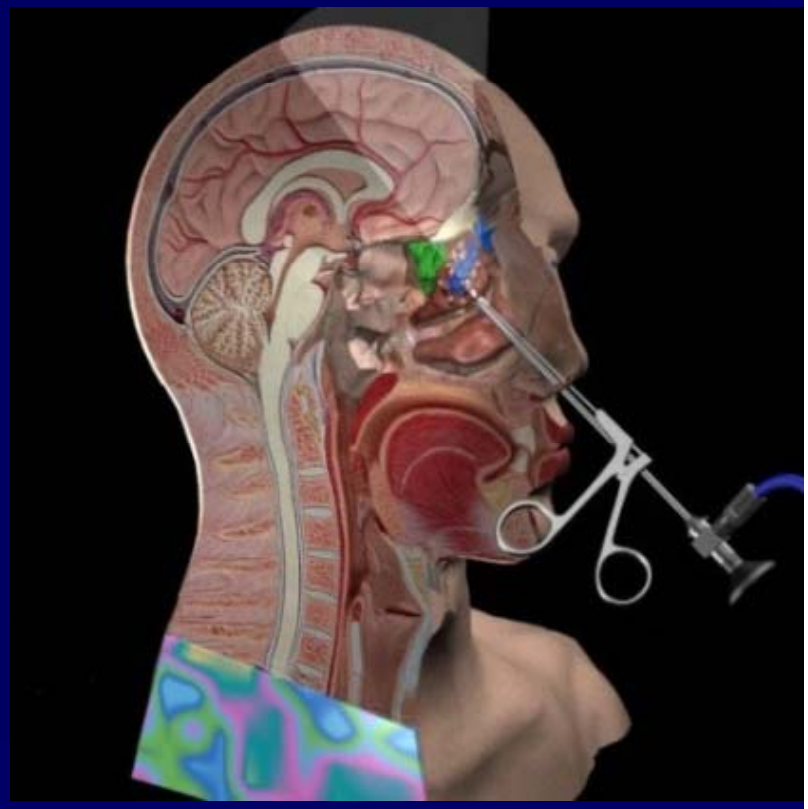
CDF silicon cooling: problems and recovery

- I will not talk..
- The CDF silicon detector cooling system
- The leak
  - Investigation
  - Repair
- Status



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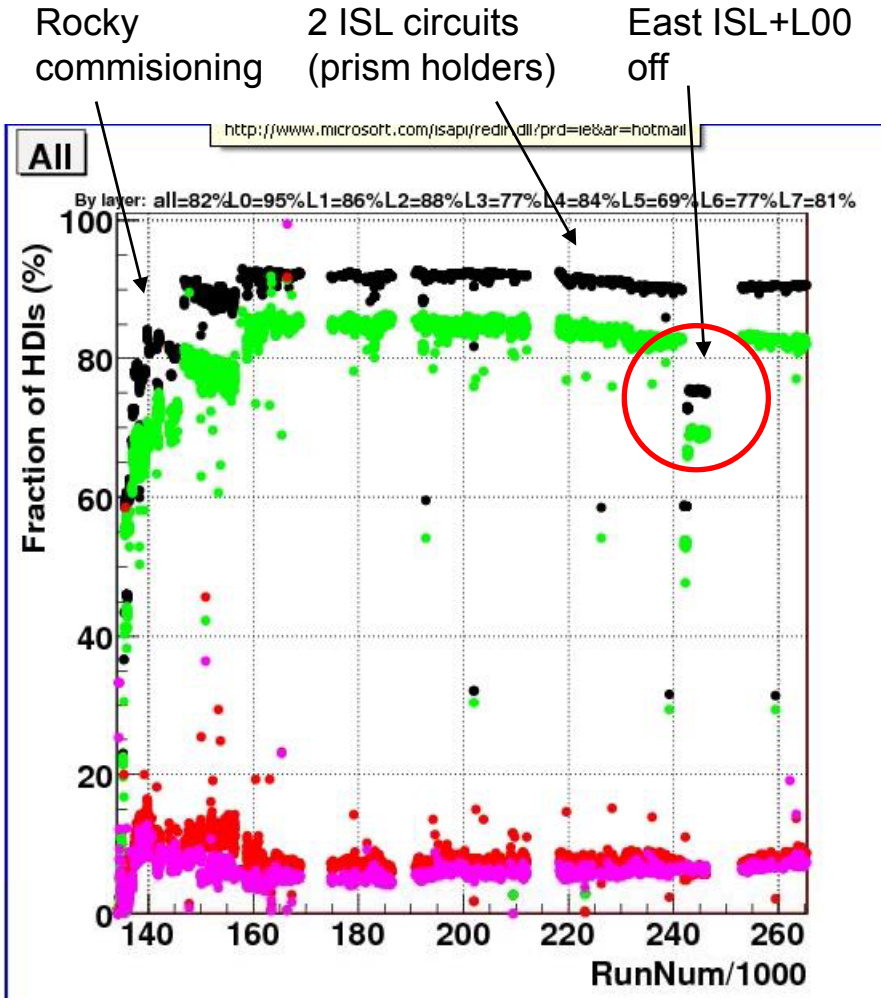
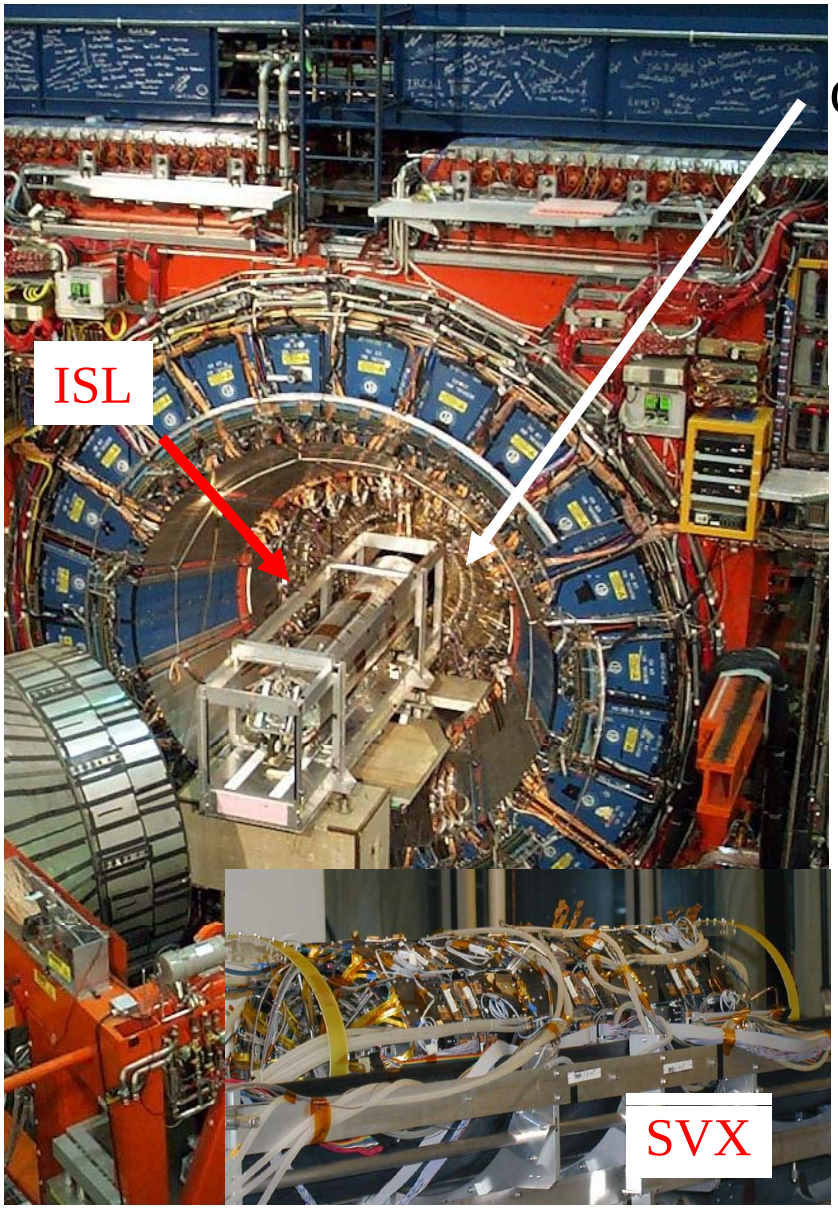
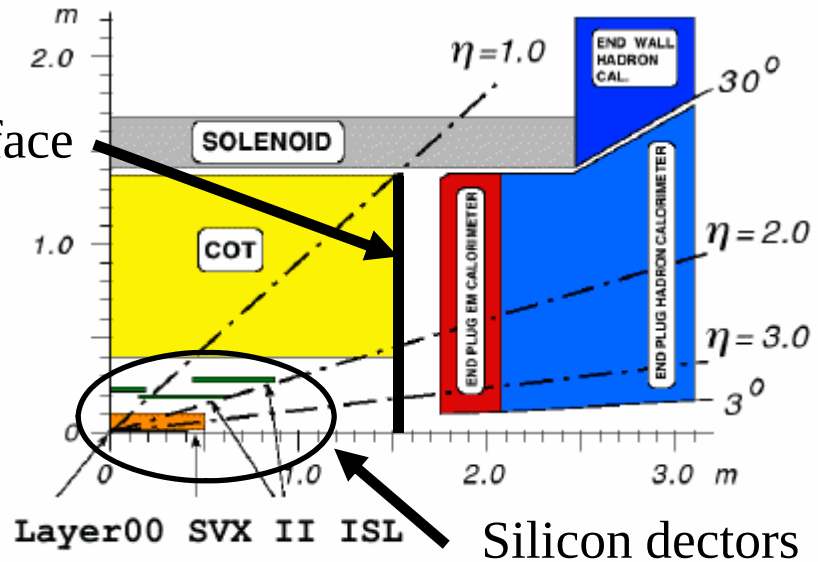
Operations

