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Aging Effects and Operational Experience with the CDF Run II Silicon Detector

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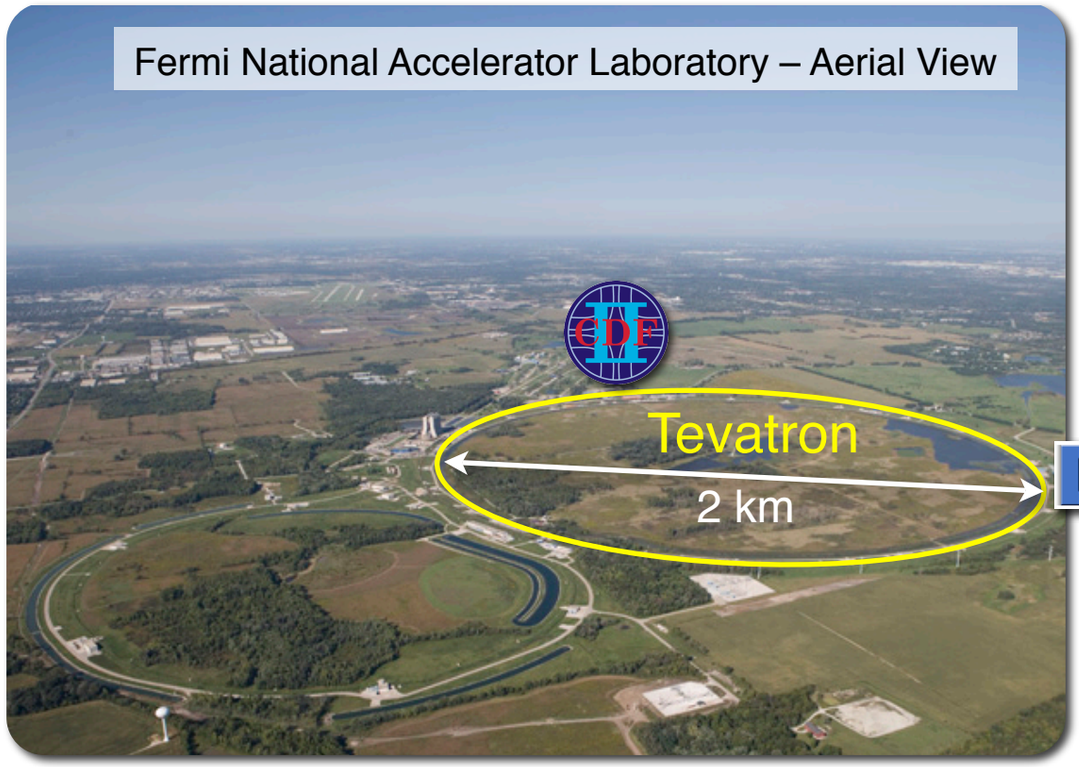
The CDF Detector at the Tevatron



[Fermilab Visual Media Service]

- Tevatron: proton-antiproton collider at $\sqrt{s}$ = 1.96 TeV
- Tevatron Run II: 2001–2009 (2010?)
- Luminosity: 5 fb^{-1} delivered (Oct '08)
- Two multi-purpose particle physics detectors: CDF & DØ

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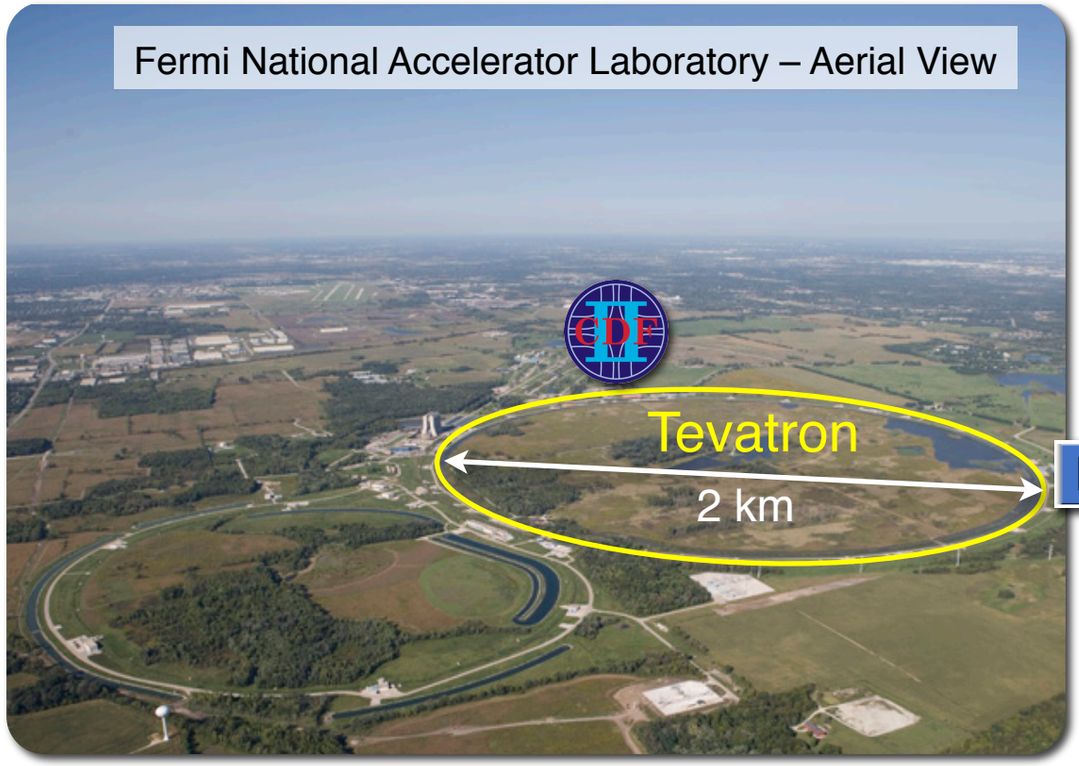

