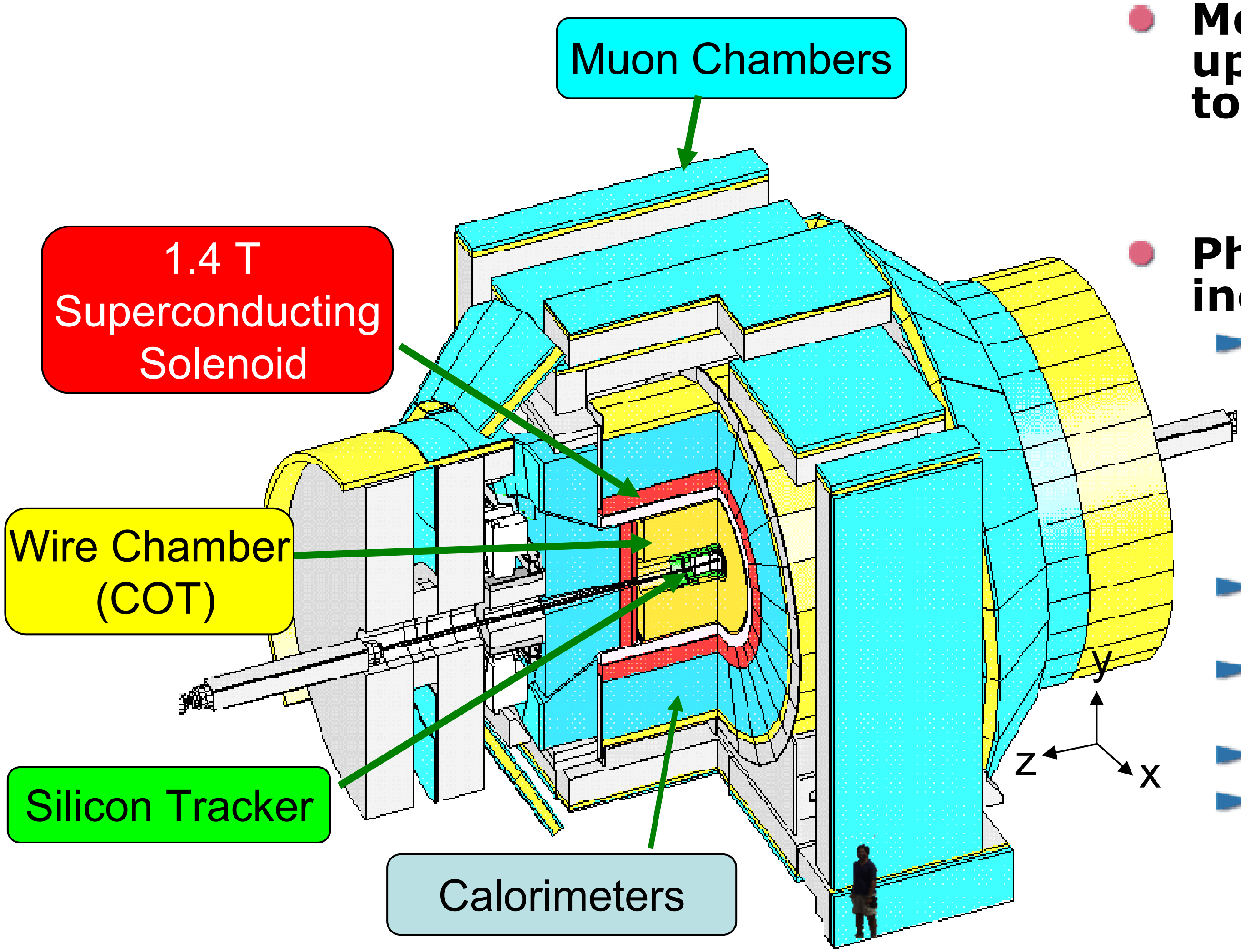
Much more complex…

Tevatron: Run II



- **Proton-AntiProton Collider**
- **$\sqrt{s}$ = 1.96 TeV**
  - Highest Energy Collider in the World (…until LHC)
- **Current Luminosity $\approx 10^{32}$ cm^{-2} s^{-1}**
  - Aim to get to $2\text{-}4\times10^{32}$
- **Collisions every 396 ns**

CDF II Detector

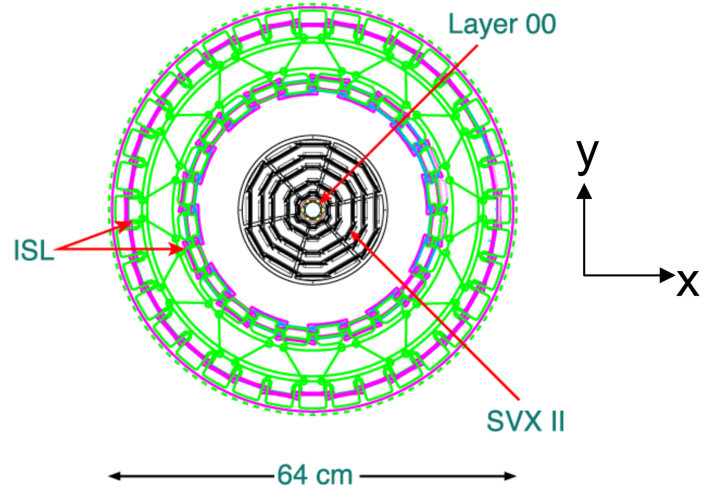


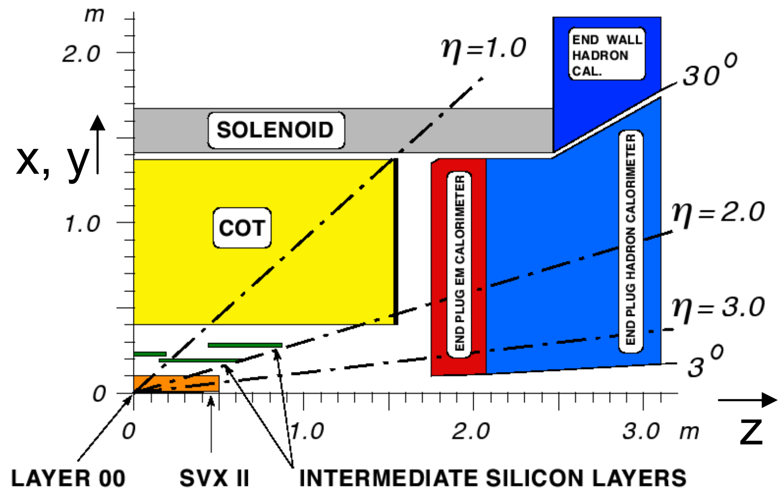
- **General Purpose Detector**
- **Most of the detector upgraded from Run I to Run II**

- **Physics Programme includes**
  - Properties of the Top Quark
    - Only facility capable of making Top Quarks (..until LHC)
  - Precision Electroweak Physics
  - CKM Matrix & B Physics
  - Tests of QCD
  - Search for Higgs Boson & New Physics

CDF Silicon Detector

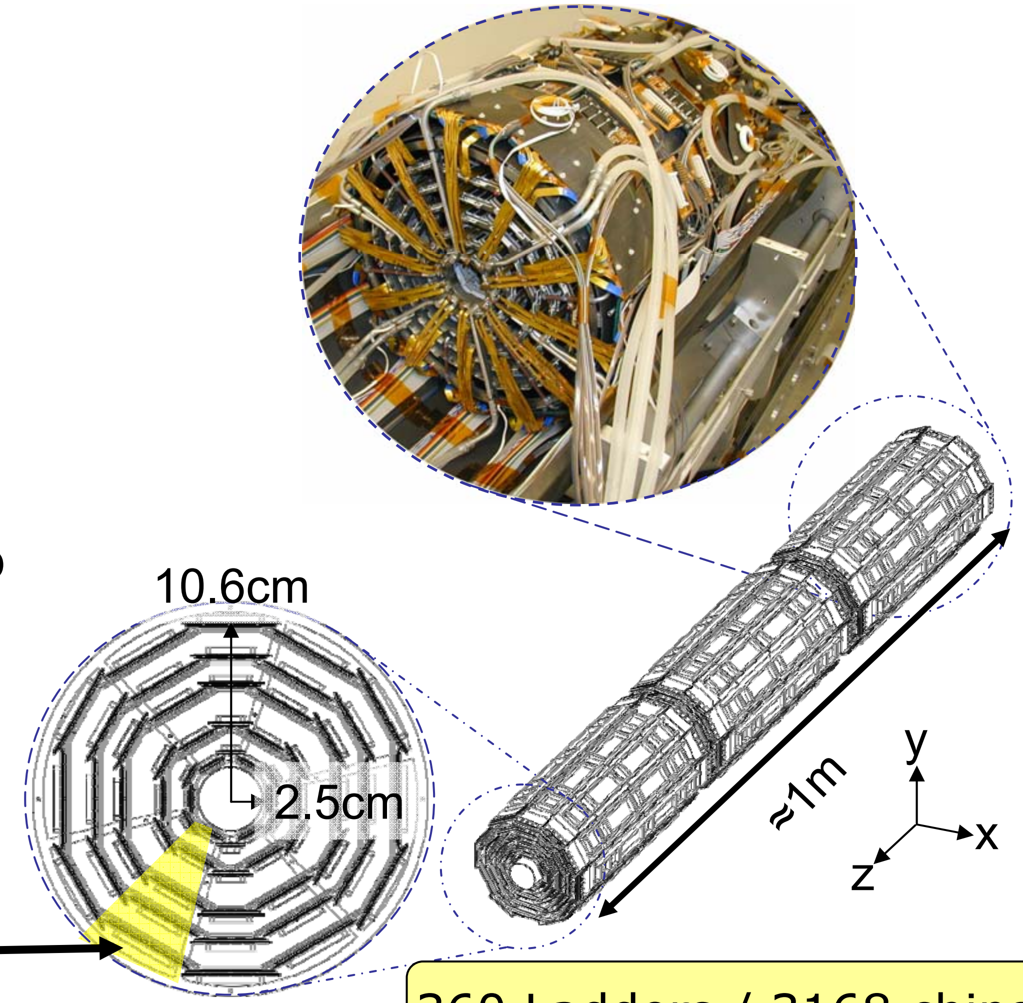
- **Run II Silicon**
  - 7-8 Silicon Layers
  - 722,432 Channels / 704 Ladders/ 5644 Chips
  - Largest operating detector in HEP
- **Silicon detector comprised of:**
  - L00
  - SVX II
  - ISL
- **Detector is inaccessible until 2009**
  - It might as well be in space!





