ATLAS Pixel Detector

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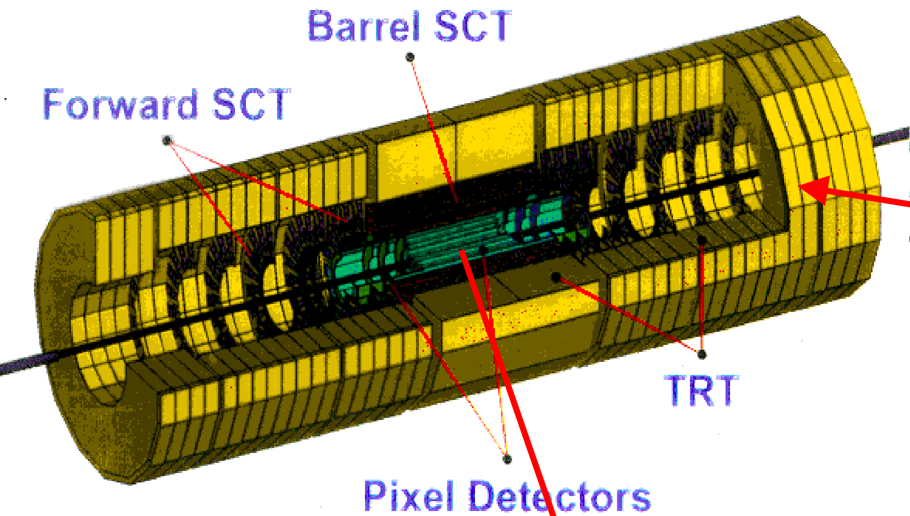
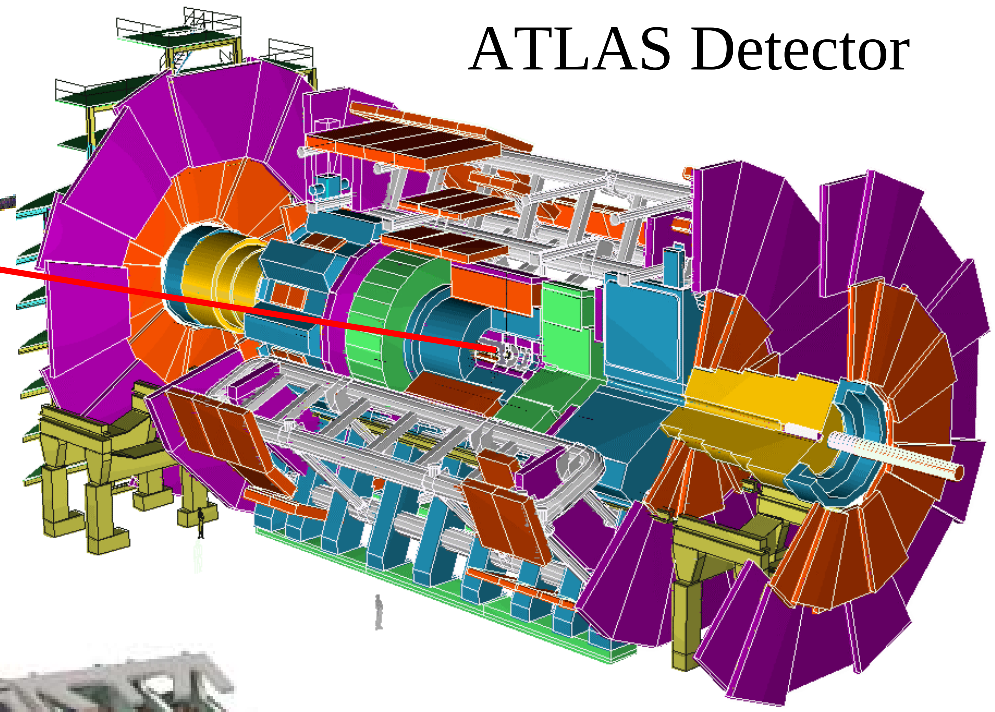
ATLAS - Pixel Detector

