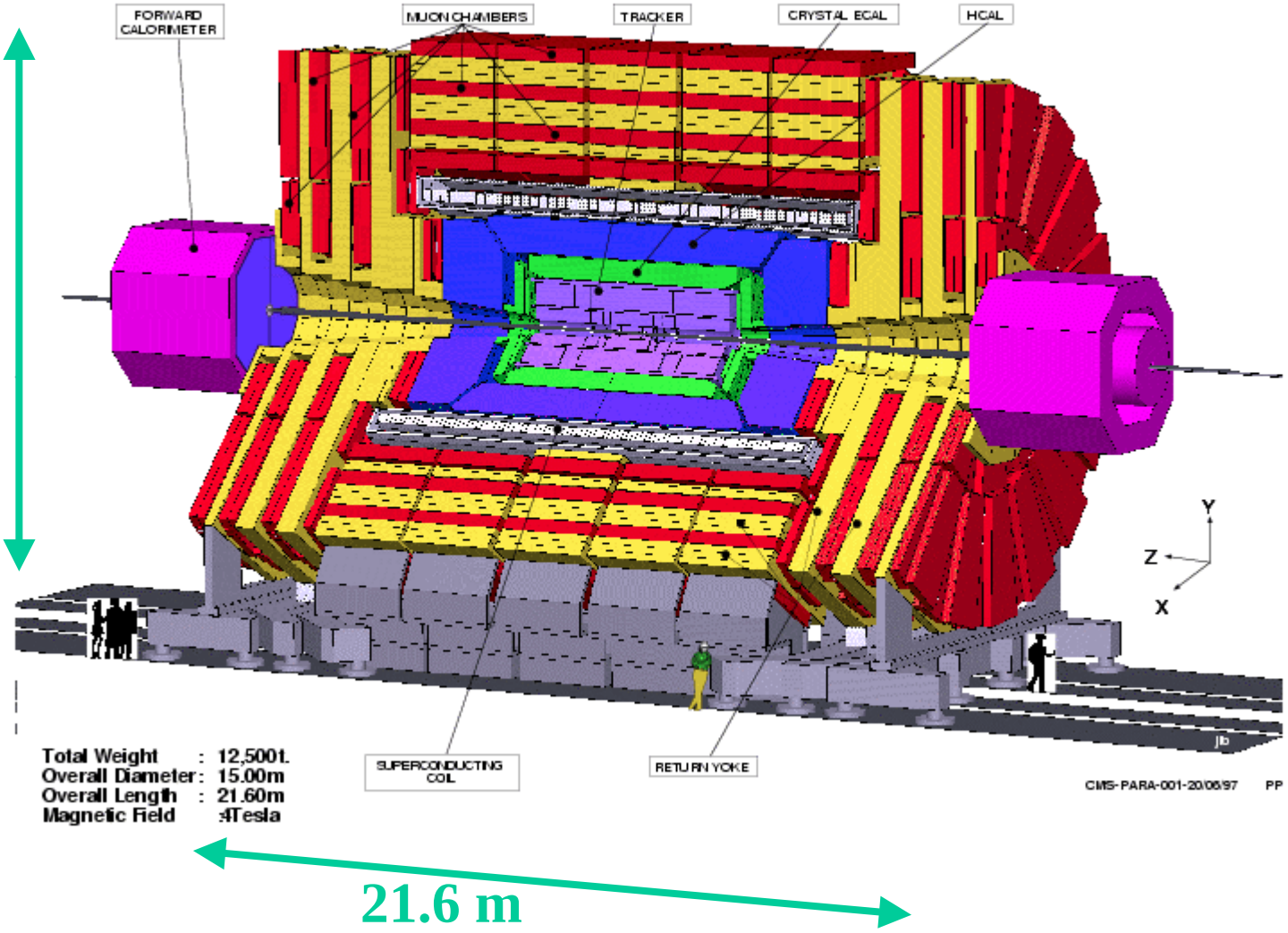
The CMS Tracker

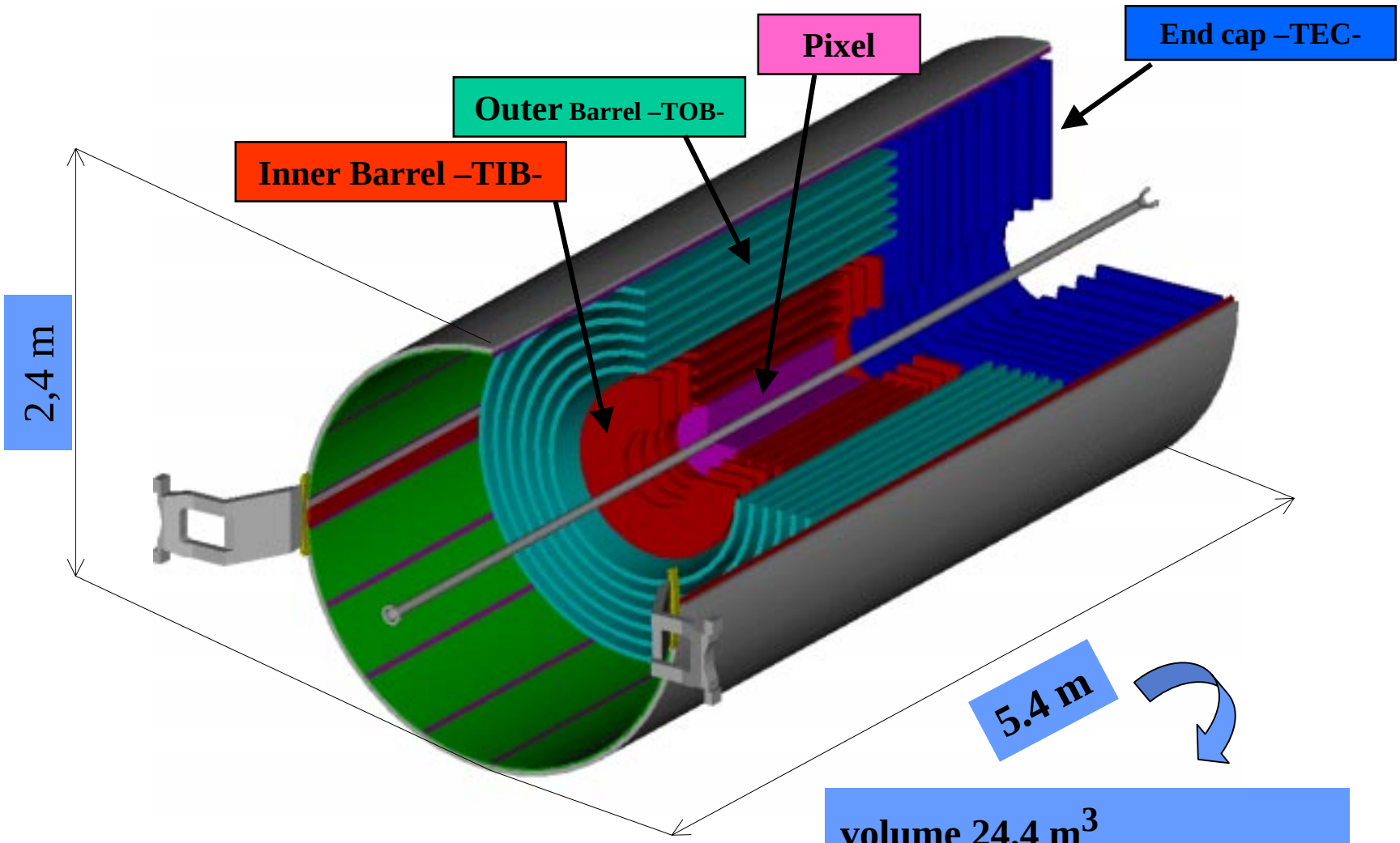
A. Cattai – CERN -

- 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

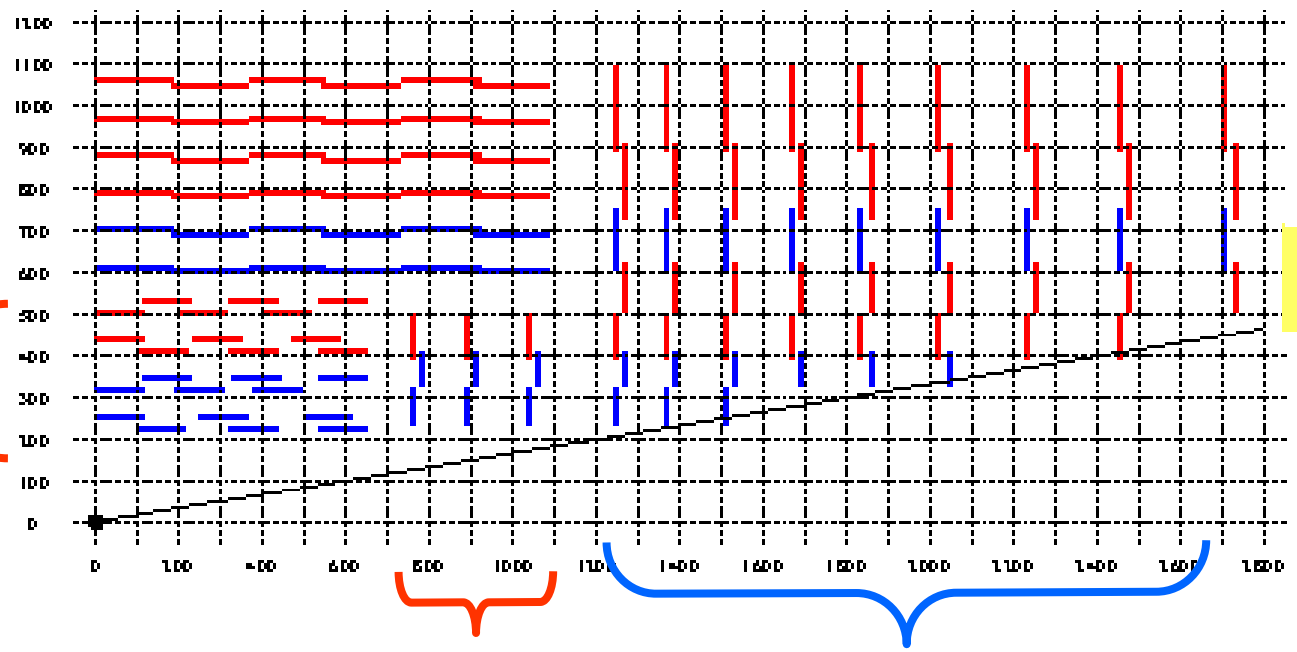


The CMS Tracker



volume 24.4 m^3
running temperature – 10 ^{0}C

Tracker lay-out as of April 2000



