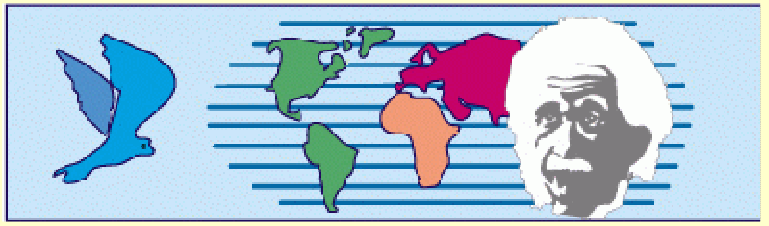
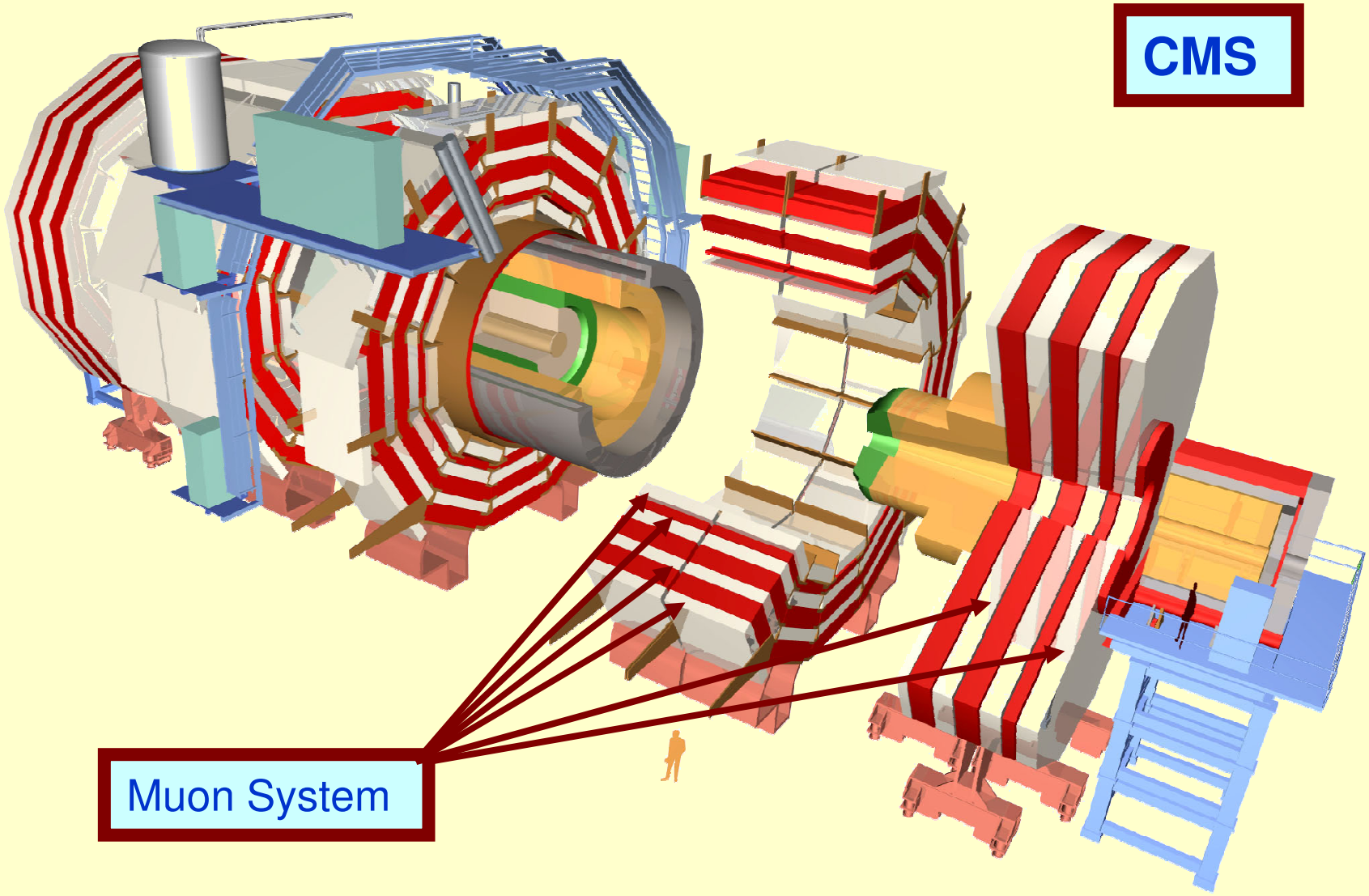