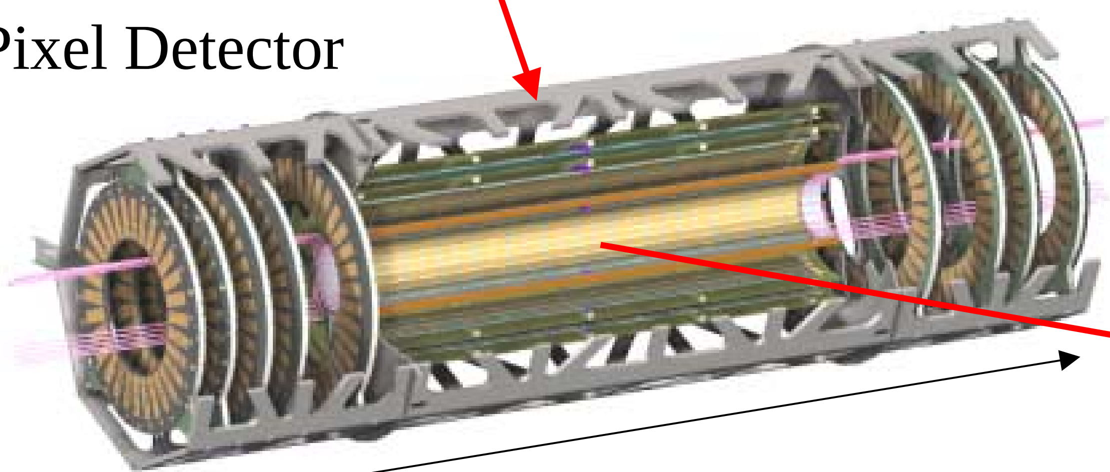
Inner Detector



ATLAS Detector



Pixel Detector

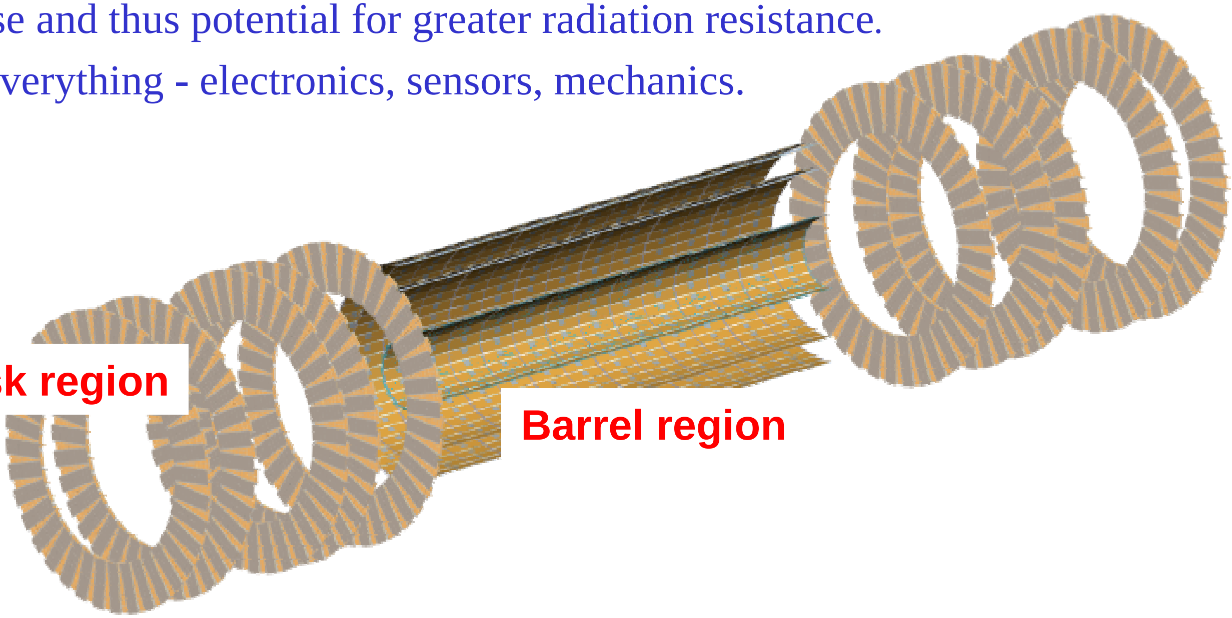


1.8 m

- Rapidity coverage < |2.5|
- About 10^8 pixels.
- 3 barrel layers, 2x5 disks
- Innermost barrel layer insertable from outside Inner Detector
- About 2 m^2 active area
- About 2,000 modules

Pixel Concept and Institutions

- LHC radiation levels prevent long-term operation of silicon strip detectors for R< 25 cm
- Pixel detectors with much smaller cell size(and lower capacitance) yield almost order of magnitude better signal-to-noise and thus potential for greater radiation resistance.
- Radiation hard(25-50 MRad) everything - electronics, sensors, mechanics.



