ATLAS Silicon Microstrip Semiconductor Tracker (SCT)

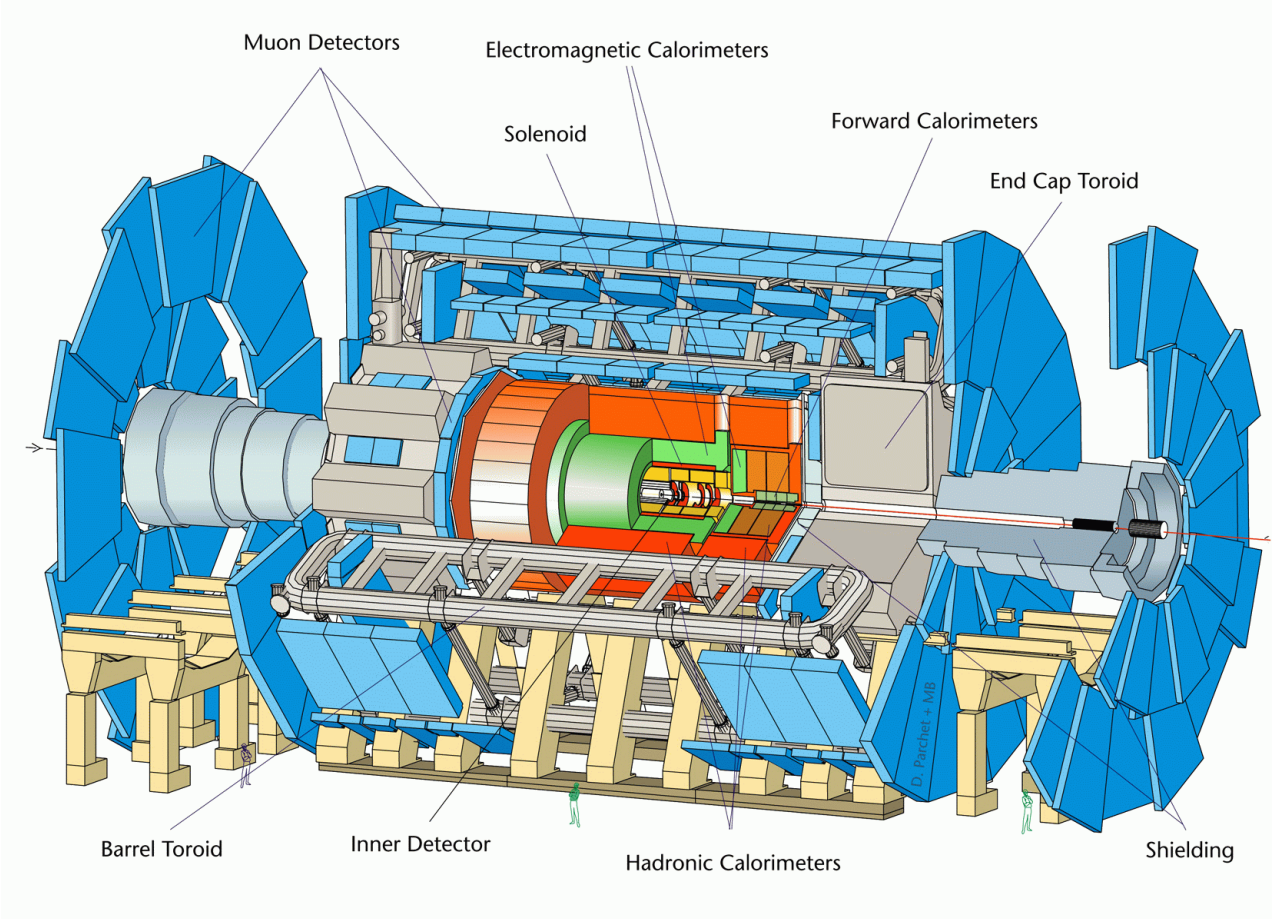
Y. Unno

KEK

representing ATLAS SCT collaboration

- **Where is it?**
- **Why?**
- **What are the issues?**
- **Where are we?**
- **When?**

ATLAS overview



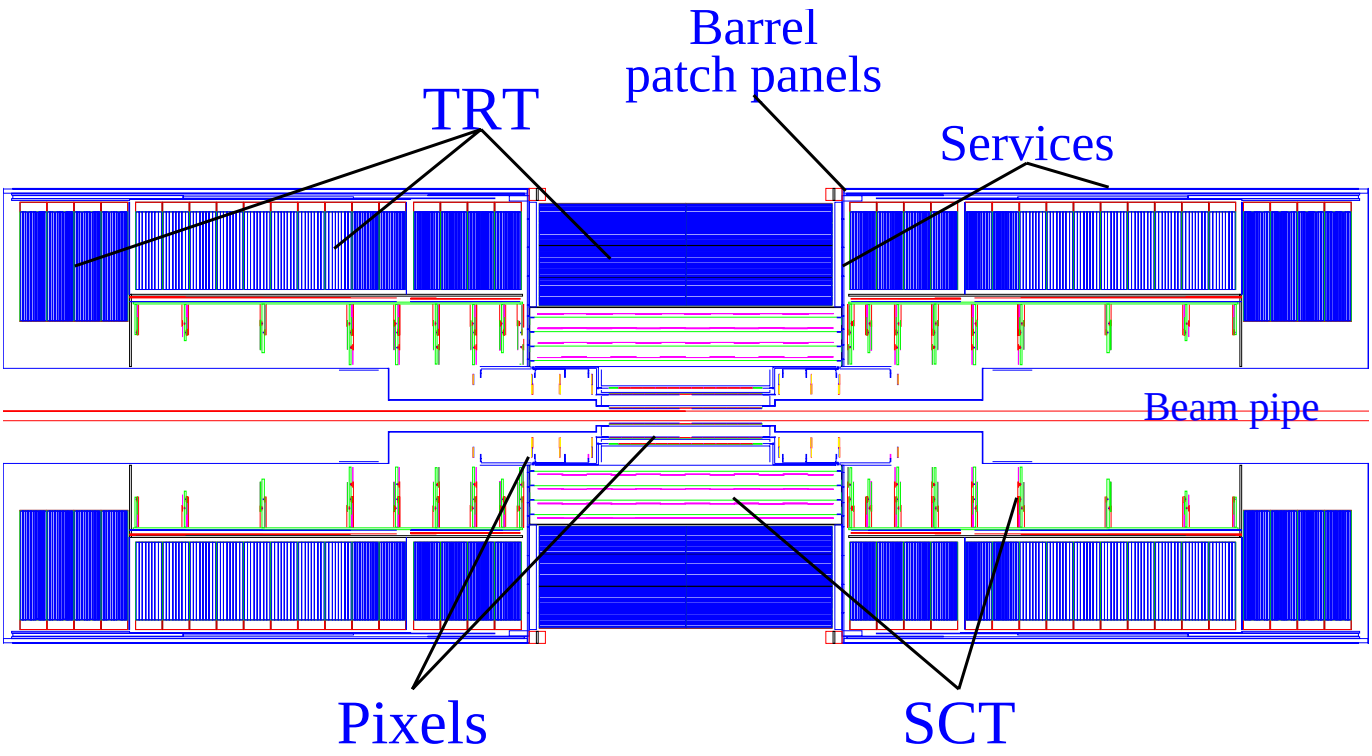
- **Inner detector is tiny, compared with**
- **ATLAS: 22 m high, 46 m long, 7000 tons**