SVX II

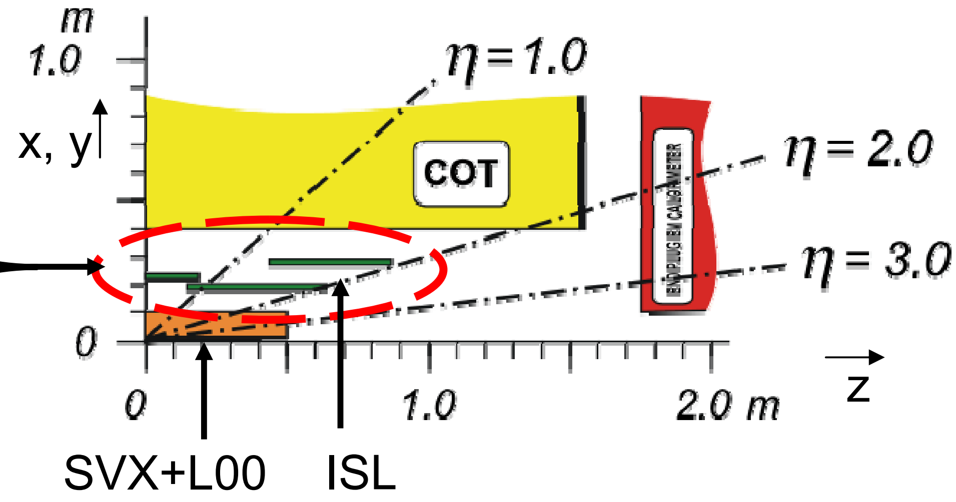
- **The *core* of the CDF Silicon Detector**
- **5 layers of double-sided silicon**
  - 3 layers with axial & 90^0 stereo strips
  - 2 layers with axial & 1.2^0 stereo strips
- **Strip pitch from 60μm to 141μm**
- **Used in L2 displaced Track Trigger**
  - Tight alignment tolerances
  - Fast wedge-wide Readout (25Khz)

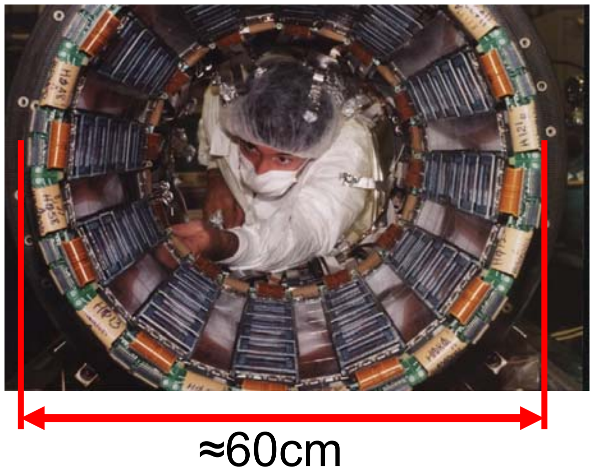


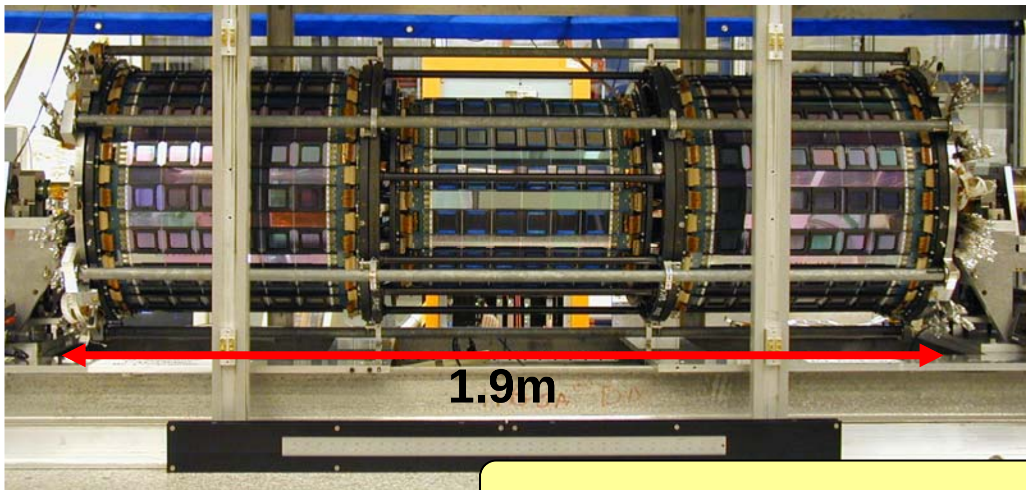
360 Ladders / 3168 chips

Intermediate Silicon Layer (ISL)

- **One central layer (|η|<1)**
  - Links tracks from SVX to Wire-Chamber (COT)
- **Two forward layers (1<|η|<2)**
  - Allows tracking at high η
- **Strip Pitch:**
  - 112μm (axial & stereo)



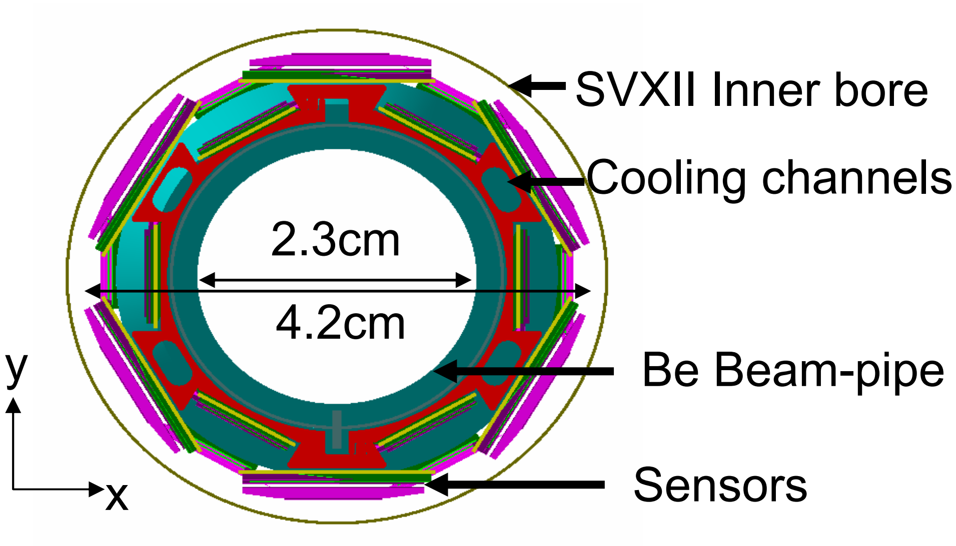


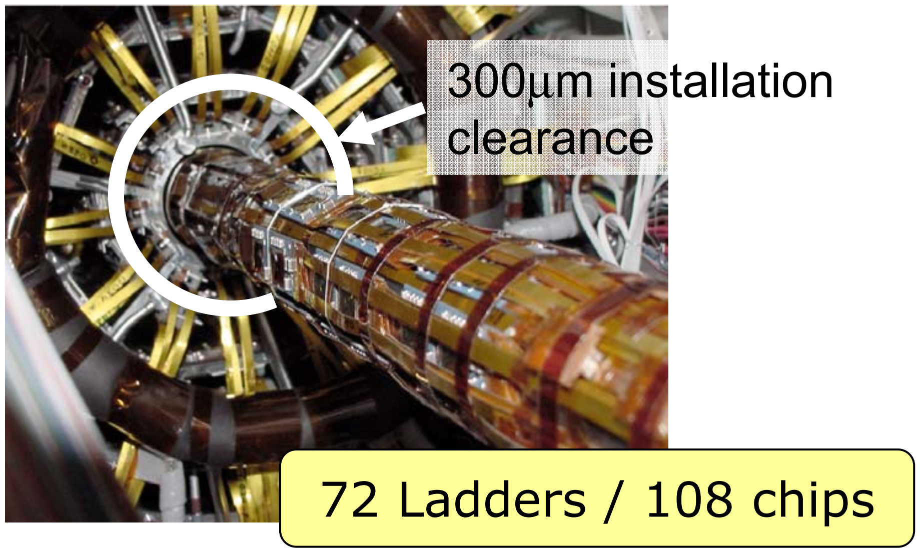


296 Ladders / 2368 chips

Layer-00 (L00)