Collaborating Countries and Institutions

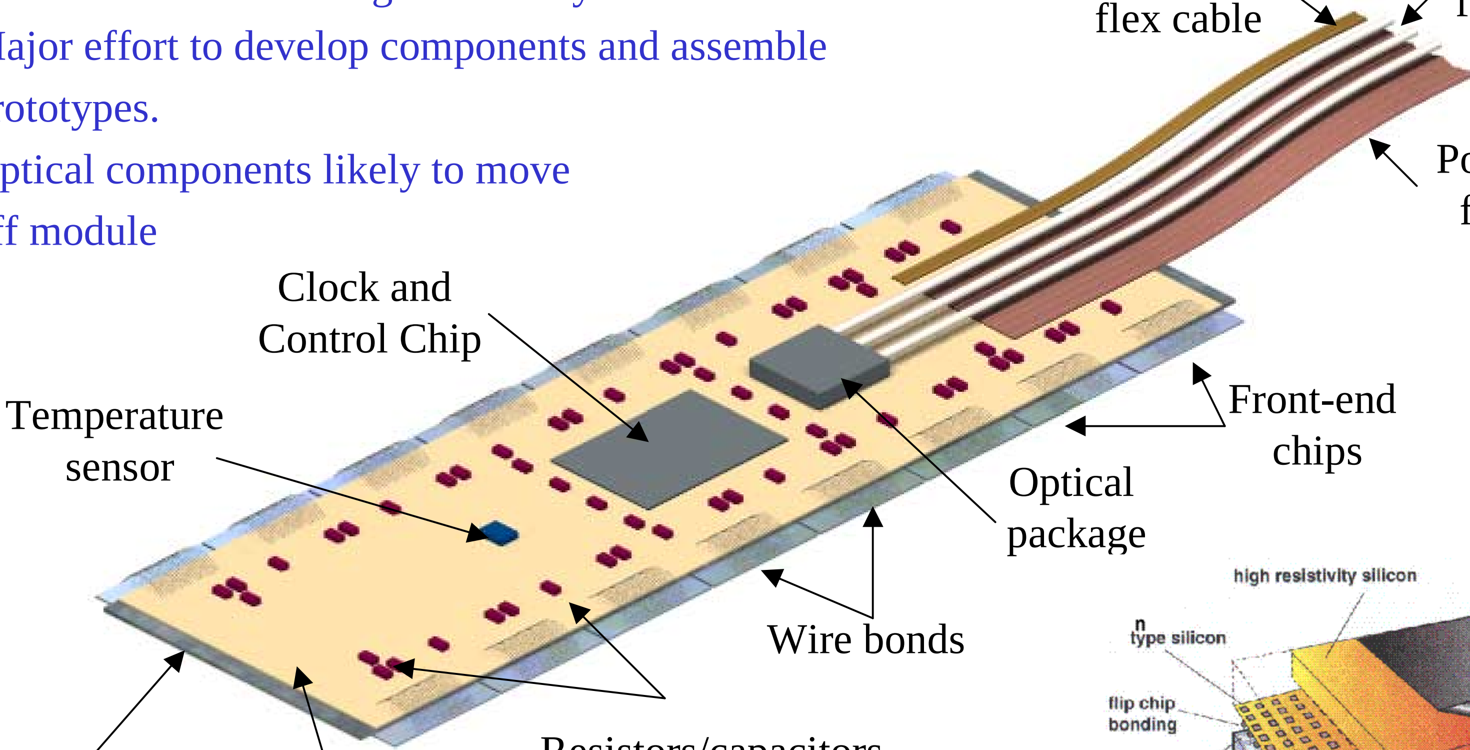
Canada(Toronto), Czech Republic(Academy of Sciences-Institute of Physics, Czech Technical University, Charles University), France(CPPM-Marseille), Germany(Bonn, Dortmund, Siegen, Wuppertal), Italy(Genoa, Milan, Udine),Netherlands(NIKHEF) United States(Iowa State, LBNL, New Mexico, Ohio State, Oklahoma, SUNY-Albany, Wisconsin)

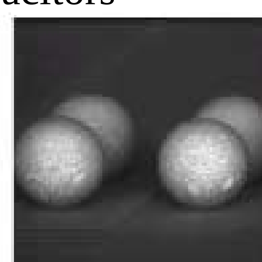
Pixel Module

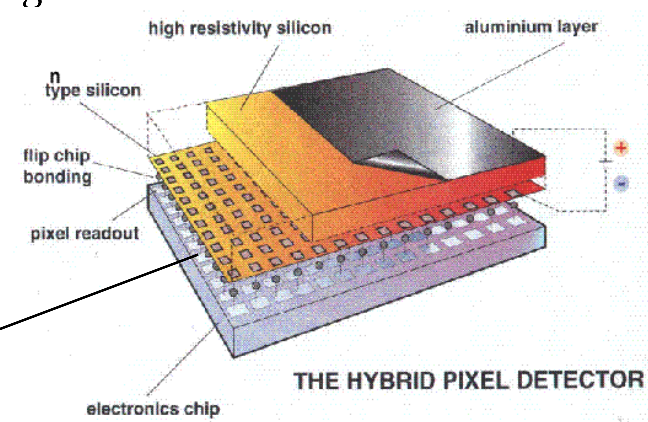
Module is basic building block of system

Major effort to develop components and assemble prototypes.