- **Although tiny, the inner detector is still complex**

  - 2.3 m diameter, 7 m long

  - PIXEL + SCT + TRT

Inner detector overview



- **2.3 m dia. x 7 m long**

Issues in tracking:

- **Precision -- Charge identification up to 500 GeV/c**
- **Speed -- Bunch tagging**
- **Radiation tolerance**
- **Material (Radiation length, interaction length)**
- **Cost**

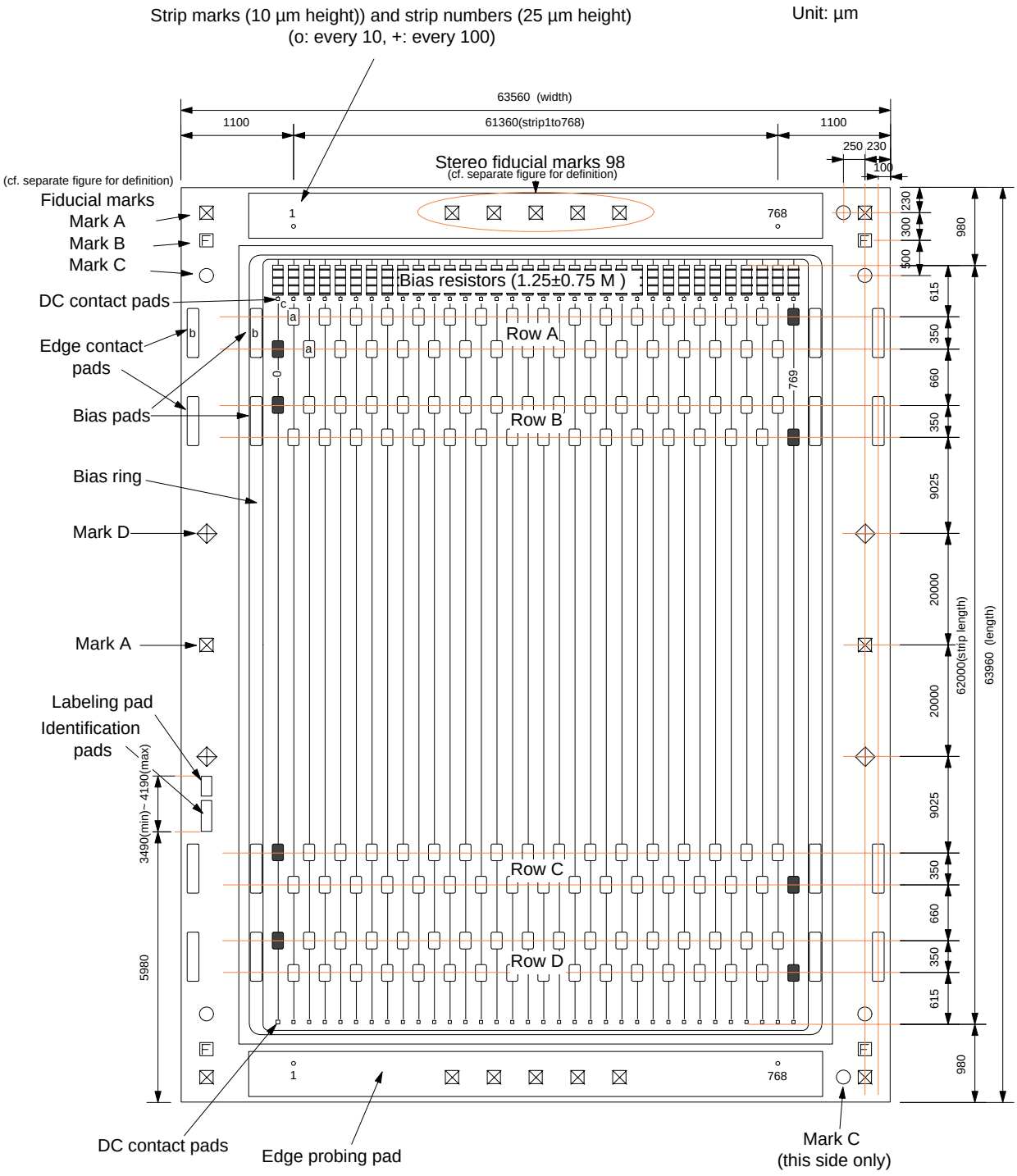
Position resolutions (rϕ):

Pixel (3 layers): 12 μm / layer

SCT (4 layers): 16 μm / layer

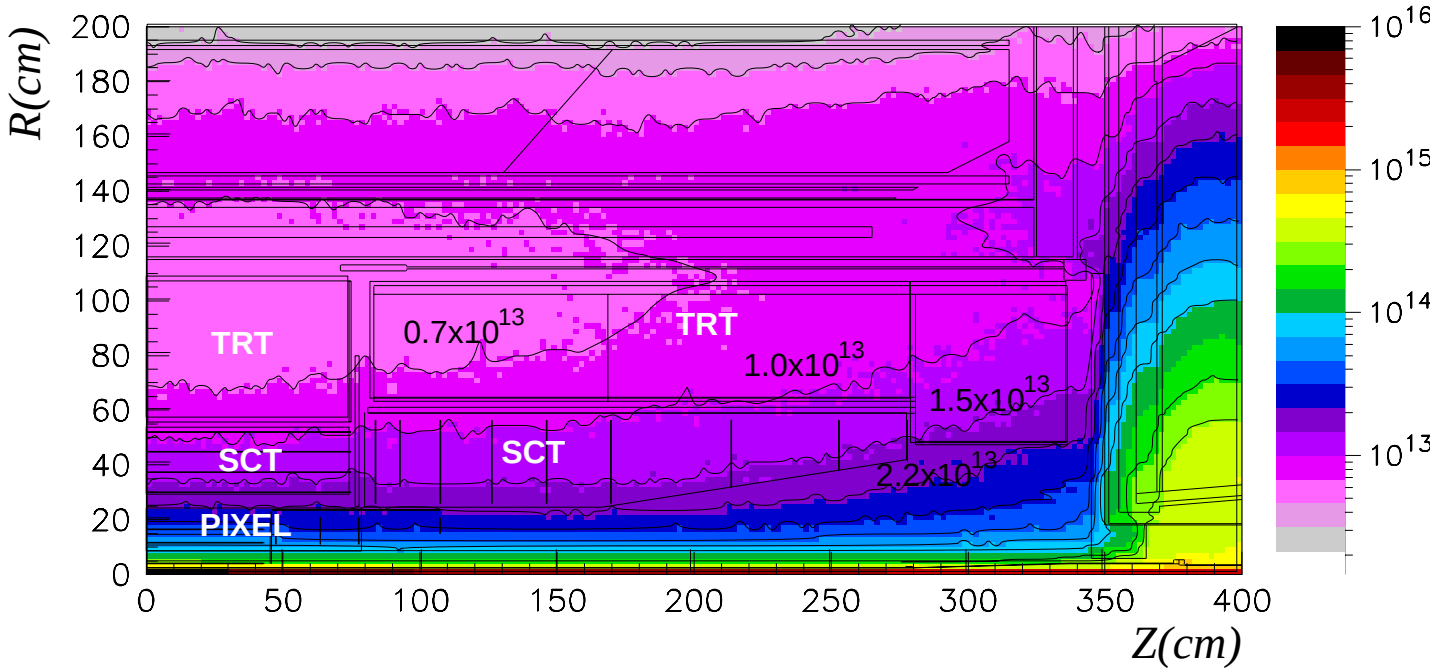
TRT (64 layers): 28 μm / 36 straws per track