$\eta = 2.5$

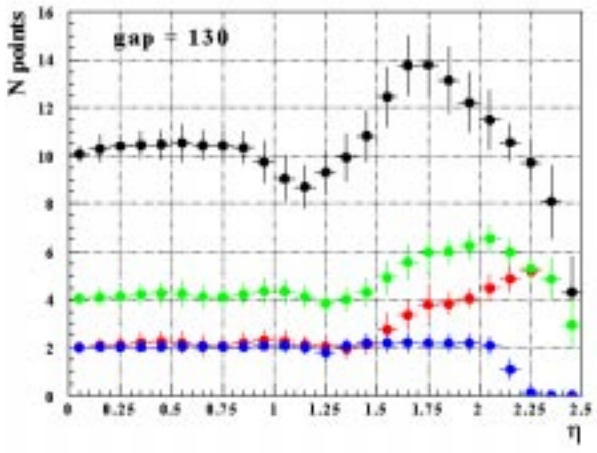
by D. Abbaneo

stereo point

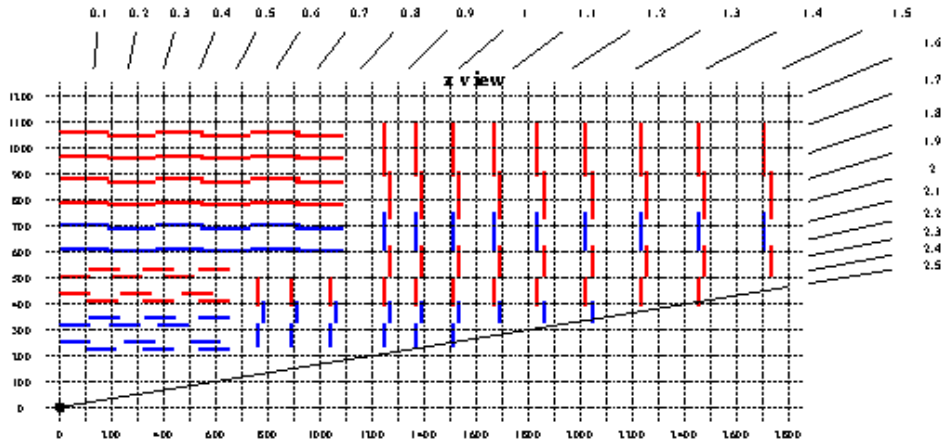
R-phi point

limited

number of points

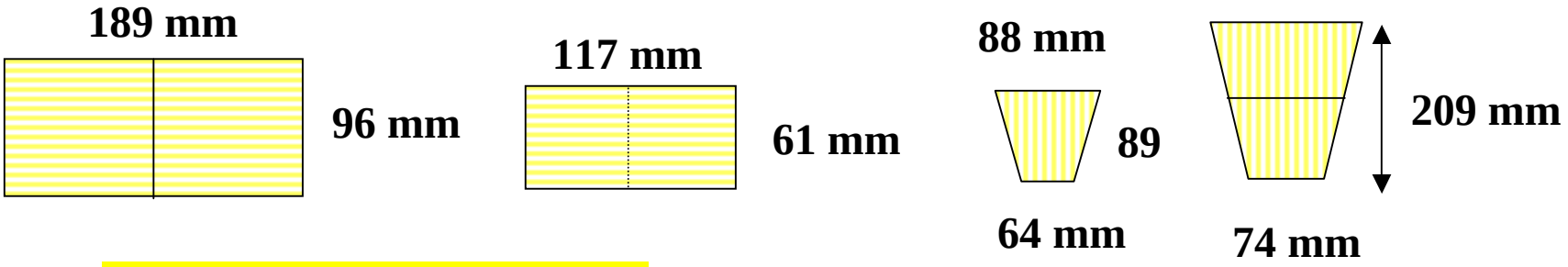


the Tracker lay-out



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.