Optical components likely to move off module

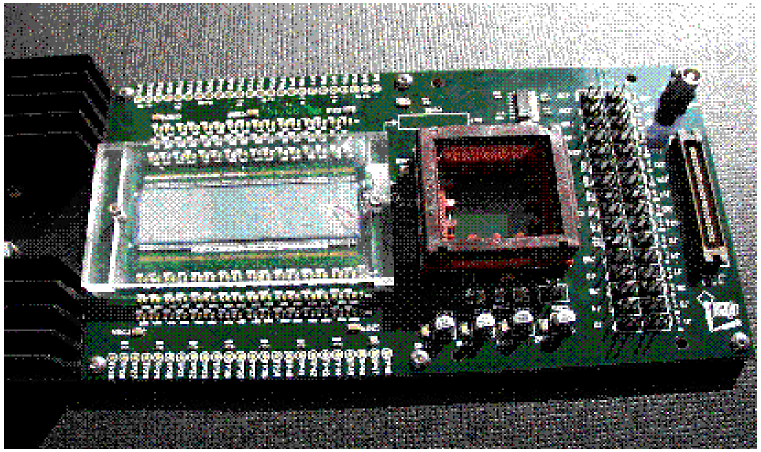




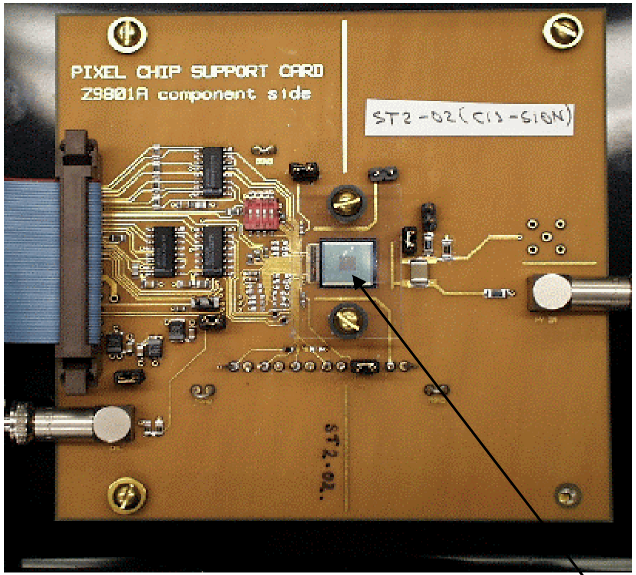


Pixel Electronics and Modules

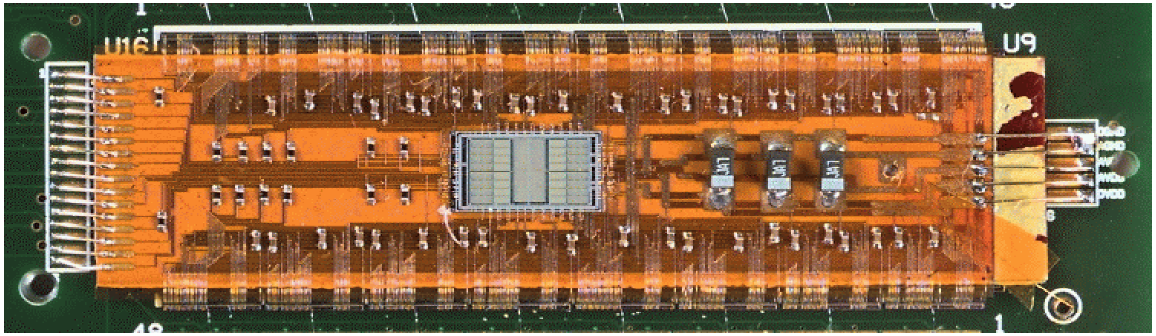
- Full-scale rad-soft electronics prototypes fabricated in rad-soft technologies in 1998 and tested extensively, including with irradiated detectors, since then.



Bare 16-chip modules



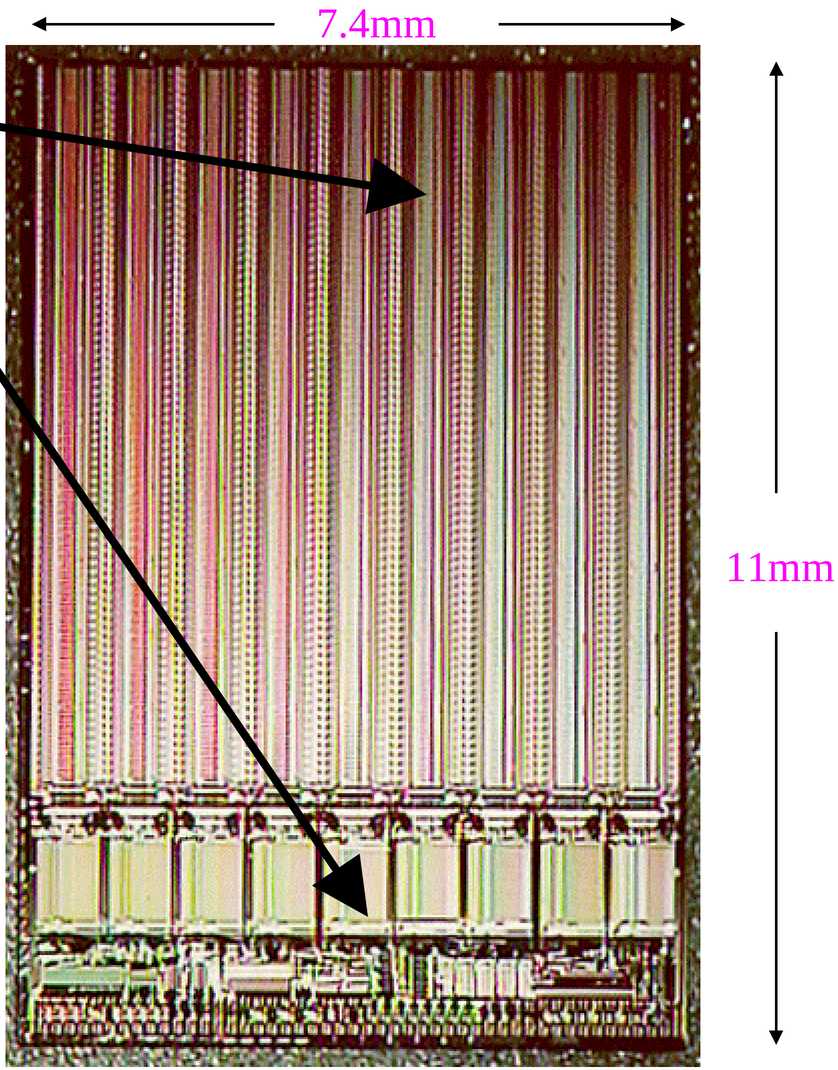
Dozens of single chip/sensor assemblies of different types