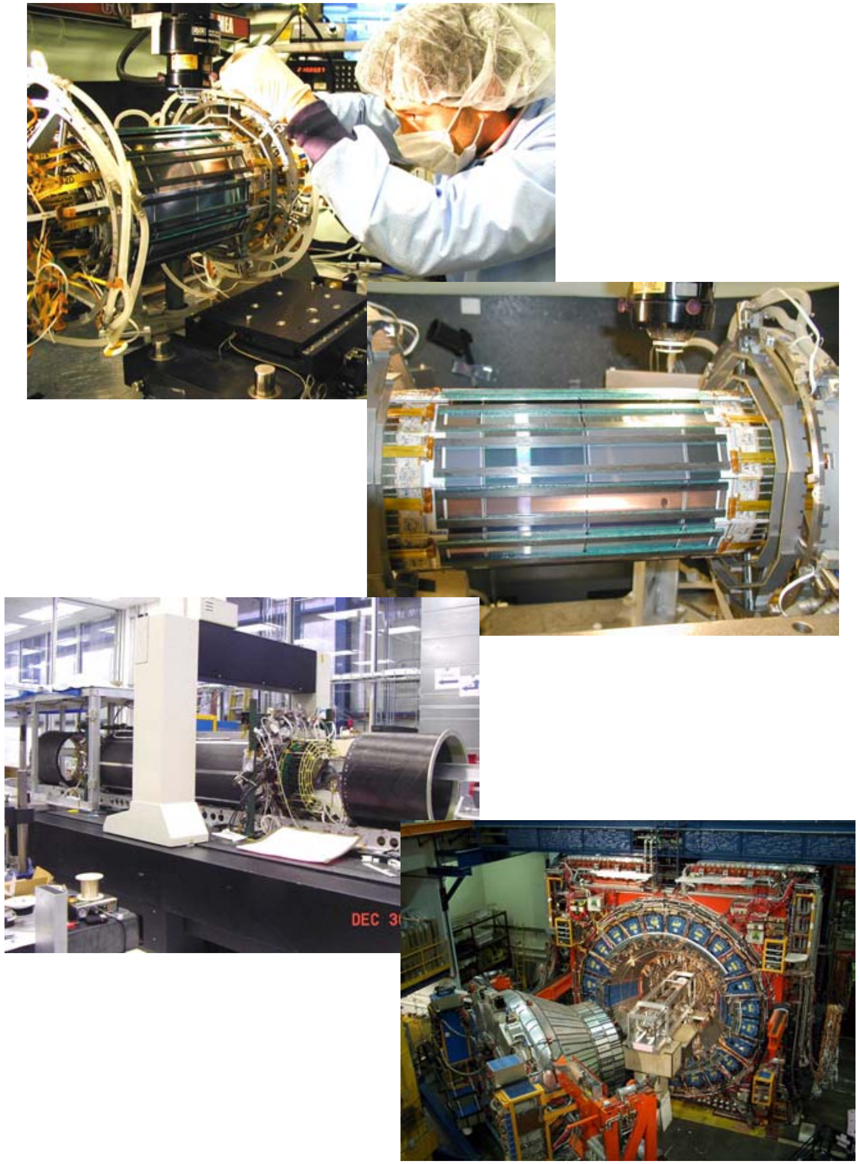
- **Precision position measurements**
  - 50μm effective strip pitch
  - Low Mass: 0.6%-1.0% X_0
  - Support structure mounted directly on Be beam-pipe
- **Rad-Hard Silicon**
  - Can be biased to 500V
  - Likely to outlive inner most SVXII layer
- **Vital for B physics**
  - Especially B_s oscillations





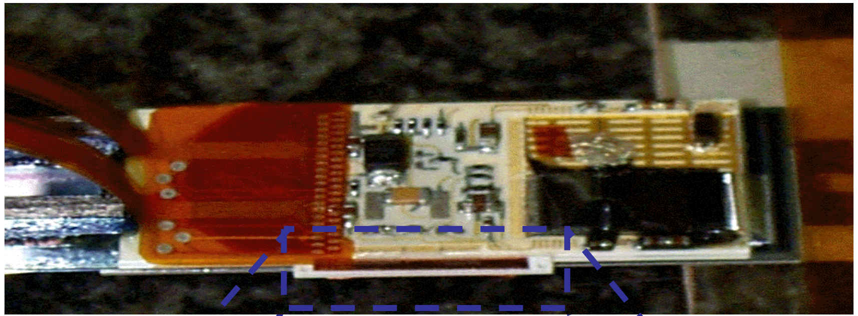
Commissioning

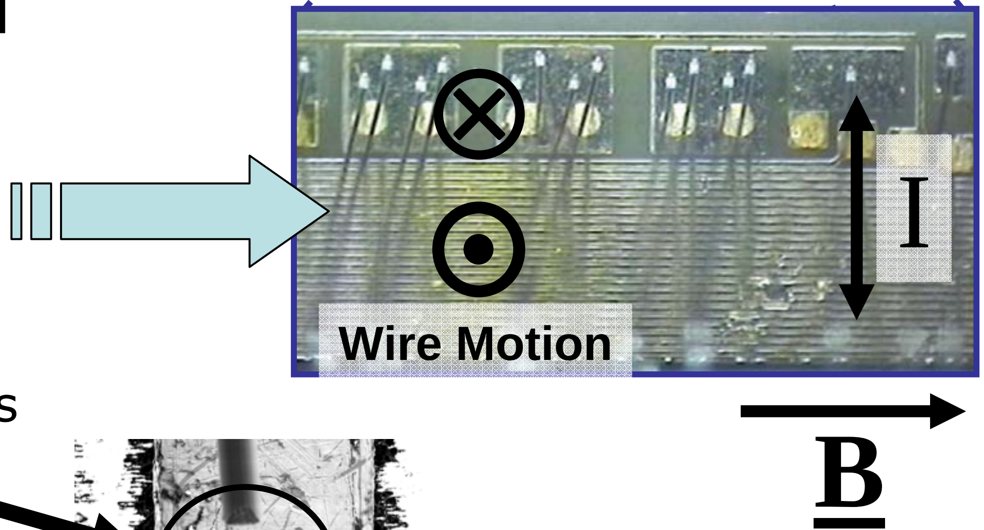
- **R&D: ≈ 4 Years**
- **Assembly + Installation: ≈ 1 Year**
- **Detector Commissioning: ≈ 1.5 Years**
- **During commissioning various problems encountered:**
  - Blocked Cooling lines in ISL
  - Wirebond Resonance Problems
  - Beam Incidents
  - Noise pickup on L00

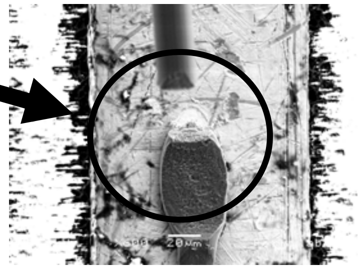


Wirebond Resonance Problems

- **Observed loss of data & power to Z sides of ladders**
  - Found to occur under anomalous trigger conditions
- **Failure due to wirebond resonances**
  - Wires orthogonal to magnetic field
  - Wires feels Lorentz force during readout
  - If frequency is right, wires resonate and break