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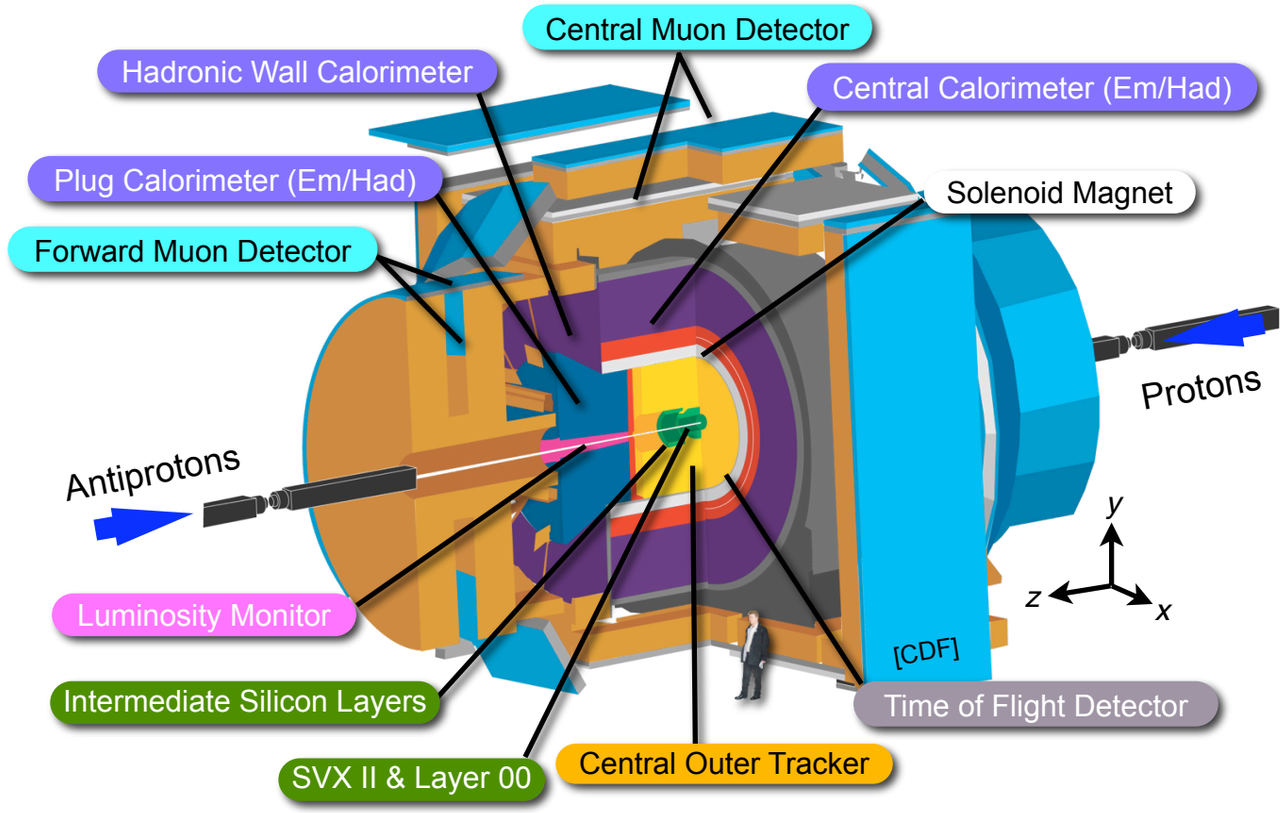
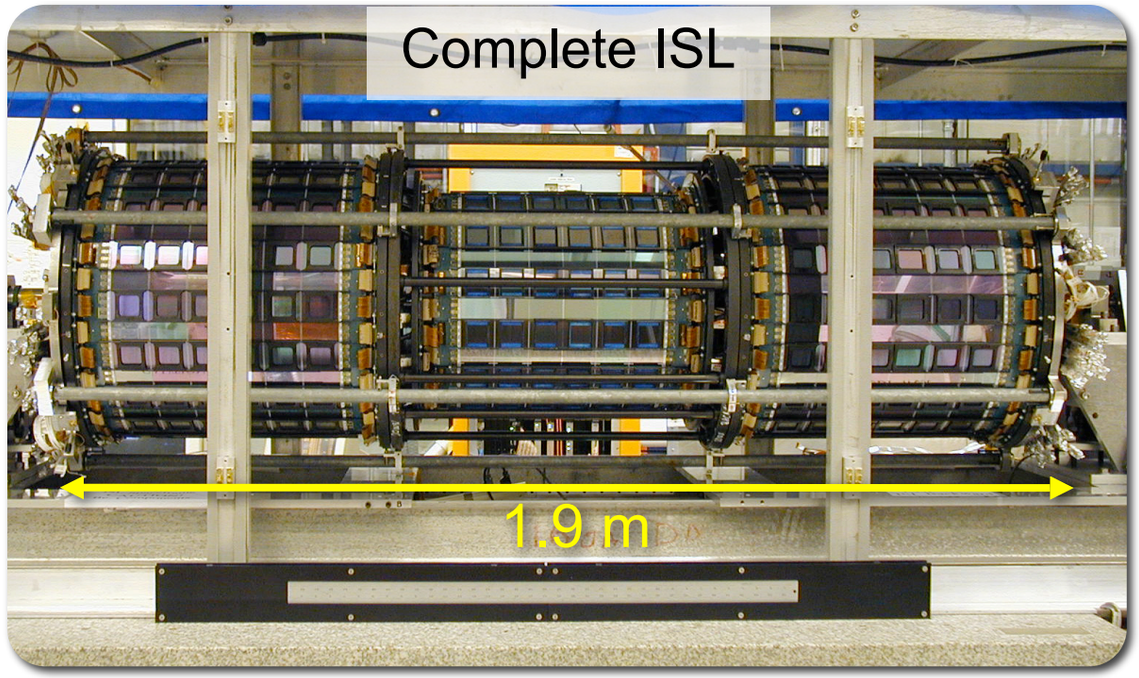
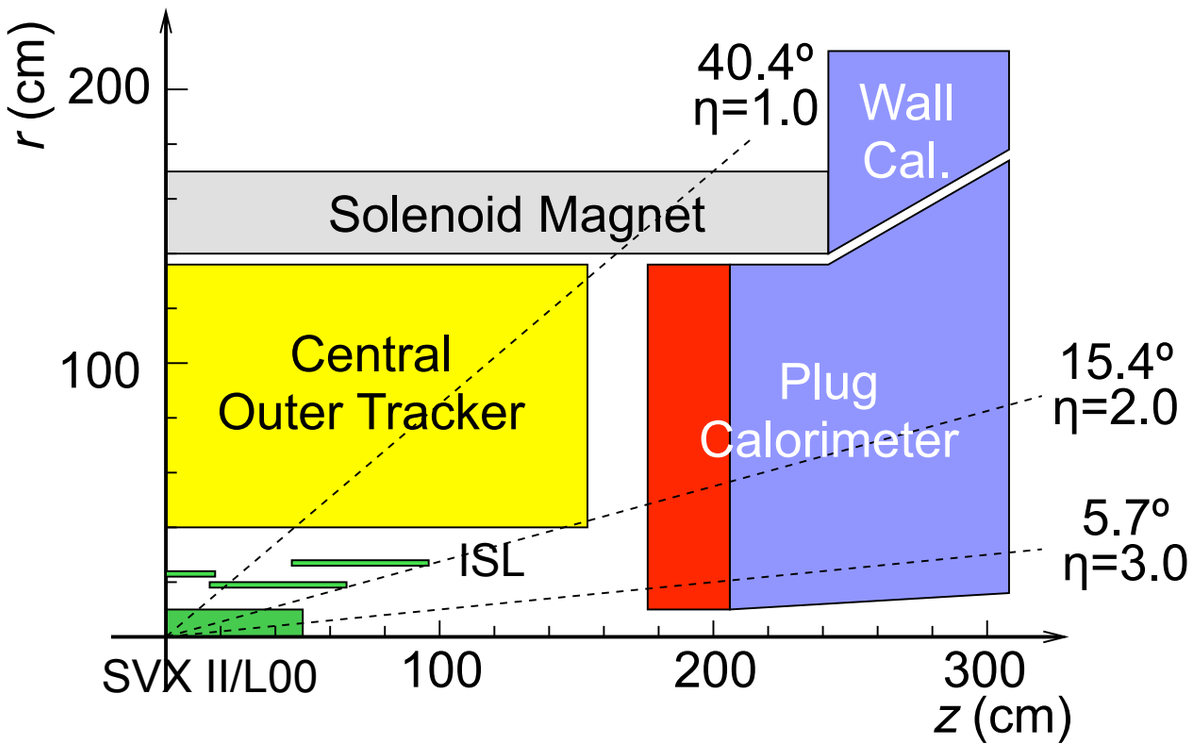
- CDF II: standard HEP detector with excellent tracking (silicon detectors & large drift chamber)
- Broad physics program: Higgs & BSM physics searches, top & B physics, QCD, …

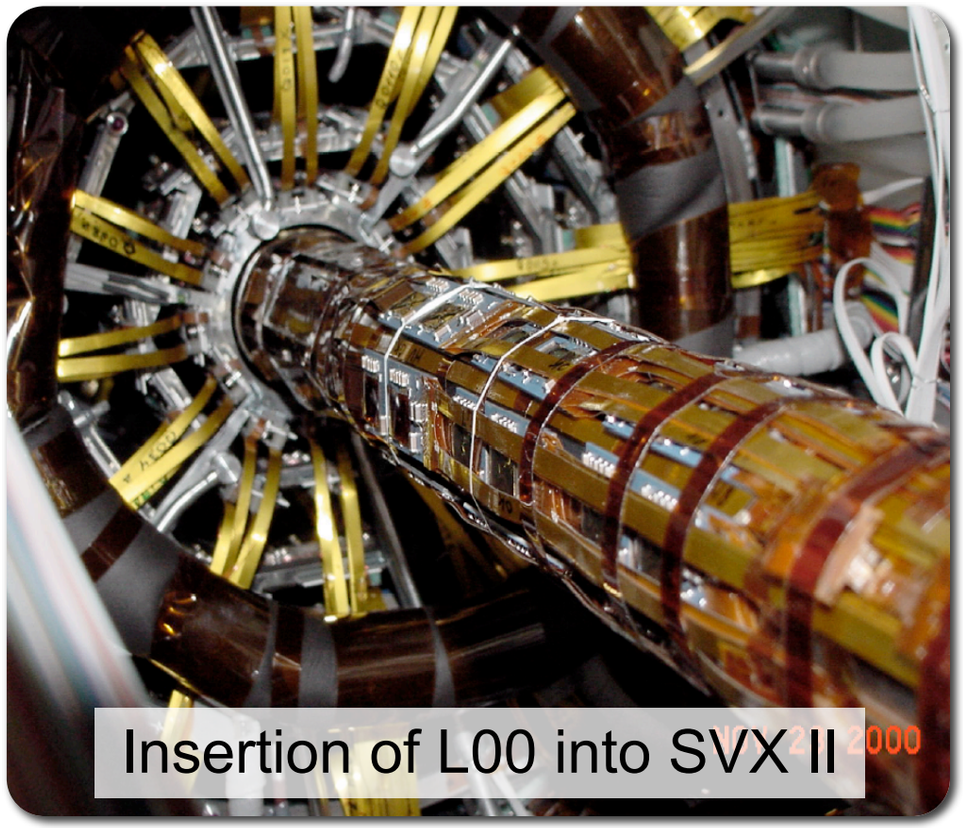


Silicon Detectors at CDF II

- CDF silicon = three subdetectors:
  - Layer 00 (L00): impact parameter
  - SVX II: workhorse for silicon tracking/vertexing & triggering
  - Intermediate Silicon Layers (ISL): link track to Central Outer Tracker drift chamber
- 7–8 silicon layers (6 m^2), 722,432 channels on 5,456 chips