16-chip modules with flex hybrid

Pixel Electronics

- General features
  - Active matrix 18x160 pixels
  - Inactive area for buffer and control
  - 50x400 micron pixel size in prototypes and most of system. Goal of 50x300 microns innermost layer.
- Critical requirements
  - Time walk <20 ns
  - Timing uniformity across array(<few ns)
  - Low threshold(2-3K e^-s)
  - Threshold uniformity (implemented by having DAC in each pixel)
  - Low noise(<few hundred e)
  - Low deadtime(<1% or so)
  - Robust(dead pixel OK, dead column not good, dead chip bad)
  - All of the above at 25 Mrad or more
- Important requirements
  - Time-Over-Threshold(TOT) measurement of charge
  - Maximize active area
  - Die size with acceptable yield
  - Thin(150 micron goal)-less material



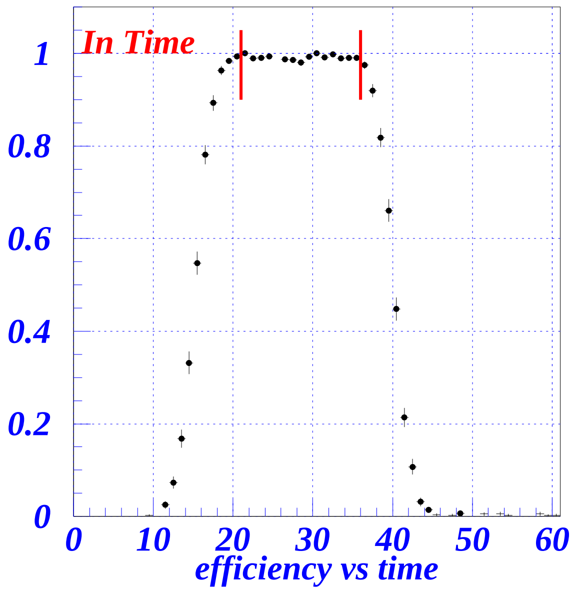
Rad-Soft Prototype Summary

- Multiple versions(FE-A, B and C) fabricated by 1998 and tested extensively in test beams in 1998 and 1999.
- Bumped bonded to detectors, including irradiated detectors.
- 16 chip modules fabricated successfully, including with thin(about 150 micron) ICs
- In general, LHC specs have been met.
- Operation with thresholds around 3,000 electrons demonstrated
- Noise values 150-200 electrons demonstrated.
- Threshold uniformity(with threshold tuning via 3 bit DACs in each pixel) also about 150 electrons.
- Proof-of-principle demonstrated.

Test Beam Data - Efficiency Example

Not Irradiated - Thr. 3 Ke

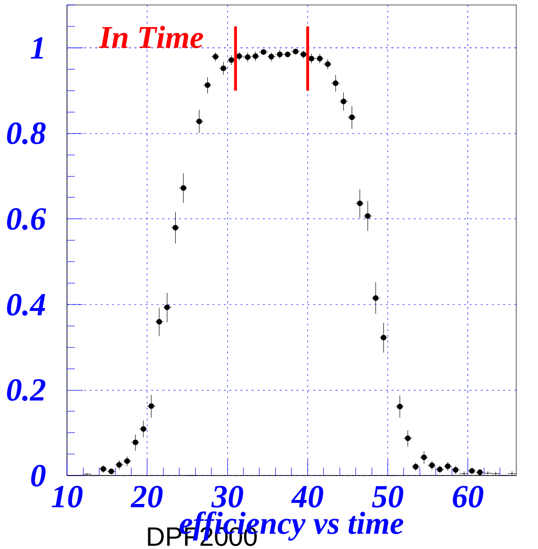
Efficiency	99.1%	Losses	0.9%
1 hit	81.8	0 hits	0.4
2 hits	15.6	not matched	0.1
>2 hits	1.7	not in time	0.4



Irradiated V_{bias} = 600 V

Fluence 10^{15} n/cm^2 - Thr. 3 Ke

Efficiency	98.4%	Losses	1.6%
1 hit	94.2	0 hits	0.4
2 hits	3.1	not matched	0.0
>2 hits	1.1	not in time	1.2