Precision



- **SCT: Silicon microstrip sensor, 80 µm pitch**
  - **80µ / sqrt(12) / sqrt(2) ~ 16 µm (sigma)**
- **63.6 mm x 64.0 mm, strip length 62.0 mm**

Radiation tolerance



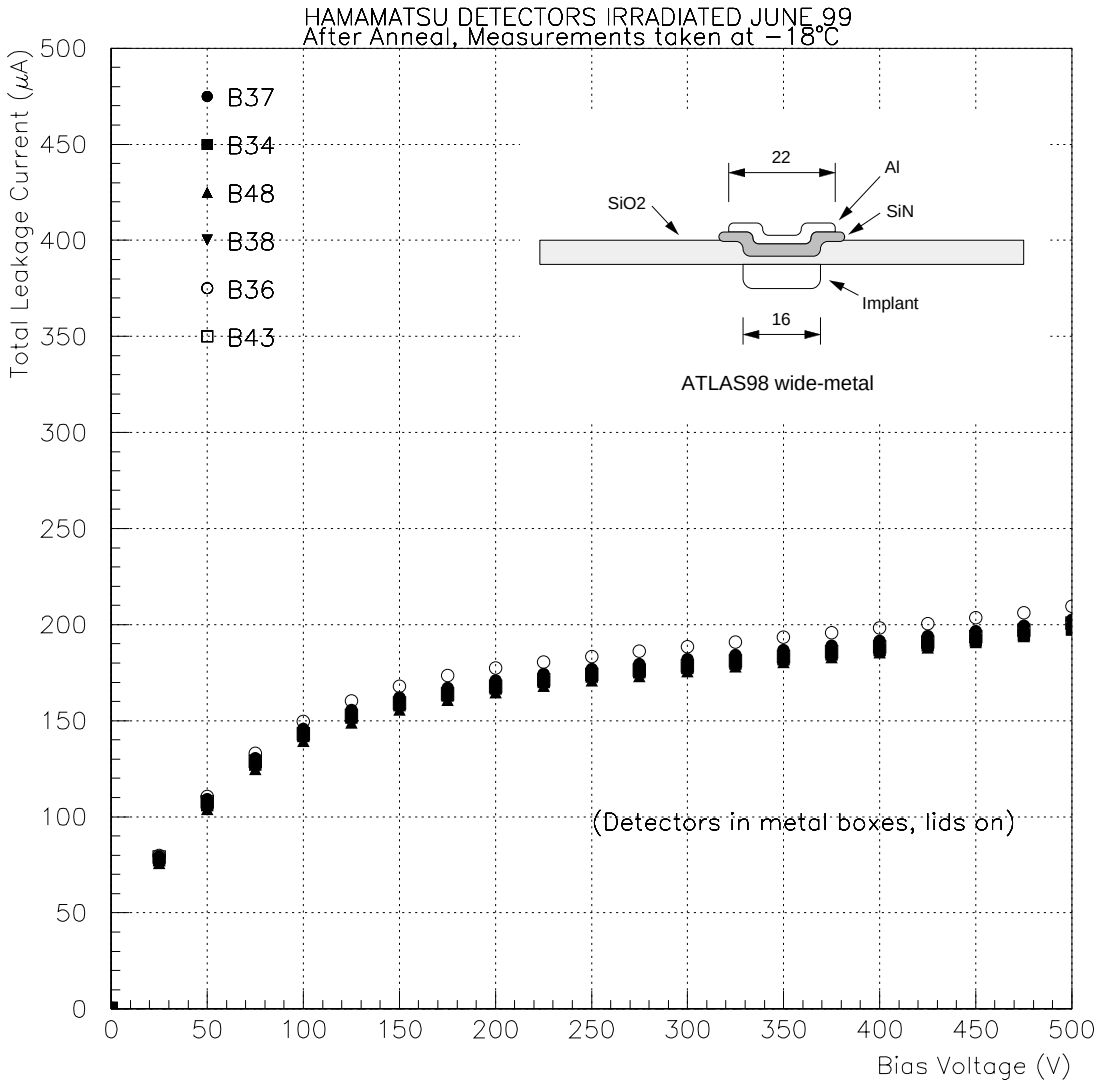
- **1 MeV neutron equivalent, yearly fluence**

  SCT: ~1.8x10^{13} n/cm^2 / yr / L=10^{34}
- **50% uncertainty in the fluence (cross section, etc.)**
- **10 yrs operation: 3 yrs at 10^{33} + 7 yrs at 10^{34}**
- **Neutron damage ~ 1.5x Proton damage**
- **Fluence over 10 yrs:**

  - Neutrons ~2x10^{14} n/cm^2 (=1.8x10^{13}x1.5x7.3)

  - Protons ~3x10^{14} p/cm^2 (=2x10^{14}x1.5)

Development of radiation-hard silicon microstrip sensor



- **History of double-sided, single-sided, n-in-n, p-in-n**
- **Choice: p-in-n single-sided**

  - Works after 3x10^{14} proton irradiation

  - Low cost (yet the largest fraction of the SCT cost)
- **Samples of Hamamatsu “Wide metal” design**

Development of radiation-hard silicon microstrip sensor

Checked out: after $3x10^{14}$ proton irradiation

- **Leakage current vs. Bias voltage**
- **Leakage current stability over 24 hrs**
- **AC shorts -- 768 strips/detector**

	Irrad Period	Before	# Shorts After @10V	After @100V
Wide Metal				
STX36742-35	April	0	0	0
STX36742-40	April	0	0	2
STX36742-45	April	0	0	1
STX36742-34	June	0	1	1
STX36742-37	June	0	3	3
STX36742-48	June	1	1	3

- 10/(6x768) = 0.2%!

- **Charge collection efficiency (with β-source)**
- **Strip noise analysis (for microdischarge)**

Strip microstrip sensors production

Quantity:

- **5 geometries (1 Barrel, 5 Forward)**

Barrel: ~10,560 (20%spare incl.)

B1	**260 μm)**	**~1,920**
B2	**285 μm**	**~8,640**

Forward: ~8,880 (20% spare incl.)