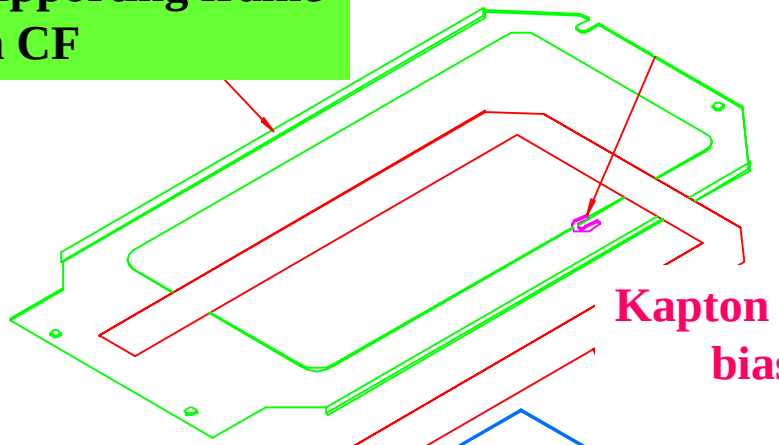
These are single side detectors made of one (thin) or two (thick) daisy-chained silicon sensors from 6” wafers.



pitches from 80 to 183 μm

the Tracker modules are composed by few independent parts…….

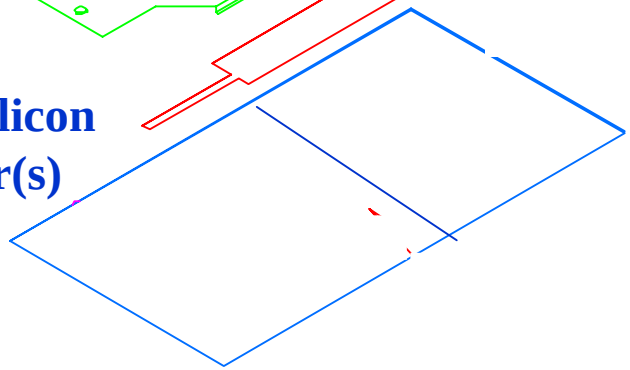
supporting frame in CF

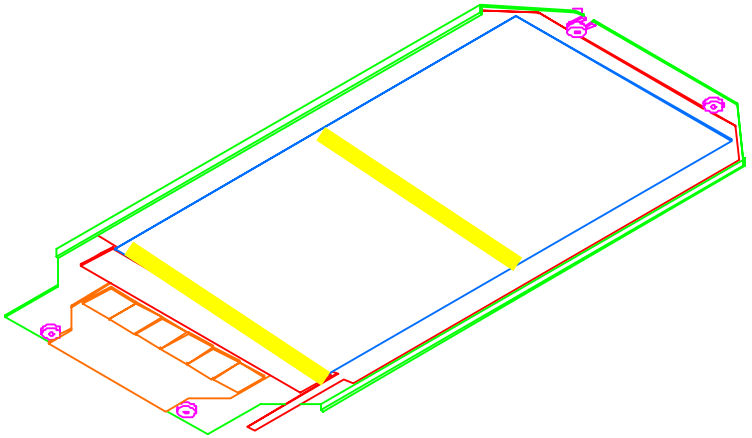


Kapton insulator and bias carrier

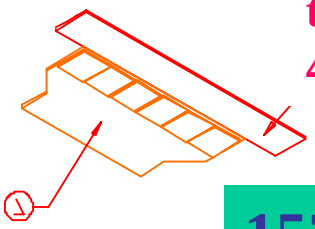
and by few key assembly & testing procedure……

the Silicon sensor(s)





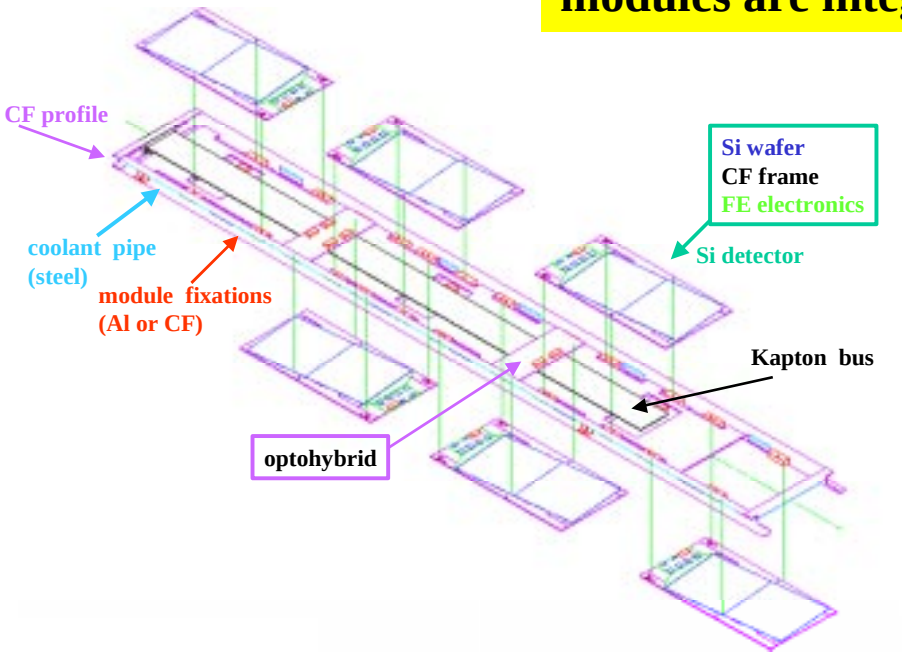
the front end RO hybrid
4 to 6 APV25 chips (128 ch)

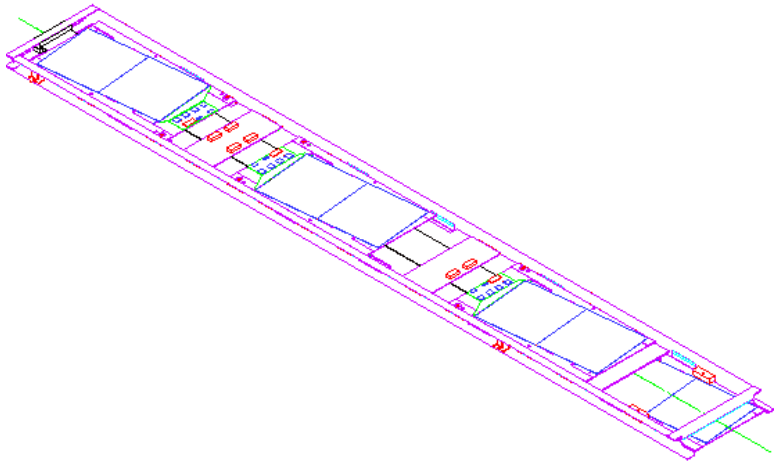


15232 detector modules working at –10 ^{0}C **…..for the whole life of CMS**

nomenklatura……

modules are integrated in sub-structures





sub-structures are installed in the sub-detector mechanics

Tracker Numbers

445 m^2 of silicon wafers

206 m^2 of silicon sensors

6,136 thin wafers

6,136 thin detectors (1 sensor)

18,192 thick wafers

9,096 thick detectors (2 sensors)