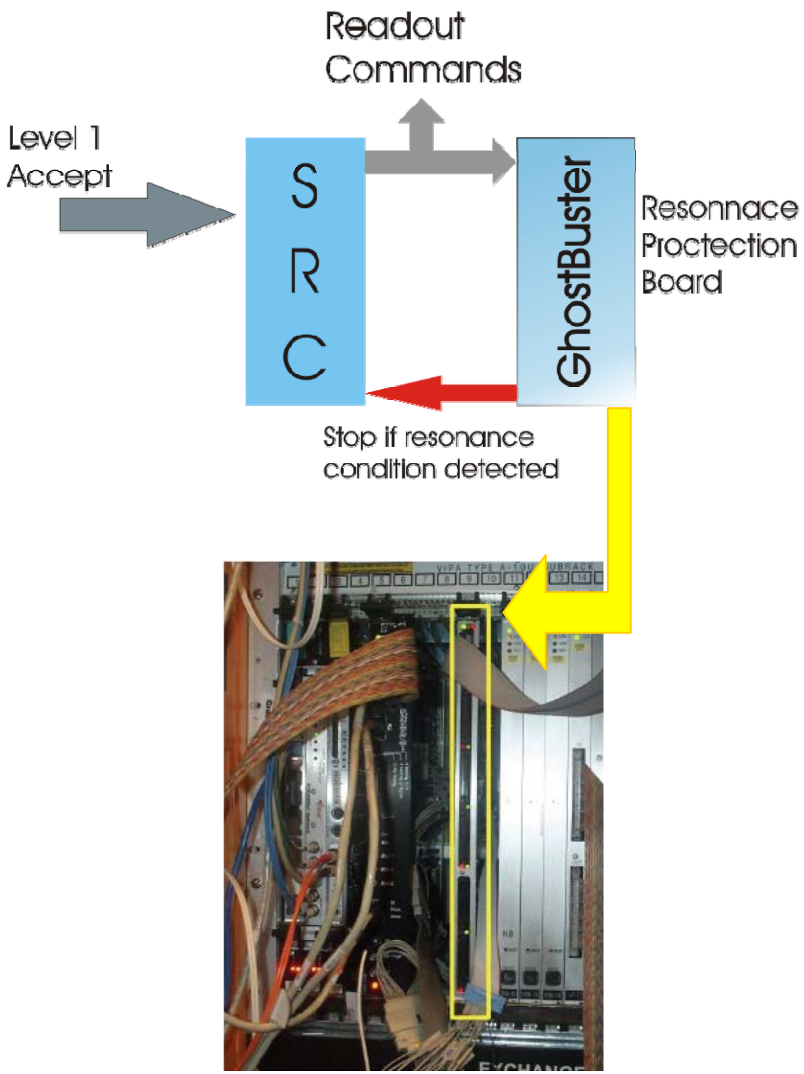




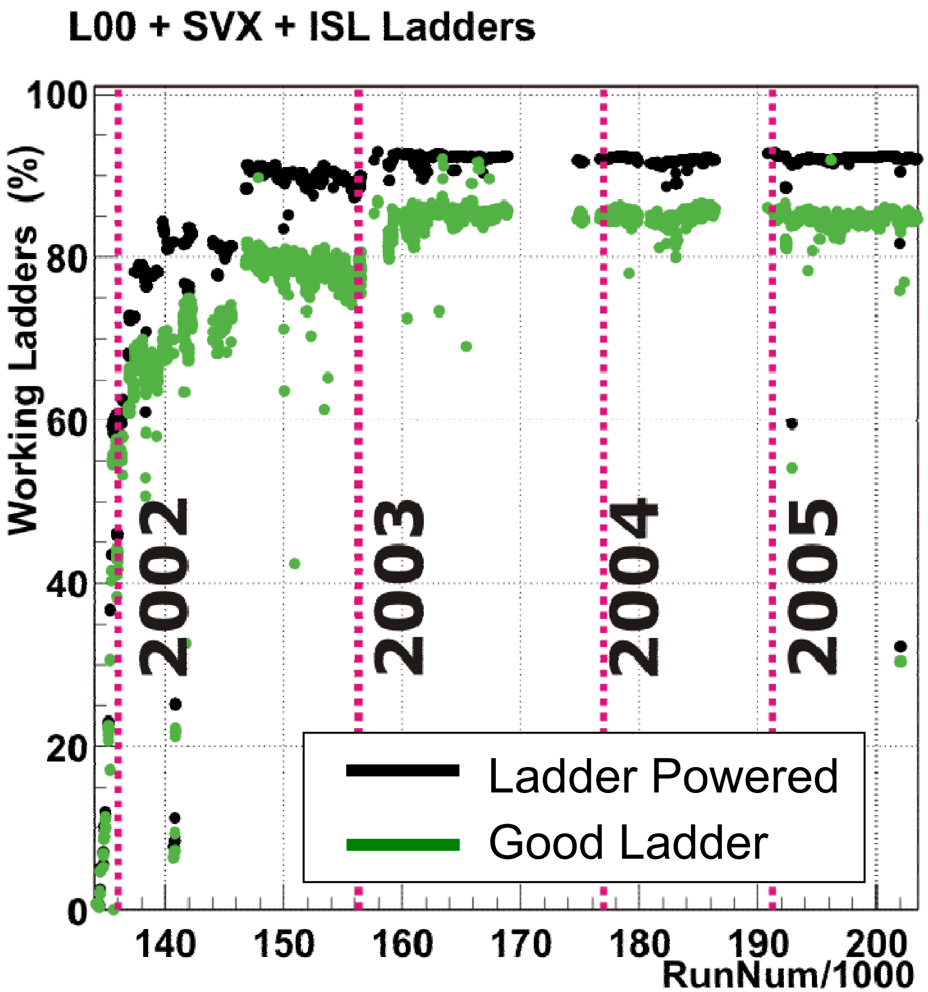
Resonance Protection System

- **Dedicated Card to monitor readout commands from SRC: *GhostBuster***
  - Immediately stops data taking if resonance condition detected

- **Has successfully prevented any further loss**



Current State of the Detector



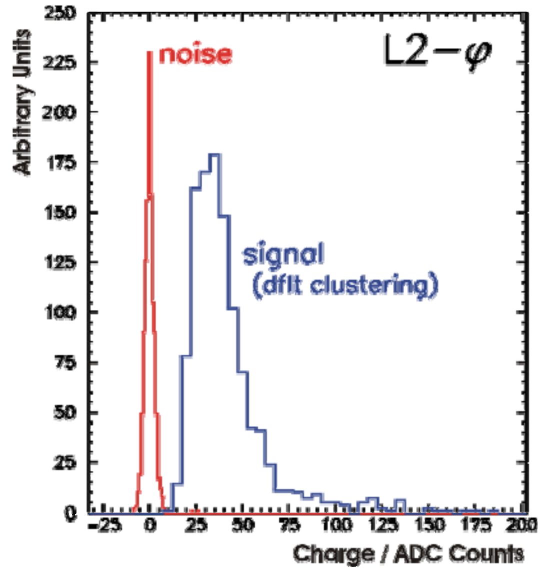
- **Detector is in steady state**
  - 93% is powered
  - 84% have <1% Error Rate
- **Used in regular data taking**

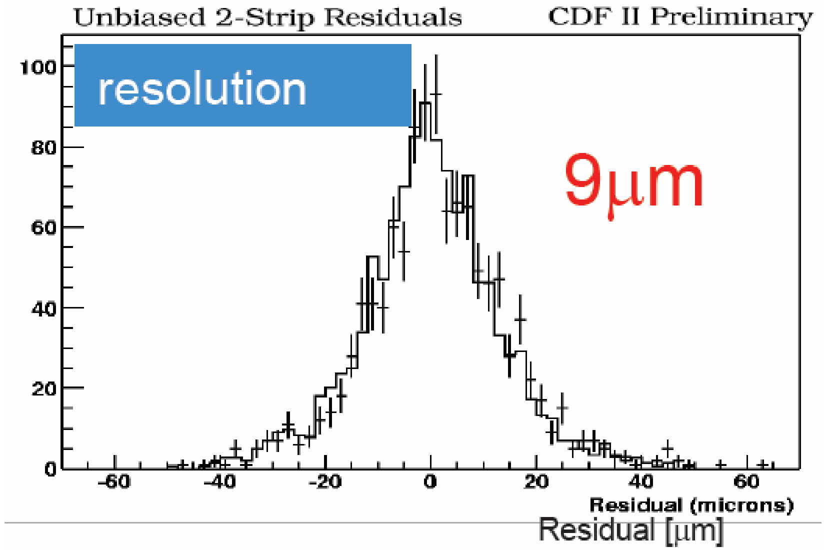
Physics Performance

- **Charge Collection Efficiency > 99%**
- **Single Hit Efficiency > 90%**
- **Resolution: 9μm**

- **Signal-to-Noise Ratio**

SNR	RΦ	Z
L00	10:1	-
SVX	14:1	12:1
ISL	12:1	12:1

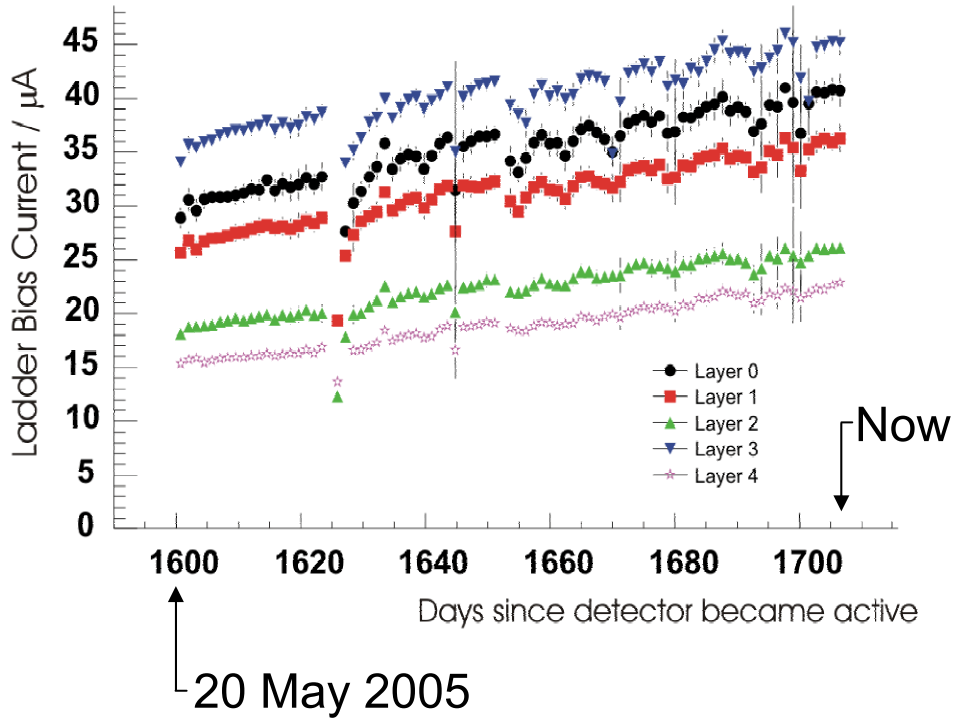




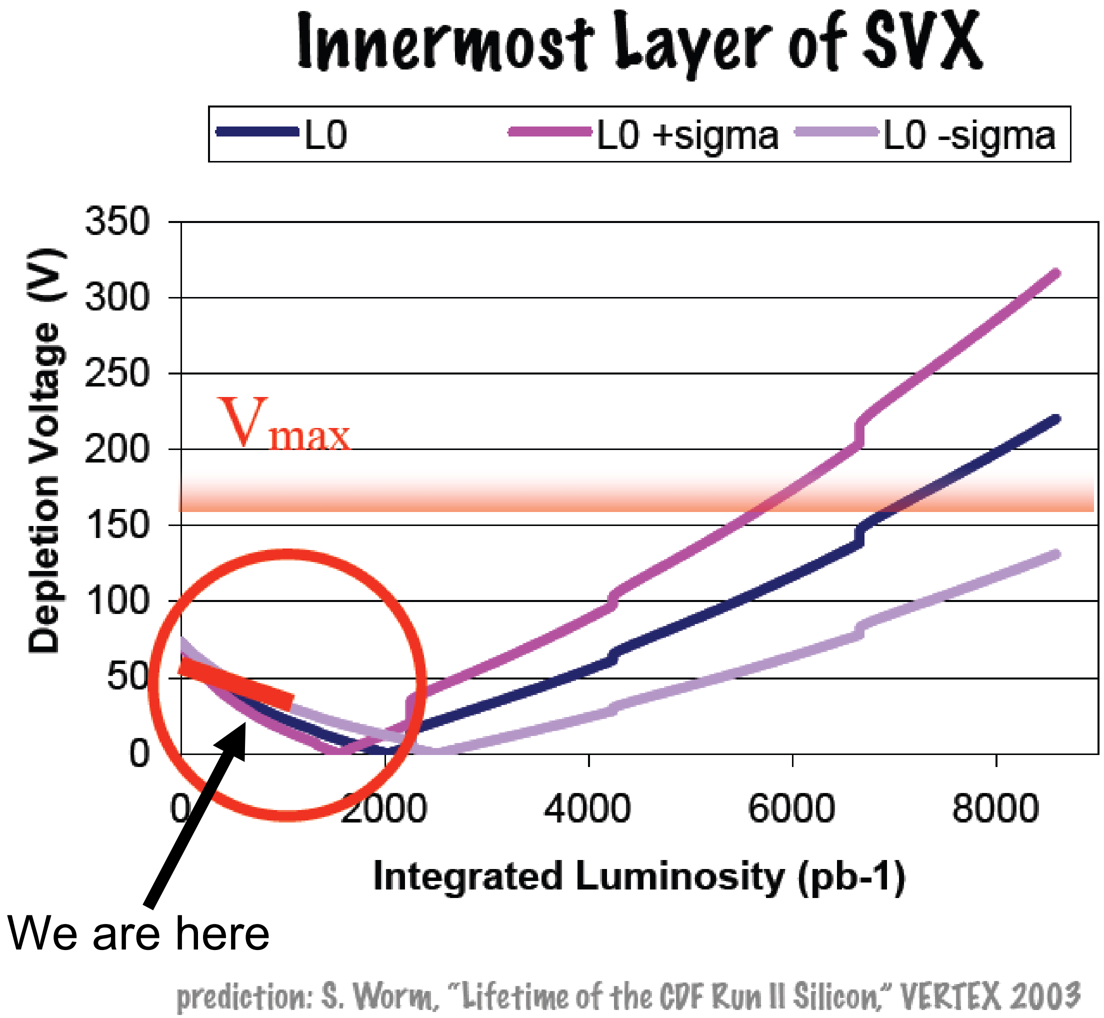
Lifetime Issues

- **SVX II was to be replaced after 2fb^{-1} (2-3 years of operation)**
- **Run IIb silicon cancelled**
  - Now have to survive to 2009 (4-8 fb^{-1})
- **What determines lifetime**
  - Signal-to-Noise is too low
  - Unable to fully deplete Silicon ladders