- Rocky commissioning: blocked cooling lines, fried chips due to bad beam aborts, connector cards that tend to disconnect, broken wire bonds due to Lorentz force resonnances, PS switching off by themselves... See *Ricardo Eusebi* INSTR 2008**,** *Marcel Stanitzki,*VERTEX 2006...
- Aggresive maintenance**.** Huge amount of work in **automation** as the operations group schrink**.**
- 2 ISL circuits lost due low flow. Both were openend with the laser. One with a stuck prism.
- East ISL+L00 off due to **cooling leak**
- **Radiation damage monitoring program**, particulary of L00 and SVX L0. I. Redondo CMS Pixel Workshop 2006, *S. Worm* Vertex 2003..
- Radiation monitoring with diamonds



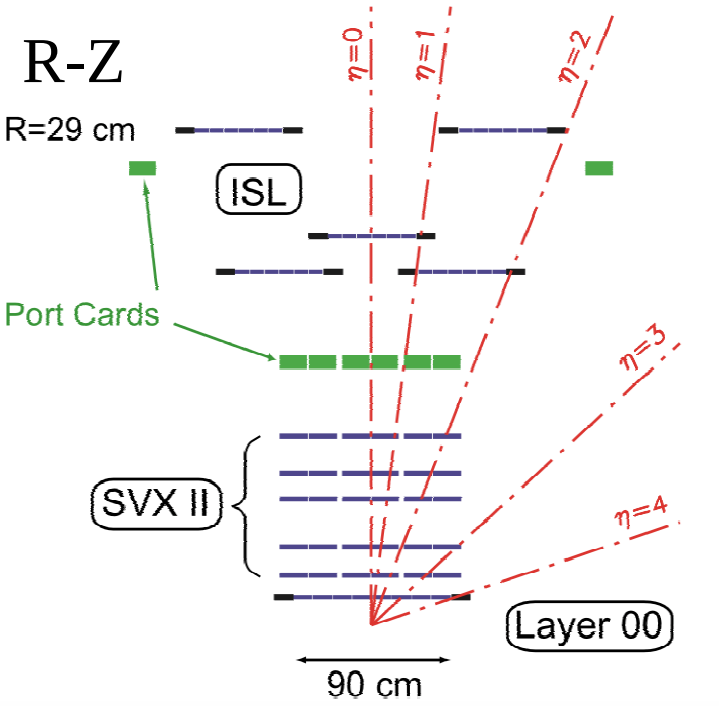
Silicon detectors inside CDF



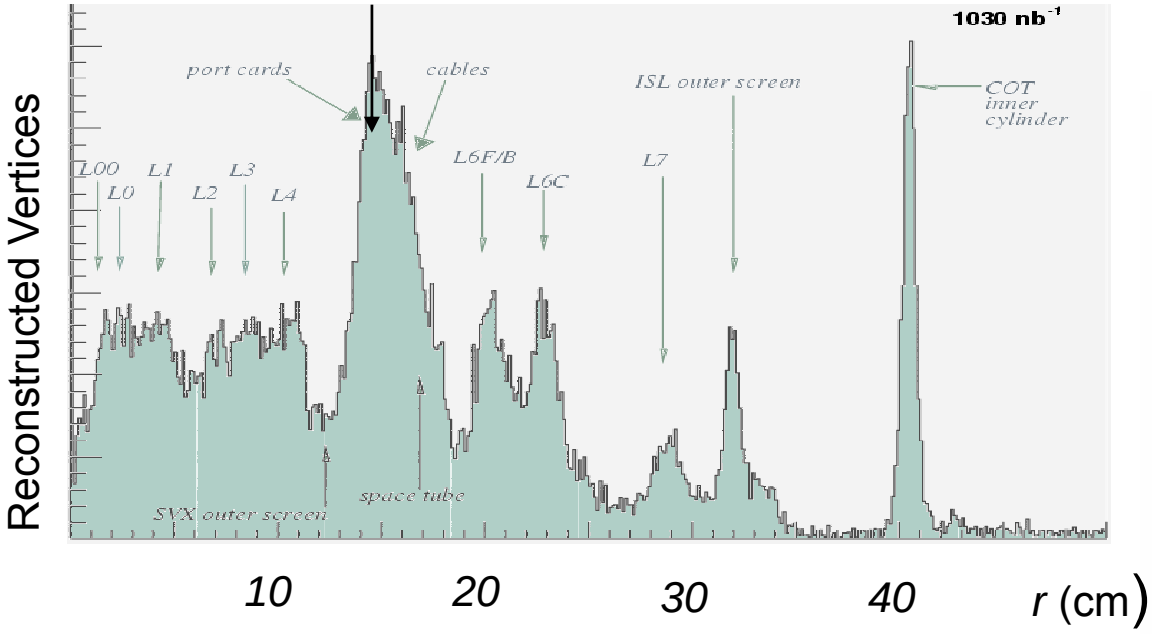


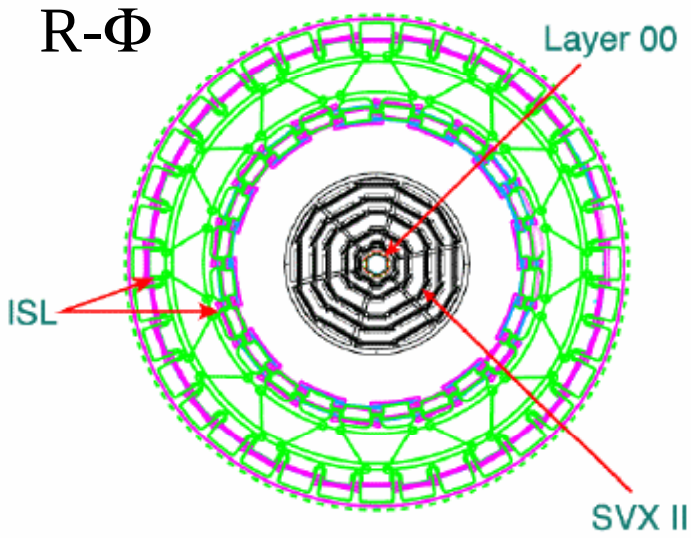
- It is (was?) the largest operating silicon detector in HEP:
  - 7 m^2 of silicon covers 1.2 cm < r < 32 cm
  - 722,432 channels/ 704 modules/ 5644 chips
- 8-bit readout, on-chip pedestal substraction
- Silicon Vertex Trigger (SVT) capable of measuring (and triggering on) impact parameter at Level 2