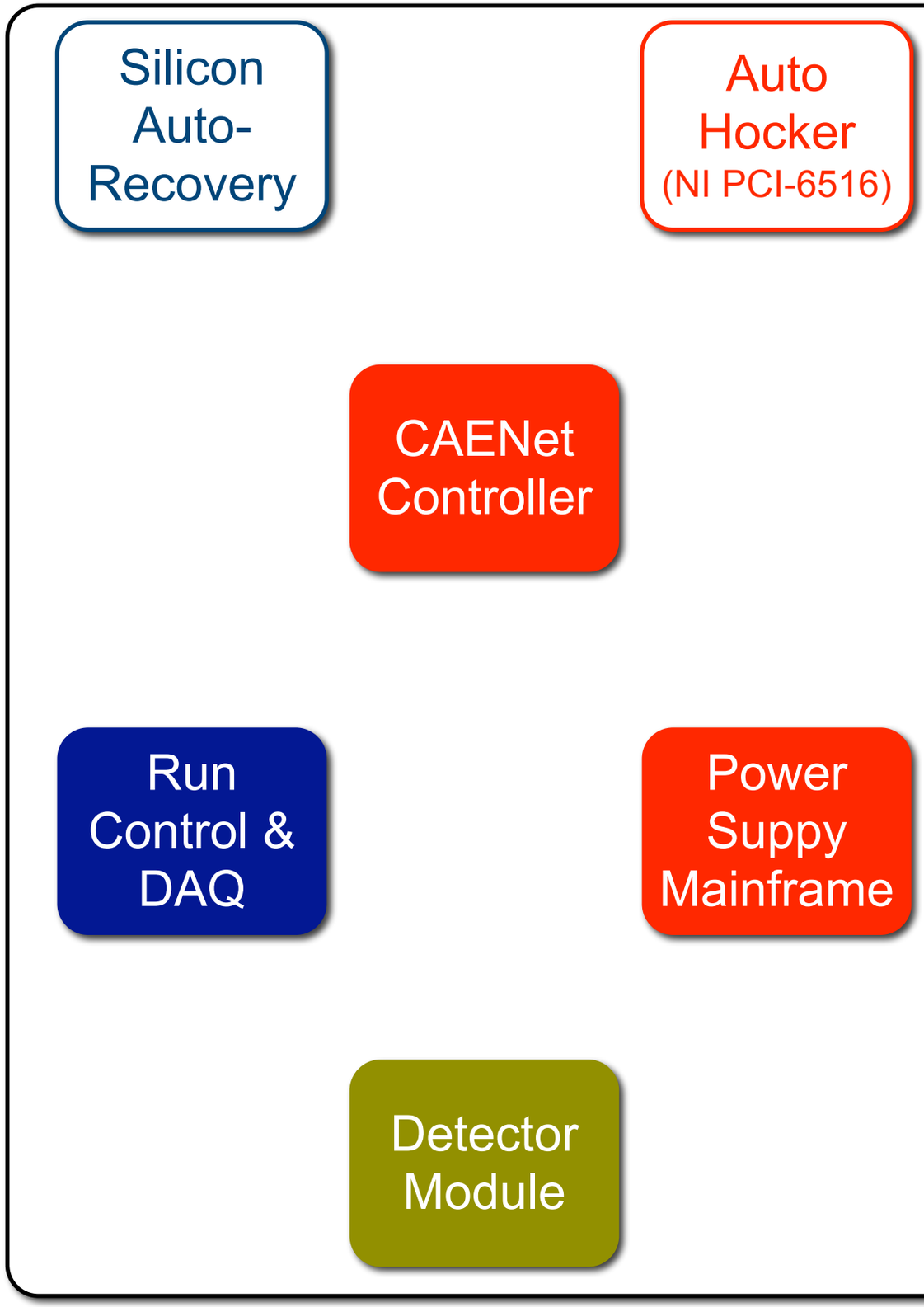






Operational Experience

- Long 1.5 year commissioning period (2001/2002)
- Phase I: "no ladder left behind" (2002–2006)
  - Vigilant monitoring on all levels: bit errors, single event upsets, …
  - Aggressive recovery of problematic modules → maximize number of working channels
- Phase II: automation (2006–now)
  - Most failure modes well known
  - Automate many routine recovery procedures → maximize data-taking efficiency with fewer people
  - Automation example: auto-recovery after lost communication with power supply trips → complex interaction with run control and DAQ



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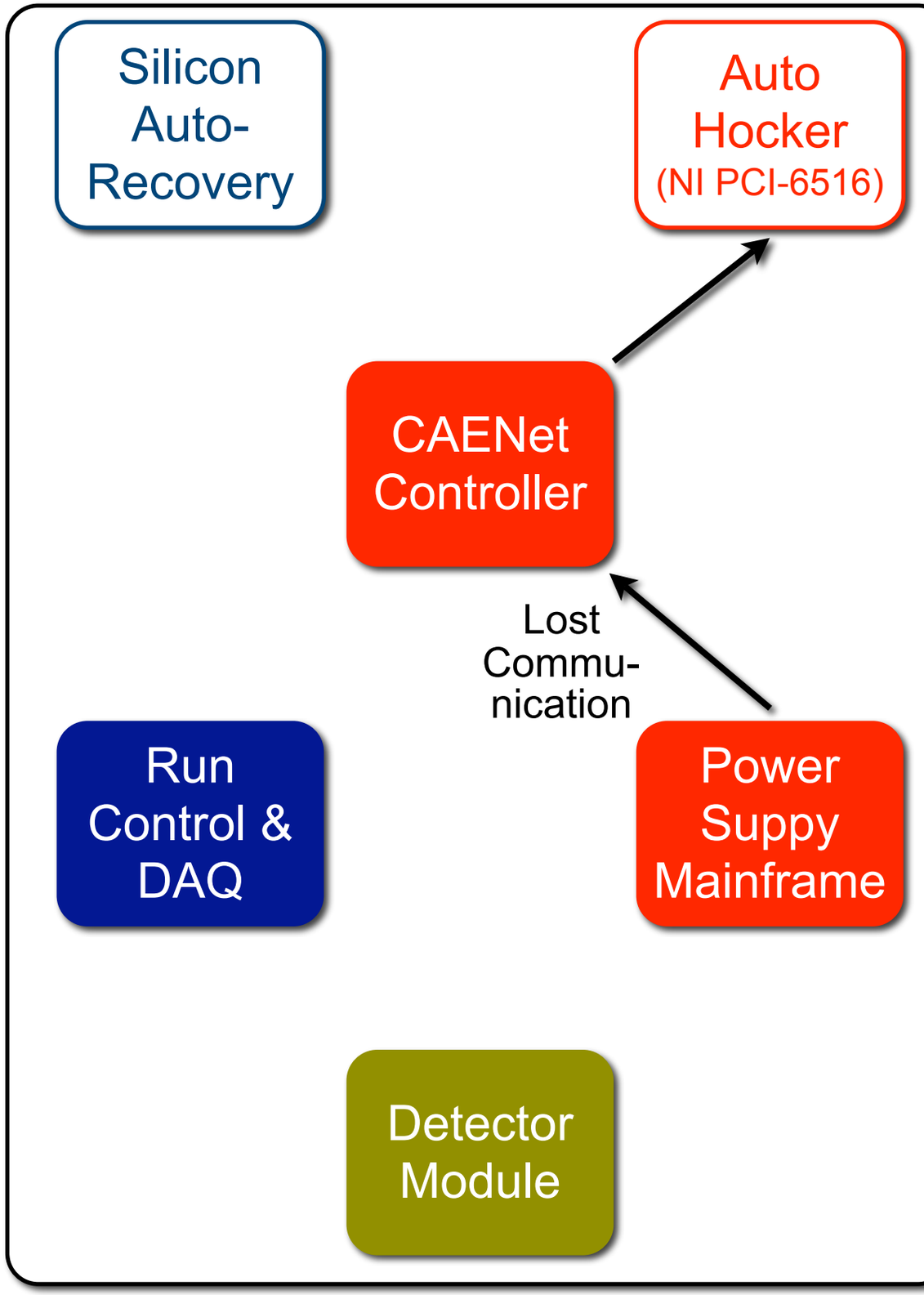

