Silicon Microstrip Detector System

Y. Unno, KEK

for the ATLAS-Japan Silicon collaboration:

Hiroshima University

KEK

Kyoto Univeristy of Education

Okayama University

Tokyo Metropolitan University

(8 physicists, 1 Engineer)

Content

- **Silicon Mircrostrip Detector System overview**

  - Layout, Barrel cylinder, Cylinder detail, Electronics

- **Issues in developing the Silicon system**

  - Radiation damage, Detector R&D, Module design, Integration
  - Stress on Contributions from Japan

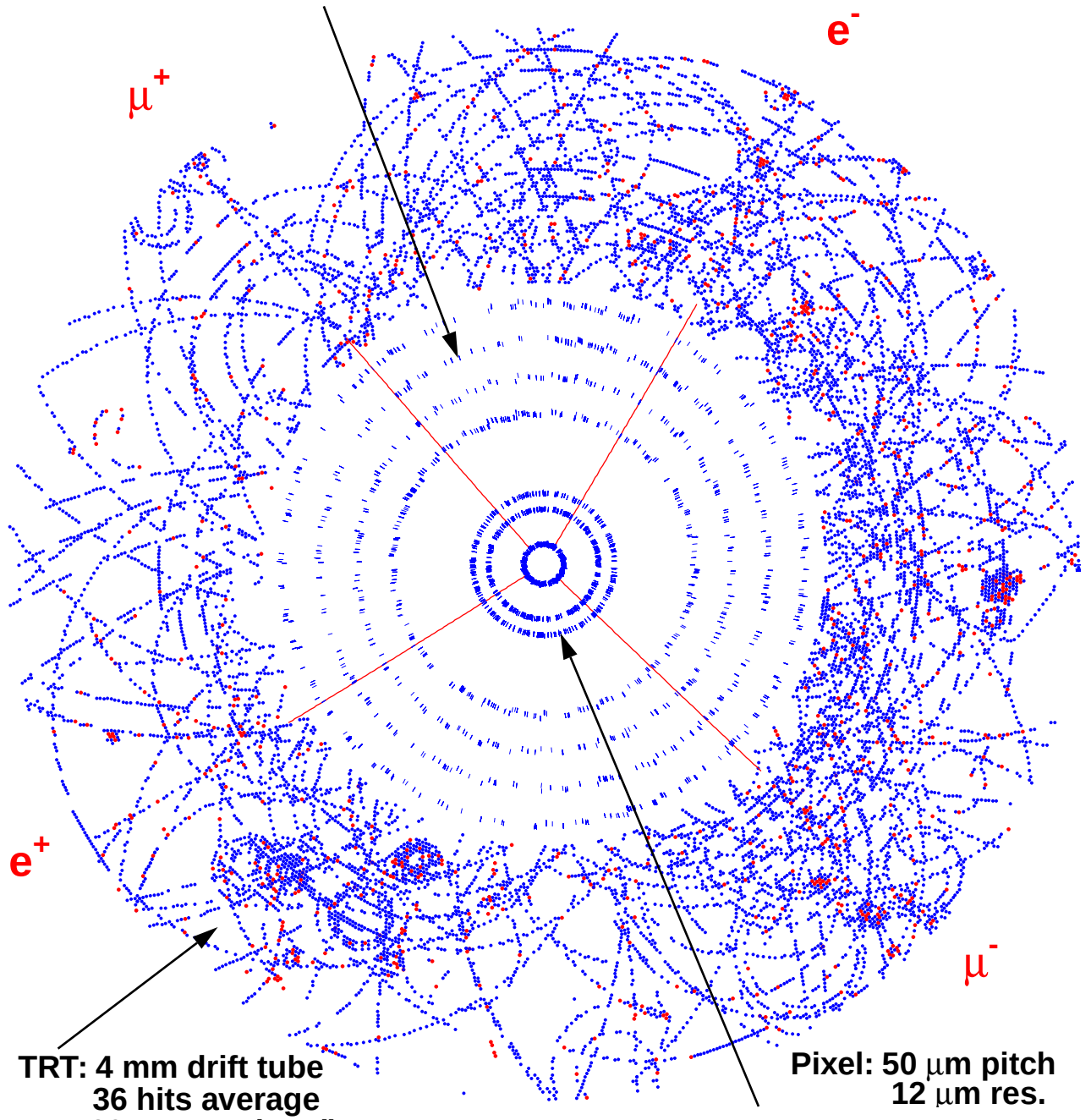
- **Construction**

  - Why silicon?, Responsibility share, Construction flow, schedule

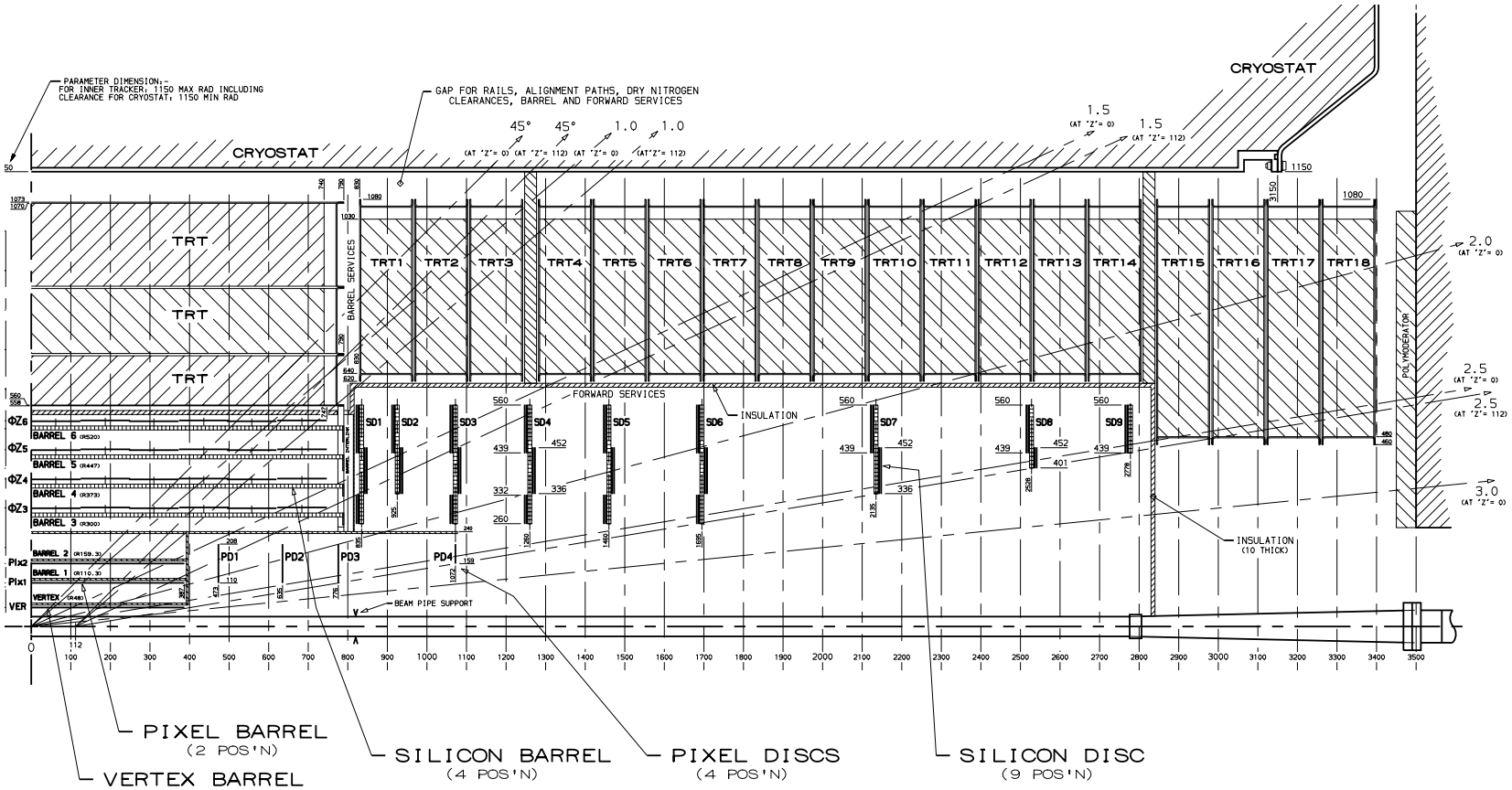
- **Summary**

ATLAS Barrel Inner Detector

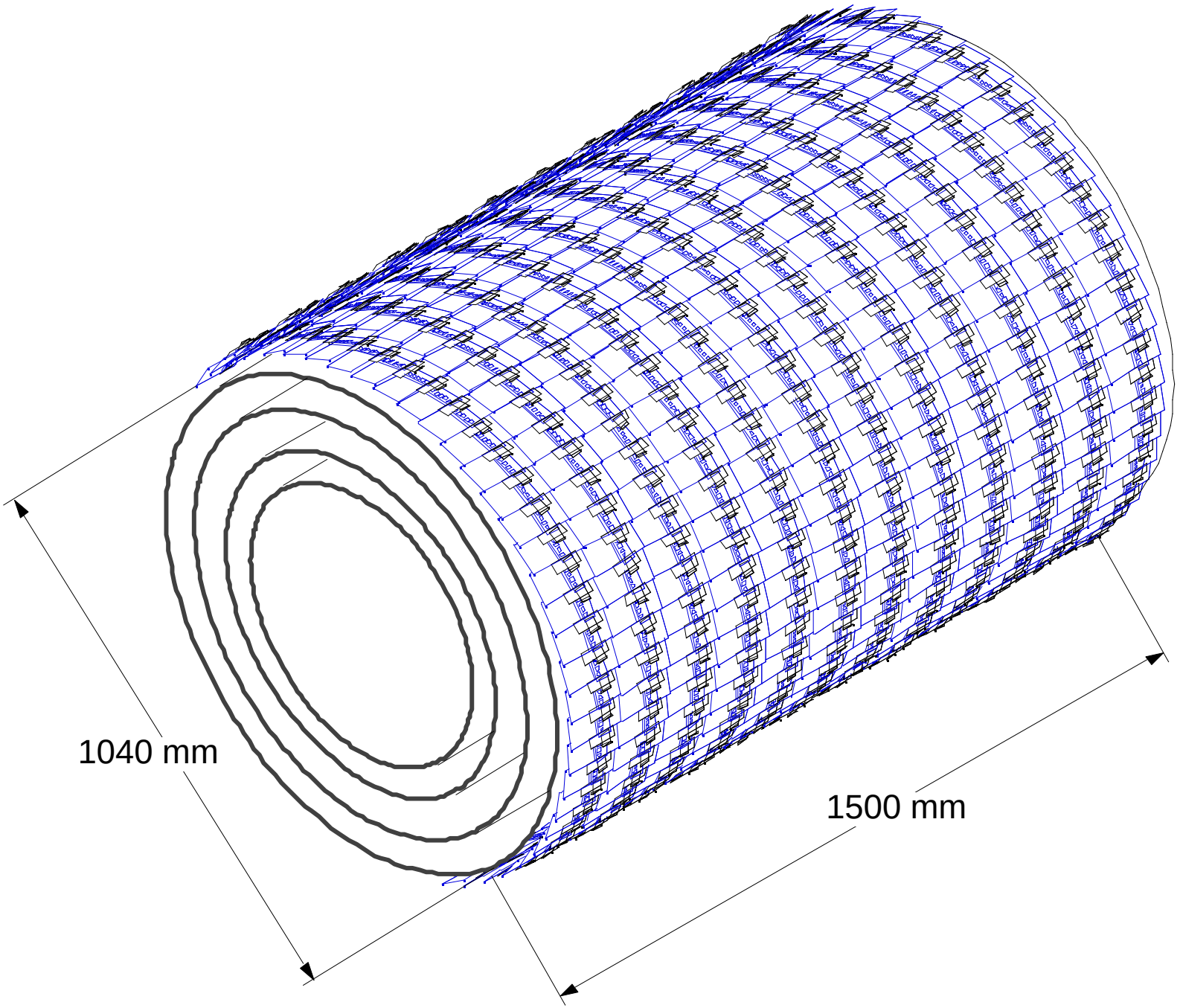
$H \rightarrow ZZ^* \rightarrow \mu^+\mu^-e^+e^-$ (m_H = 130 GeV)