- Three sub-detectors:
  - L00 – Single sided CMS-type sensors
  - SVX II – 5 double sided layers
  - ISL – Links inner silicon to outer tracker, extend forward coverage
- Extends 1.2 to 32 cm in r, up to 1.8 in η



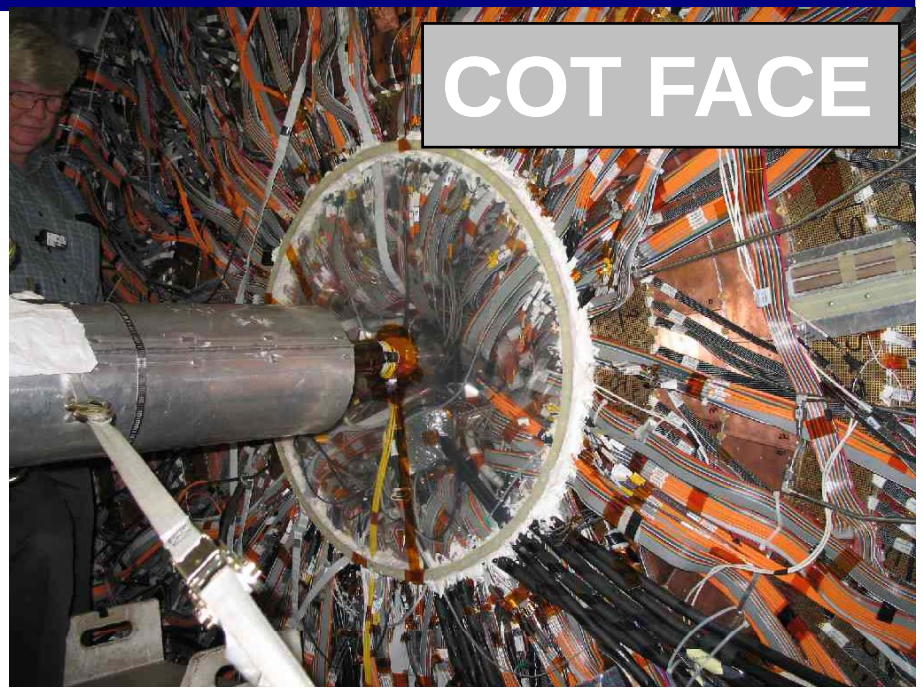
SVX portcards
(optical convertors)

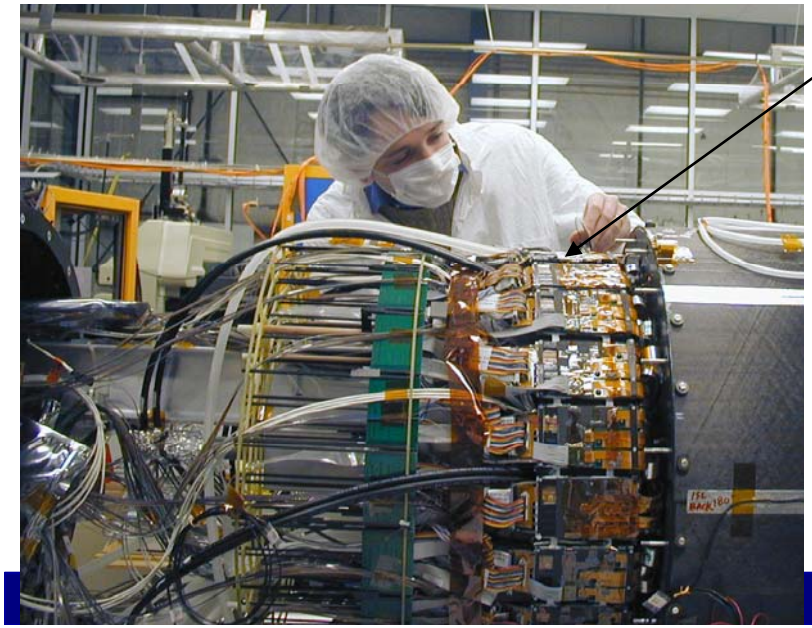


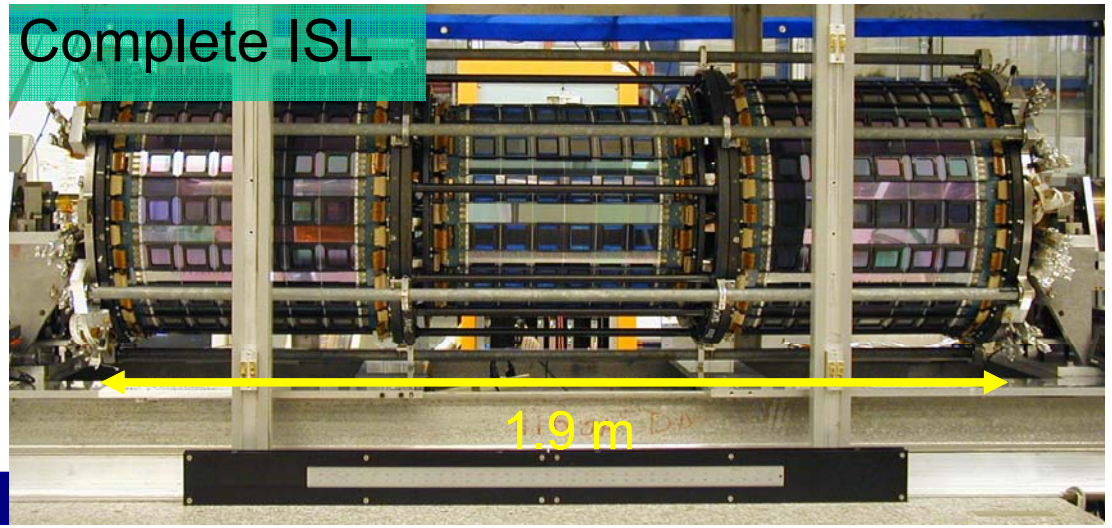


Cooling

- Everything sealed in a Nitrogen Volume
- Direct cooling of the L00 sensors to slow radiation damage
- Evacuate 3.5 kW of heat from electronics within the detector:
  - Readout Chips on top of the sensors (ISL and SVX) sensors
  - Portcards: Optical convertor and power modules.