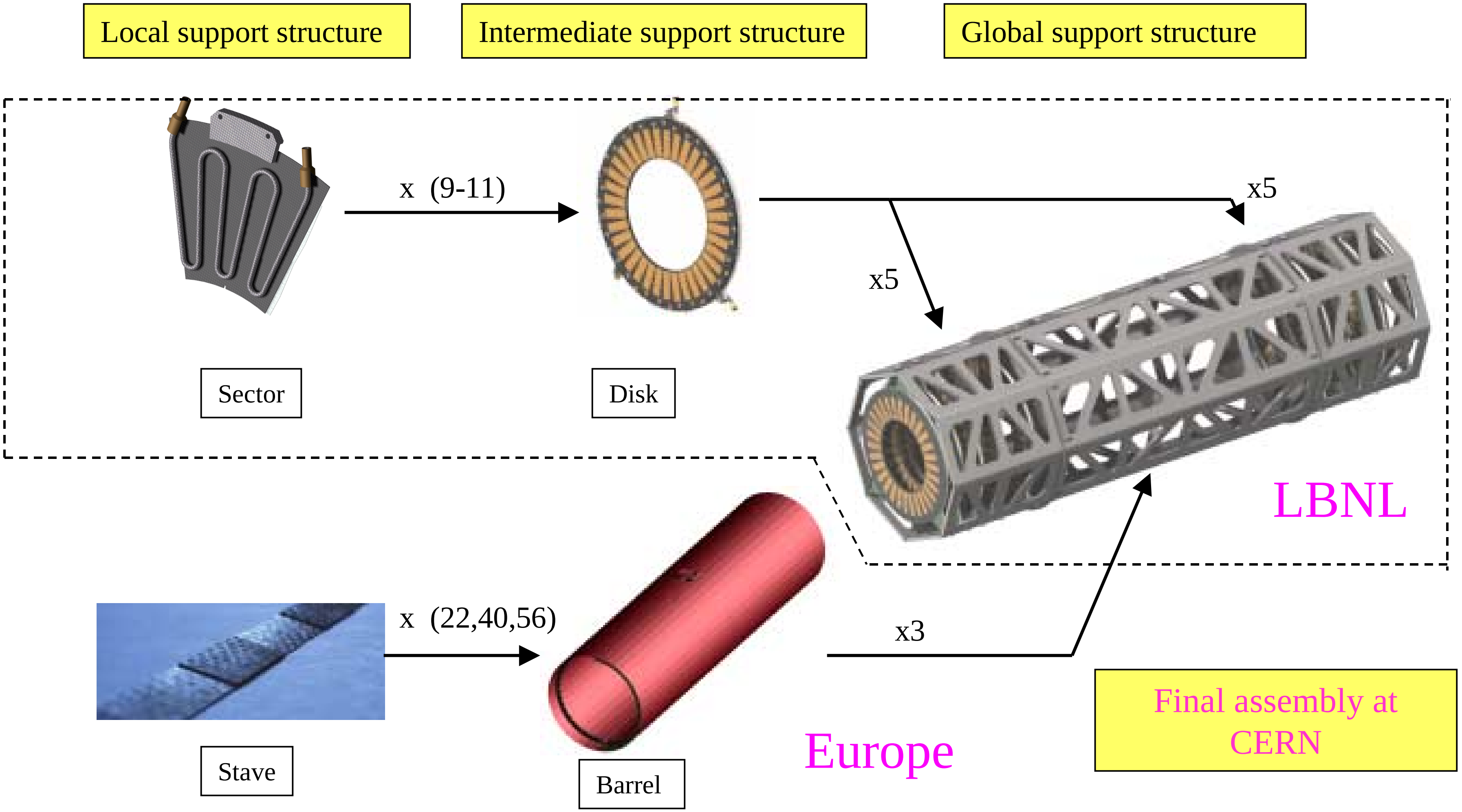
Rad-Hard Electronics Status

- Transition to rad-hard electronics started in early 1999.
- First full prototype(FE-D1) submitted to Temic(DMILL process) in August and received in October 1999.
- Most of the functionality of the chip was OK but
  - some design errors(relatively benign but slowed down testing)
  - yield was miserable, essentially zero
  - nevertheless some chips bonded to detectors and tested to extent possible
- Very detailed investigations by ATLAS and vendor to understand why yield so poor, including additional wafer fabrication at Temic's expense.
- Hints but no definitive understand by vendor(or us) of why yield is so poor.
- Design errors fixed, two versions of chip to perhaps isolate areas of concern, dedicated test devices, revised optical chips and module control chip….new run submitted to Temic on July 26, wafers back early October. Temic will also process additional wafers themselves with process variations to attempt to identify origin of yield problem.
- So, if lucky, will have idea about viability of this approach with Temic by end of the year.

More Rad-Hard Electronics Status

- It has been our policy to pursue at least two rad-hard vendors for the rad-hard chips.
- Design of front-end chip in Honeywell Silicon-on-Insulator technology advancing well
  - Denser technology than Temic(easier to cram functionality into pixel)
  - Preliminary indications are that more rad-hard
  - But more expensive(for same yield)
  - Submission of full prototype(FE-H1) on track for October, wafers to arrive early 2001.
- Third possibility is 0.25 micron processes(eg. IBM), for which there has been considerable recent success(BTeV pixel prototypes, CMS silicon strip readout…).
- Design of full-prototype in this process, FE-I1, will begin late September with target of submission for fabrication by June 2001.
- Can't continue with three vendors, so must decide which to keep when test data available
  - Temic by end 2000
  - Honeywell by mid 2000
  - 0.25 micron by end 2000
- Will consider using two vendors for final production. Safety. Schedule.