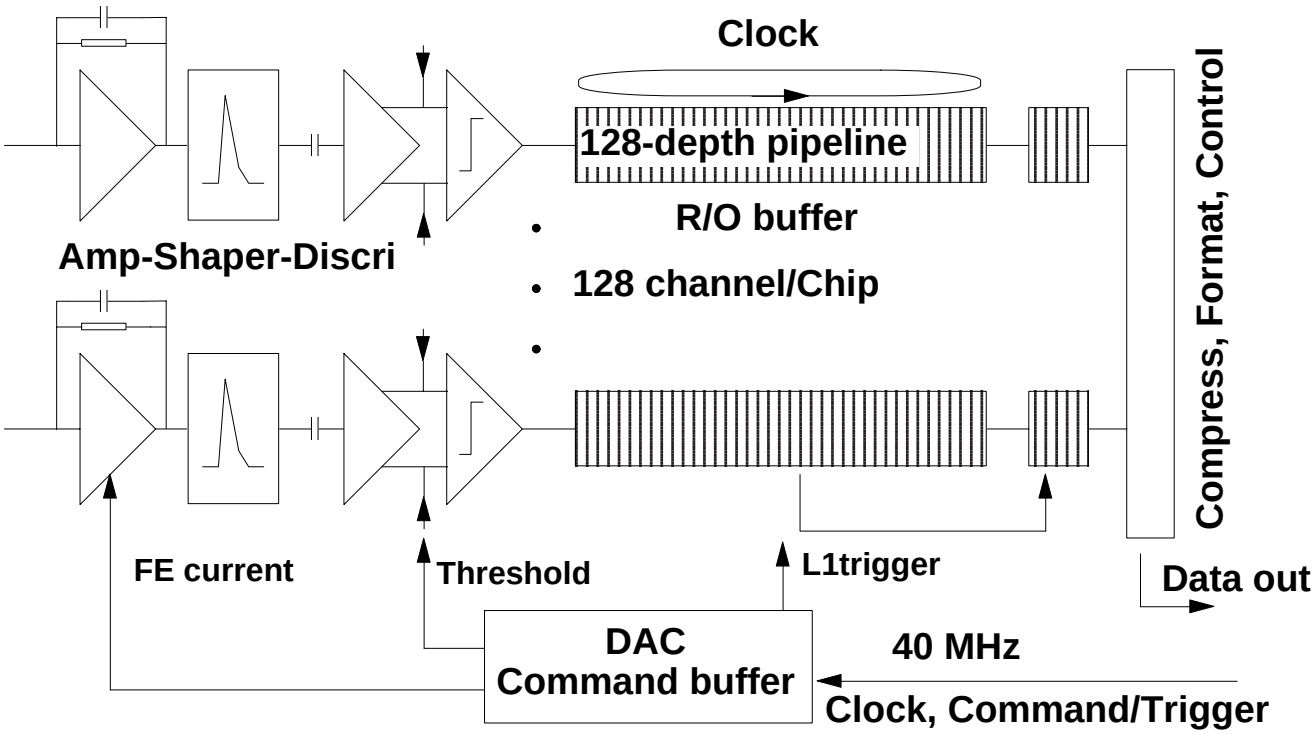
W12	**260 μm**	**~1,000**
W21	**285 μm**	**~1,400**
W22	**285 μm**	**~1,600**
W31	**285 μm**	**~2,340**
W32	**285 μm**	**~2,340**

- **Tendering completed on Oct., 1999**
- **Vendors awarded**

  - Hamamatsu, Sintef, CiS/CSEM
- **Pre-series production (5%) - April 2000**

  - PRR in Aug. 2000
- **Production complete - Fall 2002**

Read-out Electronics



- **Speed -- Bunch tagging**

  Time walk < 16 ns, Two pulse separation < 50 ns

  - High gain, high speed -- sensitive to instability, oscillations, etc

- **On-Off "binary" read-out -- simplicity, cost**

  Threshold uniformity < 4% (1 sigma)