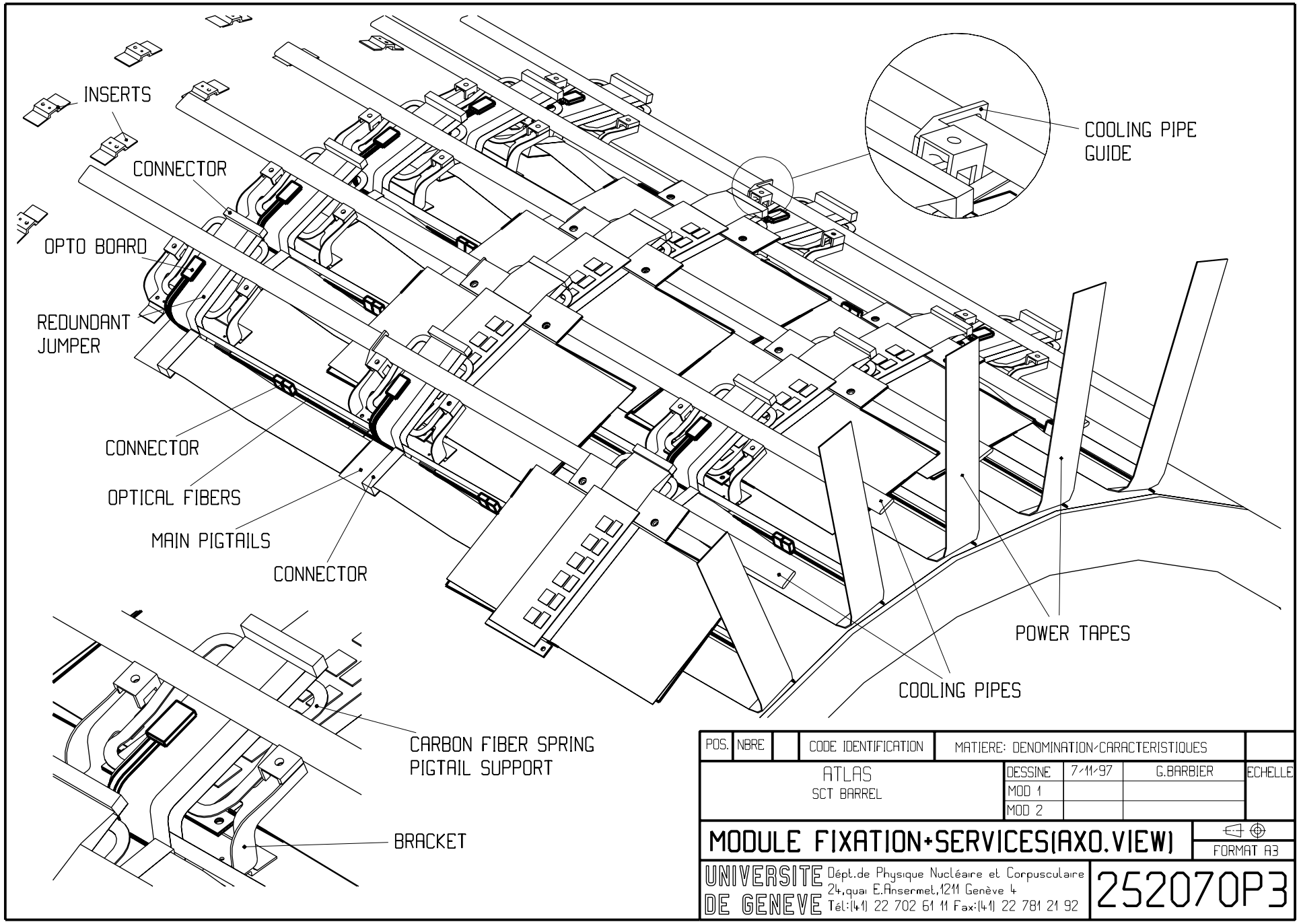


Y. Unno 23/3/98



- **Acceptance coverage: $|\eta| < 2.5$, ($R<1.1$ m, $L/2=3.4$m)** **(CDF: $R<1.3$ m)**
- **Momentum resolution: $\delta p/p = 0.0006 p_t$ (GeV/c)** **(CDF: $0.0009 p_t$)**
- **Impact resolution: $\sigma(d_0) \geq 11$ μm, $\sigma(z_0) \geq 70$ μm** **(CDF: $\sigma(d_0) \geq 17$ μm)**


1040 mm
1500 mm



POS.	NBRE		CODE IDENTIFICATION	MATIERE: DENOMINATION/CARACTERISTIQUES			
ATLAS SCT BARREL				DESSINE	7/11/97	G.BARBIER	ECHELLE
				MOD 1			
				MOD 2			

MODULE FIXATION+SERVICES(AXO.VIEW)

FORMAT A3

UNIVERSITE DE GENEVE
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PROJECTION

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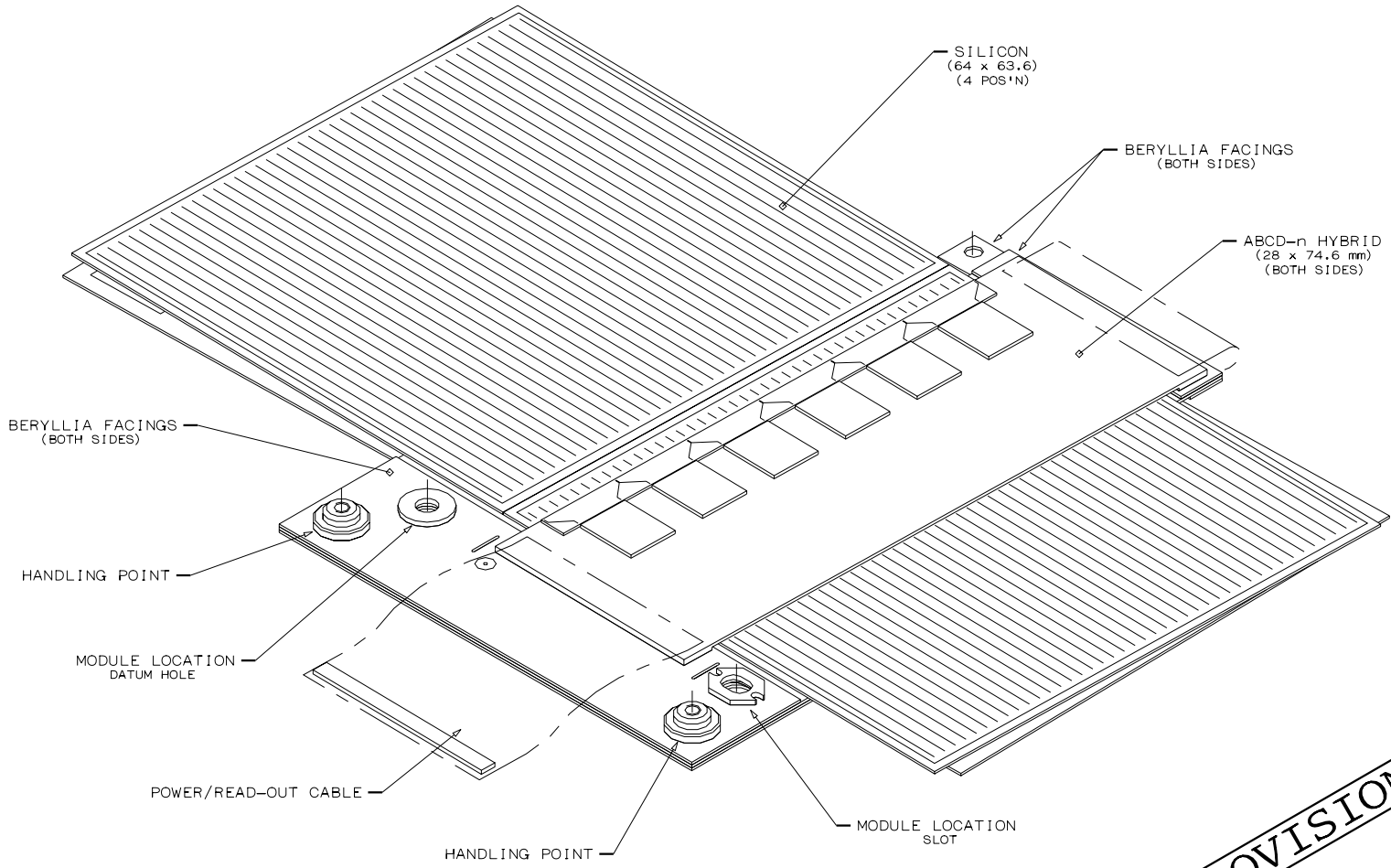

ATLAS 97 MODULE – ABCD-n

PROVISIONAL

DRN: D.MORRISSEY ISSUE: A DATE: 08DEC97

RUTHERFORD APPLETON LABORATORY, CHILTON, OXON OX11 0QX.
THE CENTRAL LABORATORY OF THE RESEARCH COUNCILS

TITLE

SCT BARREL MODULE ISOMETRIC

ATLAS 97 – ABCD-n MODULE – v1.0

ATLAS INNER TRACKER CERN

A 1-TB-0059-070-05-A

SHEET 5 OF 6

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Silicon Microstrip Detector

What is it?