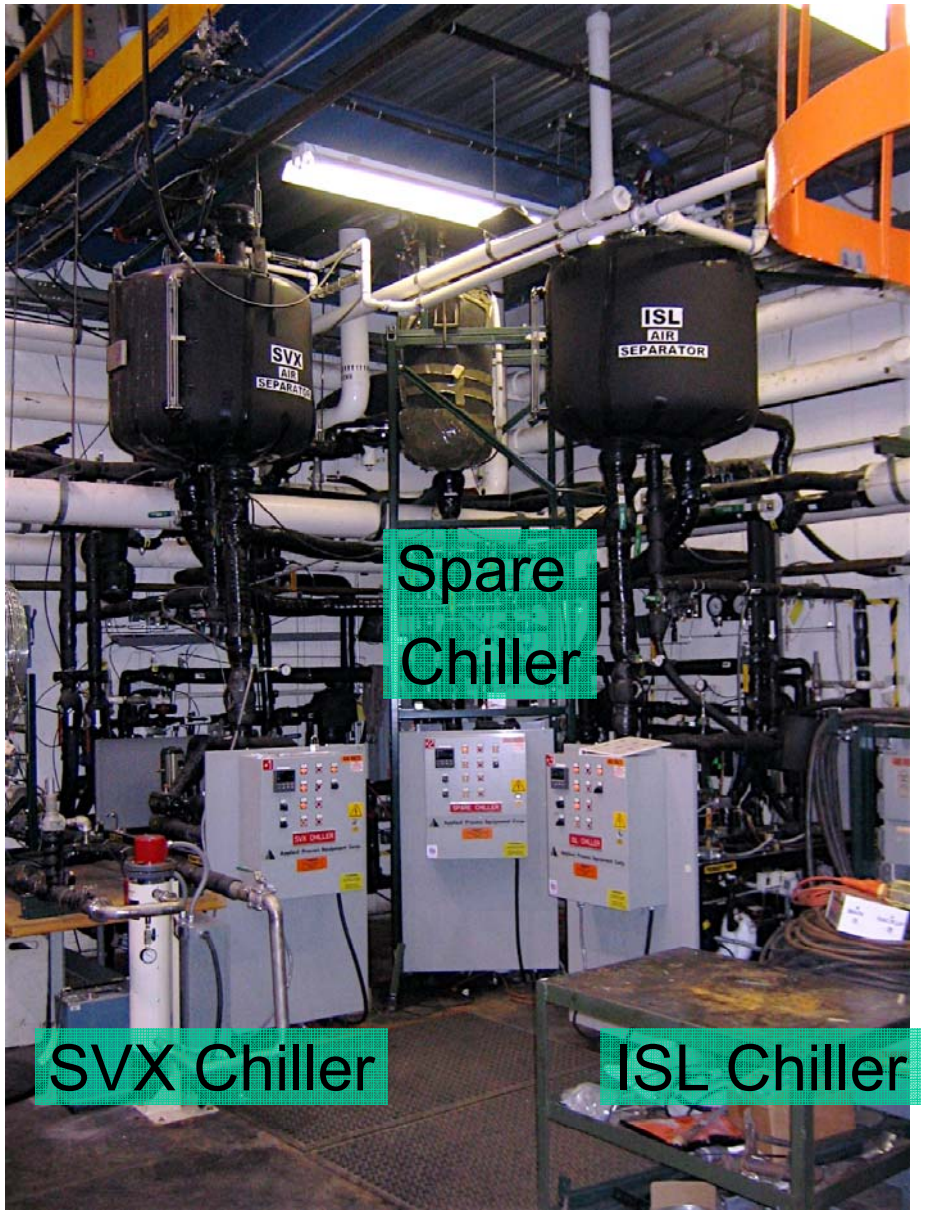






Cooling System

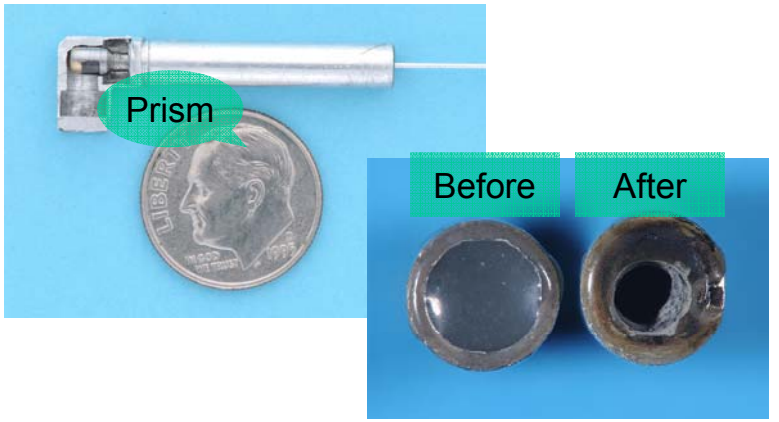
- System is subatmospheric inside the detector. Leaks suck air into system rather than pushing coolant onto detector or electronics
- DI resin + UV to keep coolent inert
- Two separated subsystems:
  - SVX and L00 sensors coolant is **30 % glycol at -10 C**. Broken into 8 *cooling circuits* on face of central detector with separate *electronic control valves.*
  - ISL sensors and optical convertor modules. Coolent (**6 C**) changed from distilled water to **10% glycol** in 2005 to avoid a rare freeze condition. Can isolate ISL Sensors, ISL Porcards and SVX Porcards (of each half).



ISL prehistory: A dfficult commissioning

- Problem: cooling insufficient to switch on parts of ISL
- Reason: 12 ISL cooling lines (~1/3) blocked by glue (discovered after installation)
- 2002: 11 lines successfully opened by strong laser (not trivial: work with borescopes, shoot laser around corner with prisms)
- Reprise in 2006:
  - Cause (2002): 2 prisms got stuck in cooling lines during retraction
  - Effect (2006): Insufficient cooling to these compromised lines due to air leak in the system