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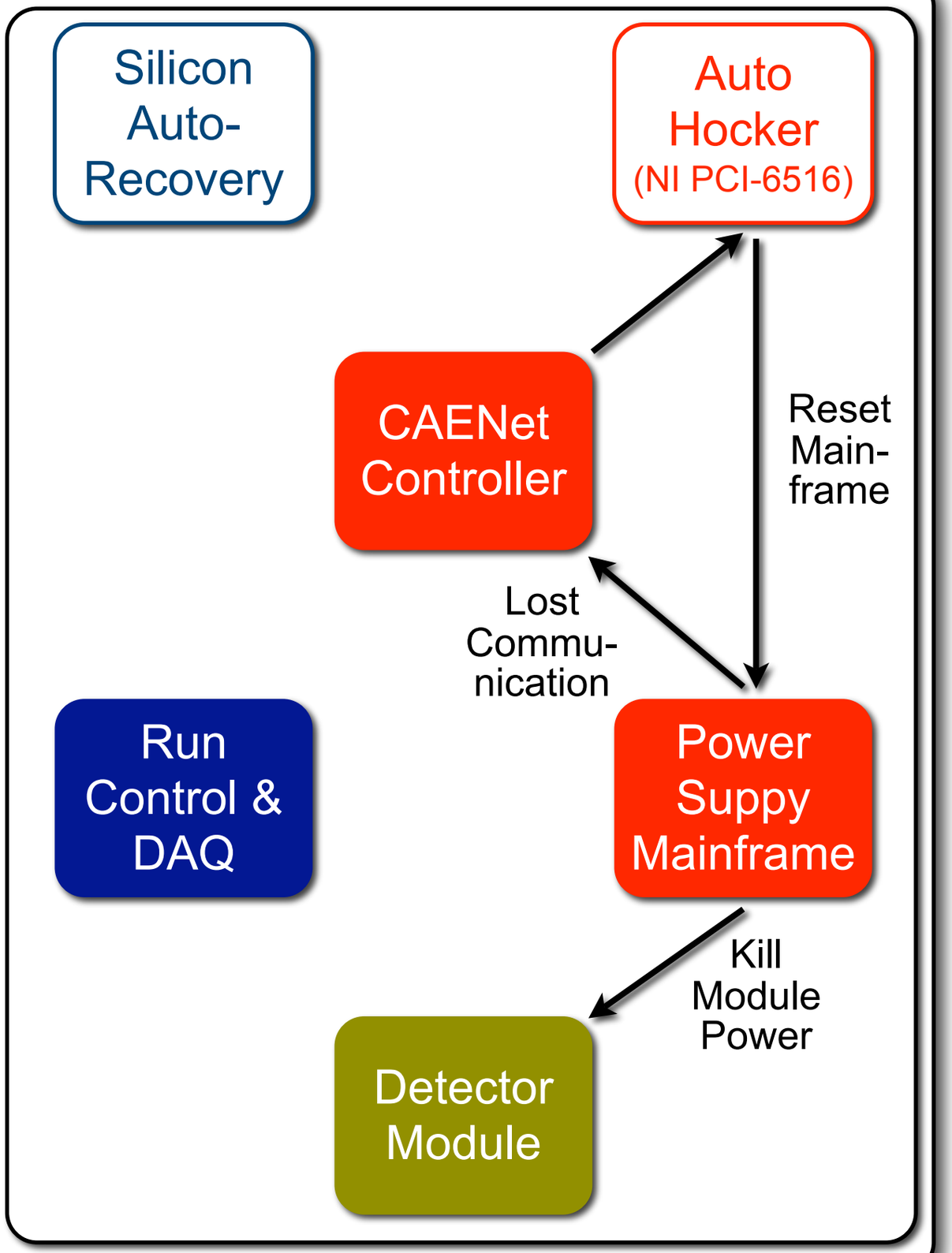

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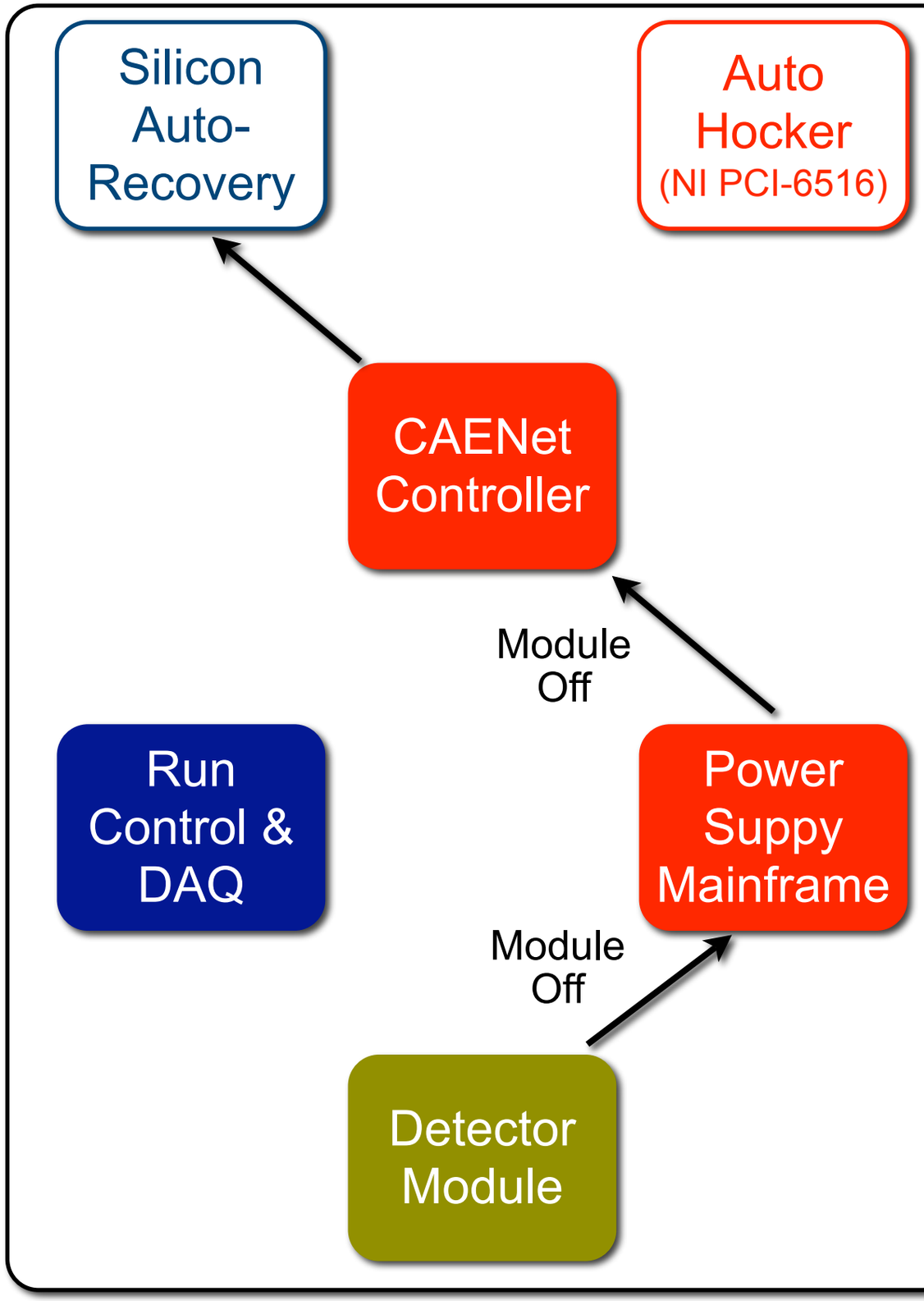

