The CMS Tracker
A. Cattai – CERN -

- overview of the CMS Tracker
- organization of the module production
- QA&C tests across the production
- logistic and control of production
- conclusion .......... in few years!
The CMS Experiment

Total Weight: 12.500 t
Overall Diameter: 15.00 m
Overall Length: 21.60 m
Magnetic Field: 4 Tesla

15 m

21.6 m
The CMS Tracker

- **Outer Barrel (TOB)**
- **Inner Barrel (TIB)**
- **Pixel**
- **End cap (TEC)**

- **Volume**: 24.4 m³
- **Running temperature**: −10°C
Tracker lay-out as of April 2000

6 layers
Outer Barrel

4 layers
Inner Barrel

3 disks

9 disks in the End Cap

$\eta = 2.5$

by D. Abbaneo

stereo point
R-phi point

number of points
The CMS TK is made with silicon detectors of two different thickness: 320 μm in the inner region ($r < 600$ mm) and 500 μm in the outer region. These are single side detectors made of one (thin) or two (thick) daisy-chained silicon sensors from 6” wafers.

**pitches from 80 to 183 μm**
the Tracker modules are composed by few independent parts……

- supporting frame in CF
- Kapton insulator and bias carrier
- the Silicon sensor(s)
- the front end RO hybrid
- 4 to 6 APV25 chips (128 ch)

15232 detector modules working at \(-10^\circ C\) …..for the whole life of CMS

and by few key assembly & testing procedure……
modules are integrated in sub-structures

sub-structures are installed in the sub-detector mechanics

nomenklatura......
Tracker Numbers

445 m² of silicon wafers
6,136 thin wafers
18,192 thick wafers

24328 wafers

9,648,128 strips = electronics channels

26,000,000 Bonds
17000 Opto-hybrids
33000 optical fibers

206 m² of silicon sensors
6,136 thin detectors (1 sensor)
9,096 thick detectors (2 sensors)

15232 detector modules

75,376 APV chips

~ 100 µm stability in space (25m³) and time (10 y) at -10 °C
how are we organized to complete this task in a limited amount of time???
生产
在工厂
QA&C

装配
在工厂或机构
QA&C

装配
在轨道架及粘合中心
QA&C

装配
在集成中心
QA&C

装配
在CERN
QA&C

DETECTOR

Si
sensor

CF ledges
Kapton
inserts

APV25
PLL MUX
DCU
hybrid……

qualified
Si sensor

frames

FE
hybrid

detector
modules

sub-structure
of the 4 sub-detectors

TOB - TIB - TID - TEC

CMS Tracker

electronics & mechanics

A. Cattai – QA Workshop, May 2001
the sensor QA&C is a pilot project in the TK (see talk of GM Bilei)
The rest is/will be organized with a similar strategy
Strategy of QuAC

TWO distinct phases:

1. the pre-production: **learning phase**
   - 200 detectors are now being produced
   - production chains (hardware-software) commissioned
   The experience gained during this period, will indicate the tests that are essential during the module production

2. the production phase
   - established a list of tests to be performed on independent parts & modules
   - identified when/where, along the module production chain, the tests will be performed
   - constructing the tools/equipment
in the Tracker there are:

**OBJECTS:** hybrids - frames – sensor – electronics - mechanics

**PROCEDURES:** module assembly - bonding - testing – module integration into the mechanics….

for each object/procedure we instituted a working group responsible of:

- in case of an **object:** design and standardization of the part for the whole TK
- in case of a **procedure:** definition - conception - realisation - commissioning of the tools and software
- the compilation of the technical-specification documents
- contact with factories – tenders – contracts – procurements of parts
- the product risk analysis
- the definition of the quality assurance and control
- the definition of the non-conformities and the assessment of their severity level
- the compilation of a quality plan document
- the definition and standardization of the repair procedures
- the provision, distribution and trace-ability of spares parts
- the definition of shipping procedures