24328 wafers

15232 detector modules

9,648,128 strips ≡ electronics channels → 75,376 APV chips

26,000,000 Bonds

17000 Opto-hybrids

33000 optical fibers

~ 100 μm stability in space ($25m^3$) and time (10 y) at -10 ^{0}C

how are we organized to complete this task in a limited amount of time ???

production
at factories
QA&C

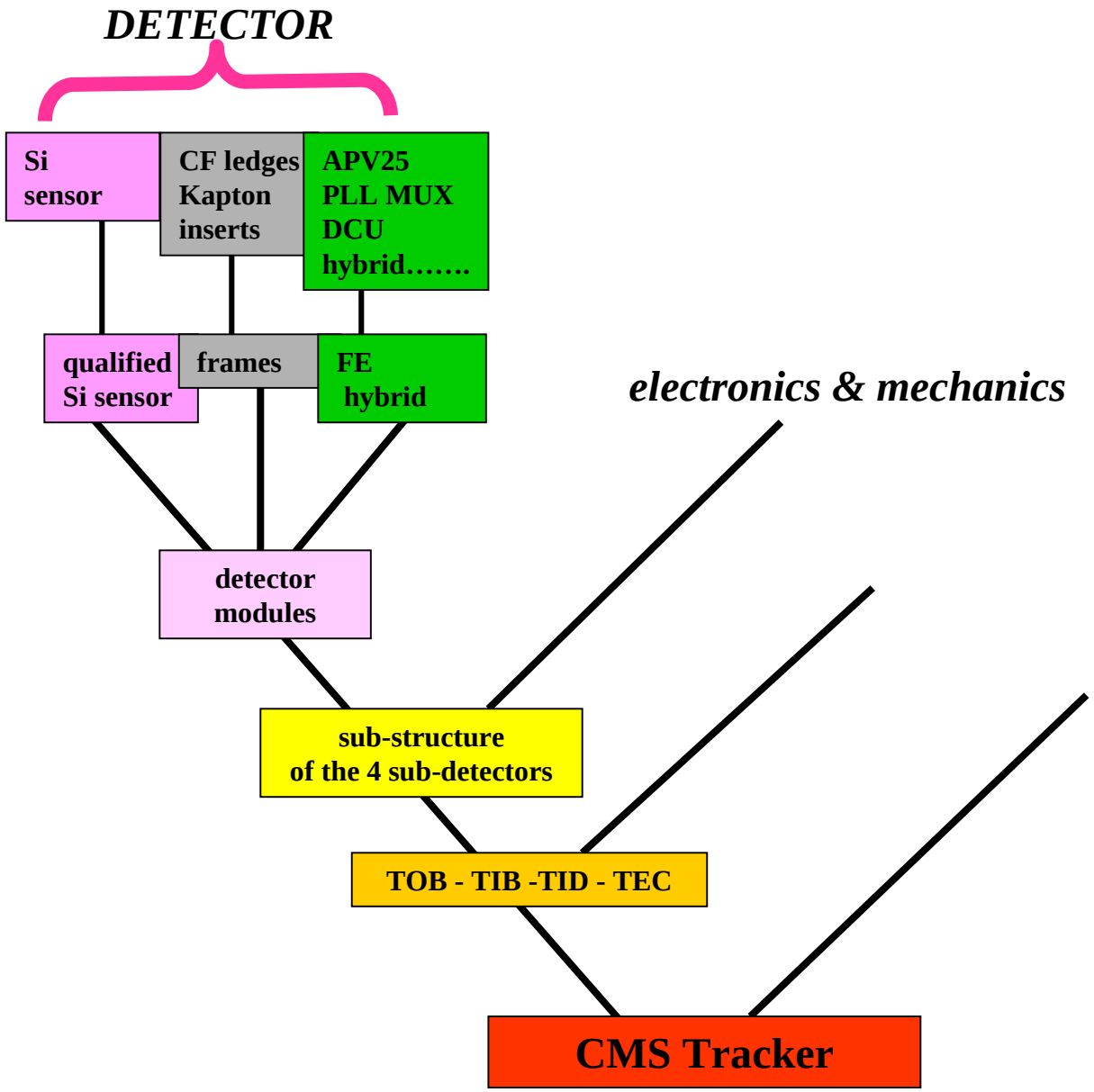
assembly
at factories
or institutes
QA&C

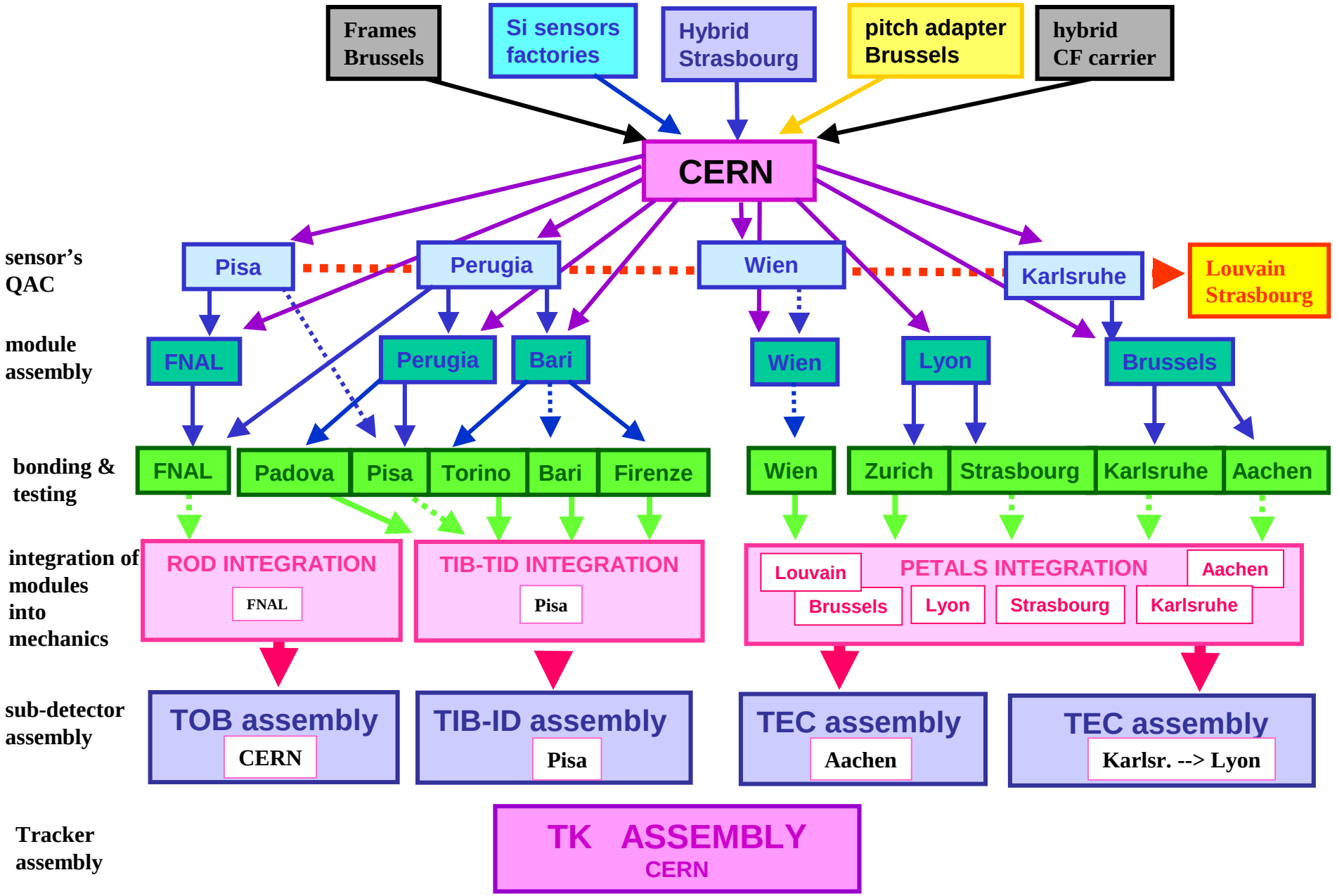
assembly
at Gantries &
bonding centers
QA&C