Blocked ISL Cooling Lines

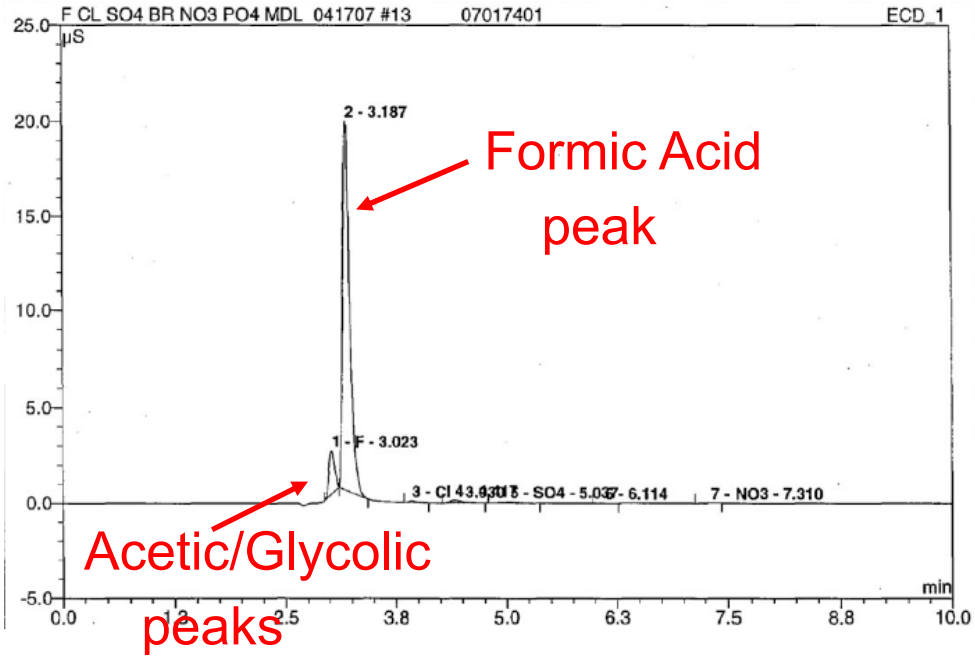


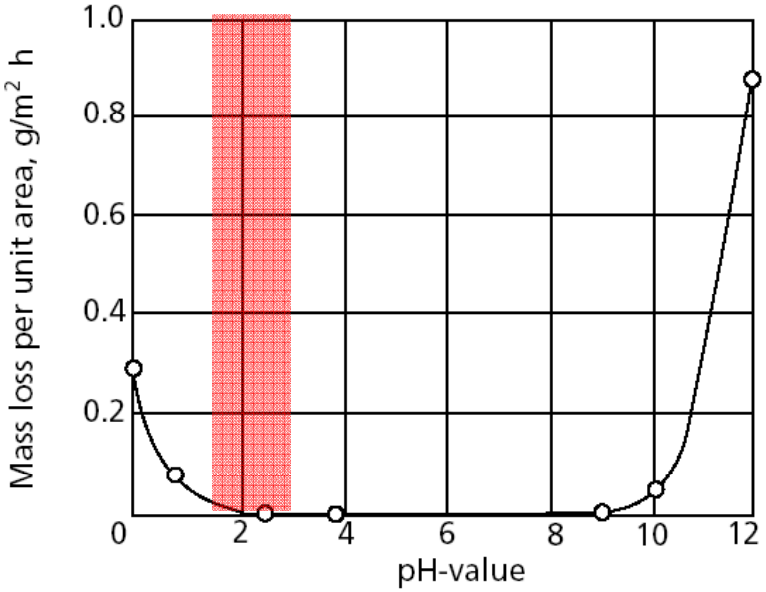
Developing symptoms

- Since March 2006: the conductivity of the ISL system went out of scale during a shutdown.
  - This behaviour had been observed before as the detector warms up. It was considered normal.
  - Several attempts to bring it down after the shutdown were not successful.
  - Problem was investigated but no effect on the system was oberved
- Beginning of 2007: ISL Cooling System degrades
  - The ISL cooling system became more *unstable*. After a trip or a power outage the flows used to operate the detector were not easily recovered.
  - At the beginning of 2007 some of the *electronic valves started to fail*. This problem got worse with time.
  - pH was only measured on March 07: ~ 2 (between gastric acid and lemon juice!).

Source of Acidity?

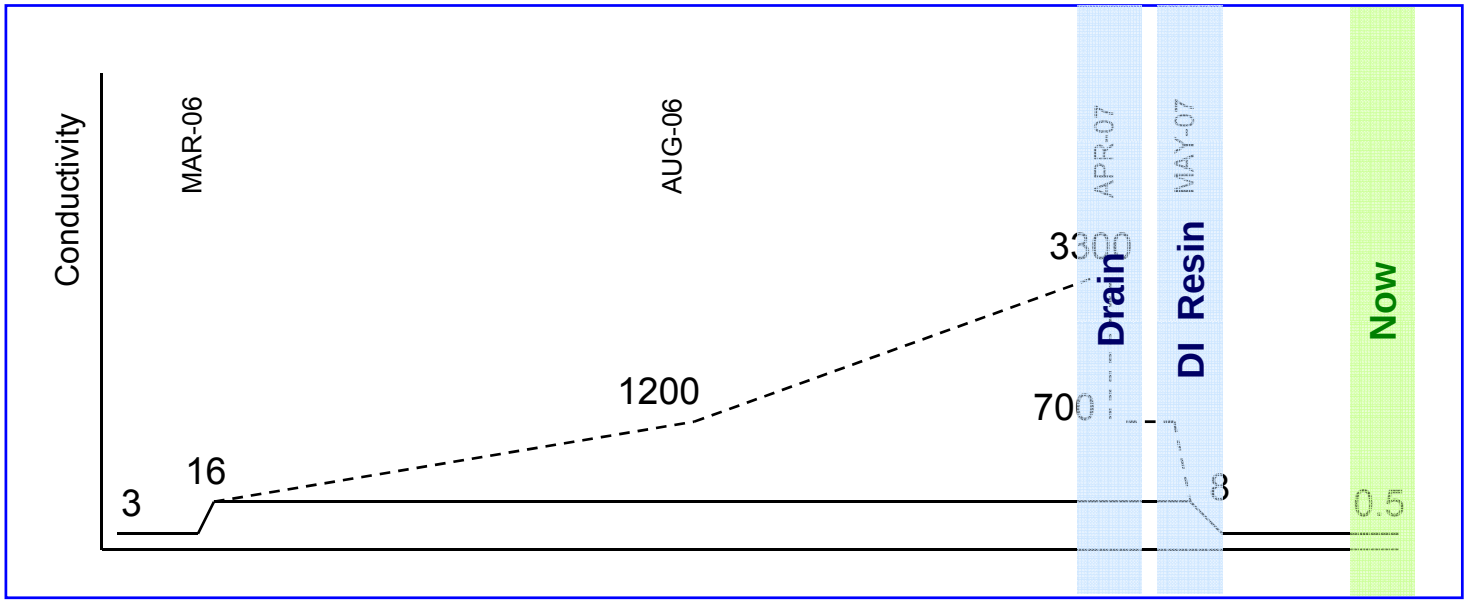
- No significant concentration of inorganic ions
- Glycol can oxydate into carboxylic acids, similar proccess to wine turning to viniger.
- Ion chromatography analysis shows carboxylic acids, mostly formic acid, as source of the low





- Al vulnerable to corrosion below pH 2 because Alumina becomes soluble
- Corrosion resistance is alloy-dependent:
  - Heat affected zone in 6061-Al welds (ISL portcard rings) most sensitive
  - 1100-Al test sample (pipes cooling the sensors) shows no corrosion or mass loss

Conductivity history



- March 2006 ISL conductivity went out of range of the inline conductivity meter
  - Dashed line shows the estimated behavior of the conductivity
  - Numbers show measurements performed by external labs
- e-valves failures in February – March 2007.
- pH was only measured on March 07: ~ 2 (between gastric acid and lemon juice!).
- **Problem was agressively attacked!!!**

System drain

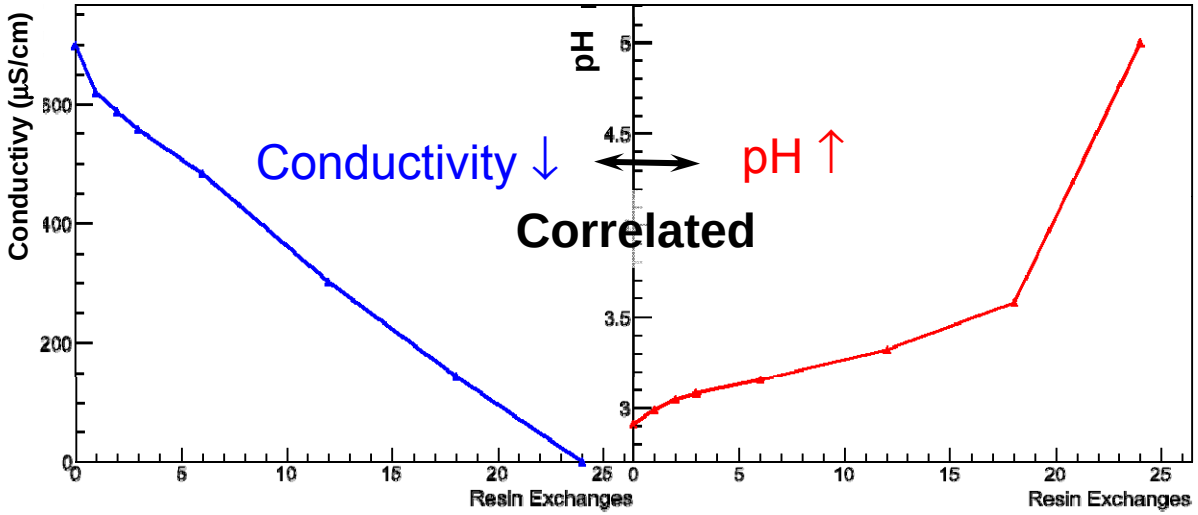
- In March 2007, pH of the ISL cooling system was **1.9** and the conductivity **3300** μS/cm.
- Treating the coolant with **chemicals** was **discarded** without a complete risk assessment.
- Diluting and/or draining the system was the desired coolant quality. This option would a system.
- 16 h access was requested to perform the contained in the system and replace dama
- The piping system was divided operational them was drained.
- Around 3 – 4 barrels (55 gallons per barrel system. Glycol was almost completely rem remained in the system)

Conductivity = 700 μS/cm **pH = 2.8**

- But the operation had to be repeated several times (~5) to reach pH > 4

Infrastructure: ISL Cooling

- We used a setup with 1/100 of coolant in the system to emulate the effect of the dionizing resin on the ISL system.