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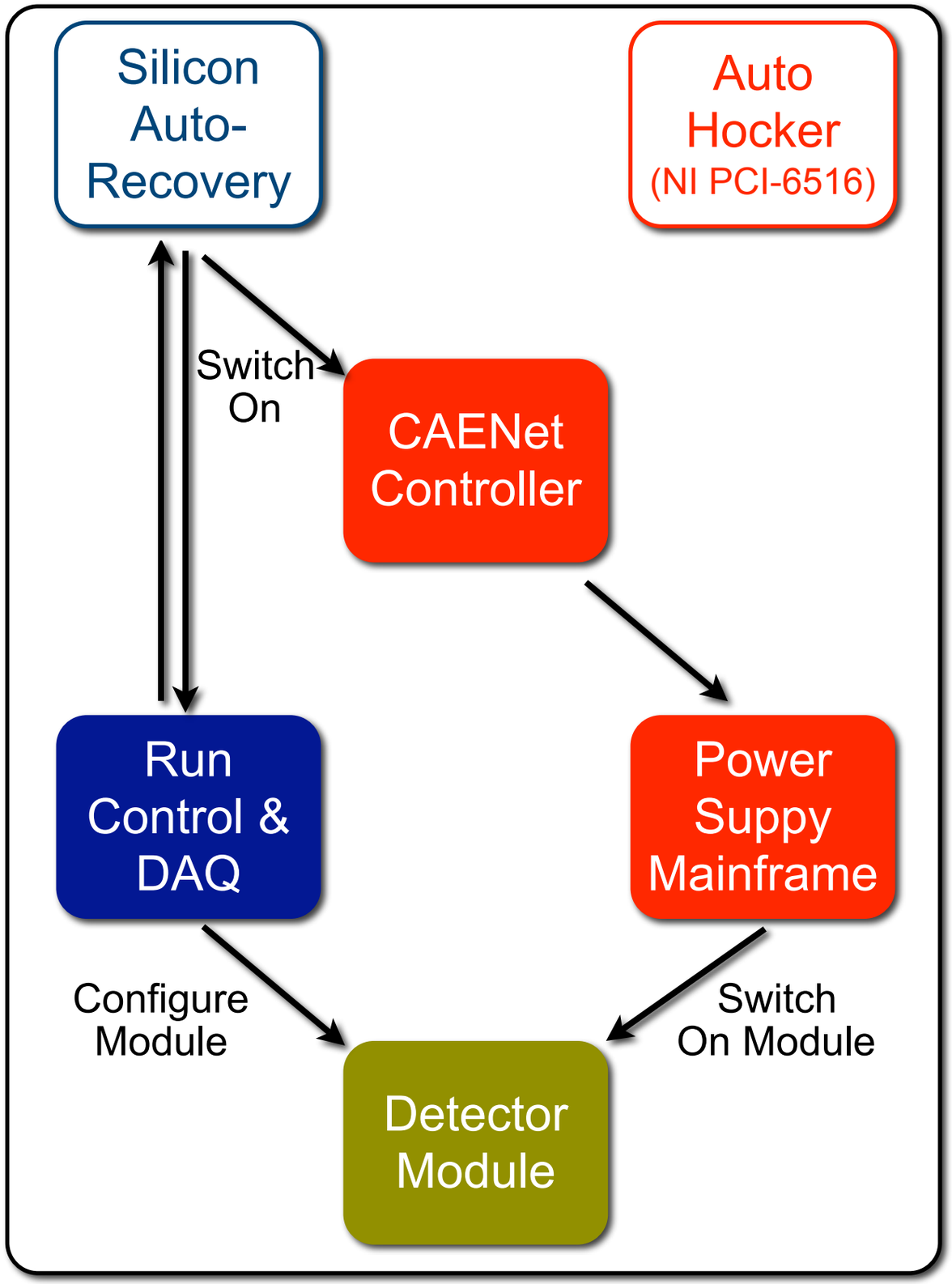
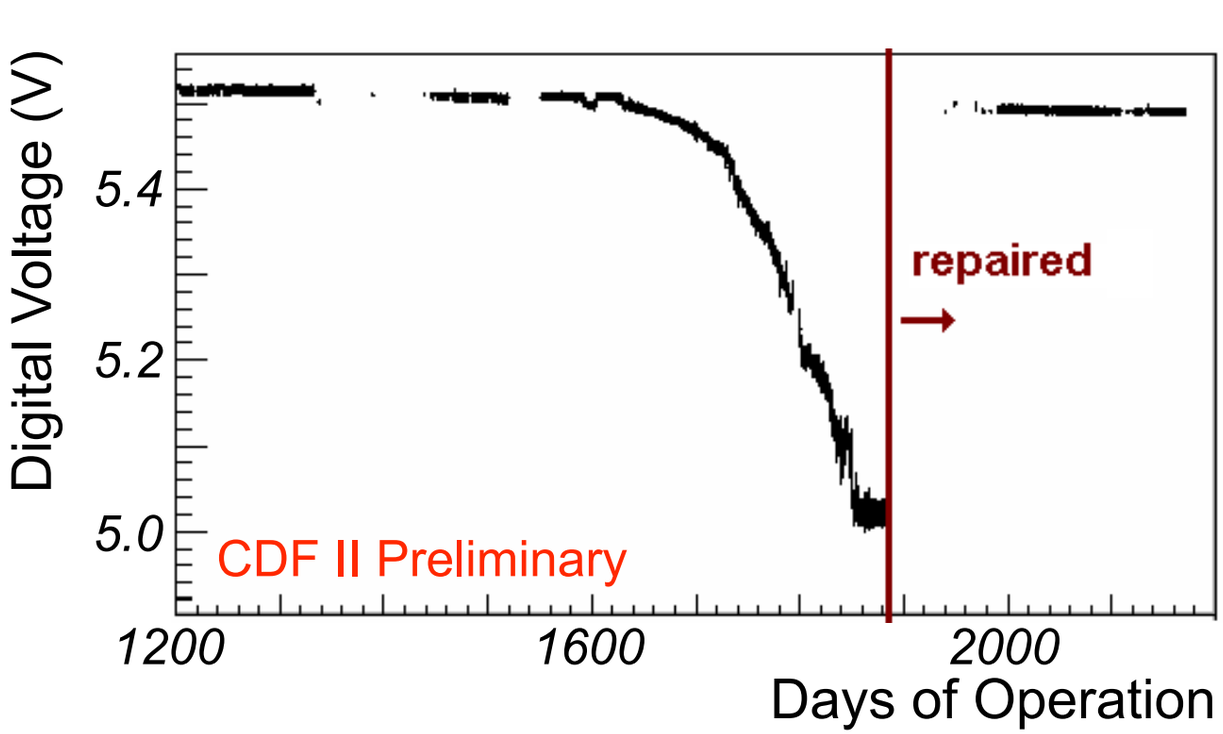
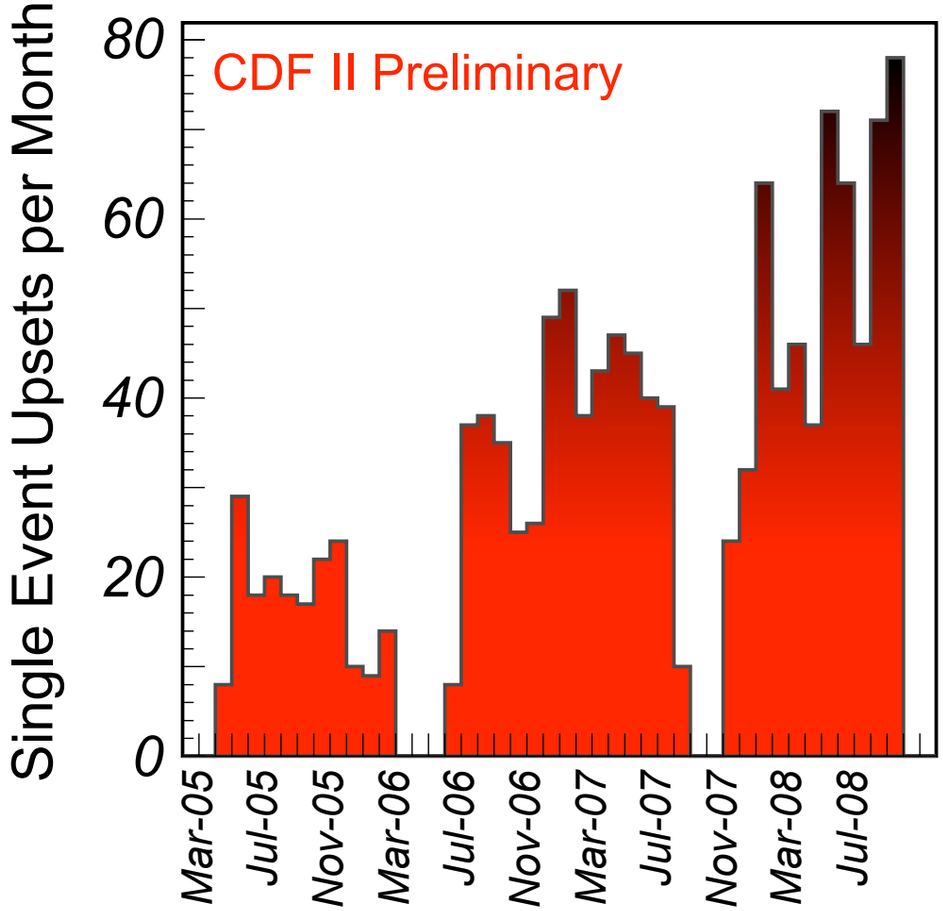


Infrastructure: Aging & Radiation

Power supply aging:

- Problem: several LV lines showed drooping voltages of O(100) days
- Diagnosis: aging regulating capacitor, needs to be replaced
- Fix: repair all (>100) power supplies during long shutdown