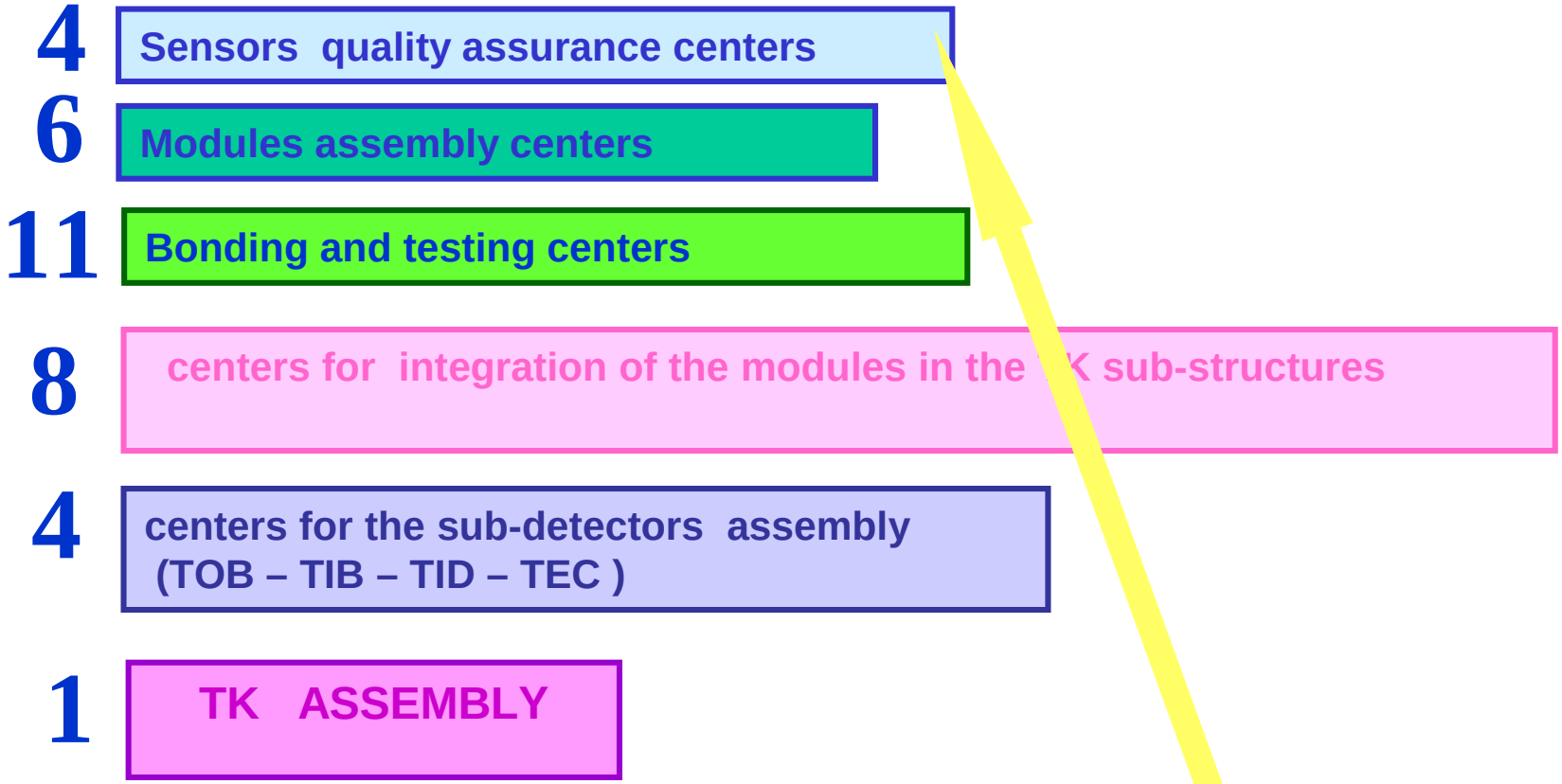
assembly
at integration
centers
QA&C

assembly
at integration
centers
QA&C

assembly
at CERN
QA&C




Frames Brussels
Si sensors factories
Hybrid Strasbourg
pitch adapter Brussels
hybrid CF carrier
CERN
sensor's QAC
Pisa
Perugia
Wien
Karlsruhe
Louvain Strasbourg
module assembly
FNAL
Perugia
Bari
Wien
Lyon
Brussels
bonding & testing
FNAL
Padova
Pisa
Torino
Bari
Firenze
Wien
Zurich
Strasbourg
Karlsruhe
Aachen
integration of modules into mechanics
ROD INTEGRATION
FNAL
TIB-TID INTEGRATION
Pisa
PETALS INTEGRATION
Louvain
Brussels
Lyon
Strasbourg
Karlsruhe
Aachen
sub-detector assembly
TOB assembly
CERN
TIB-ID assembly
Pisa
TEC assembly
Aachen
TEC assembly
Karlsr. --> Lyon
Tracker assembly
TK ASSEMBLY
CERN



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

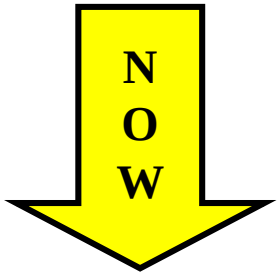
TWO distinct phases:

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:

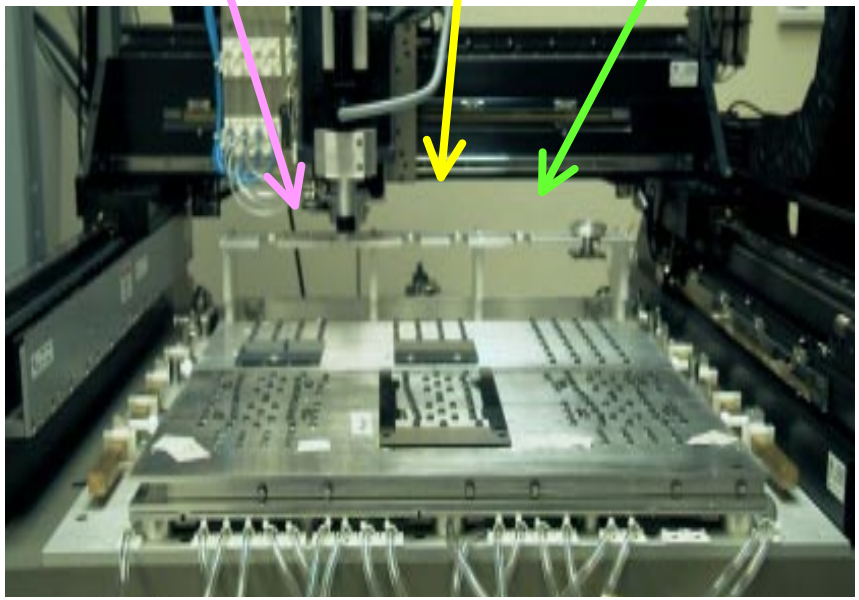
- **the product trace-ability**
- **performing the operation according to the specification document**
- **performing the testing according to the specification document**
- **qualifying the product according to predefined acceptance criteria**
- **recording the non-conformities**
- **repairs (when applicable)**
- **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