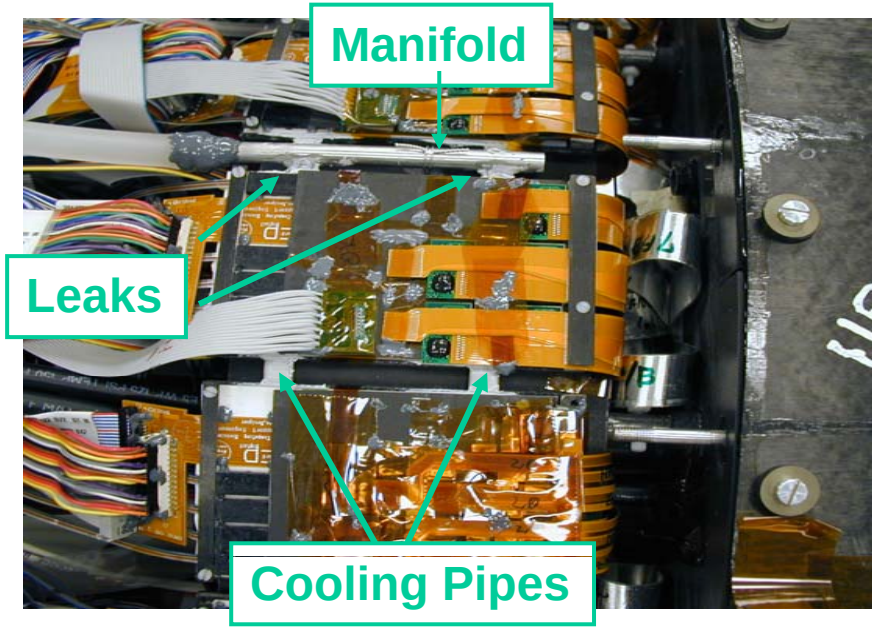


- Our tests in the lab showed that at pH ~ 2, the resin worked perfectly.
  But samples not only had a decrease in conductivity, pH Iso increased.
- Obtained a prediction of the quantity of resin needed to get the desired pH and Conductivity.
- We used a larger resin bed to decrease conductivity and increase pH.
  Values obtained were:

Conductivity = 8 µS/cm pH = 4.5

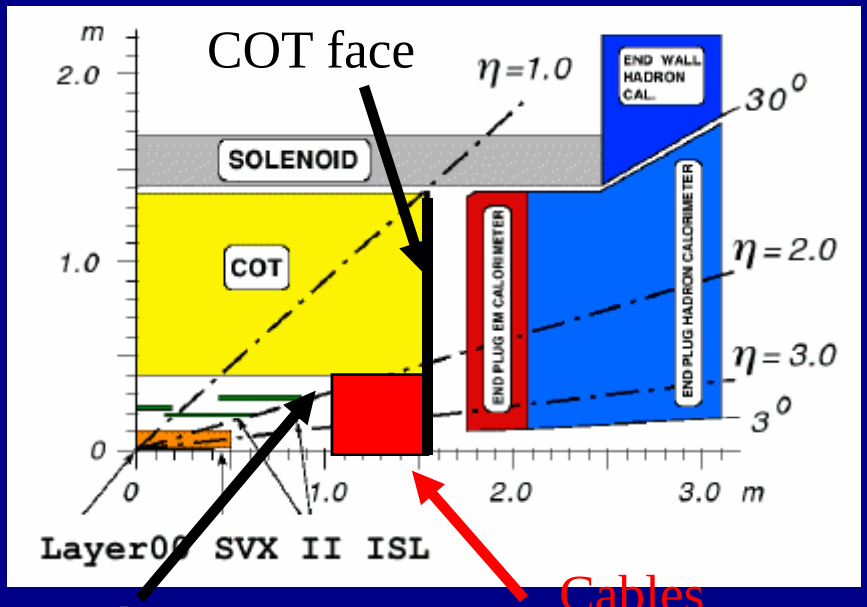
Infrastructure: ISL Cooling

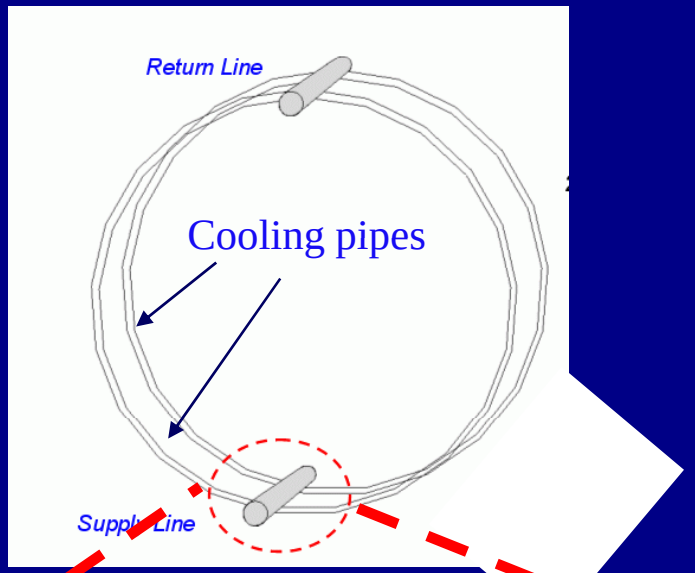
- Coolant was successfully neutralized by draining (to 700 µSi/cm, pH 2.8) and de-ionizing with resin (to 8 µSi/cm, pH 4.5).
- Degradation on West portcard flows stopped after pH was increased.
- No additional flow problems observed in ladder lines.
- But…
- **Welds of the aluminium rings which cool the optical transmitters (portcards) had already corroded.**
- Since the system is sub-atmospheric, leaks result in lower flows. In May flow was too low to operate the portcards.