What's good?

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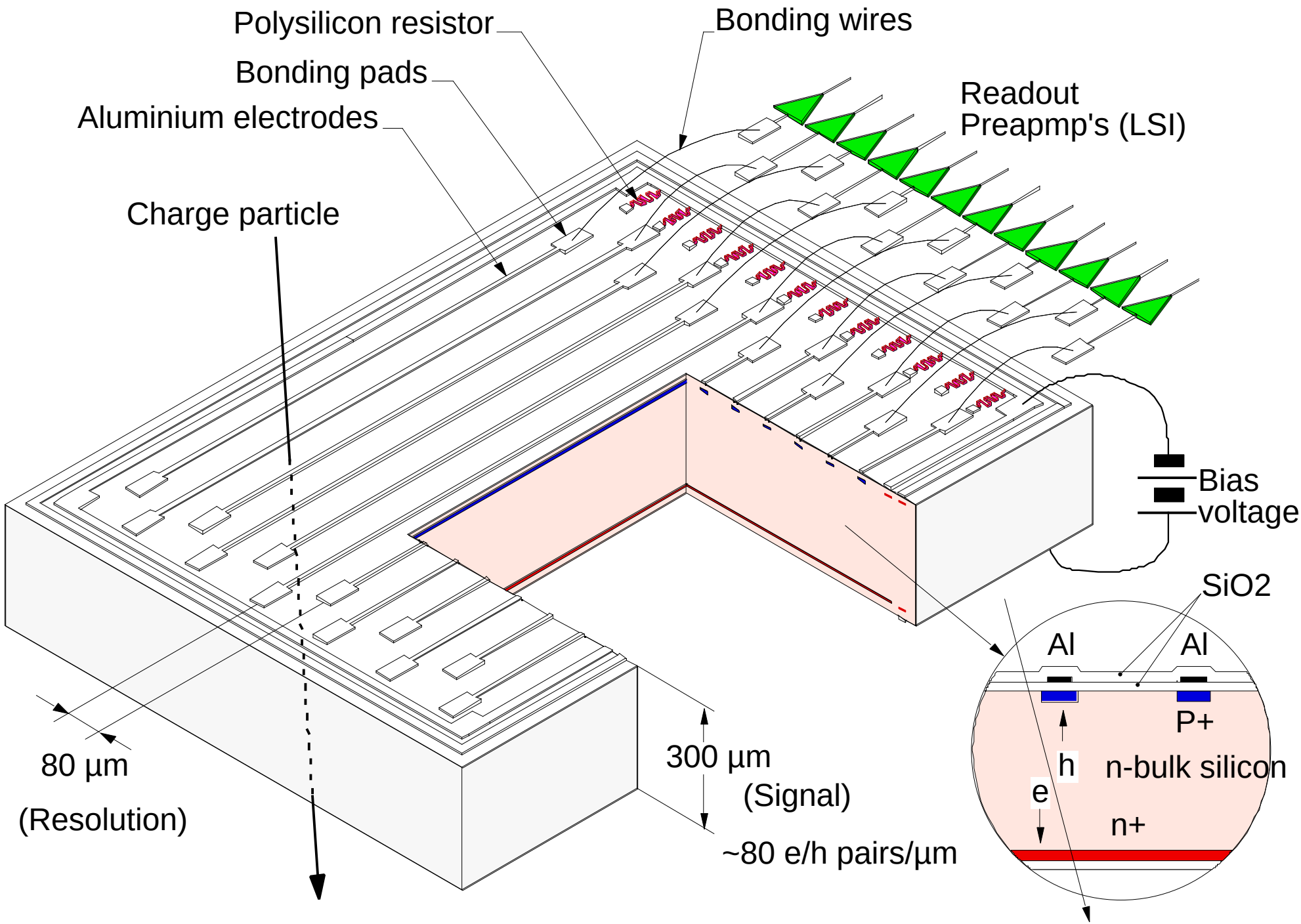
Polysilicon resistor
Bonding wires
Bonding pads
Aluminium electrodes
Readout
Preapmp's (LSI)
Charge particle
Bias
voltage
SiO2
Al
Al
P+
h
n-bulk silicon
e
n+
80 µm
(Resolution)
300 µm
(Signal)
~80 e/h pairs/µm

Issues in the Silicon Microstrip Detector

- **High radiation enviroment - Radiation damage**

  1.Rad-hard Silicon Strip Detector

  2.Development of Silicon-strip Module

- **Integration of Modules into a macro structure**

  - No previous scale: 17 m^2 (Barrel) surface, 34 m^2 silicon area

  - CDF SVX-II vertex detector: 1.3 m^2

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Radiation damage

- **Radiation level**

  - 3 x 10^{14} protons/cm^2 in 10 years

- **Large depletion voltage**

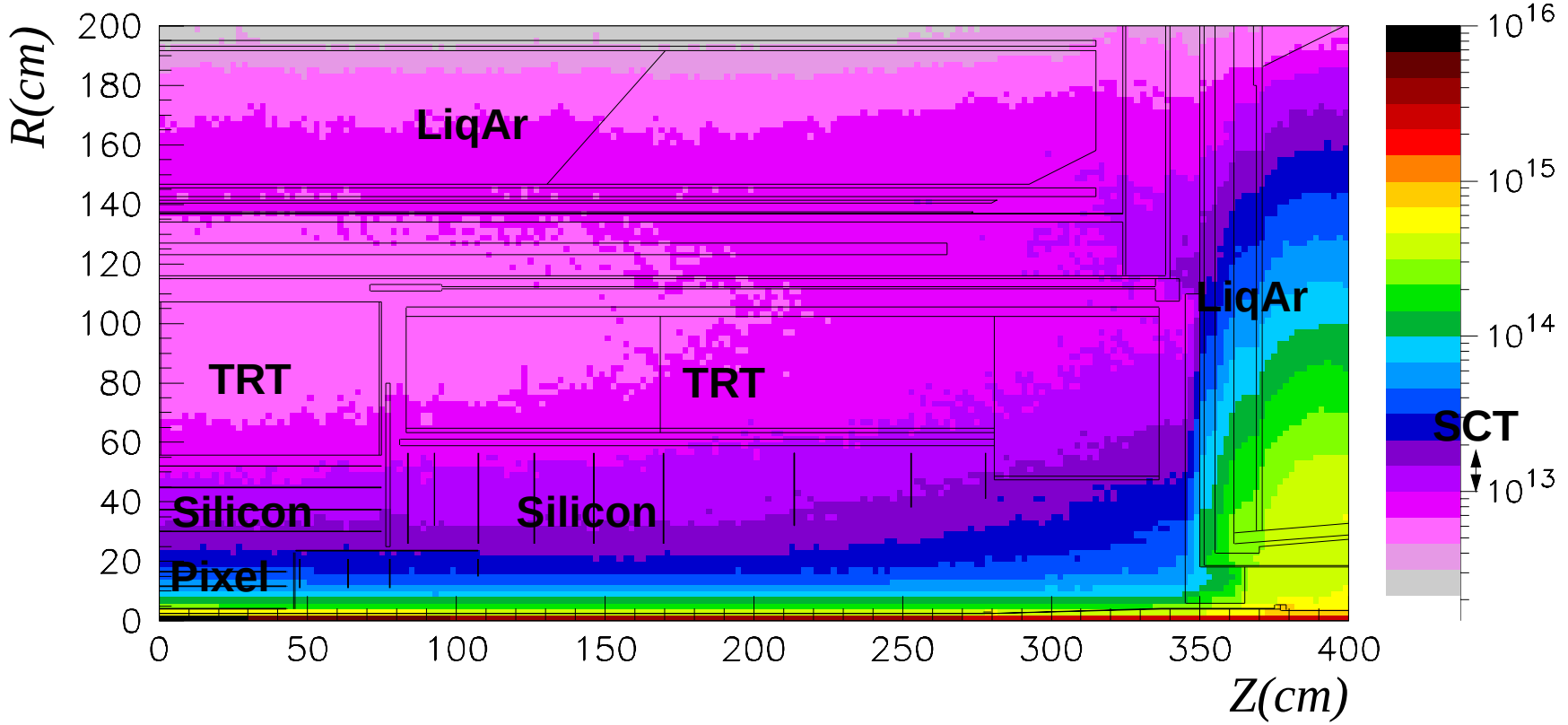
  - ~400 volts (in the worst case) prediction
  - Suppression of activating damages: -7 °C
  - Full, partial depletion operation?