- **Rad-hard chip development**

  - 1 chip =Temic BiCMOS process

  - 2 chips = Maxim Bipolar + Honeywell CMOS

- **ABCD2T**

  - 2nd generation "1 chip" chip with Trim DAC

Radiation tolerance of chips

Irradiations

- **10Mrad γ's (ionizing)**
- **2×10^{14} 1MeV-equivalent neutrons**

  - 3×10^{14} 24 GeV protons

  - 2×10^{14} 10 MeV neutron from reactor
- **Still on-going...**

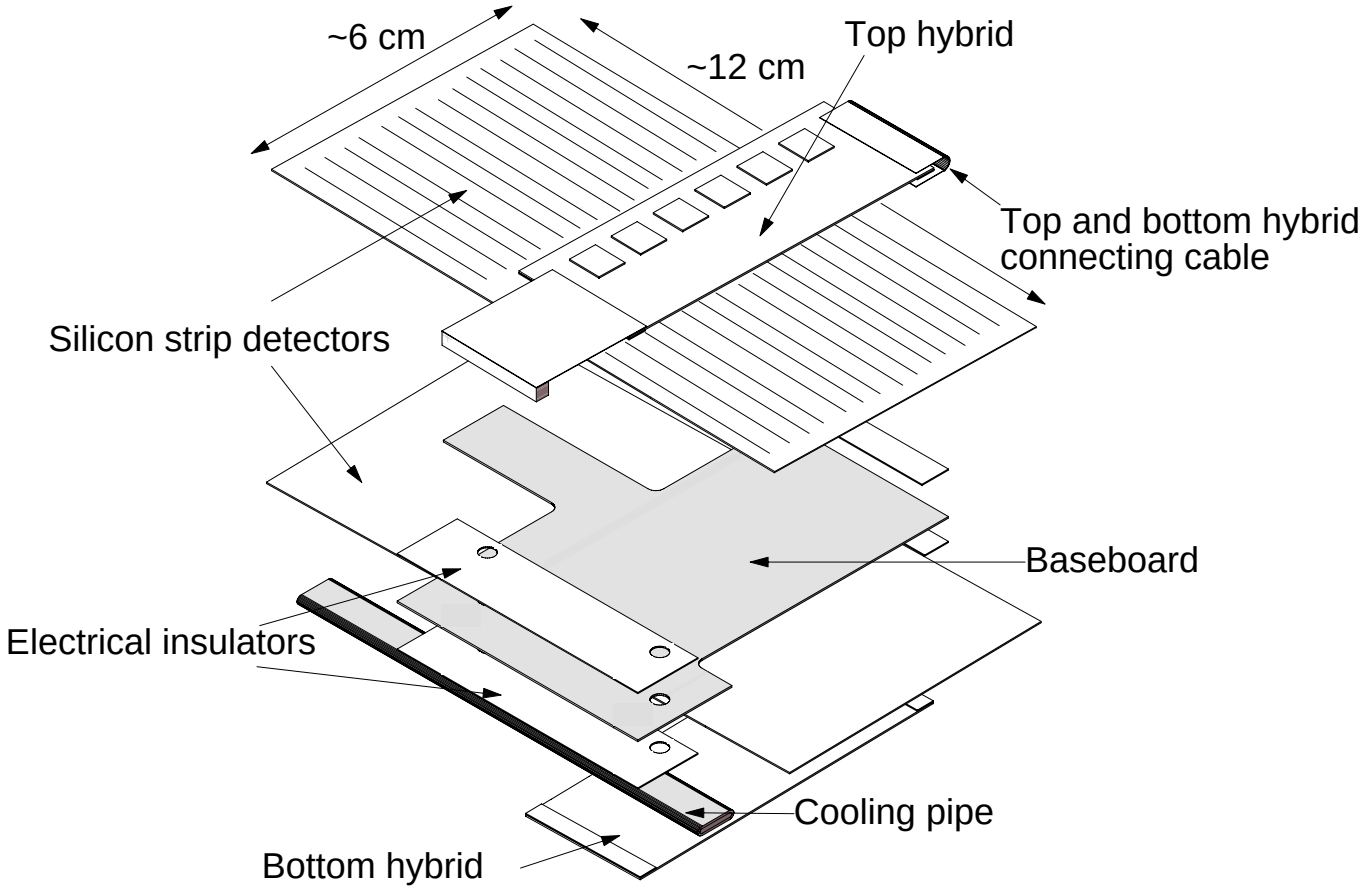
Radiation damages

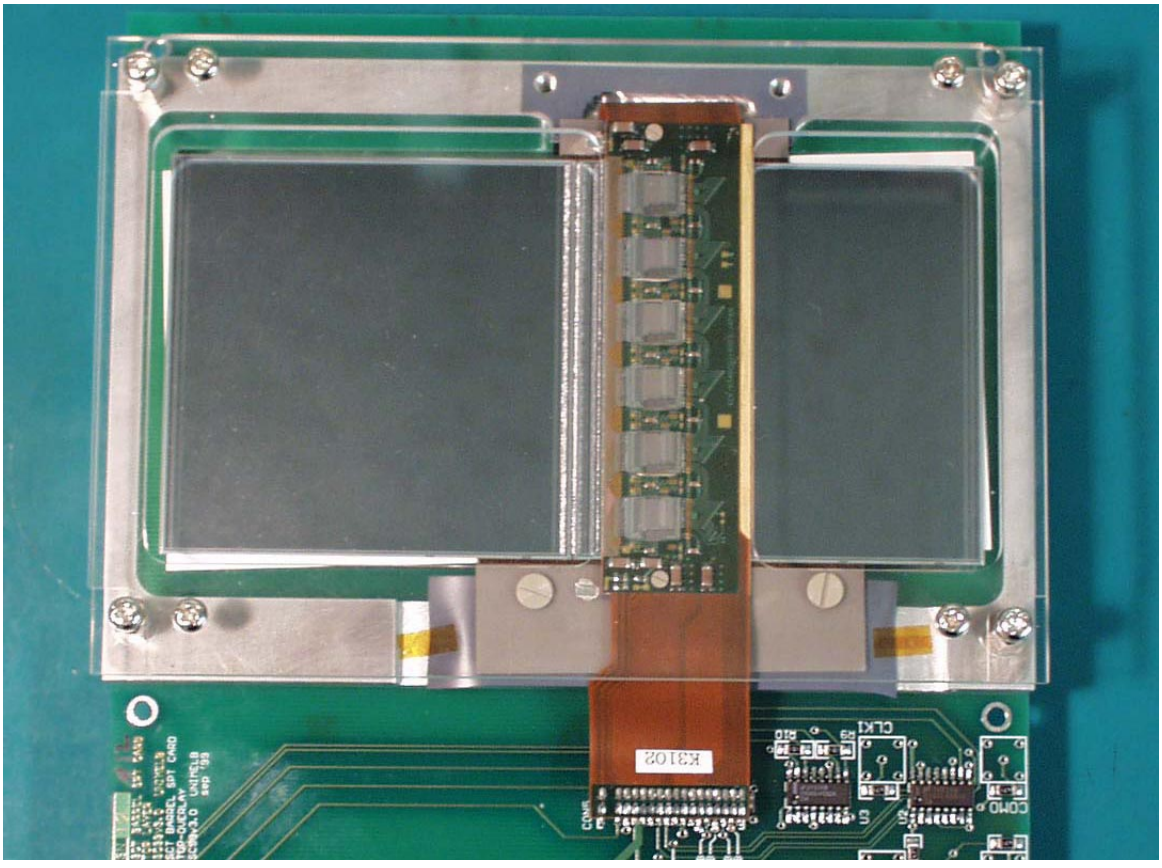
- **Degradation of β in BJTs**
- **V_t shift in MOSFETs**
- **Resistance increase in resistors**

Results

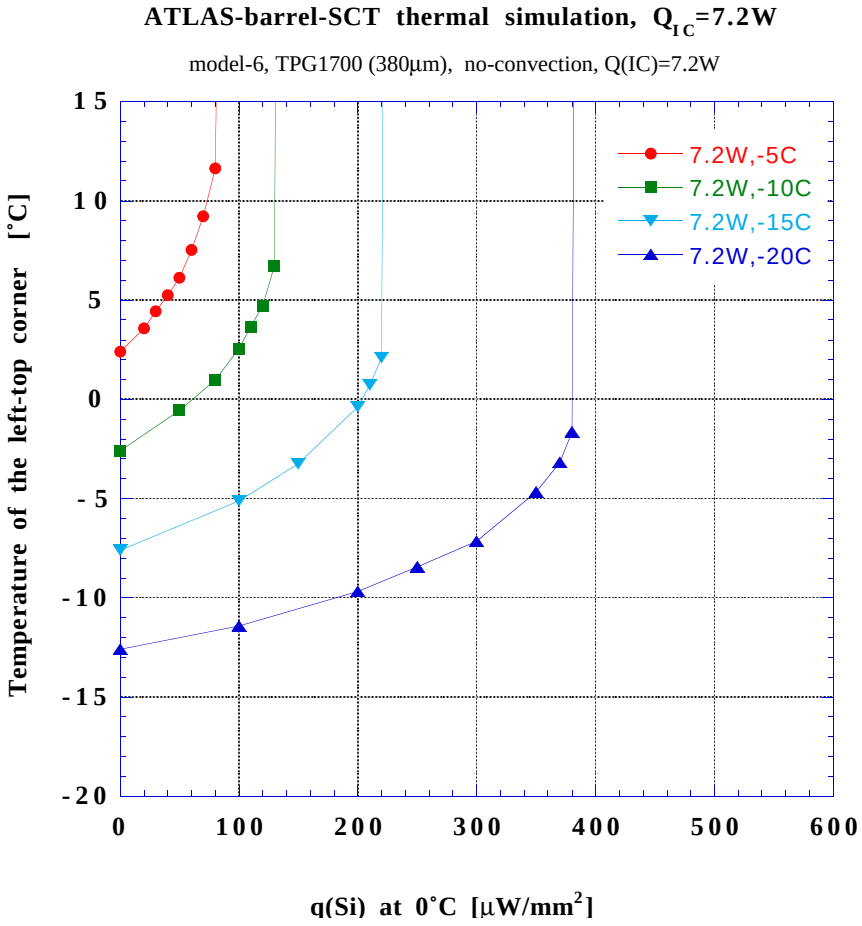
- **ABCD2T, CAFE, almost(?) met requirement**
- **Still evaluating whether all requirements are fully met**
- **Noise, channel-to-channel matching, time-walk, etc.**
- **Studies with more statistics are under way**