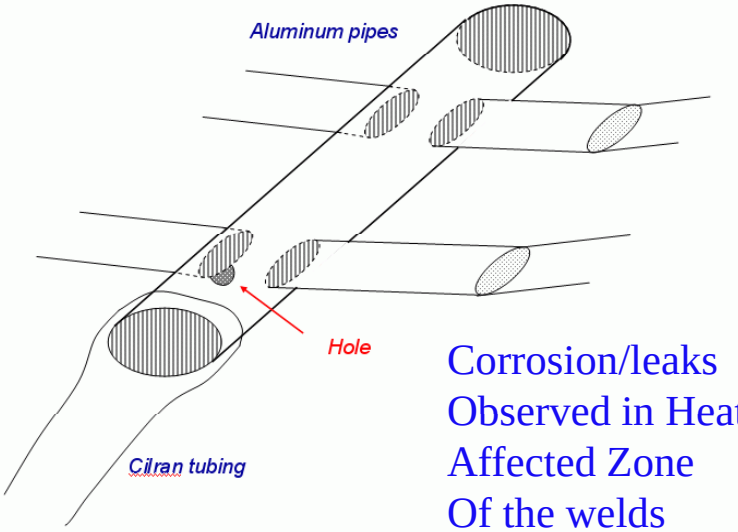
Since May and up to the shutdown in August we were not able to operate East ISL/L00 (affected 300 pb^{-1})

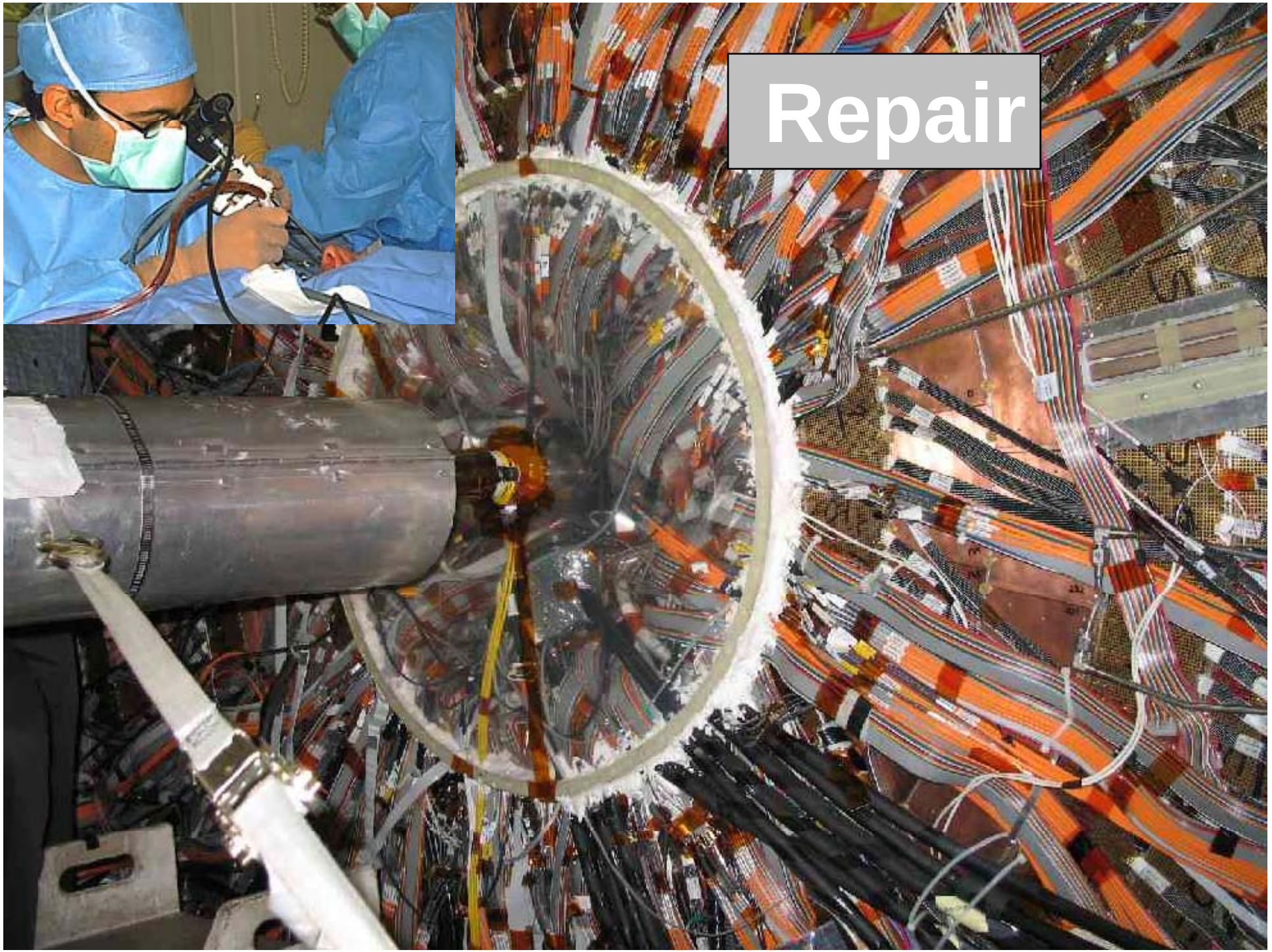
ISL Portcard rings



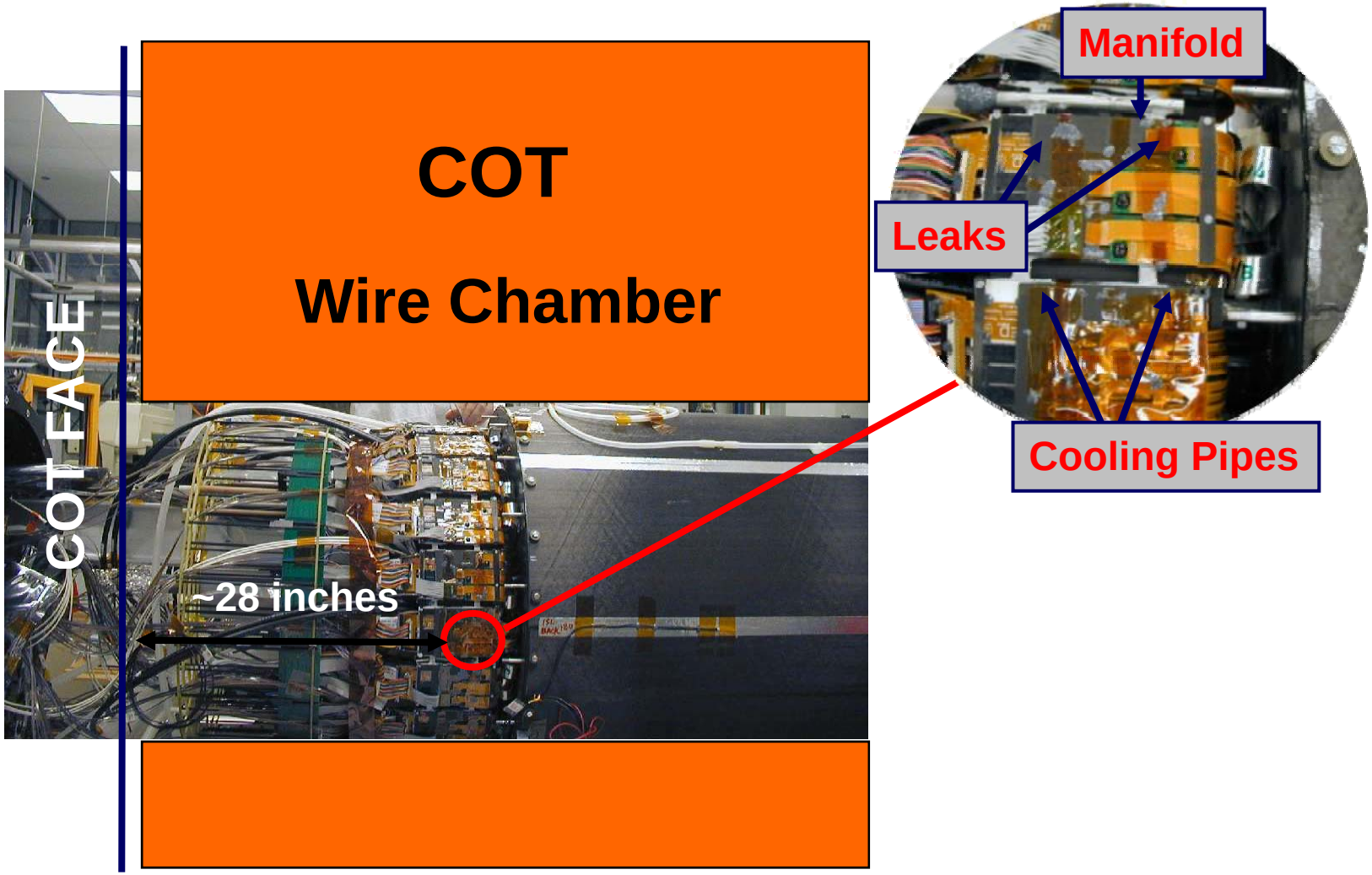


- Manifold - AL 6061-T6, 0.7 mm wall, 127 mm long tube 6 mm ID
- Cooling Rings - AL 5052, 5 mm wall, oval tubes (21 sided)
- Welded - either 5356 or 4043 filler
- Inner surface area: 0.12m^2
- Fed by Cilran (Silicon) tubing from COT face
- **Impossible to access from outside, isolated by volume full of cables,~60cm in z.**