- **Large leakage current in silicon strip detector**

  - Suppression of leakage current: low temperature
  - ~700 μA/detector (62 mm x 62 mm) at -7 °C
  (~200 nA initial at room temperature)
  - Heat generation: 100 μW/mm^2 (at 0 °C, 300 V)
  - Thermal runaway

Radiation level in Inner Detector

(1 MeV neutron equivalent fluence per year at L = 10^{34} $cm^{-1}s^{-1}$)



- **50% systematic error in fluence (cross section, number of particles,...)**
- **At R=30 cm, 2 x 10^{14} n/cm^2 (50% sys err upper bound) over 10 years**
- **Equivalent proton, 3 x 10^{14} p/cm^2**

Development of Rad-hard Silicon Strip Detector

- **Good collaboration with industry**

  Hamamatsu Photonics

- **Long history of R&D in Japan**

  Hiroshima Univ., Okayama Univ., KEK, ...

- **Hot-electron analysis**

  T. Ohsugi et al., MICRODISCHARGES OF AC COUPLED SILICON STRIP SENSORS, Nucl.Instrum.Meth.A342:22-26,1994

  T. Ohsugi, et al., MICRO-DISCHARGE NOISE AND RADIATION DAMAGE OF SILICON MICROSTRIP SENSORS, Nucl. Instrum. Meth. A383(1996)166-173

  T. Ohsugi, Y. Iwata et al., Micro-discharge study by IR sensitive CCD camera, 3rd International Symposium on the Development and Application of Semi-conductor Tracking detectors, Melbourne, December 9-12, 1997

  Y. Unno et al., Novel P-stop Structure in the N-side of N-on-n Detectors, 3rd International Symposium on Development and Application of Semiconductor Tracking Detectors, Melbourne, Dec. 9-12, 1997

- **1064 nm Laser illumination**

  Y. Unno (KEK, Tsukuba), et al., NEW LASER TEST STAND FOR SIMULATING CHARGED PARTICLE TRACKS., Nucl. Instr. Meth. A383:238-244,1996

  Y. Iwata, T. Ohsugi et al., Optimal P-Stop Pattern for the N-Side Strip Isolation of Silicon Microstrip Detectors, IEEE Nuclear Symposium, Albuquerque, New Mexico, November 9-15, 1997

- **Irradiations of prototype detectors - KEK PS EP1-A line**

  98 - Jan

  97 - Apr, Aug(CERN), Nov

  96 - Jun, Oct

  95 - Jul, Nov

  S. Terada, et al., PROTON IRRADIATION ON P BULK SILICON STRIP DETECTORS USING 12-GEV PS AT KEK, Nucl.Instrum.Meth.A383:159-165,1996

- **Beamtests - KEK PS pi2 beamline**

  98 - Feb

  97 - Feb, Jun, Nov(CERN)

  96 - Feb, Aug (CERN)

  95 - Feb

  94 - Jun

  93 - Mar

  Y. Unno, et al., BEAM TESTS OF A DOUBLE SIDED SILICON STRIP DETECTOR WITH FAST BINARY READOUT ELECTRONICS BEFORE AND AFTER PROTON IRRADIATION., Nucl.Instrum.Meth.A383:211-222,1996

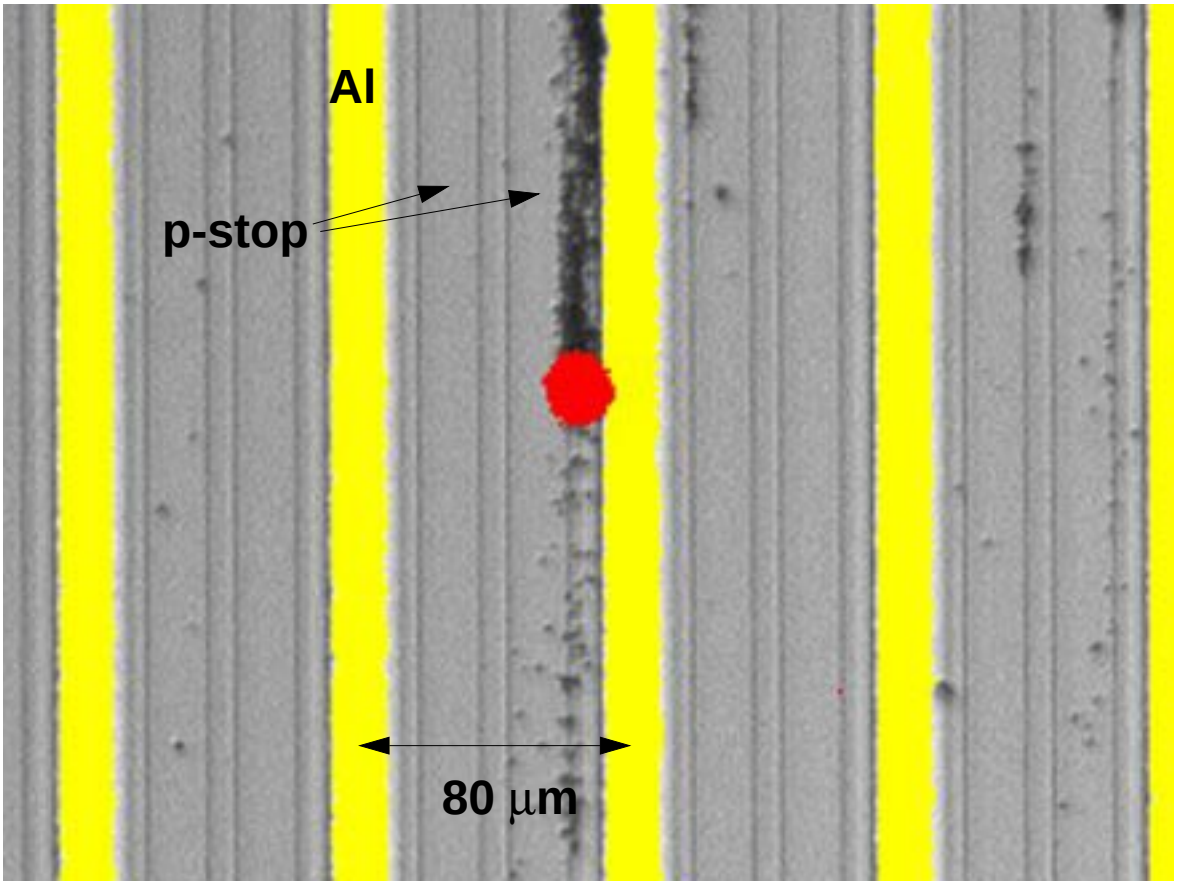
  Y. Unno, et al., BEAM TEST OF A LARGE AREA N-ON-N SILICON STRIP DETECTOR WITH FAST BINARY READOUT ELECTRONICS, IEEE Trans. Nucl. Scie. 44, 736-742, 1997