SCT silicon strip barrel module





SCT silicon strip modules



Issues

- **Thermal runaway in Silicon wafer**

  - High leakage current after 10yrs of fluence ~1.2 mA@0°C

  - High operation voltage ~350 V

- **Nominal 100 μW/mm^2 heat flux**
- **Module is designed to be safe in a factor 2 for runaway**

Silicon strip modules

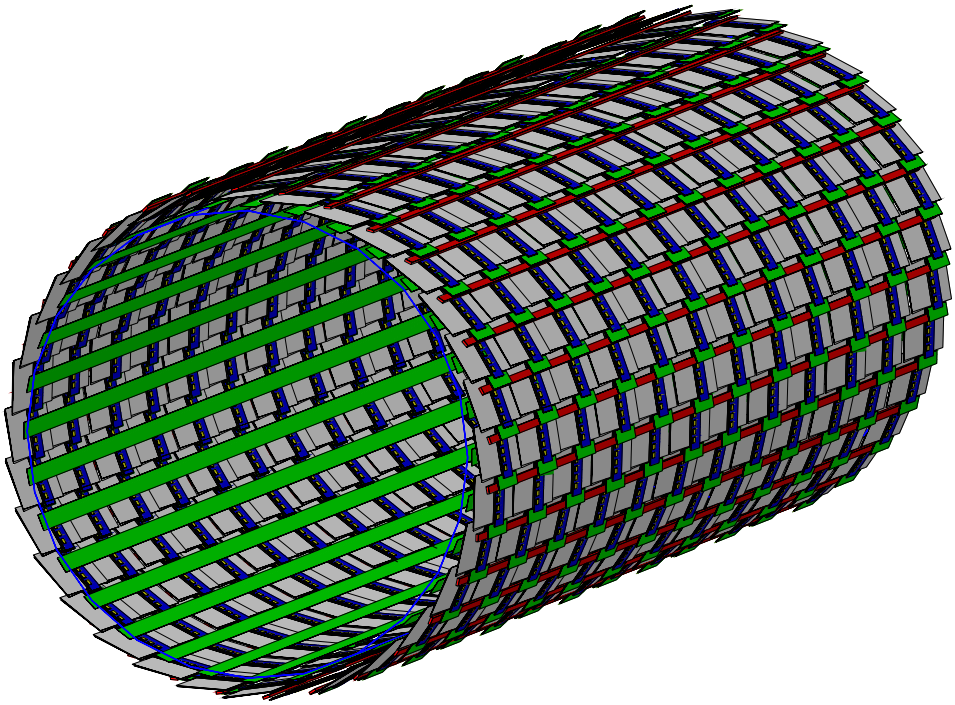
Number of modules

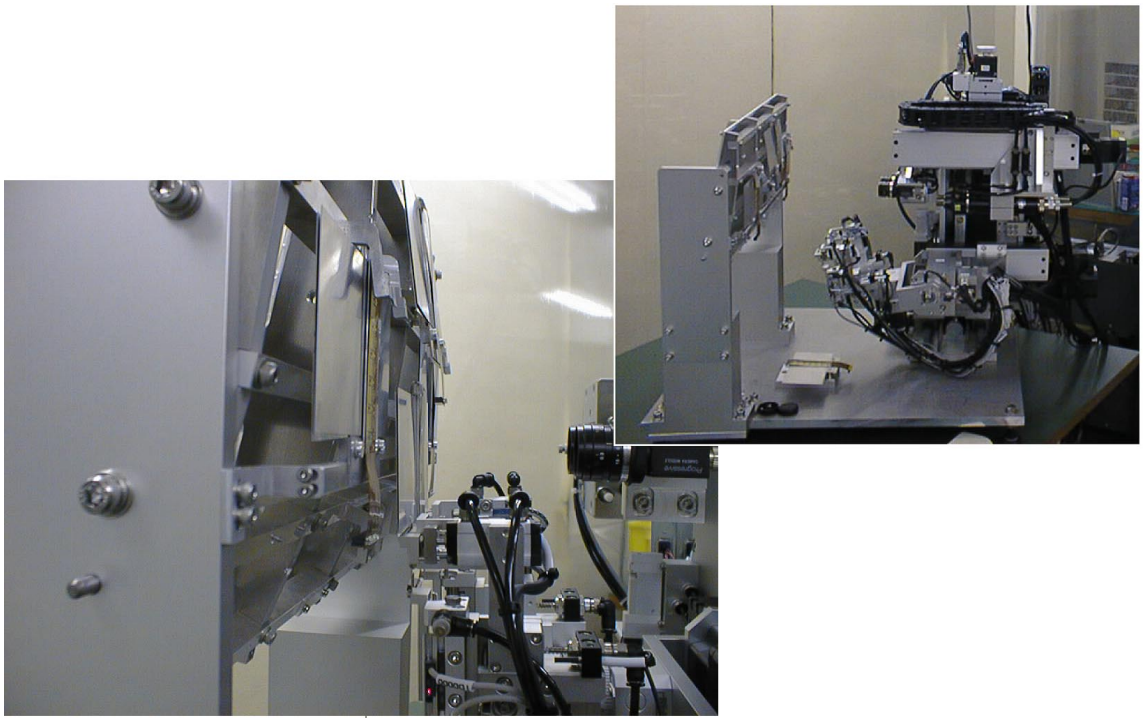
Layer/Disk	R/Z [mm]	Modules
B1	300	384
B2	373	480
B3	447	576
B4	520	672
		2112
D1	835	264
D2	925	184
D3	1072	264
D4	1260	264
D5	1460	264
D6	1695	264
D7	2135	184
D8	2528	184
D9	2778	104
		1976
		4088