ATLAS Pixel Mechanics

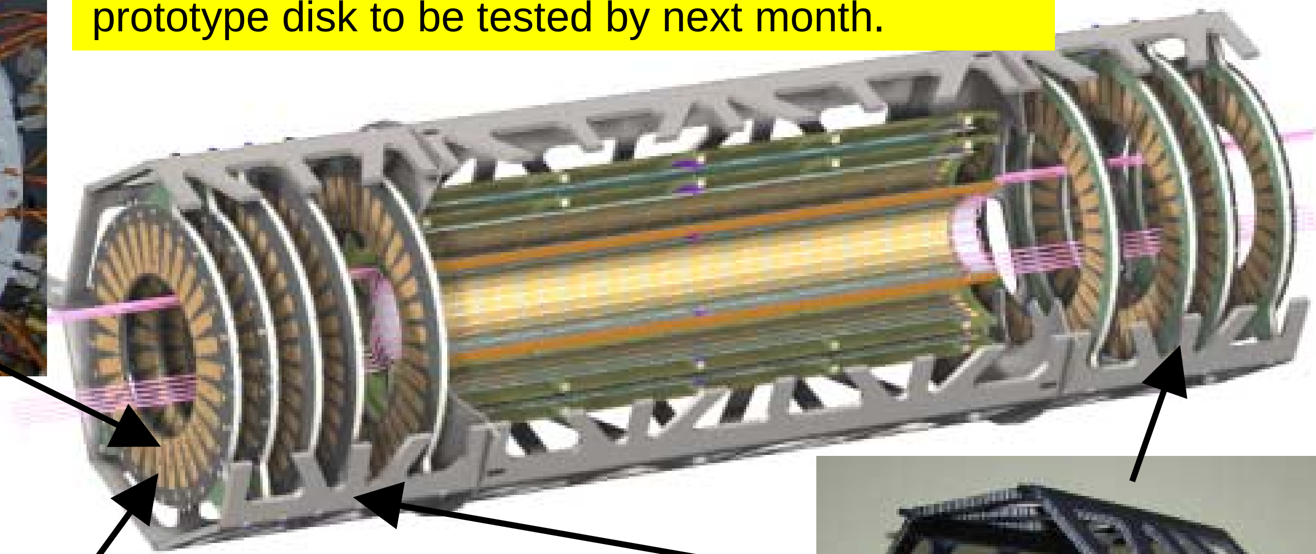


ATLAS Pixel Mechanics - Goals

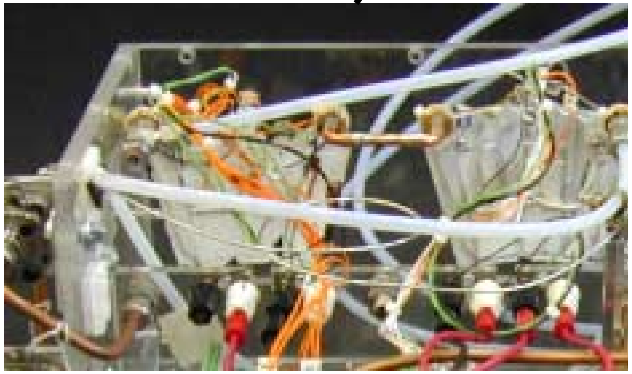
- Large heat load - 15kW - from electronics
- But must keep silicon detectors below 0^0C.
- Low radiation length/interaction length as possible
- Ultra-stable structure. Instrinsic resolution(in ϕ) about 10 microns.
- Low coefficient of thermal expansion, coefficient of moisture expansion…build at room temperature but operate cold and dry.
- This has led us to
  - Integrated mechanics and cooling
  - Use of carbon-carbon material(high thermal conductivity+stiffness) for local cooling/supports
  - All carbon(carbon-carbon or carbon fiber) structures.

US Pixel Mechanics Prototypes

Thermal/mechanical prototype disk fabricated and tested successfully for stability. Second full prototype disk to be tested by next month.



Evaporative cooling tests of disk sectors successfully done.



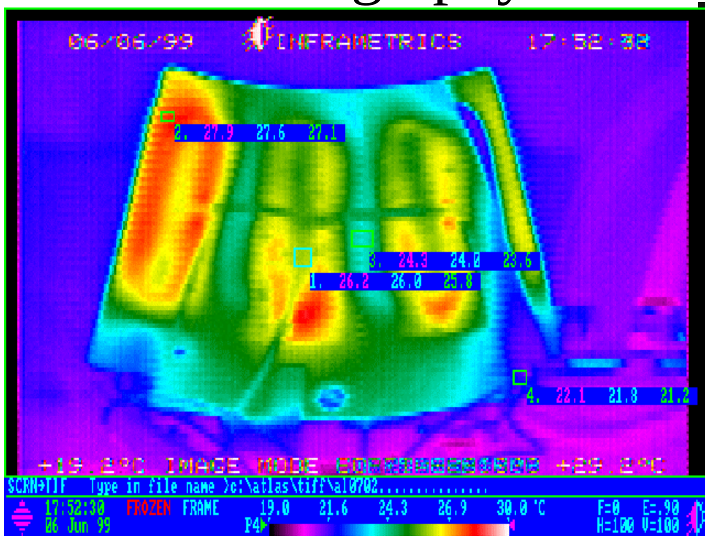
Prototype end frame section fabricated by December 1999.