  Y. Unno et al., Evaluation of P-stop Structures in the N-side of N-on-n Silicon Strip Detectors, to appear in IEEE Trans. Nucl. Scie. Vol. 45, Number 3, June 1998

  Y. Unno et al., Beamtests of Silicon Strip Detector Modules with N-on-n Detectors, 3rd International Symposium on Development and Application of Semiconductor Tracking Detectors, Melbourne, Dec. 9-12, 1997

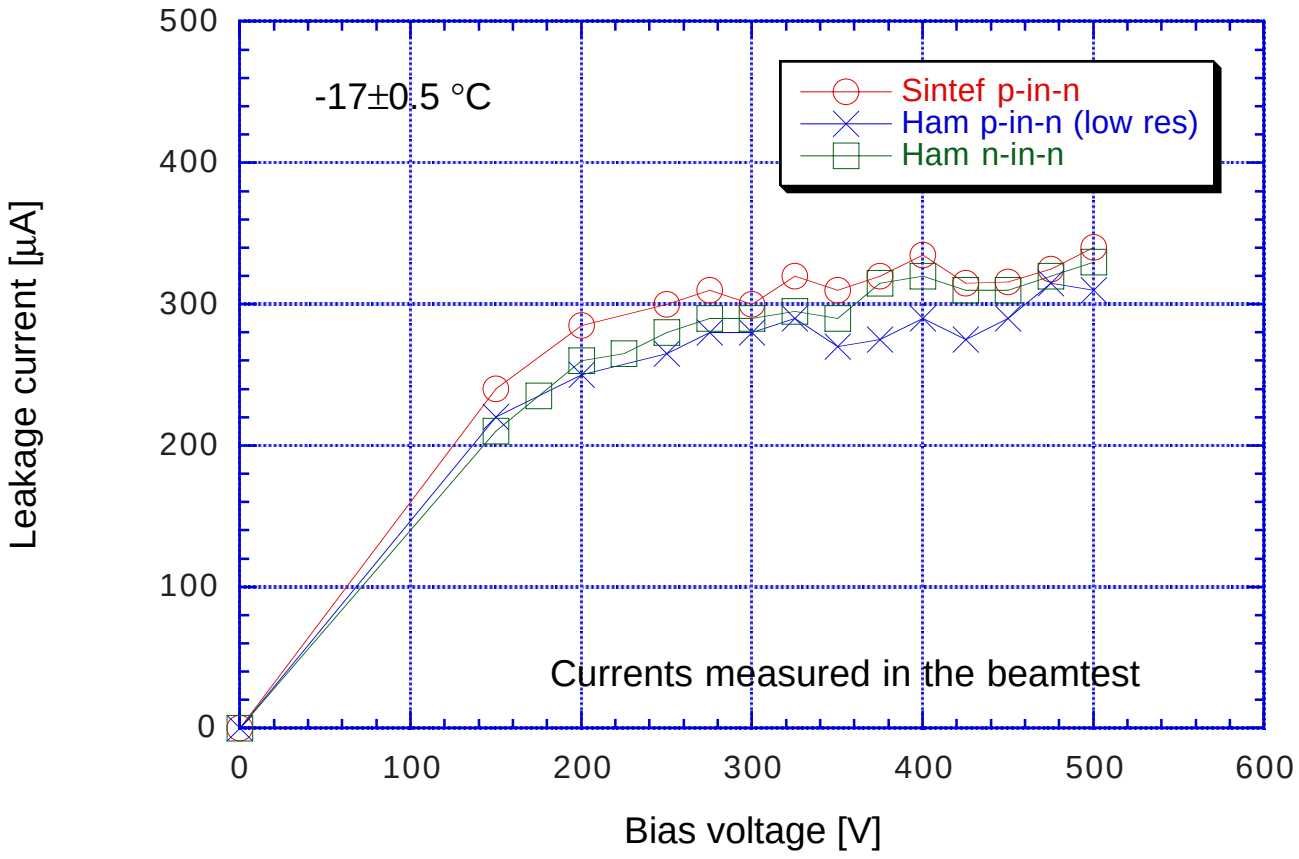
Hot-electron analysis

- **T. Ohsugi et al.,**



- **“Hot-electron”= electrons accelerated in high electric field causing avalanche breakdown, Infra-Red light from e-h recombination**
- **n-side readout prototype**
- **Powerful tool to pin-point where the problem is**
- **Invention of a new p-stop structure (Y. Unno et al., Novel p-stop structure ...), e.g.**

Leakage currents in “p-in-n” and “n-in-n” detectors



- **Irradiation at KEK: ~ 3 x 10^{14} protons/cm^2**
- **Two “p-in-n” and one “n-in-n” detectors were beamtested at KEK**
  - **Hamamatsu p-in-n and n-in-n**
  - **SINTEF p-in-n**
- **Both detectors were operated up to 500 V!!**
- **ATLAS SCT choice: p-in-n detector**

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Development of Silicon-strip Module

- **Many iterations and optimization of the following aspects**

  - Contribution of Japan has been always in the fore-front and in the centre of the activity

- **Module topology**

  - Comparison between “Centretap-module”, “Endtap-module”, and “Z-module”

  - “Centretap-module” for the barrel

- **Thermal runaway**

  T. Kohriki, T. Kondo, H. Iwasaki, S. Terada, Y. Unno (KEK, Tsukuba), T. Ohsugi (Hiroshima U.), FIRST OBSERVATION OF THERMAL RUNAWAY IN THE RADIATION DAMAGED SILICON DETECTOR, IEEE Trans. Nucl. Sci. 43 (1996) 1200-1202