- Production in 2 years
- 4 barrel + 3 forward assembly sites

  ~8 modules / week / site

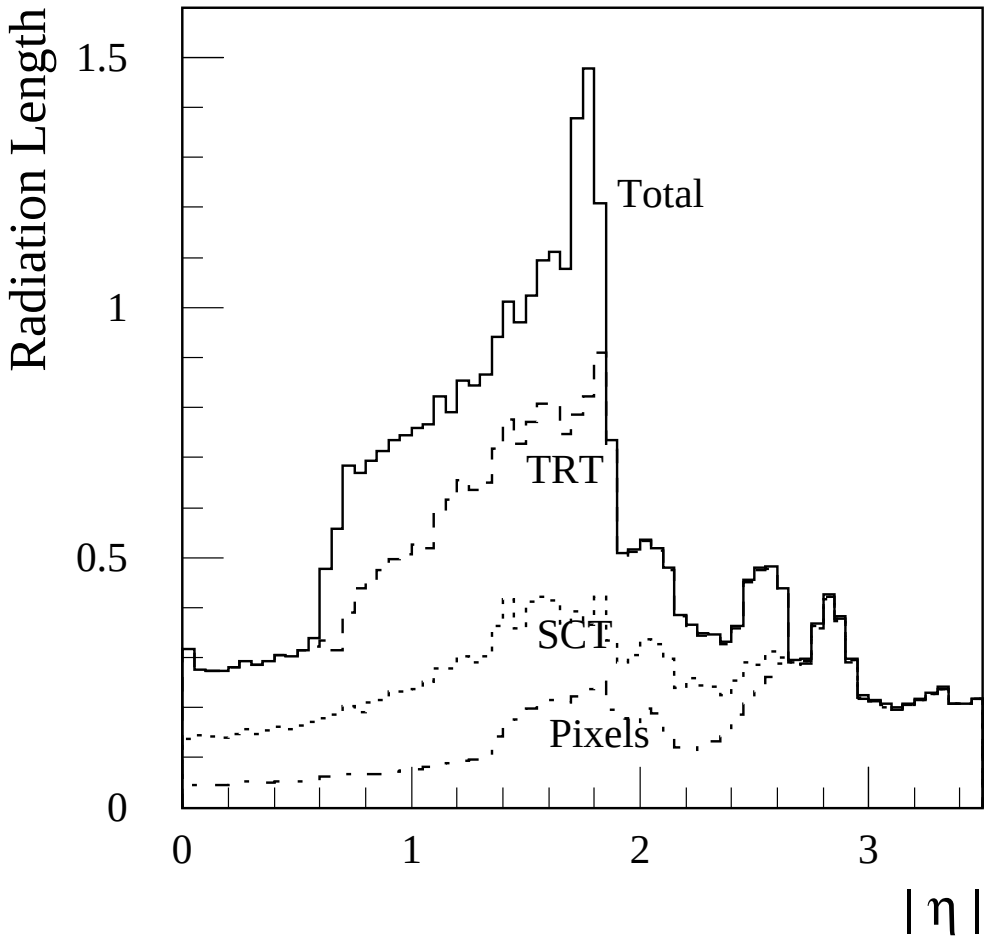
SCT silicon strip barrel cylinder





- **Barrel cylinder (1st) drawn with Geant4**
- **Developing a Module mounting robot**

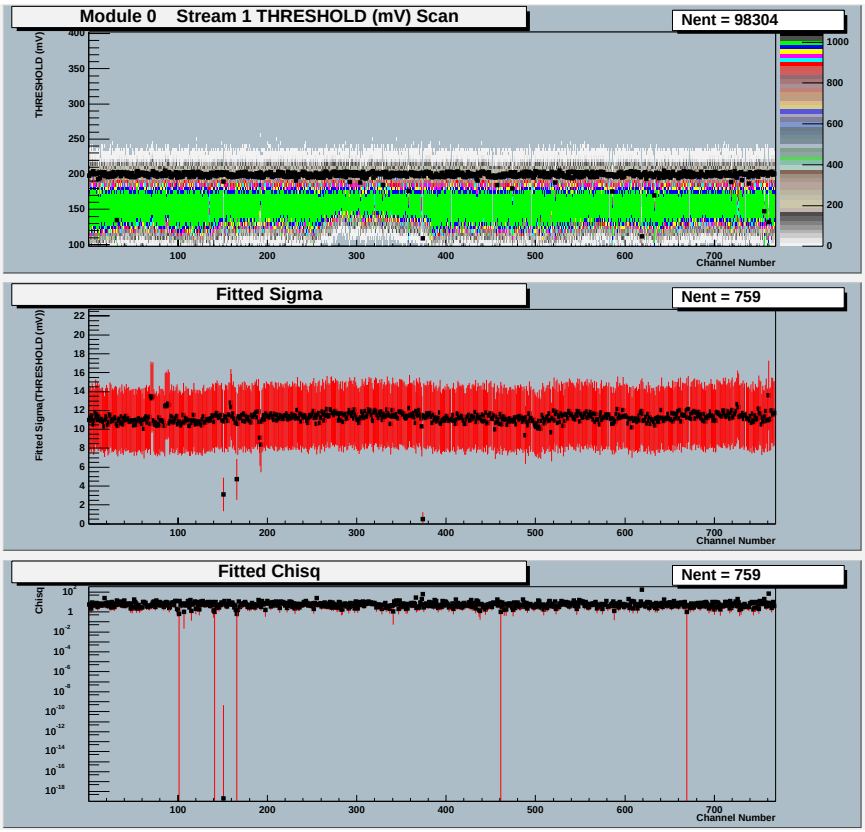
Radiation length

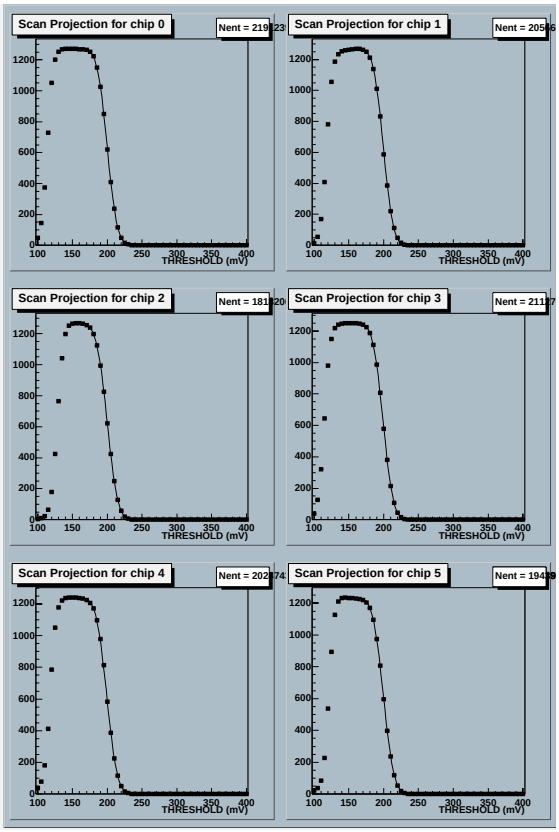


- **Total = including the cables in front of the cryostat**
- **p_t=1 GeV/c, eff. for isolated μ, π, e: 97, 84, 76%**
- **High pt, eff. μ, π, e: 99, 95, 95%**

Module test (ABCD2T)