bari

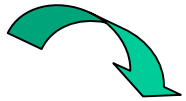
wien

they are all equipped with the same hardware and software – they follow the same assembly procedure and tests

perugia

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

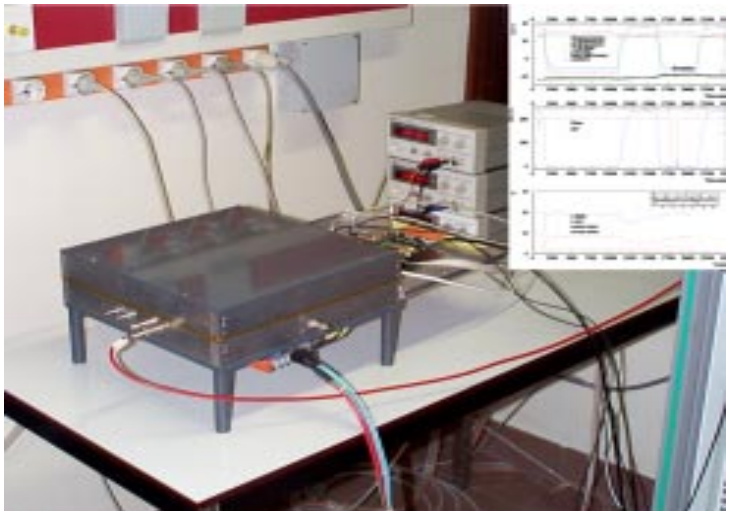
after the module assembly 

- 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)

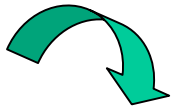


hardware "is" standardized among the 12 centers

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

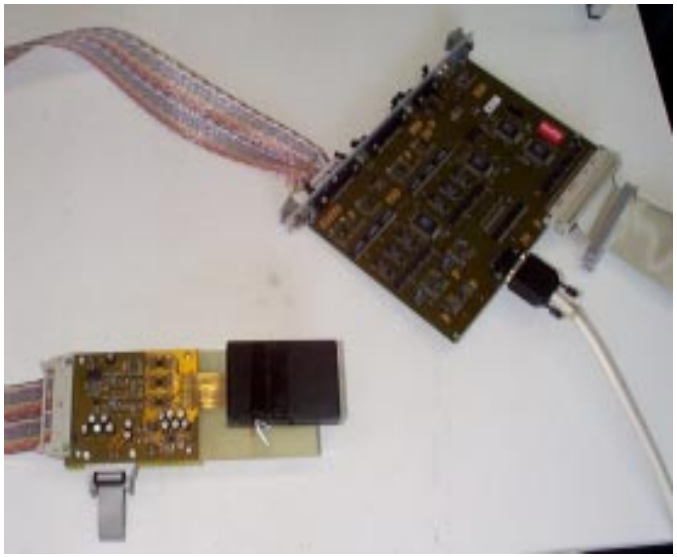
classified for the full acceptance tests
(V bias scan and infrared light response)

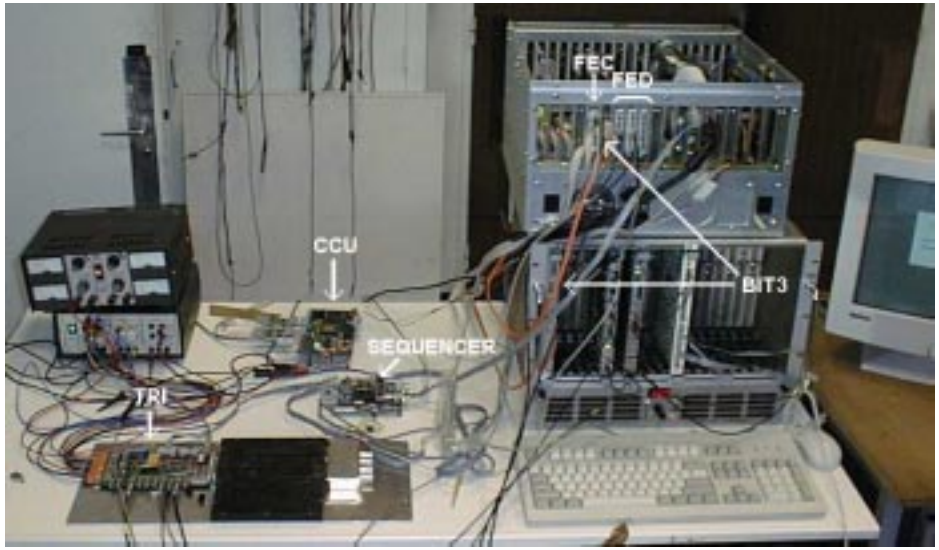
18 module testing centers

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.





24328 wafers

15232 modules

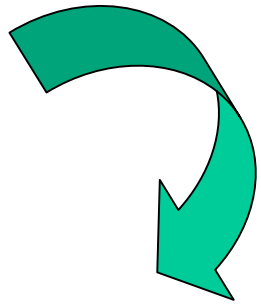
how can we cope and follows so many parts?