  - Finite element analysis - Measurement optimization

- **Least material**

  - Optimization in mechanical strength

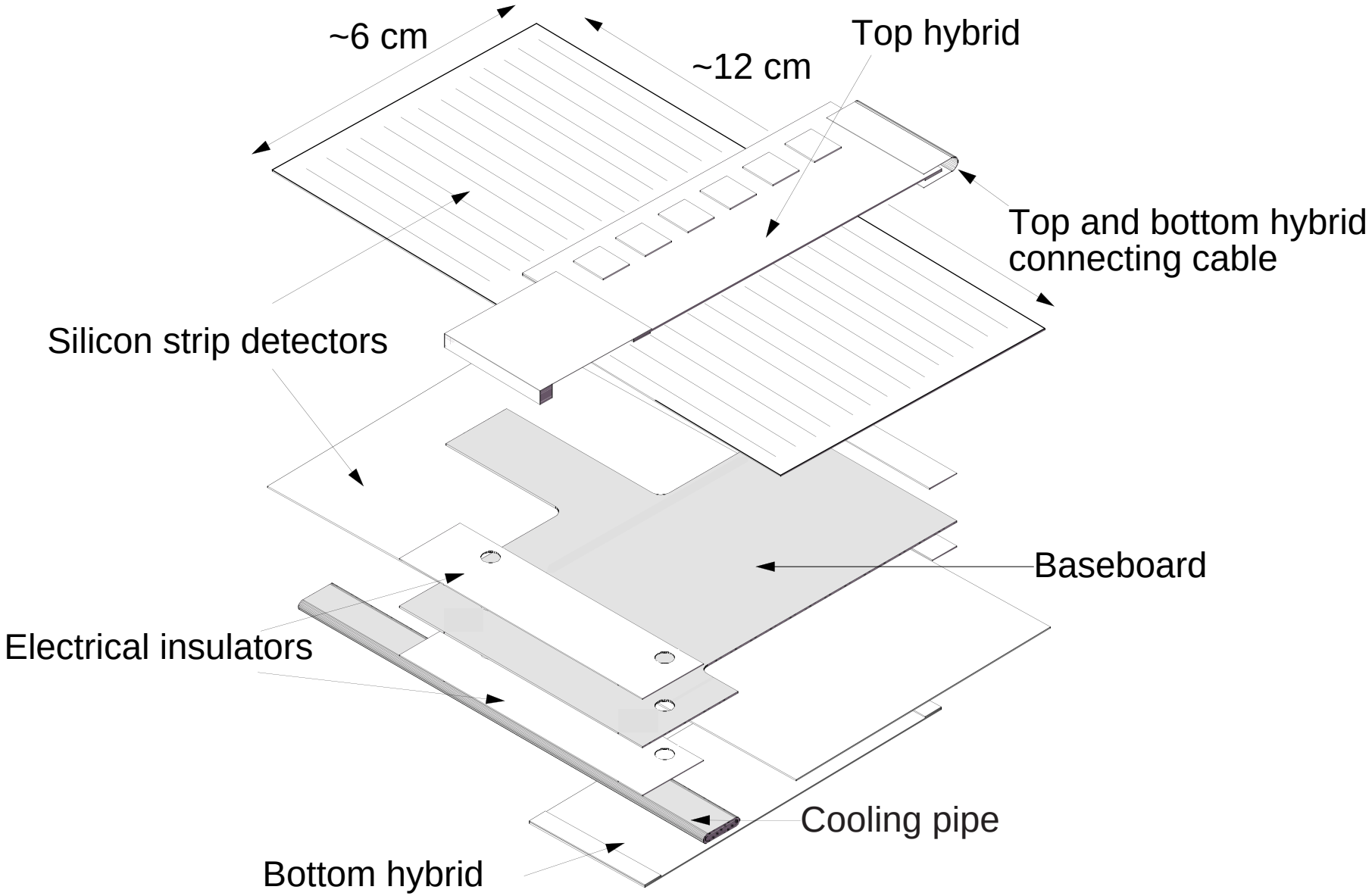
  - Thermal performance

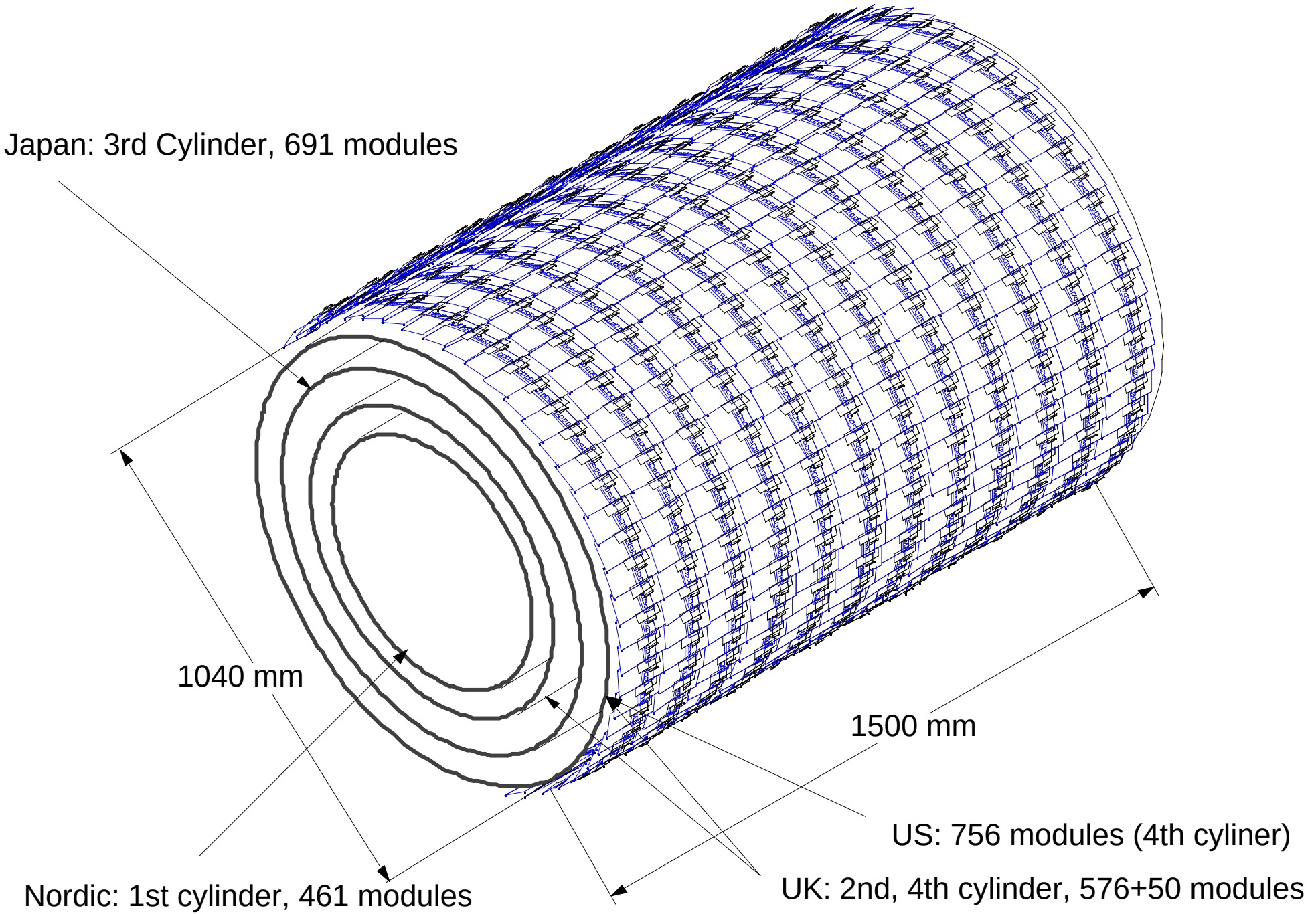
  - Be+Kapton hybrid - Less material than BeO ceramic hybrid