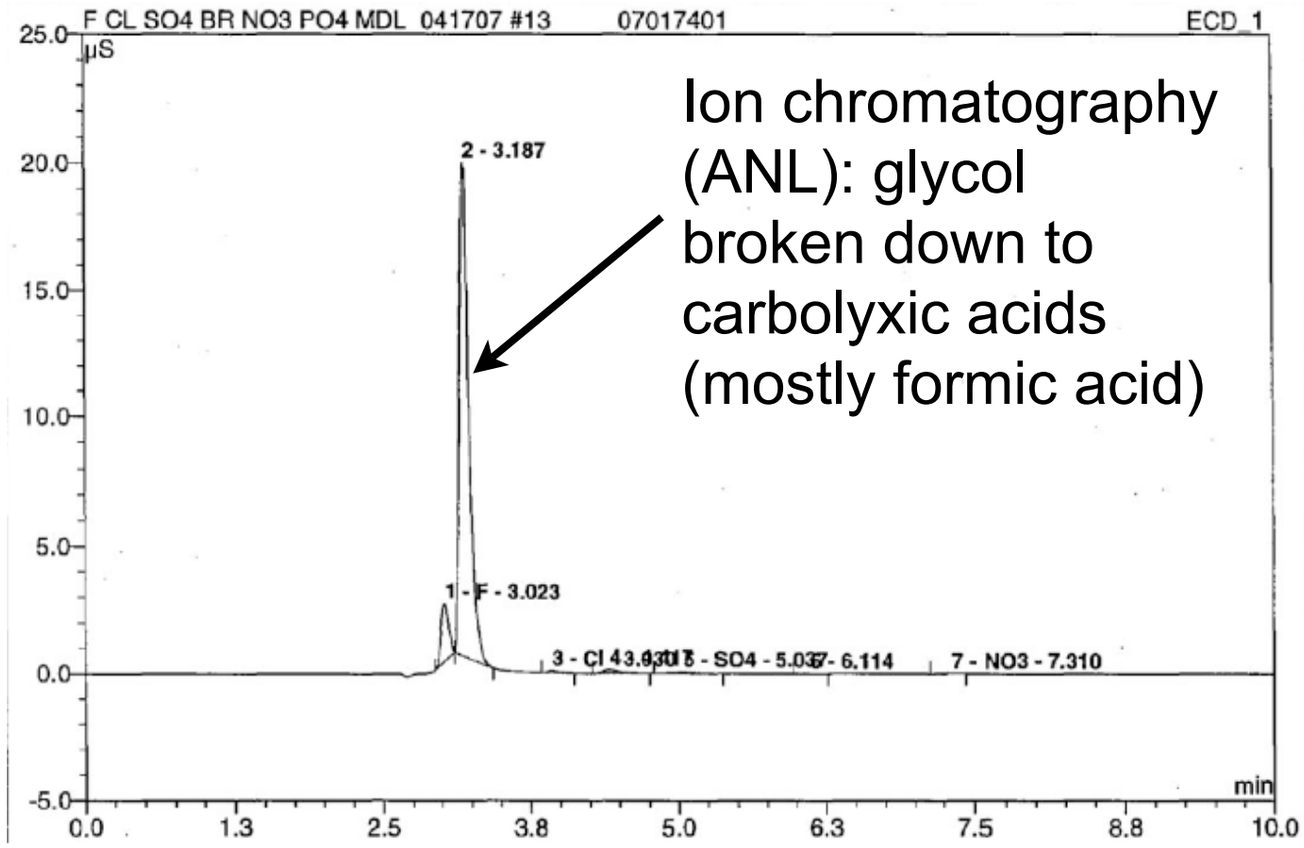


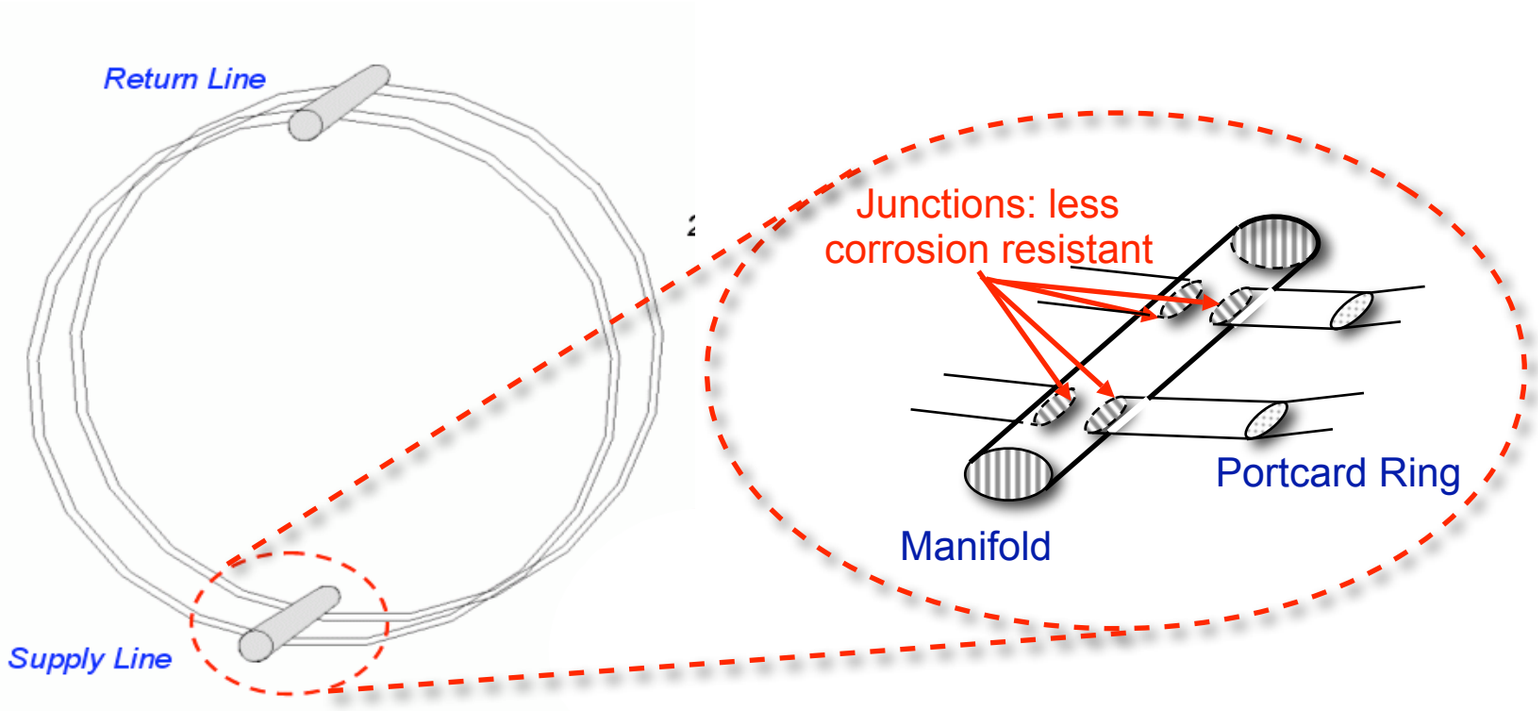
Radiation-induced single event upsets:

- Corrupted micro-sequencer memory in collision hall DAQ boards (“FIBs”)
- Scaling with luminosity

Infrastructure: ISL Cooling Leak

- First symptoms: electronic valve failures (early 2007)
- Problem: ISL coolant (10% ethylene glycol in water) became acidic (pH ≈ 2 = vinegar) during 2006 shutdown
- Solution: coolant neutralized by drain and flush procedure and large de-ionizers, unfortunately too late…
- … May 2007: leaks in heat affected zone around aluminum welds in ISL Portcard ring (alloy: 6061-Al)





ISL Cooling Leak: The Fix

- Repair during 2007 shutdown (1 month of work for 4–5 people)
- Challenge #1: radiation damage
  - Must keep Silicon cold (and dry)
  - Solution: set up plastic tent, use air dryer to keep dew point below –10ºC at all times
- Challenge #2: Portcard ring inaccessible from outside
  - Inside detector, approx. 1 m away from COT face
  - Repair through cooling tubes using borescopes, catheters, syringes, …
  - Cover holes with epoxy using 0.75 mm brass tube
- Result: all leaks fixed, stable running since October 2007 (with improved instrumentation)