75376 APV chip

17000 FE- hybrids

17000 Opto-hybrids

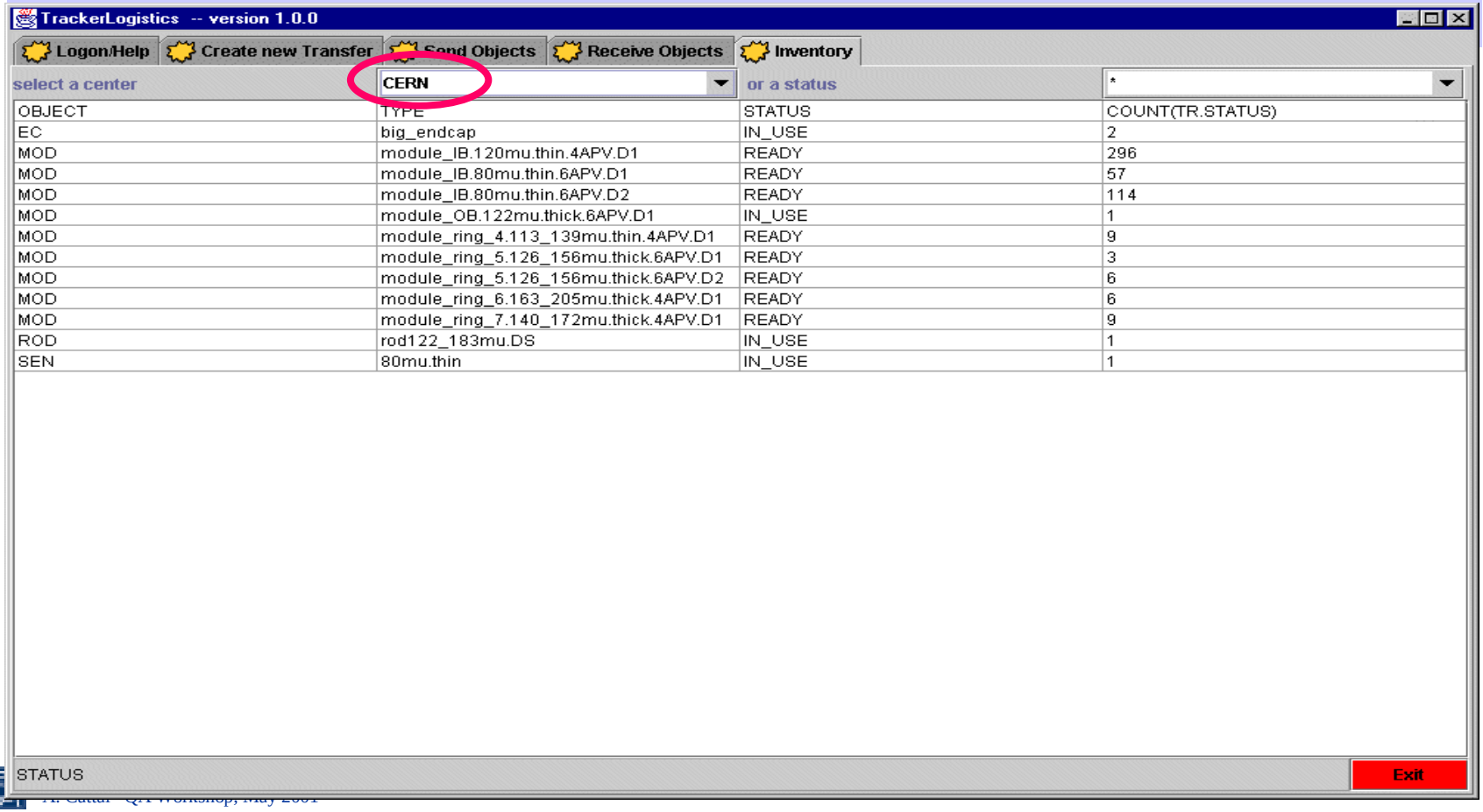
and all the information related to the tests???



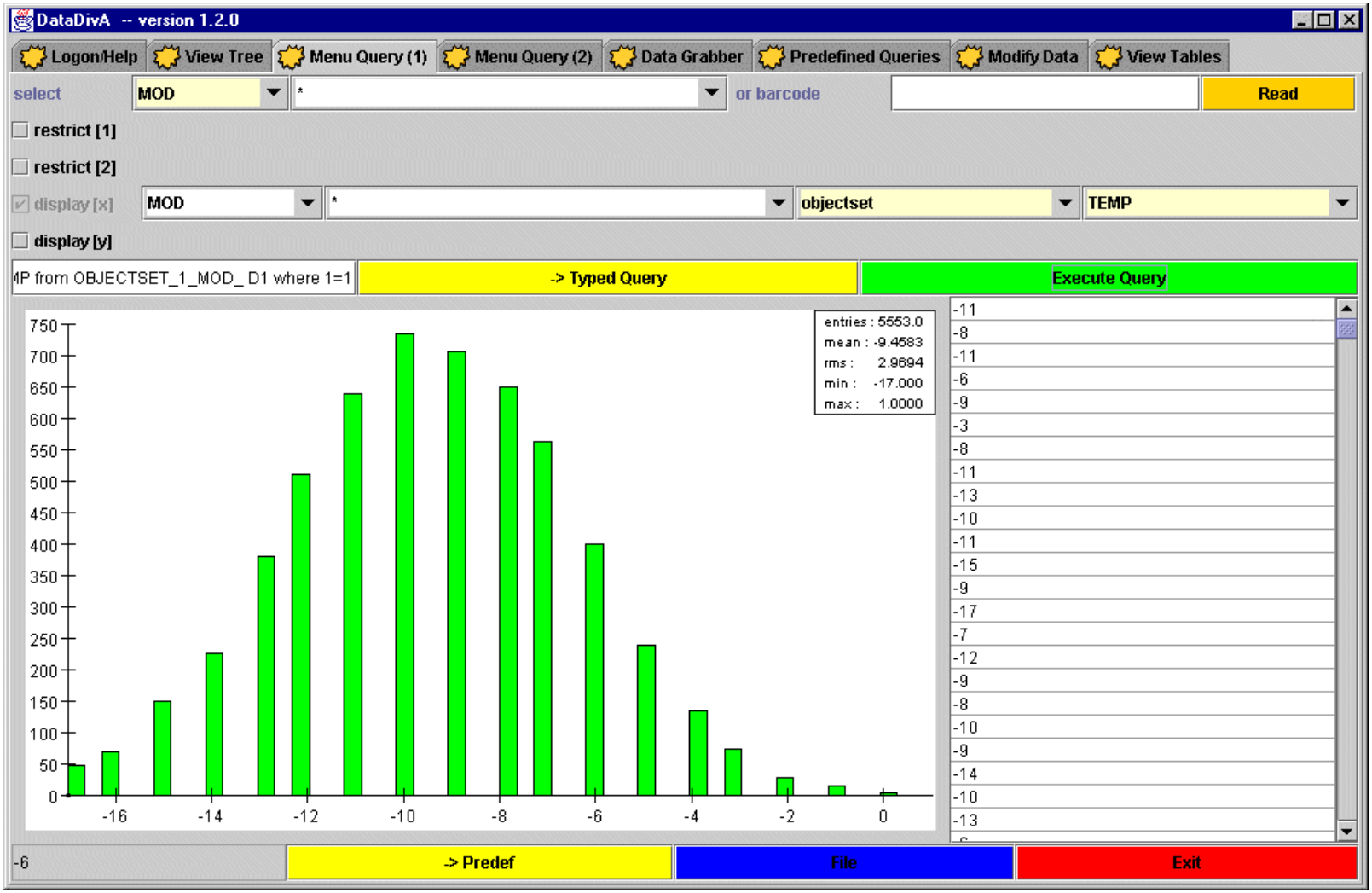
with the LOGISTIC program !!