- **Thermo-distortion measurements**

  - KEK thermal module

  - Oxford Univ. ESPI measurement system


~6 cm
~12 cm
Top hybrid
Top and bottom hybrid
connecting cable
Silicon strip detectors
Baseboard
Electrical insulators
Cooling pipe
Bottom hybrid


Japan: 3rd Cylinder, 691 modules
1040 mm
1500 mm
US: 756 modules (4th cyliner)
UK: 2nd, 4th cylinder, 576+50 modules
Nordic: 1st cylinder, 461 modules

Responsibility, Schedule

- **Japan - 3rd Barrel Cylinder**

  Barrel detectors: 57% (about 5,800 detectors)

  - Natural to concentrate on expertise

  - Share the full 3rd barrel cost with producing detectors

  Barrel hybrids: 27% (for 691 modules)

  Barrel modules: 27% (691 modules for 3rd cylinder)

  Optical links: 18% (flex part of the links for the barrel)

  Barrel cylinder component: 25%

  Assembly of the 3rd barrel cylinder

- **Why Silicon?**

  Complementary physics to muons: electrons, b-jets,...

  High quality semiconductor industry

  Long history of R&D

  Active involvement in detector, module,... development in SCT

  -- In short, Silicon is an recognized expertise of Japan

- **Prototyping and Preproduction**

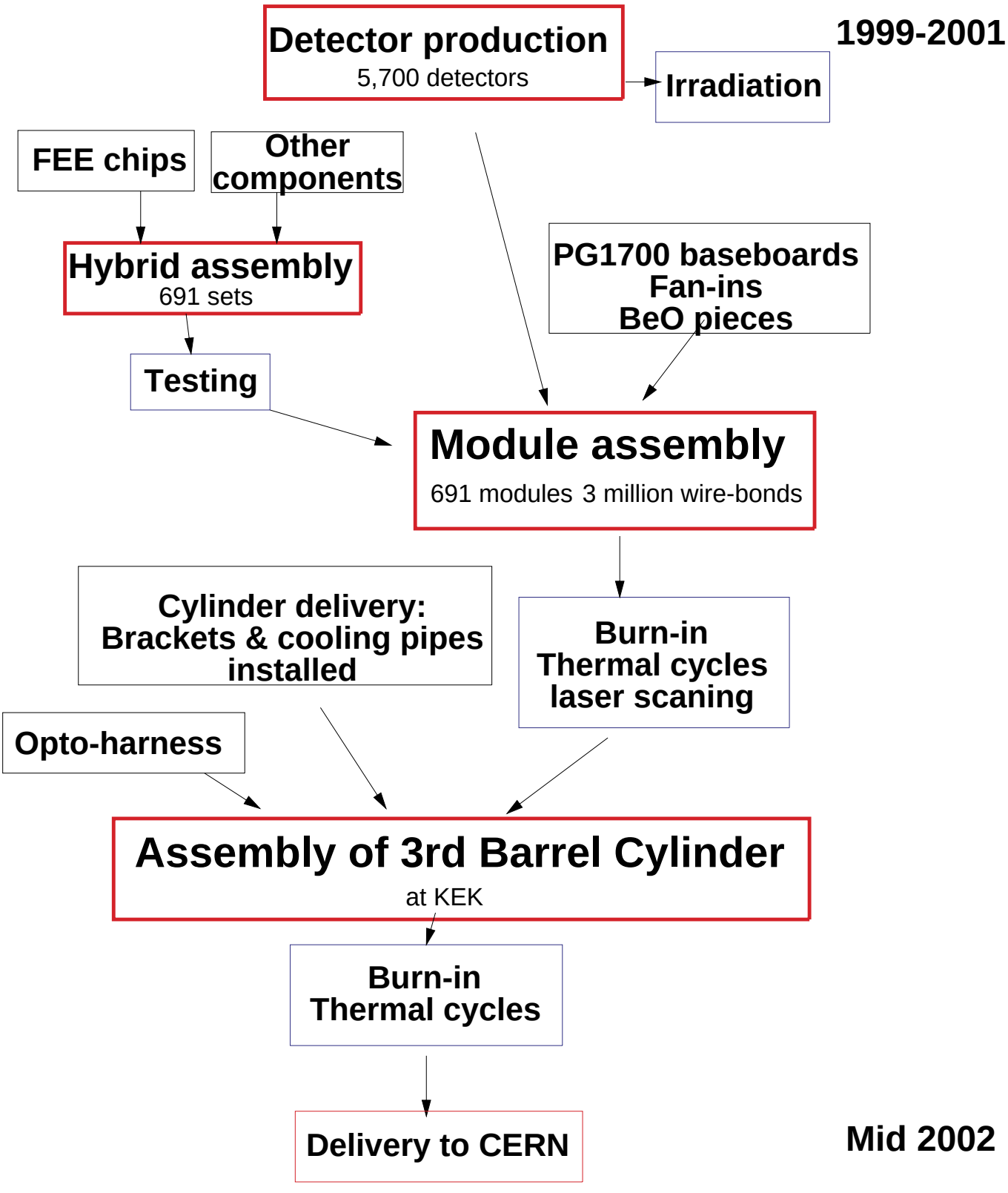
  - 98 and early 99

- **Production schedule**

  - From 1999 till end of 2001

  - Shipping the completed cylinder to CERN in Spr-Summer of 2002

Construction flow



Man power

- **Supervision and Testing**

  Detectors, Hybrids, Modules, Cylinders

  Mainly University staffs and students:

  T. Ohsugi, Y. Iwata - Hiroshima Univ.
  I. Nakano - Okayama Univ.
  R. Takashima - Kyoto Univ. of Edu.
  C. Fukunaga - Tokyo Met. Univ.

- **Module and Cylinder assembly**

  KEK staffs:

  Y. Unno, S. Terada, T. Kohriki, (T. Kondo)

  Help in cooling:

  T. Haruyama

- **In all, the current man-power is the bare minimum**

  Need one or two additional man-power at KEK (and Univ.)

Summary

- **Silicon microstrip detector is a central device in the tracking of the ATLAS detector**
- **Radiation-tolerant detector has been emerged from the world-wide R&D, specially from the contribution of Japanese collaborators**
- **Japanese collaborators have provided critical contributions in defining the silicon microstrip module**
- **Japan has fair responsibility in construction of the SCT silicon strip detector, completing the 3rd barrel cylinder**
- **Man-power is critical to accomplish the project. The current man-power is the bare minimum and need to be enhanced.**