Bias Currents for SVX Barrel 0 Wedge 0



Lifetime Projections



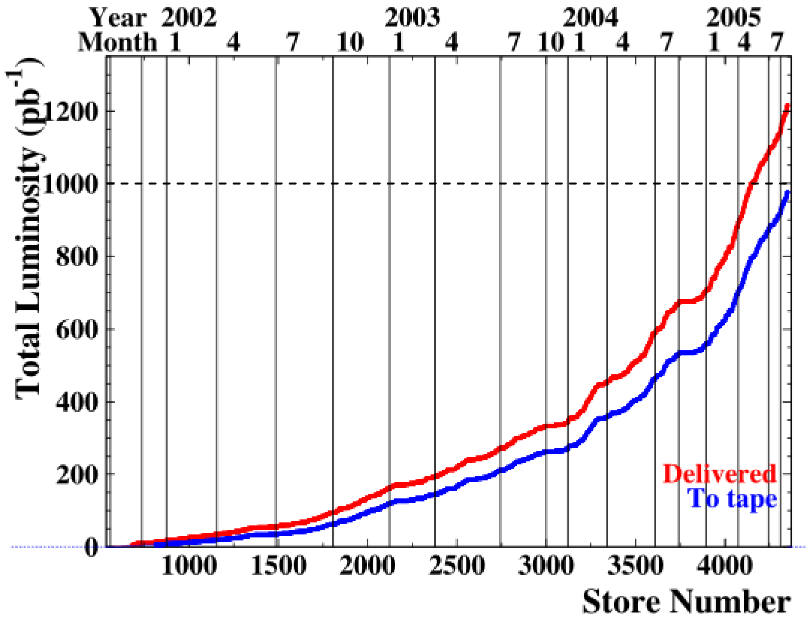
- **According to predictions and current data, we seem to be following the optimistic trend**
- **Hopefully we'll survive to 2009**

Conclusions

- **Despite the long commissioning, the CDF Silicon detector is fully operational**
- **The Silicon detector is used in regular data taking**
- **The lifetime predictions are encouraging. Hopefully the detector will survive to 2009**

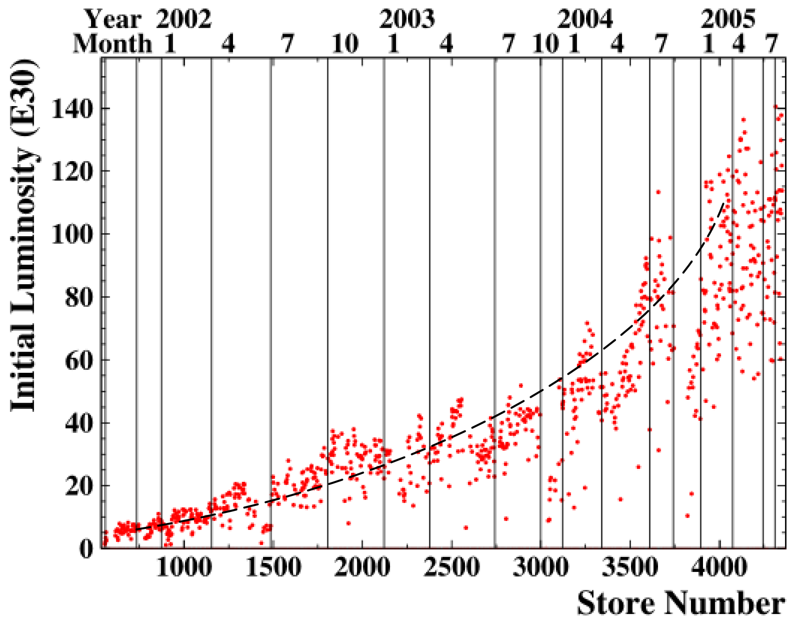
Backup Slides

Tevatron Performance



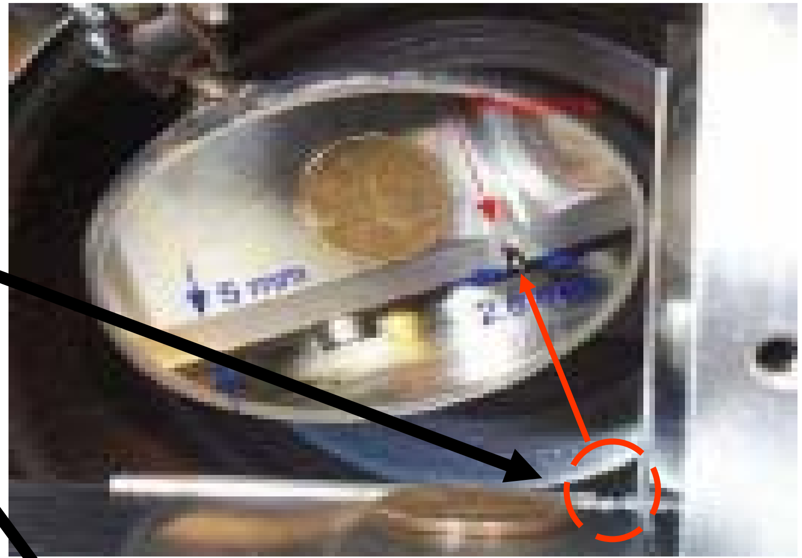
- Almost 1fb^{-1} on tape
- Run I only acquired 110 pb^{-1}

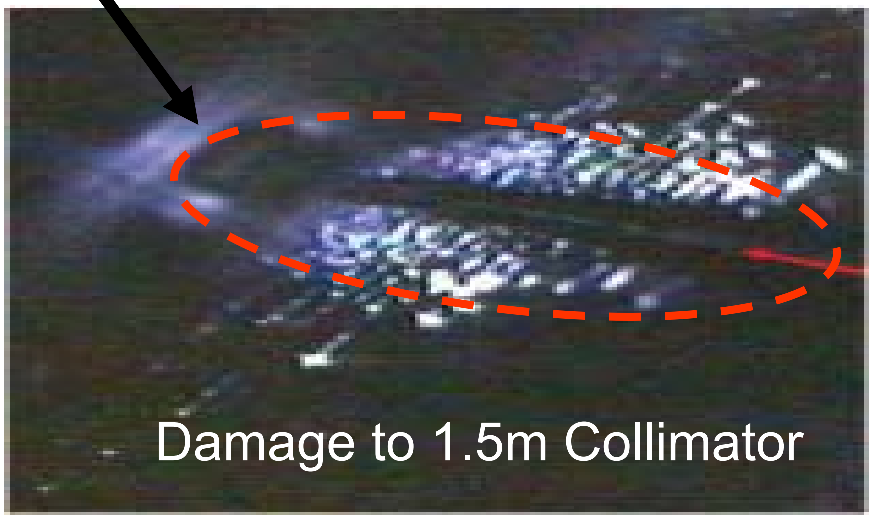
- Store initial luminosity steadily increasing
- Greater luminosity expected once Electron Cooling has been commissioned
- Run I ended at 25E30 cm^{-2} s^{-1}
- Run II expects to reach 200-400E30 cm^{-2} s^{-1}



Beam Incidents

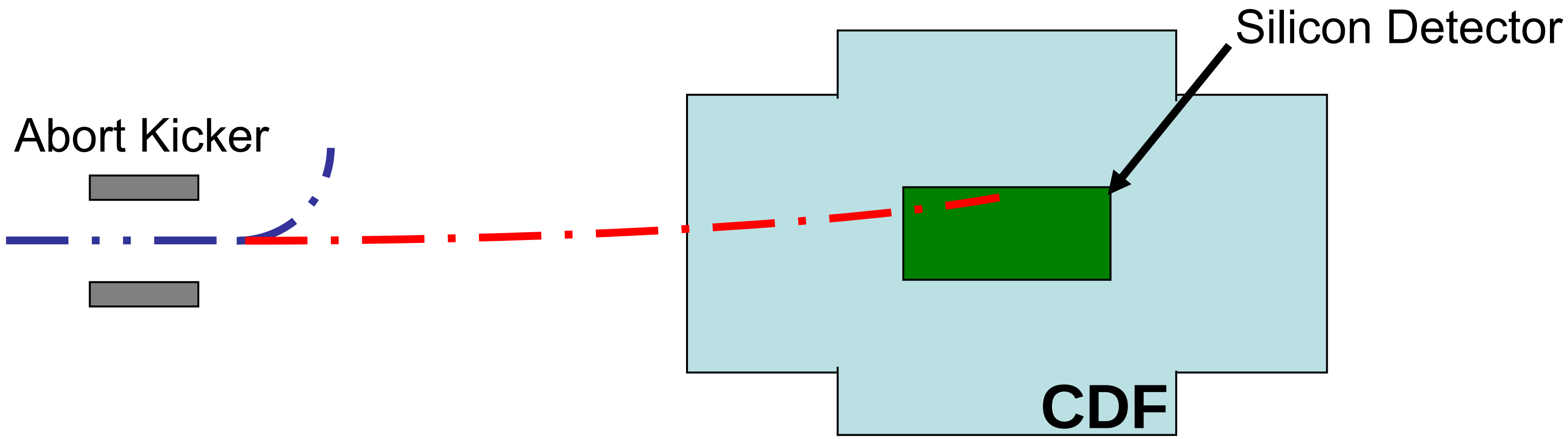
- **1TeV beams have a lot of energy!!**
  - Can cut through solid steel
- **Quenches**
  - If beam is not stable it can quench the Tevatron’s superconducting magnets
- **Kicker Prefires**
  - By far, most serious incident (…see next slide)