Disk Sector Concept

- Combined structural support with cooling.
- Carbon-carbon faceplates. Front and back faceplates offset in phi to provide full coverage(no gaps).
- Reticulated carbon foam CVD densified between faceplates.
- Aluminum coolant tube between faceplates.
- Three precision support points to disk ring.
- Modules mounted on both sides.

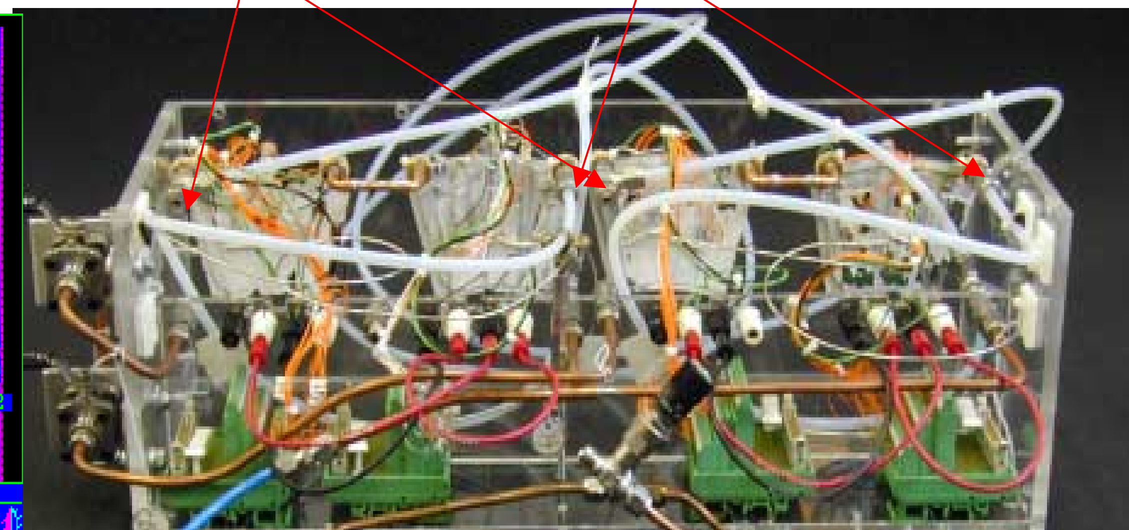
Cooling Tests

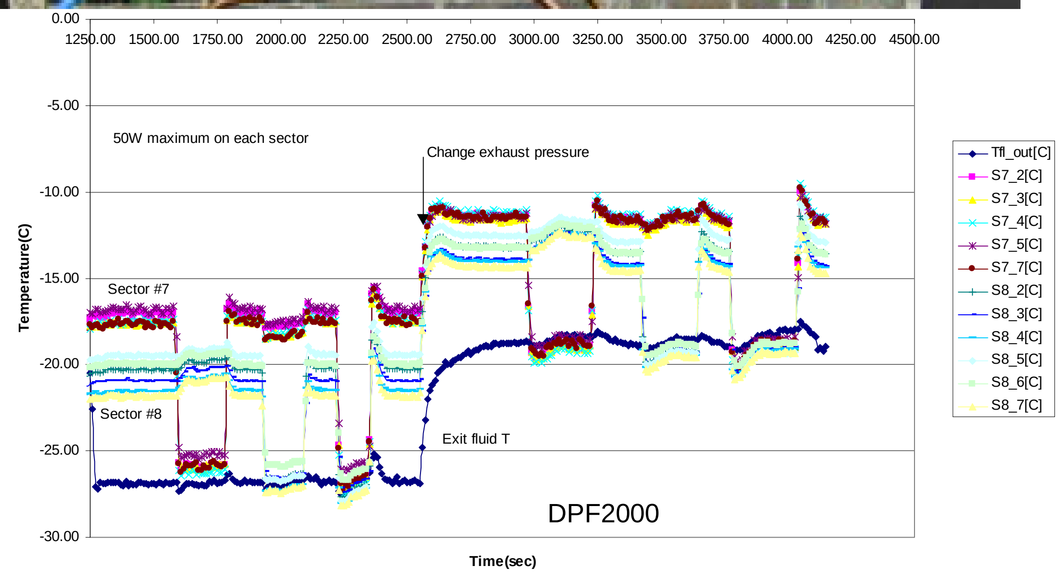
IR Thermography



Capillary(0.030" ID 1.2 m long)

Exhaust lines





- Cooling is provided by evaporation of C_3F_8.
- This minimizes radiation length of coolant, avoids water.

Status Summary

- Silicon detectors
  - Ready to start preproduction in next month.
- Modules
  - Assembly techniques understood although more experience needed, ready to begin preproduction early next year.
- Mechanics
  - Ready to start production early next year.
- Electronics
  - Rad-soft prototype IC program very successful
  - Off-detector electronics advancing well, ready to begin production mid-next year.
  - Transition to rad-hard ICs slower and more difficult than we would like but still advancing steadily, but must cope with impact on overall schedule.