FOUR SEAS CONFERENCE
ISTANBUL 2004

The CMS muon system

L. Litov
CERN & University of Sofia

CMS: design & construction



System Conditions & Requirements

System Conditions

Barel $\eta < 1.3$

Particle rates < 10 Hz/cm^2

Low Magnetic field

Endcap $0.9 < \eta < 2.4$

Particle rates **100-1000 Hz/cm^2**

Magnetic field

Uniform axial **> 3 T in ME1/1**

Highly non-uniform radial field

Up to 1 T in ME1/2

Requirements

- **Muon identification**
- **Muon Trigger**
  - **Unambiguous BX identification**
  - **Trigger single and multimuon with well defined pt thresholds few GeV to 100 GeV**
- **Muon momentum measurement**
  - **Charge assignment correct to 99% confidence level up to 7 TeV**
  - **Momentum resolution**
    - **Stand alone**

dpt/pt = 8 - 15% at pt = 10 GeV

dpt/pt = 20 - 40% at pt = 1 TeV

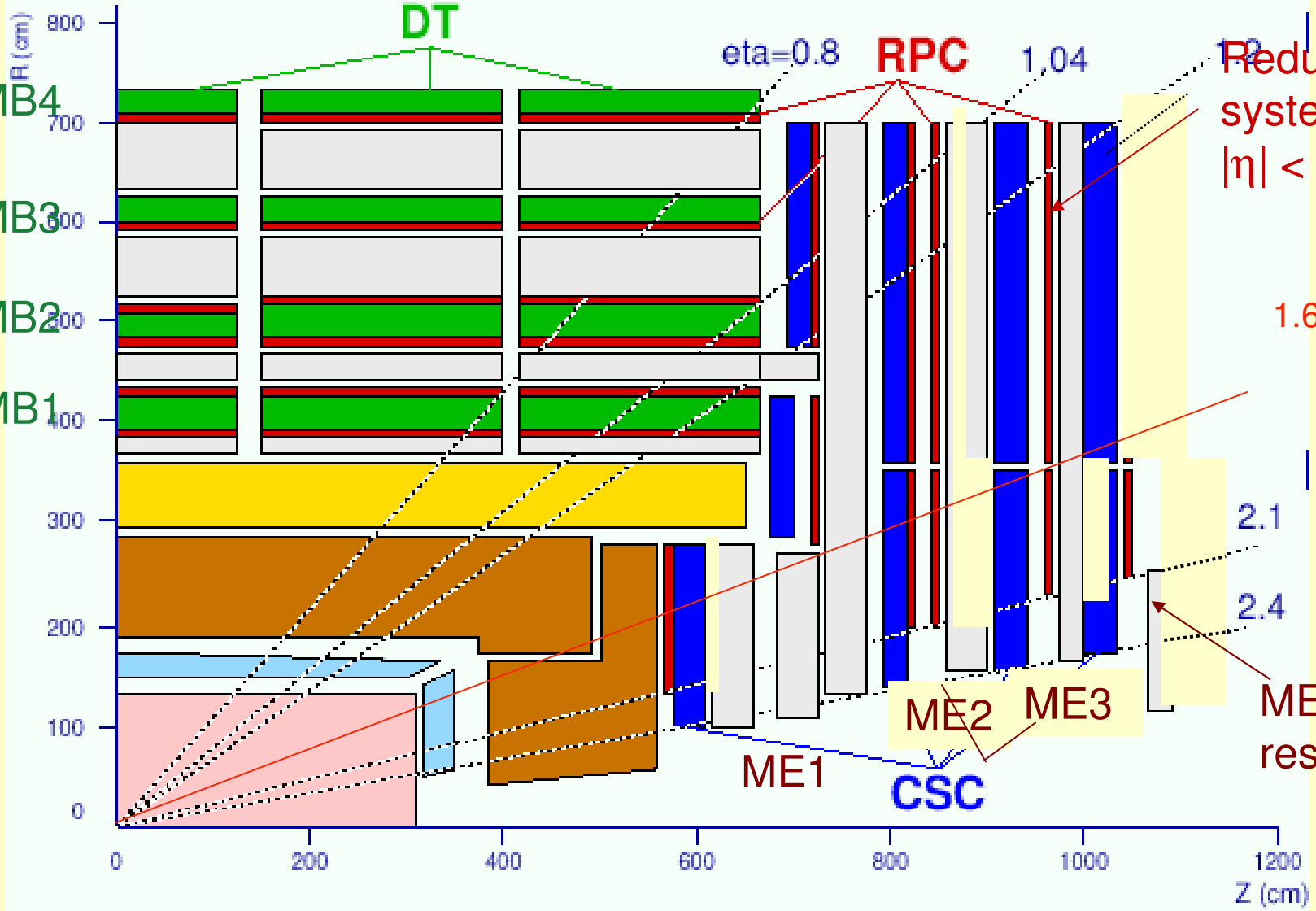
- **Global**

dpt/pt = 1 - 1.5% at pt = 10 GeV

dpt/pt = 6 - 17% at pt = 1 TeV

CMS Muon System

¼ longitudinal slice



Requirements

Resolution (per station)

Position RΦ : 100 μm

Z : 150 μm

Angle: 1 mrad

BX identification Efficiency

>98% per station

Spatial resolution (Φ) (per station)

75 μm ME1/1 and ME1/2

150 μm for the others

(At the trigger level < 2mm)

Correct BX identification

> 92% per chamber (→ 99% global)

Trigger Track Efficiency >99 % per chamber

Drift Tubes - DT

Cathode Strip Chambers - CSC

BARREL

ENDCAP

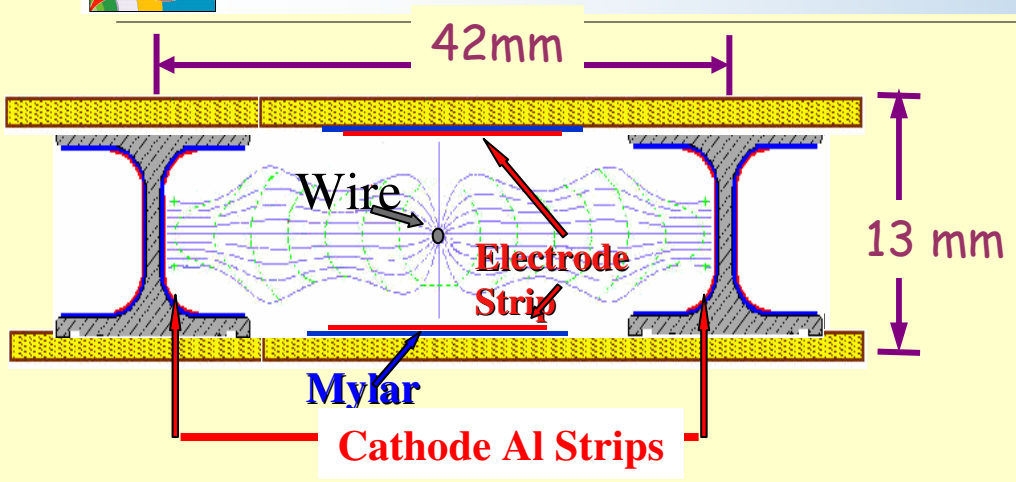
Resistive Plate Chambers - RPC

(Dedicated Trigger Detector)