Repair

Leak location

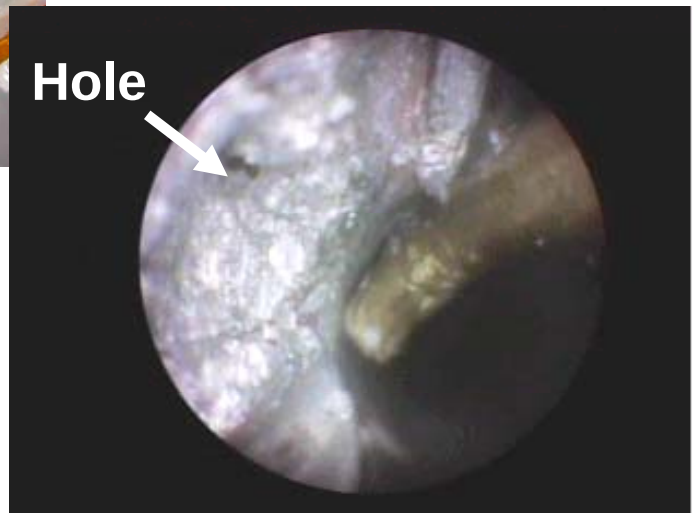


ISL Cooling Repair

- **Keep the silicon cold and dry:**
  - Plastic barrier encloses wire chamber bore, 600cft volume.
  - Desicant based air drier will provide 300cft/min to the volume.
  - Dewpoint always below –10 C.
- **Cover holes with epoxy DP-190 from the inside of the pipe using borescopes and catheters.**

- Repairs performed over a month with 4 people shifts lead by FNAL specialist ("*head surgeon*") Ken Schultz.
  - Vacuum tests show that the Al lines are as tight as the stainless steel ones (SVX portcards)
  - **Cooling running stable for a year**

Repair



Current Status

- System running reasonably stable for a year
- New inline conductivity meters with larger range installed
- Samples are taken to measure pH and conductivity on a weekly basis
- Oxygen and Nitrogen levels coming out from the system are monitored

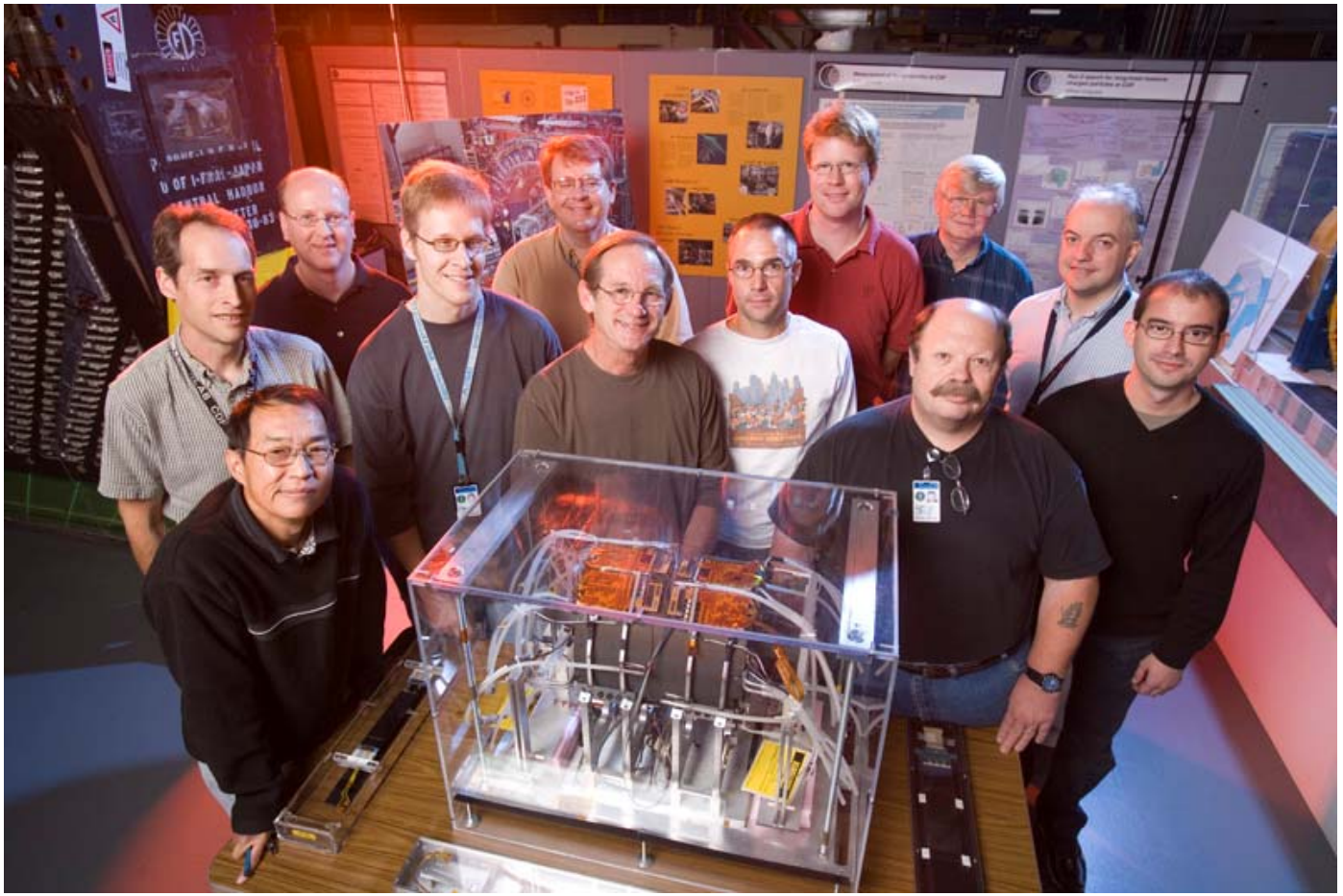
Conclusion

- The 2007 summer shutdown allowed us to patch the cooling system.
- 1(2) more years to go!

ISL repair task force

•Del Allspach, Mary Convery*, Jose Enrique Garcia, Doug Glenzinski , Ignacio Redondo Fernandez*, Ulrich Husemann, C.M. Lei, Mike Lindgren, Aseet Mukherjee*, Bill Noe, Robert Roser*, Ken Schultz, David Stuart*, Bob Wagner, Peter Wilson

***not shown in the photo**



Tevatron

- Proton-Antiproton Collider
- 1.96 TeV Center of Mass Energy
- 36 x 36 bunches, Δ t=396 ns
- Current Instantaneous Peak Luminosity: ~3 10^{32} cm^{-2} s^{-1}
- Integrated Luminosity:
  - Current: 3.8 fb^{-1}
  - Expectation for **2009: 5.8-6.8** fb^{-1}
  - Running in 2010 under discussion
- Two Experiments Collecting Data: CDF & D0