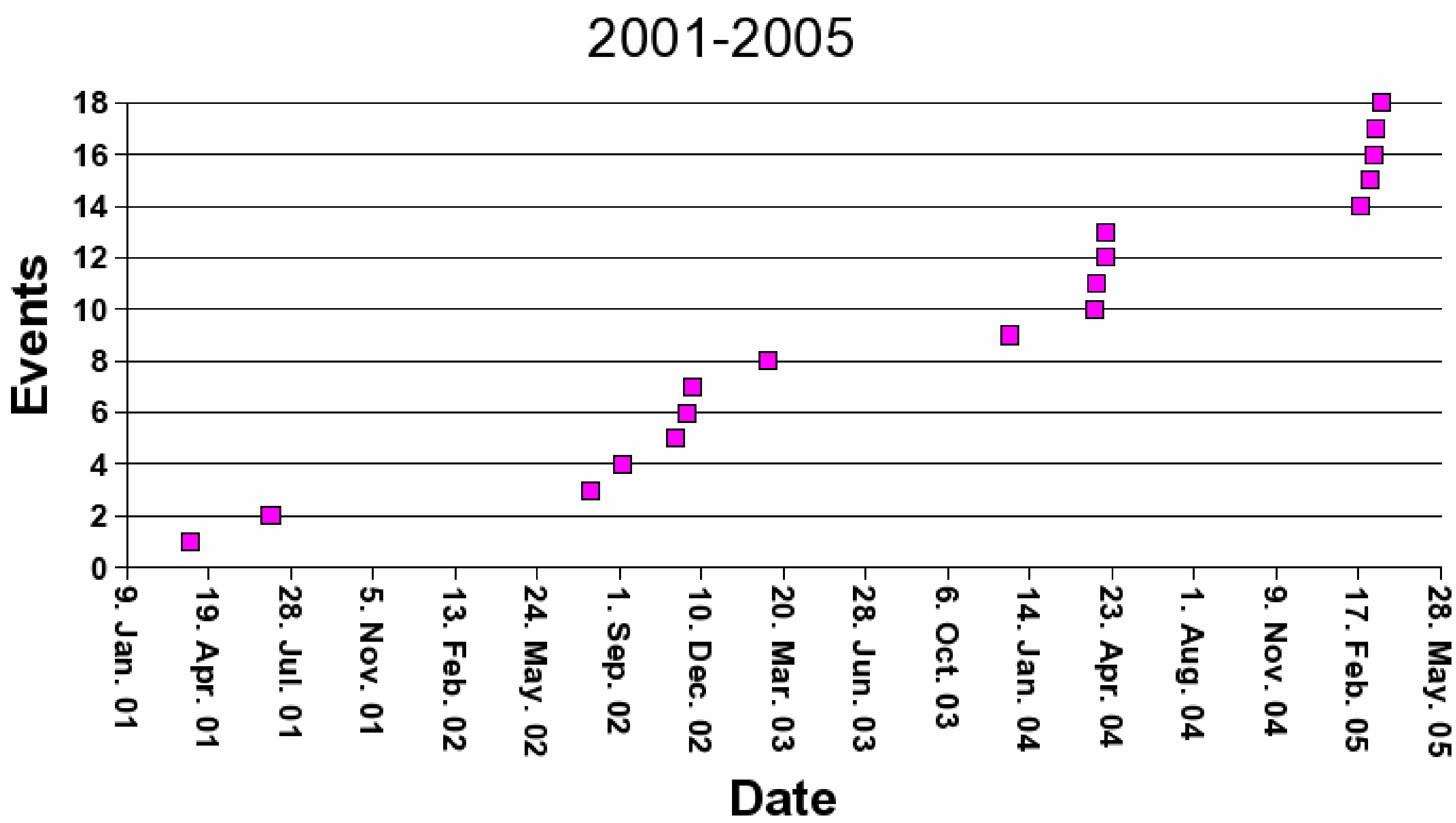
Damage to 1.5m Collimator

Kicker Prefires



- **If beam has to be dumped, *Kicker* fires in abort gap**
- **If Kicker spontaneously fires, sends uncontrolled beam into CDF**
  - Worst incident: 31 chips lost (out of 3168)
    - But many did recover with time
  - 18 Kicker Prefire incidents since the start of Run II
    - Overall rate is small but is serious when it occurs
- **Will add extra collimators during next shutdown**

Kicker Prefires



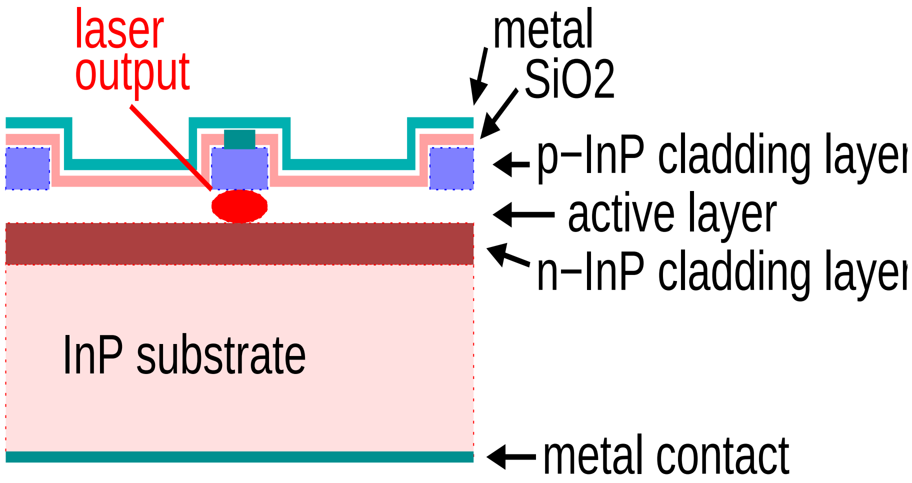
- **Kicker Prefires seems to have a preference for spring**
  - Reason: Unknown
  - May be a coincidence ?
- **Allegedly, LHC will use same kicker system**

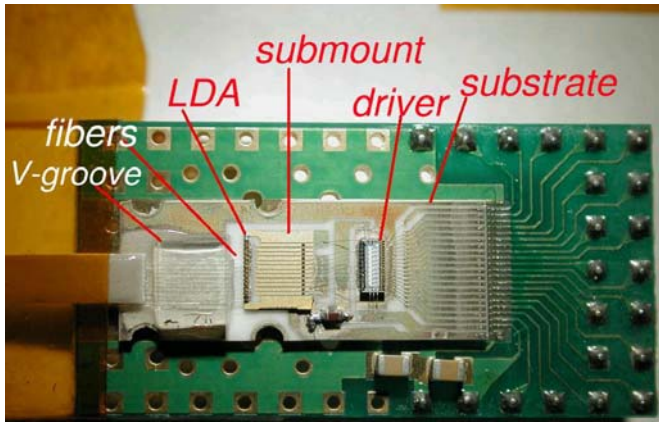
CAEN Power Supply Problems

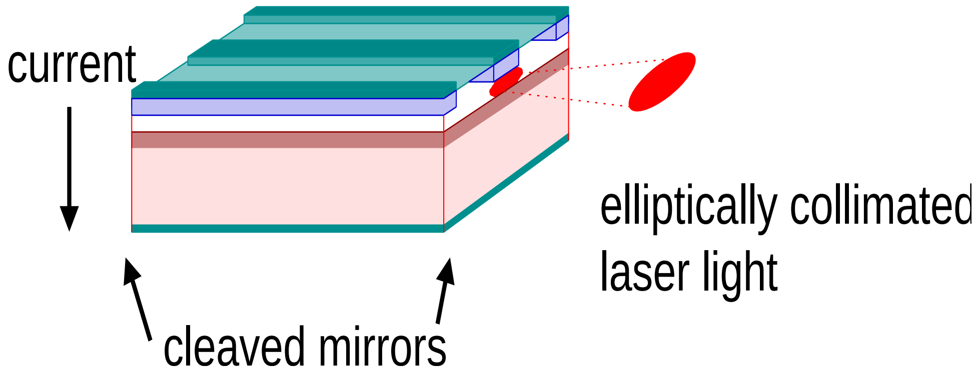
- **From time-to-time, power supply crate goes into undefined modes during data-taking (beam)**
  - Apparently, Power-Supply crates are not Rad-Tolerant
- **Failure Modes:**
  - Spontaneously turns off
  - Gives false readings for ladder & chip currents
  - Communication between crates and monitoring systems fails
- **Only solution (so far) is to reset crate (*Hockerisation*)**
- **One of the major contributors to down-time during data-taking**

Dense Optical Interface Module (DOIM)

- **InGaAs/InP Edge Emitting Diode lasers**
  - 12 Channel Diode Array (Only 8 data lines + 1 Clock line are used)
  - 53MBit/S per Laser
  - λ = 1550nm
  - Rad-Hard: No deterioration in output signal at 200kRad
- **Used to transmit data from ladder to Silicon DAQ**