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…)



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

shall be used for the Tracker construction or not

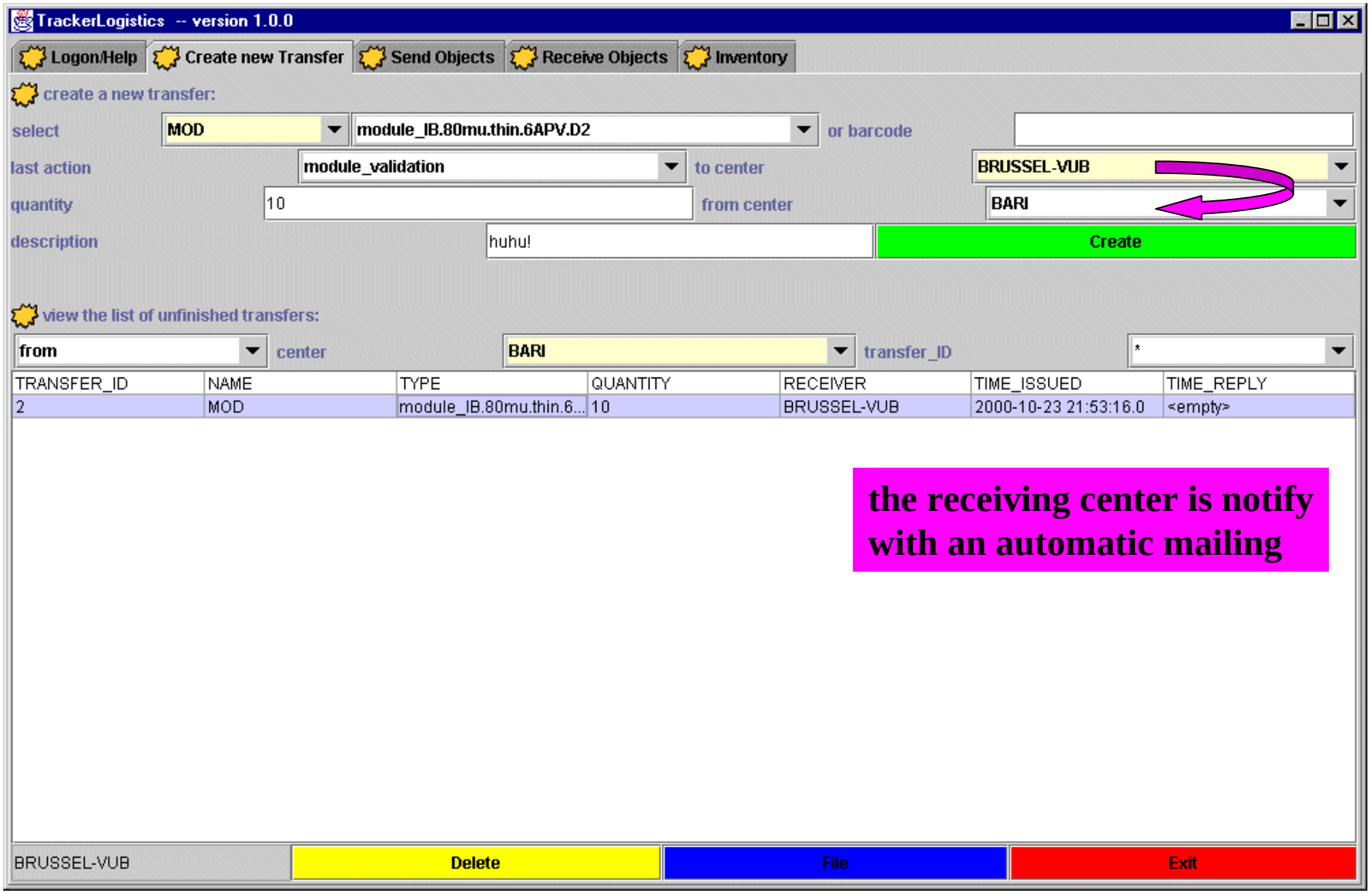
The construction quality will be checked by monitoring continuously:

- 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

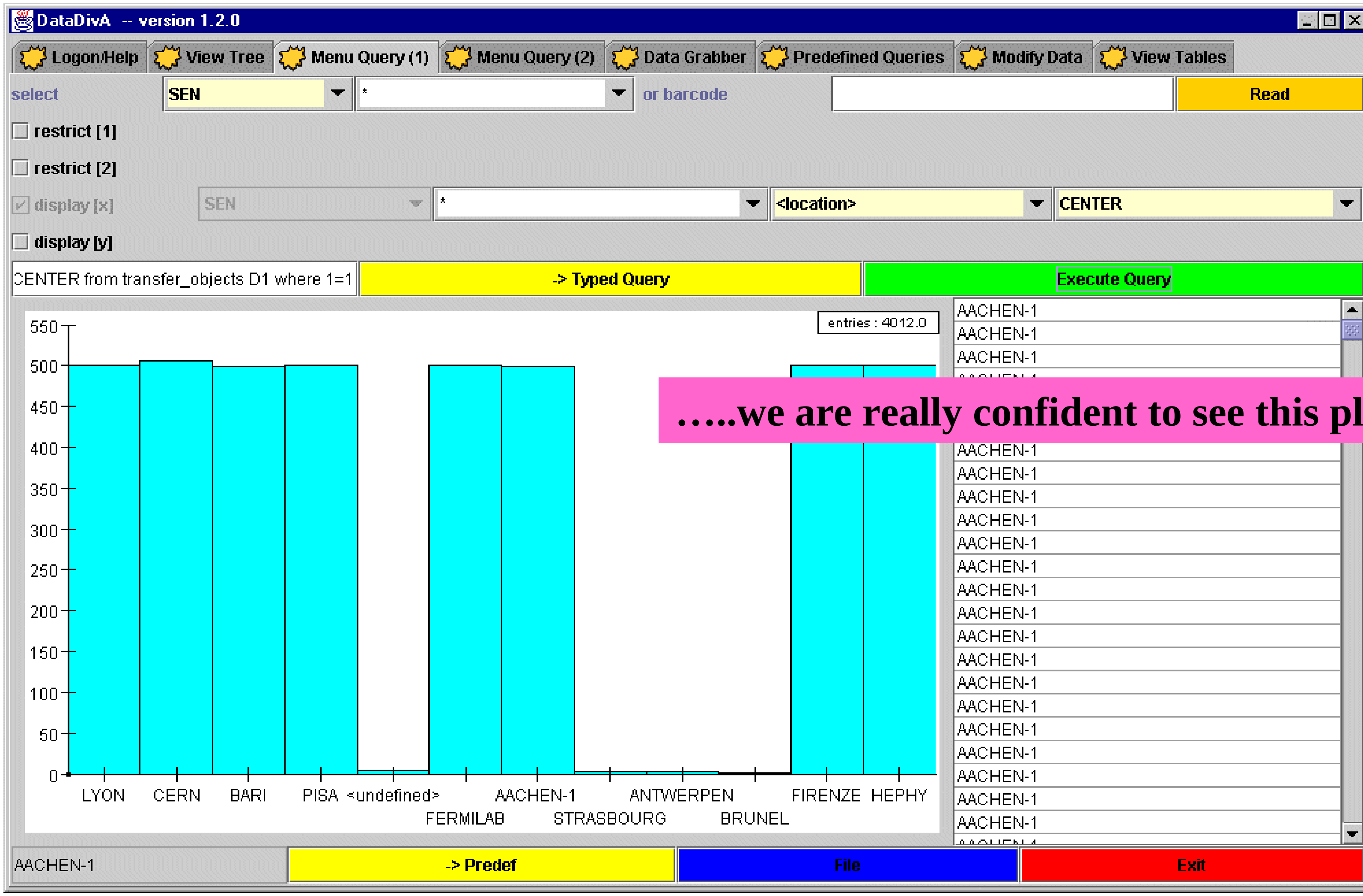
reduction or total holding of all production activities
verification of all equipment (hardware/software)
running of the equipment with calibrated parts till debugging
reinforcement of the production chain by other centres (if needed)

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!!!