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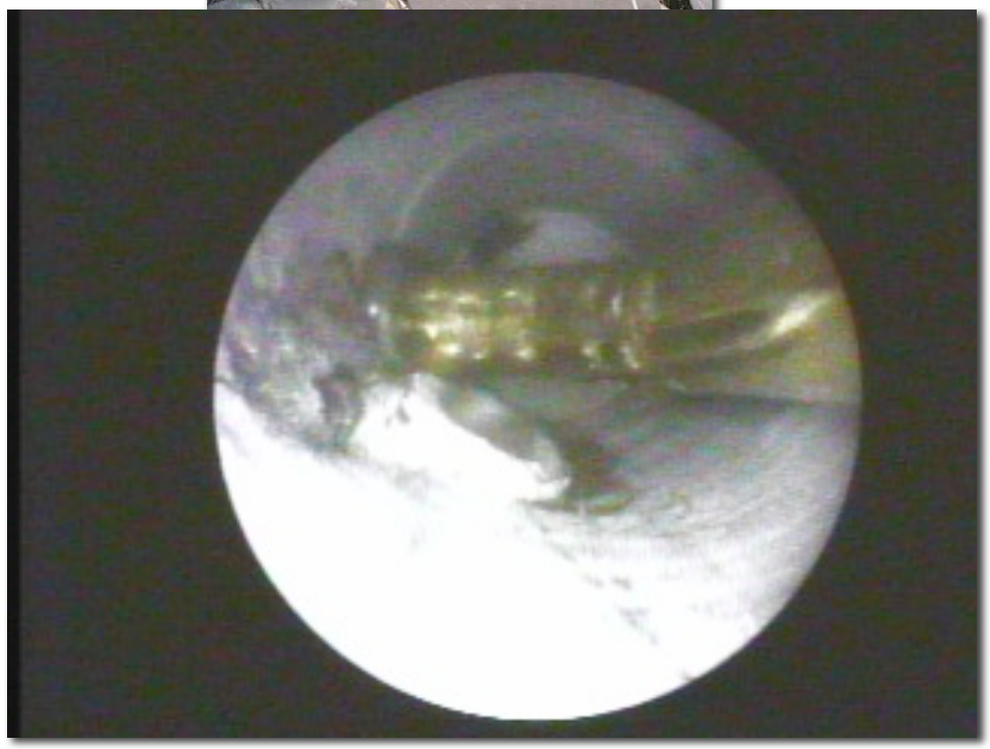
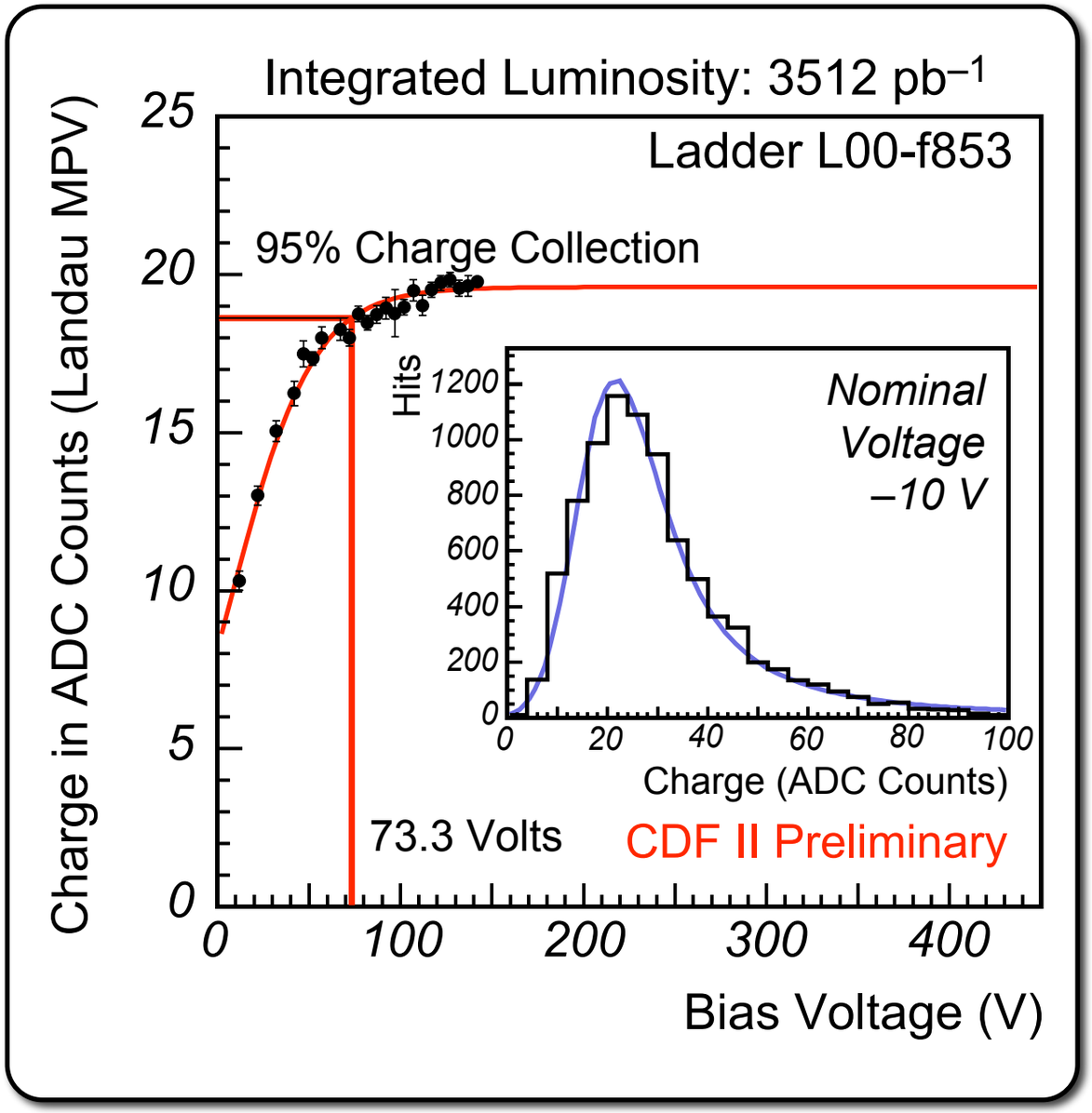


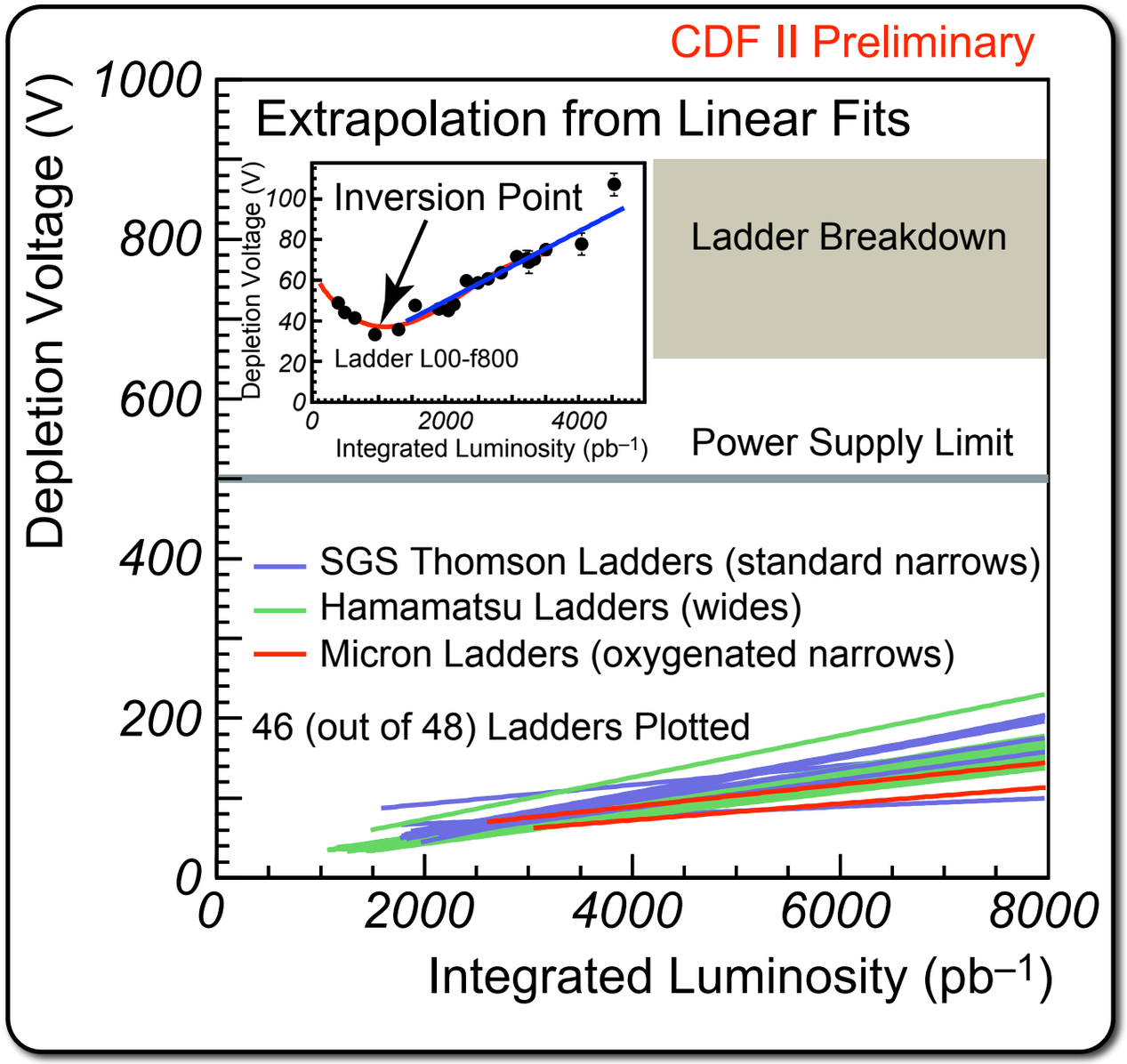
Radiation Damage



- Challenge: operate CDF silicon for 6–7 fb^{-1} of integrated luminosity (designed for 2–3 fb^{-1})
  - Radiation damage: change in effective number of charge carriers
  - Depletion voltage V_{dep} decreases until type inversion of sensor material, then increases → may hit technical limit
- Method: dedicated data-taking runs ("Signal Bias Scans")
  - Study collected charge of silicon hits from good tracks during colliding beams operation
  - V_{dep} from peak of ADC spectrum for different bias voltages
  - Consumes valuable beam time (but alternative "Noise Bias Scan" works only for double sided sensors before type inversion)