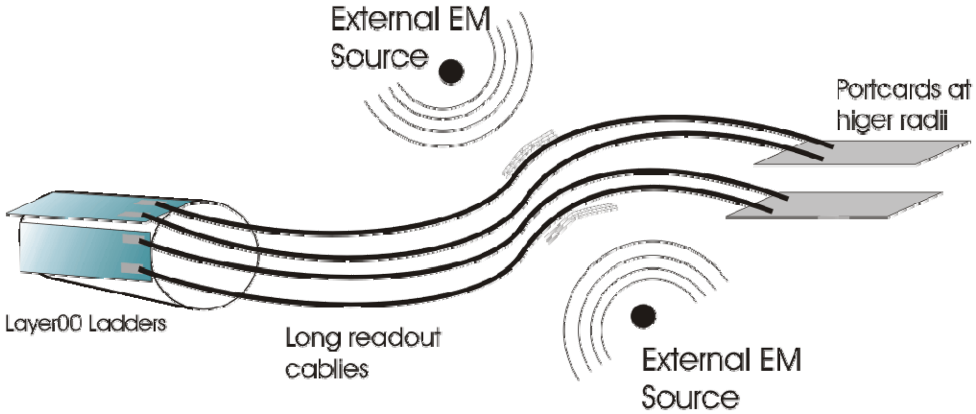




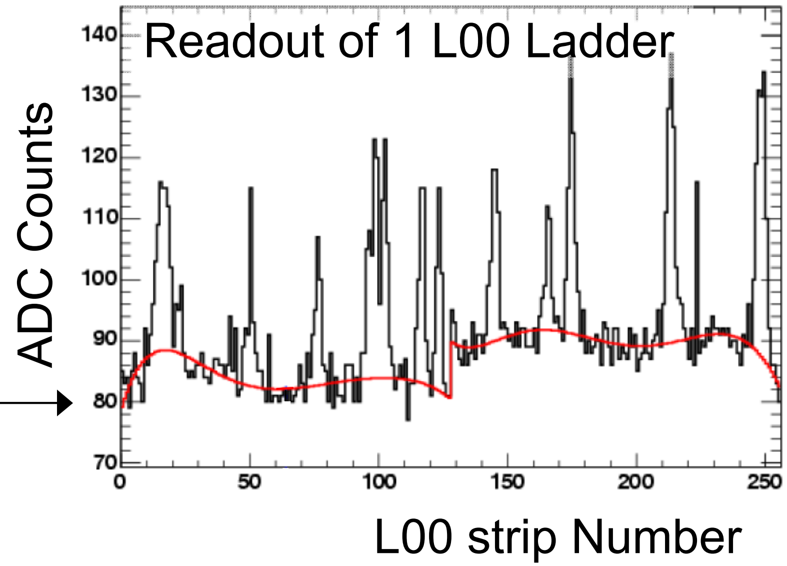


L00 Noise Pickup

- **Due to space constraints, L00 readout is at high radii.**
  - Large pickup on leads
  - Non-Uniform pedestals: DPS cannot be used

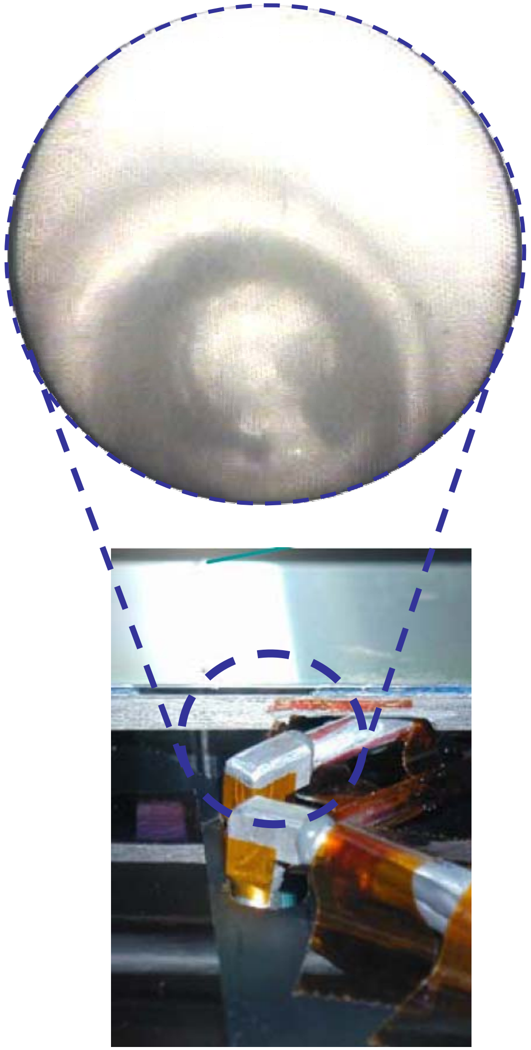


- **L00 readout completely**
  - Pedestal subtraction now done offline
  - Chebyshev Fit to Pedestal

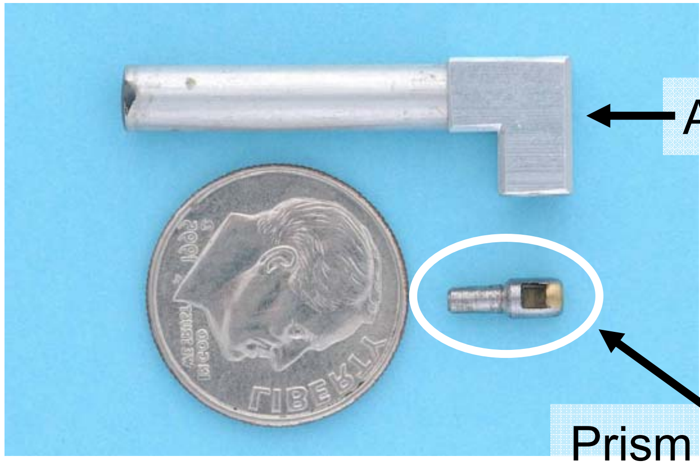


Blocked ISL Cooling Lines

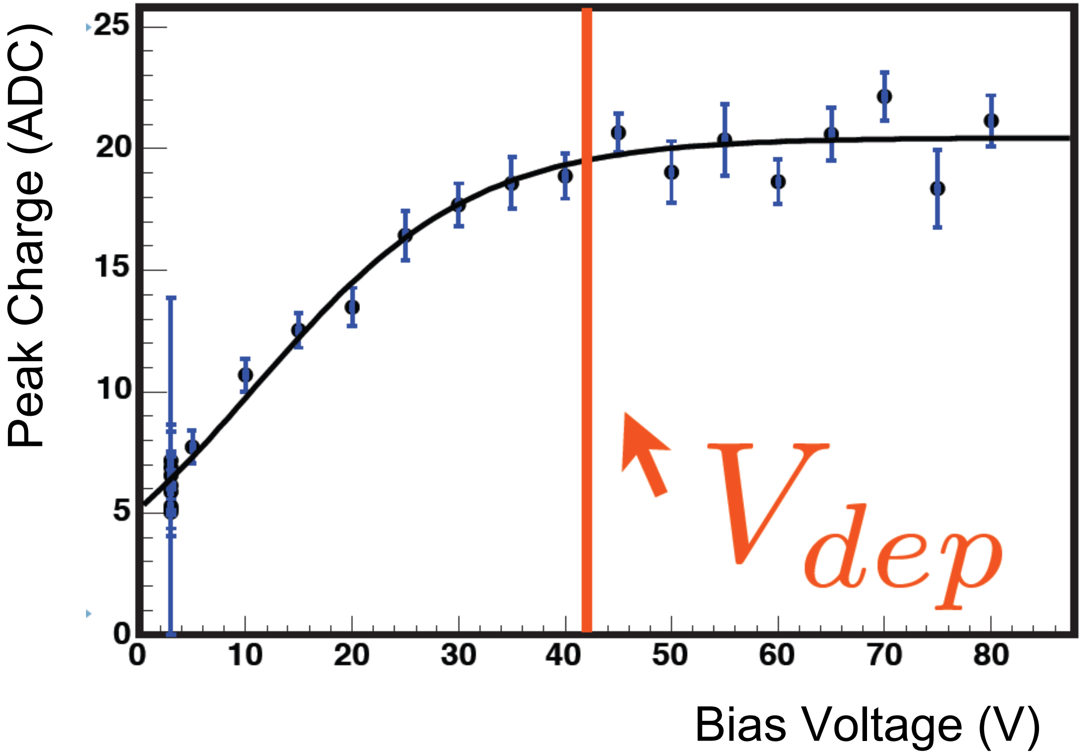
- **Central ISL could not be cooled**
- **Glue blocked lines at Al elbows**
  - Observed with endoscope
- **"De-tuned" industrial wielding laser used to cut through blockage**
  - PMT used to distinguish glue from Al tube



- **Laser cut through 11/12 lines**



Bias Scans



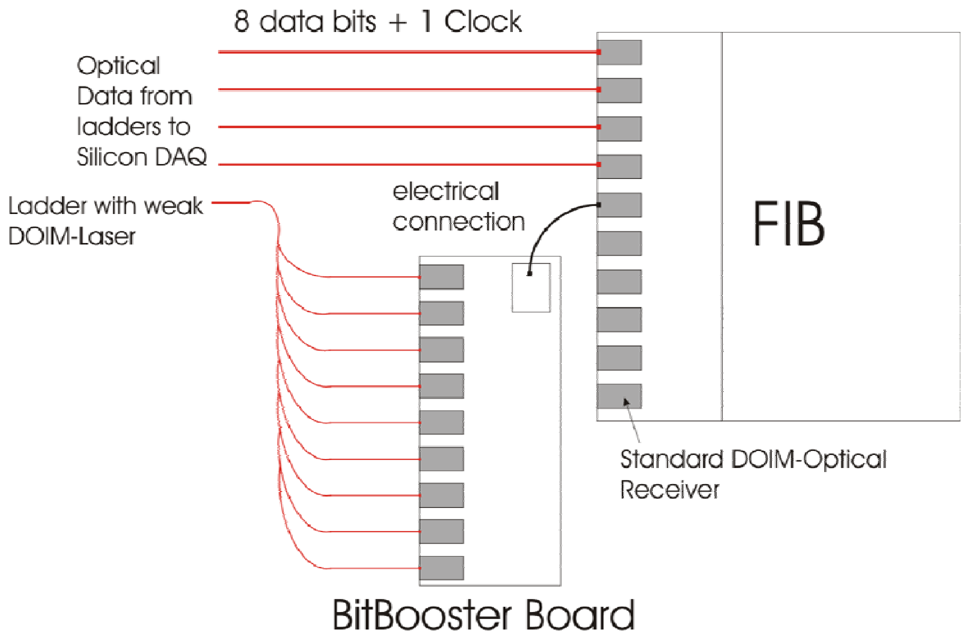
- **Vary bias on ladders:**
  - With beam: Monitor change in collected charge
  - No beam: Monitor change in noise (used in practice)
- **Used to monitor depletion voltage**

Developments: Clock Cloning Card (CCC)

- **SVX3D Feature:**
  - Powers up uninitialised
  - Current consumption rapidly increases with no clock
- **The Silicon is tied to the Tevatron Clock. If this is lost, the entire detector "trips" due to above *feature***
- **CCC generates a clock if the Tevatron clock is not present**
  - Prevents the detector tripping
  - Avoids unnecessary thermal cycles