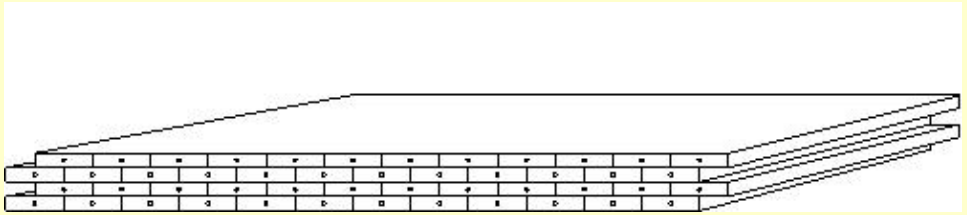
- Good timing : Resolution < 3ns (RMS), 98% within a 20ns window
- Good Rate capability
- Low cluster size
- High efficiency > 90% per chamber (→ 95% global)
- rΦ resolution ~ 1cm

Barrel Drift tube chambers

Drift Tube Chambers



4 Layers = 1 *Superlayer* (SL)



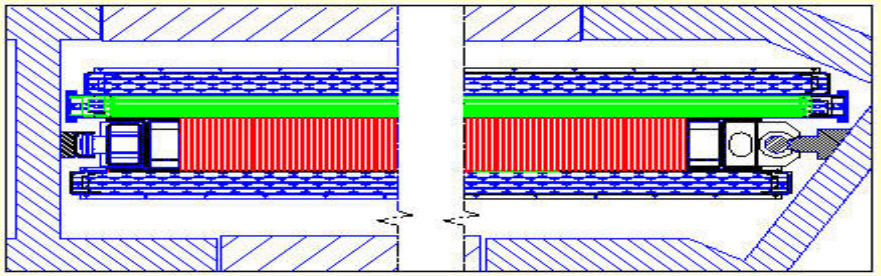
Independent Subunit

(Gas tightness, HV, Front End)

GAS: Ar/CO_2 (85/15)

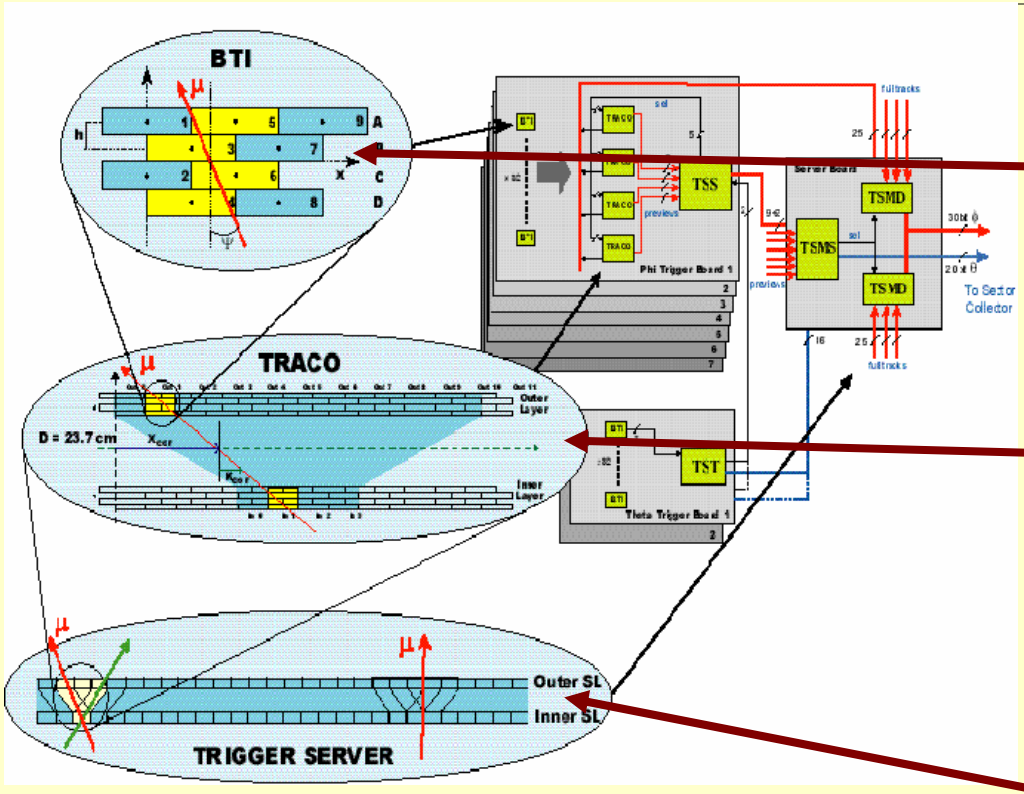
HV: Wires 3600 V
Strips 1800 V
I-beams -1200 V