We achieved the standardization of parts, assembly/testing procedures among the centres
work is executed in Regional Centers:
2 hybrids - 1 frames - 6 sensor qualification - 7 assembly - 12 bonding - 18 testing
each Regional Centers is responsible for the work done in the center and to follow strict and common rules for production and testing:

- the product trace-ability
- performing the operation according to the specification document
- performing the testing according to the specification document
- qualifying the product according to predefined acceptance criteria
- recording the non-conformities
- repairs (when applicable)
- the data trace-ability
- informing the Production Committee of damages or faults in the production chain
- functioning and maintenance of the local equipment
- training of personnel
- shipping of parts or materials
7 module assembly centers; „the“ Gantry

frames  sensors  FE hybrid

they are all equipped with the same hardware and software – they follow the same assembly procedure and tests
Tests at the Gantry assembly centres

- All the sensors, frames and hybrids are optically inspected upon reception.
- Fast tests are performed on the FE hybrid after the module assembly.
- Mechanical tests (planarity and alignment) are performed on sample basis.
- Fast tests are performed on all the FE hybrids.
- Mechanical tests (traction and/or shear) of glue samples from each module assembly batch will be done systematically.
After being assembled at the Gantry centers, the modules go to

12 bonding and testing centers

where they are (after bonding) installed on adequate single module supports and they undergo long-term stability tests at low temperature (Si sensors at T= -10 C)

hardware “is” standardized among the 12 centers
Rules for modules at the bonding and testing centres

- All the modules are optically inspected at reception
- Modules will be tested upon their arrival depending on the status of the shock recording system installed in the package
- Fast tests are performed on all the FE hybrids

**after bonding**

- Fast tests are performed on all the FE hybrids
- Bonding quality is checked
- All modules undergo a thermal cycling ranging between $T = -20$ C and $T = +40$ C. (FE electronic is not powered. The thermal stress will force weak bonds to fail)
- All the modules undergo fast acceptance tests at room temperature

repair procedure in situ or shipped to the Repair center classified for the full acceptance tests (V bias scan and infrared light response)
Only **two** test set-ups are foreseen at different level of production. Set-ups and the software tools are **standardized** therefore the results will be homogeneous and compatible among all different centres

**Set-up 1** investigates the functionality of the FE electronics, identifies dead and noisy channels - writes results into the DB. It integrates the slow control

**Set-up 2** allows to readout the hybrid as foreseen in the final Tracker system. It enables the test of several modules in parallel
It has safety interlocks for currents, temperature, low and bias voltages.
It include cooling system of adequate capacity
It is fully automated and interfaced to the database.
how can we cope and follow so many parts?

and all the information related to the tests???

with the LOGISTIC program !!
Each part (sensor, hybrids, modules…) is identified by a bar-code (input to a DB system). The results of each measurement performed on the part, at any time along the production chain, are stored in the DB with the bar-code identification of the part.

Supervision process:
what we have in the various centers and where specific parts are located
Inventory and status of objects in each center
Distribution of a measured value (broken strips, average noise, gain...)

[Graph showing distribution of measured values with histograms and statistical data]
Monitoring of the construction quality and non-conformities everywhere

When a measure on a part do not satisfy its specification the DB automatically set the non-conformity flags:

- **OK**
- **BAD**

shall be used for the Tracker construction or not

The construction quality will be checked by monitoring continuously:

- the statistics on non-conformities stored in the DB
- time-evolution of the non-conformities

Any statistically significant trend in the distribution of the non-conformities will set an alert level:

- reduction or total holding of all production activities
- verification of all equipment (hardware/software)
- running of the equipment with calibrated parts till debugging
- reinforcement of the production chain by other centres (if needed)
Logistic process:
Create transfer of objects from center A to center B

the receiving center is notify with an automatic mailing
Supervision process:
Where is a specific class of objects (sensors, hybrids, modules ……)??

…..we are really confident to see this plot!!!