1. Threshold uniformity

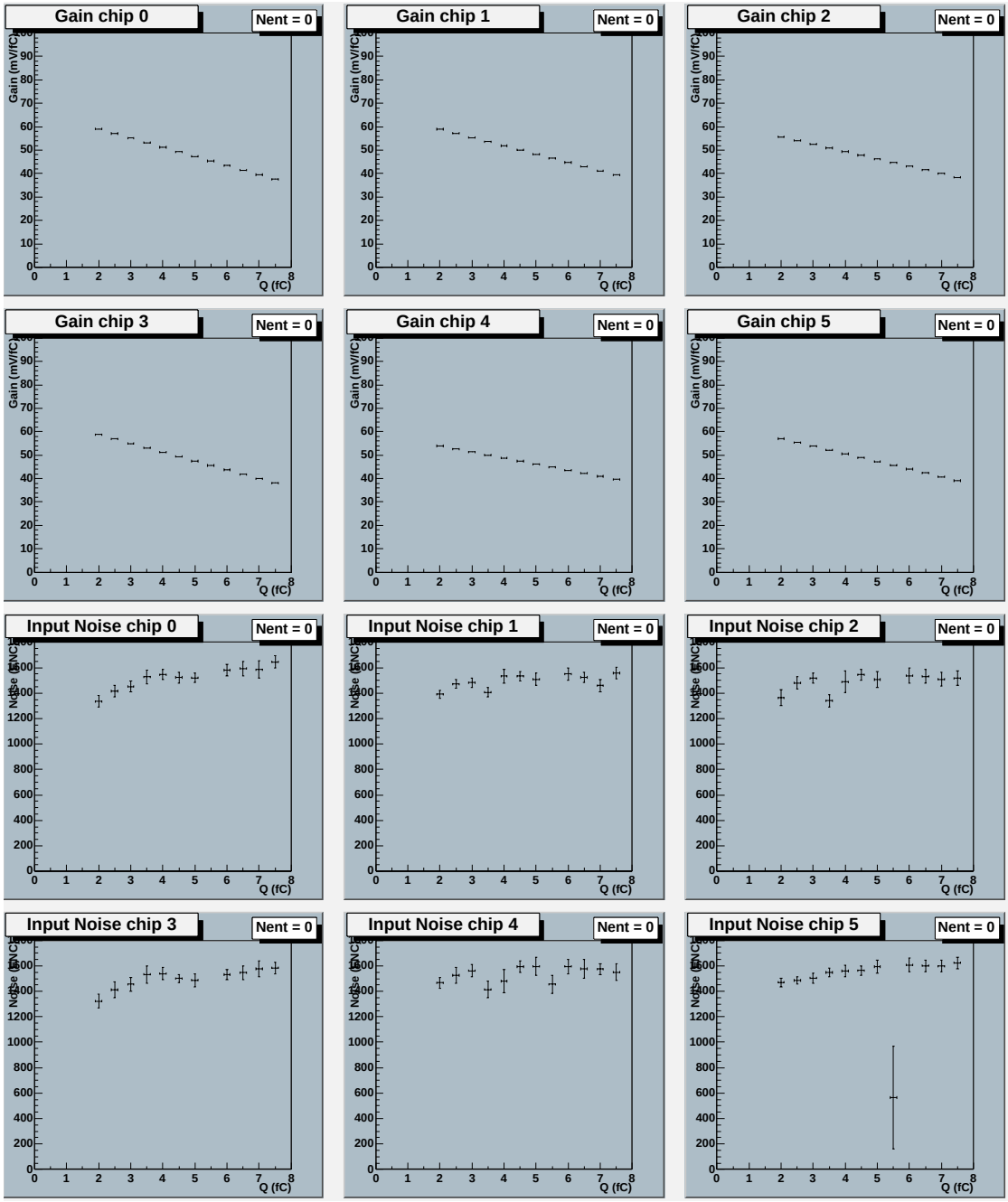




- **PRELIMINARY!!!**
- **Threshold at 2 fC**
- **Trim DAC adjusted at 2 fC**

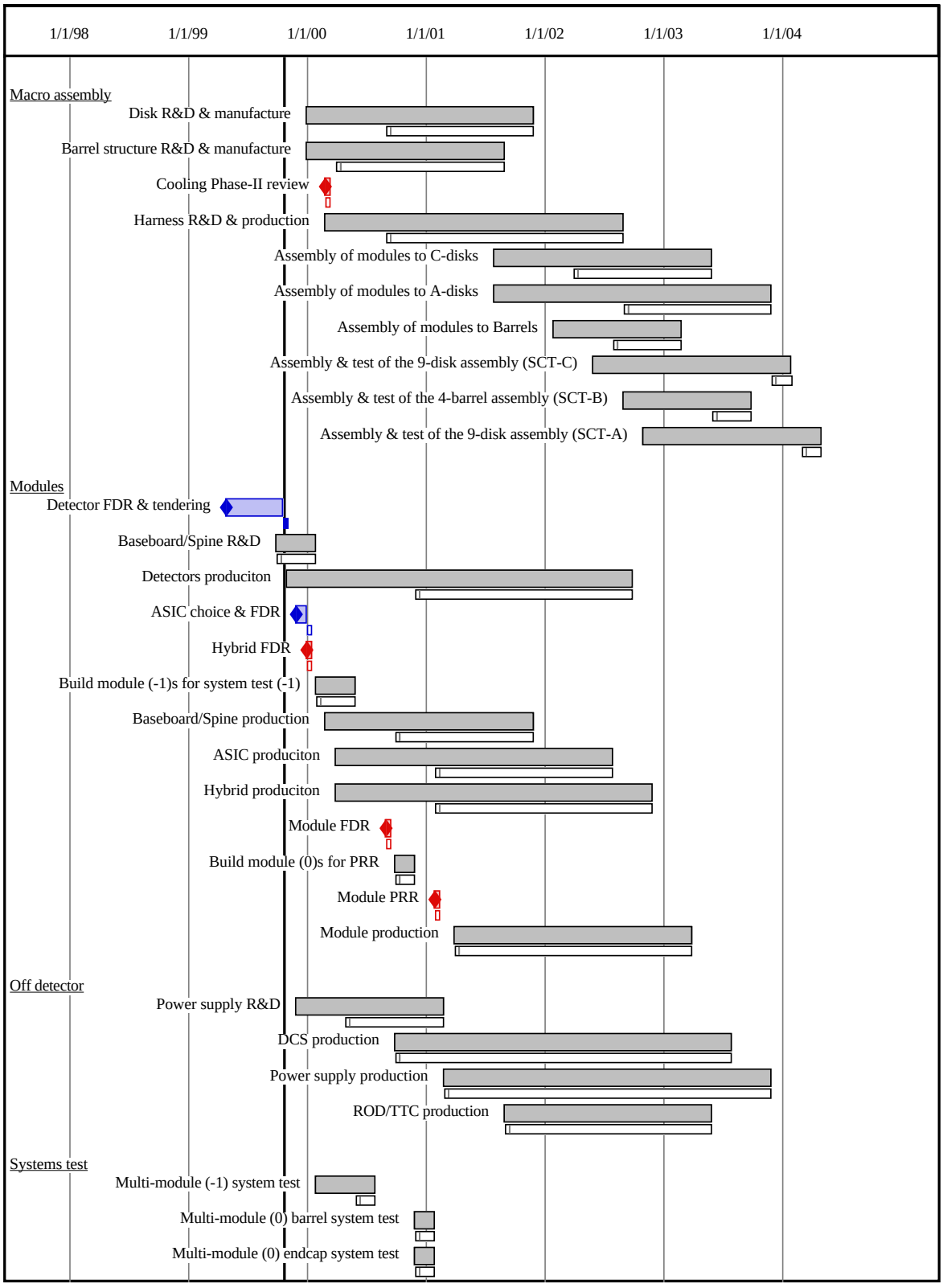
Module test (ABCD2T)

2. Gain and Noise



- **PRELIMINARY!!!**
- **Gain ~ 60 mV/fC (at 2fC)**
- **Noise = 1300 ~ 1350 e**

Schedule



- **As of now, NOT final!!**

Summary

- **ATLAS detector is under construction**
- **Silicon microstrip semiconductor tracker (SCT) is in it's final design phase and moving rapidly to the construction phase**
- **Silicon microstrip detector tendering has completed, Hamamatsu has received a large fraction of order from the total about 19,000 detectors**
- **Rad-hard frontend electronics, which has been a critical path, has made progress, but still needs works**
- **Preliminary, but, ABCD2T double-sided 12 chips module has worked stably**