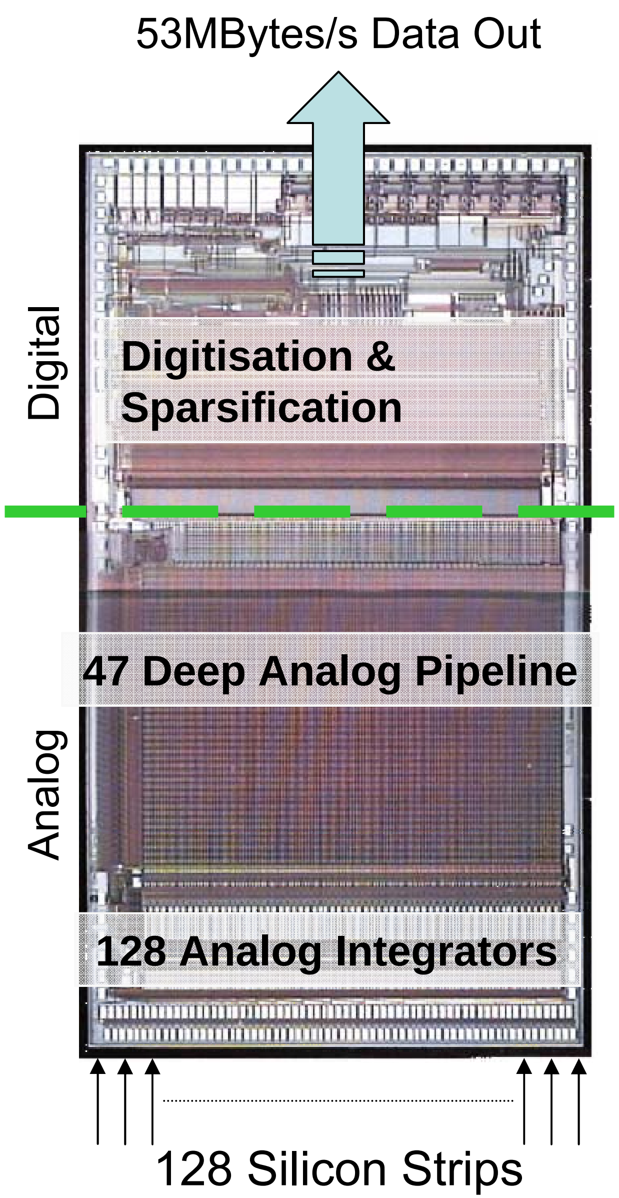
Developments: Bit-Booster

- **Light from some DOIM-Lasers is below 50μW design threshold of the DOIM-Receivers**
- **Current Solutions**
  - Replace the DOIM-Receiver: No guarantee of success
  - Adjust DOIM-TX voltage: Affects entire wedge. Always the risk of damaging an entire wedge
- **DOIM-Lasers emit at 1550nm: Standard Telecoms Wavelength**
- **Off-the-shelf Telecoms receivers are sensitive to <1μW and operate at Giga-Bits**
  - More than sufficient as replacement receivers for CDF silicon

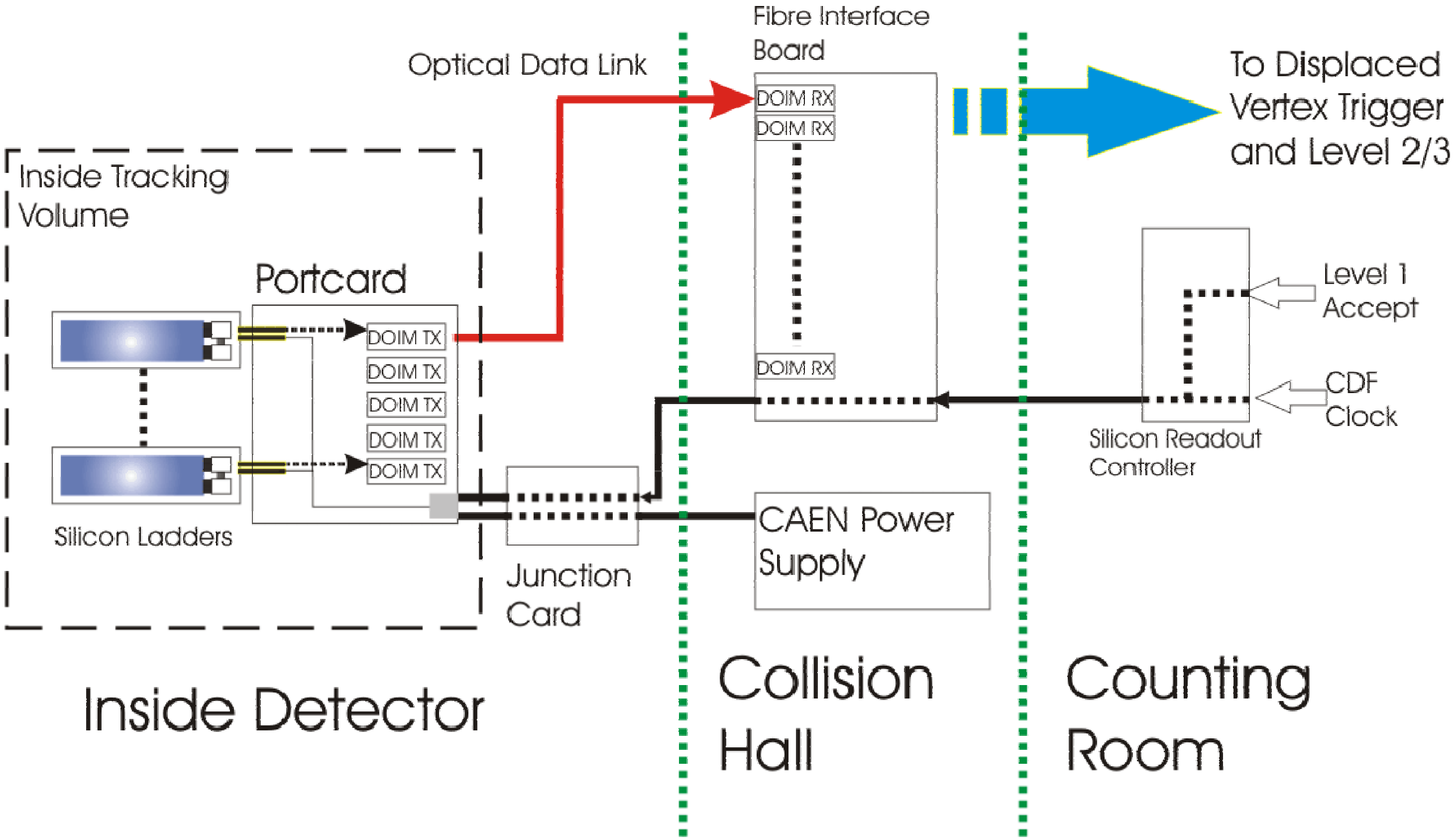


SVX3D Chip

- **All Silicon ladders readout by SVX3D chip**
- **Integrated Analog Front-End and Digital Back-End**
- **Dead-timeless:**
  - Can collect charge and digitise simultaneously
- **Honeywell Rad-Hard CMOS 0.8μm Process**
  - 4 MRads with Co^{60} Source
  - 15 MRads with 55MeV Proton Source
- **Fast: Capable of running at 132ns clock rates**
- **Dynamic Pedestal Subtraction**
  - Subtracts common mode noise
- **Sparsification**
  - Removes channels below programmable threshold
  - Reduces data-rate and readout time



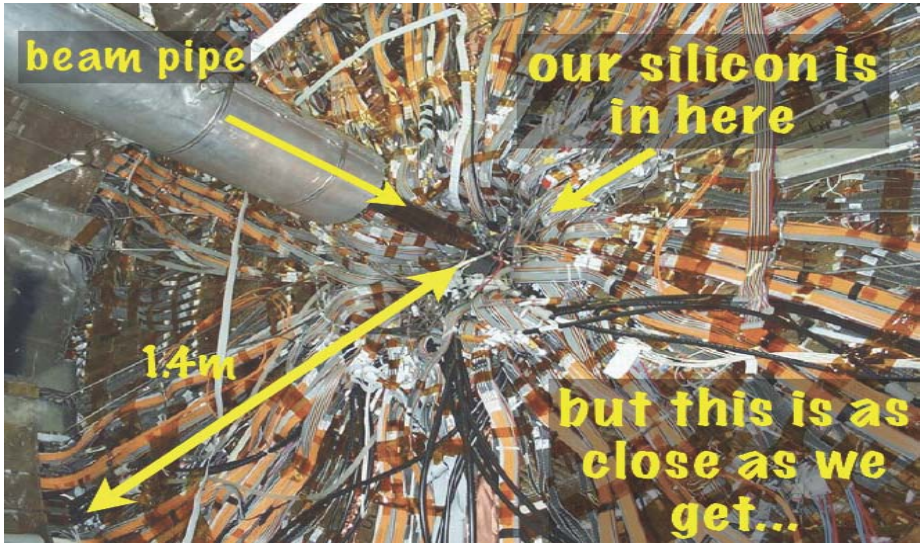
Simplified Silicon DAQ (for 1 wedge)



- **Controlled by Master "Silicon Readout Controller"**
  - Sends timing & control signals to chips
- **Wedgewide Readout**
  - Allows SVX (3168 chips / ≈O(100kB) to be readout in ≈ 70μs

Silicon Operations

- **The Silicon detector is not a "plug-N-play" device.**
- **The Silicon is NOT accessible until end of CDF**
- **Requires a dedicated team to provide 24/7 support and maintenance**
- **Daily operation requires 5-10 FTE**
- **With >700K channels, you have to aggressively attack all problems**
  - Otherwise it snowballs very quickly



Silicon Vertex Trigger (SVT)

- **For the first time, a silicon detector is used in the online (L2) trigger**
- **The SVT takes data directly from the SVX**
  - Does fast track reconstruction using a set of templates
  - Looks for displaced vertices
  - Great for heavy quark tagging
- **Uses 4/5 ladders in one SVX wedge**
- **Requires good SVX alignment**