Radiation Damage: Results for Layer 00

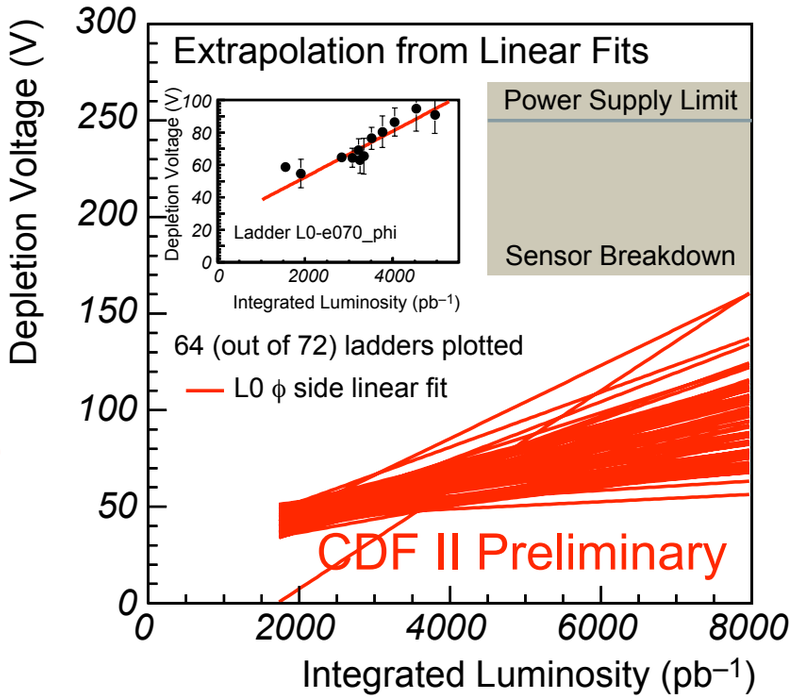
- Layer 00
  - Radii: 1.35 cm (“narrow” sensors), 1.62 cm (“wide” sensors)
  - “LHC style” sensors: single sided, p-in-n, orientation <100>, some sensors oxygenated
  - Measured radiation dose: 2–3 × 10^{10} MIPs per cm^2 and pb^{-1} [R. J. Tesarek et al., IEEE NSS 2003]
- Results with 4.5 fb^{-1}:
  - Type inversion observed in all sensors → very consistent
  - Oxygenated narrow sensors invert after standard narrows and wides
  - Fit to bias scan data after inversion: Layer 00 will outlast Run II

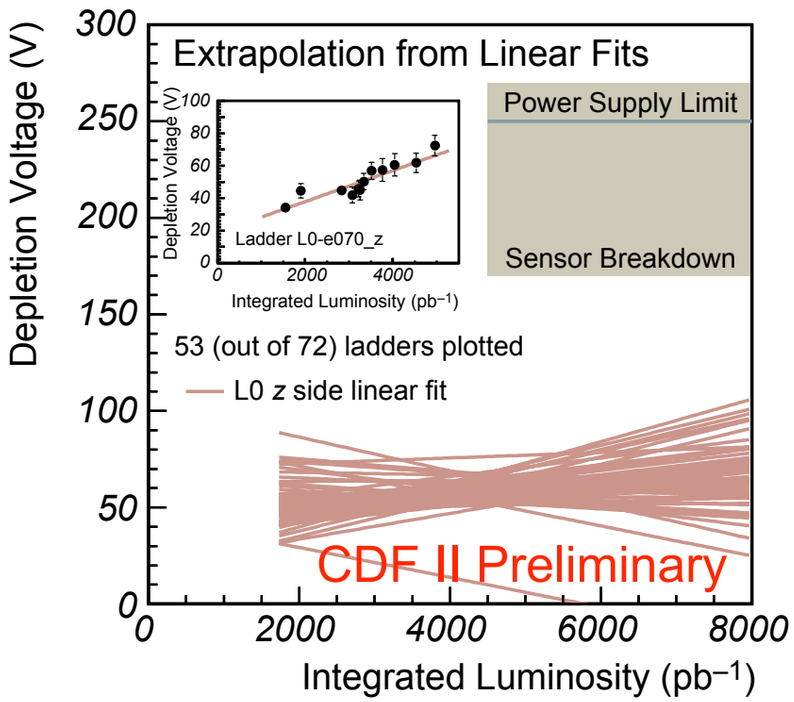


Radiation Damage: Results for Layer 0/1

Layer 0:

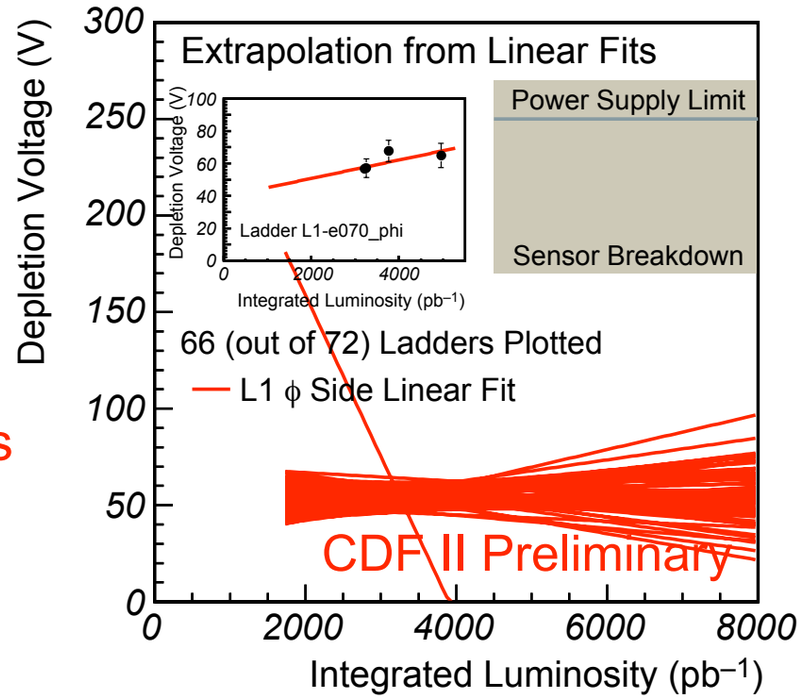
- r = 2.5 cm
- Double-sided Hamamatsu sensors
- <111>
- No indications for problems after 5 fb^{-1}

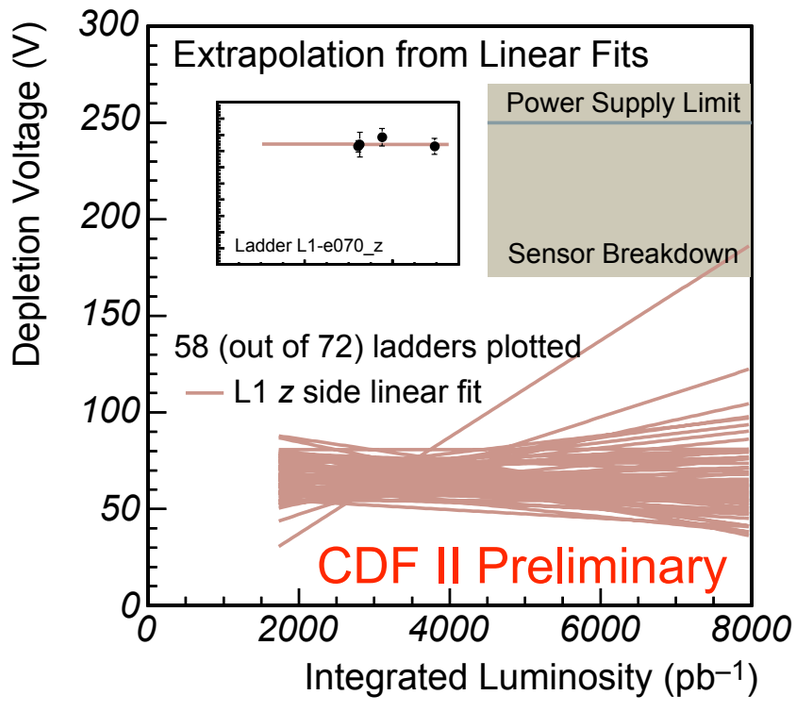




Layer 1:

- r = 4.1 cm
- Double-sided Hamamatsu sensors
- <111>
- No indications for problems after 5 fb^{-1}





Summary and Conclusions

Augustus the Strong, Elector of Saxonia

- CDF Run II silicon detectors: Layer 00, SVX, ISL
- Many years of operational experience: asset for the LHC experiments
- Important lesson: don't forget about infrastructure (cooling, power supplies, etc.)
- Radiation damage after 5 fb^{-1}:
  - Inner layers: all modules well beyond type inversion
  - Silicon detectors will outlast Tevatron Run II