Φ SL
θ SL
Honeycomb
Φ SL



Tmax:	380 ns	Single Wire ➡	100μm Φ
Drift Velocity :	~ 55μm/ns	Resolution : < 300 μm	150μm θ

DT Local Trigger



Bunch Track Identifier (BTI)

- Combines superlayer hits in track segments
- Allows effective BX identification

TRAck COrellator

Combines segments from 2 Φ SL

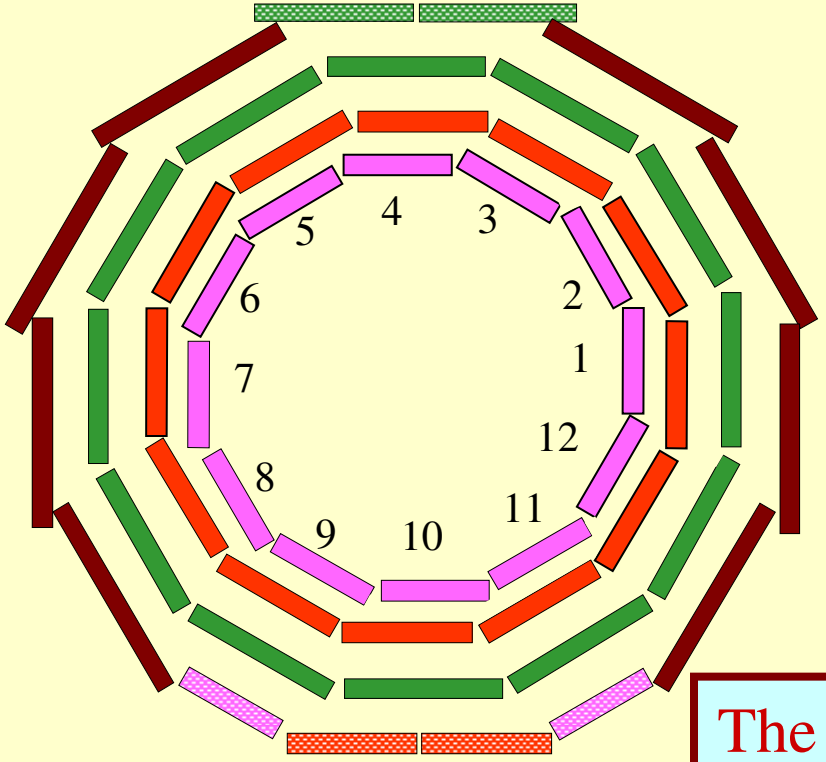
Trigger Server (TS)

Collects TRACO combinations and η segments
Selects the 2 best segments for the DT Track Finder

Track Finder

Connects the track segments into a full track and assigns Pt , Φ and η → **2 best track are send to Global Muon Trigger**

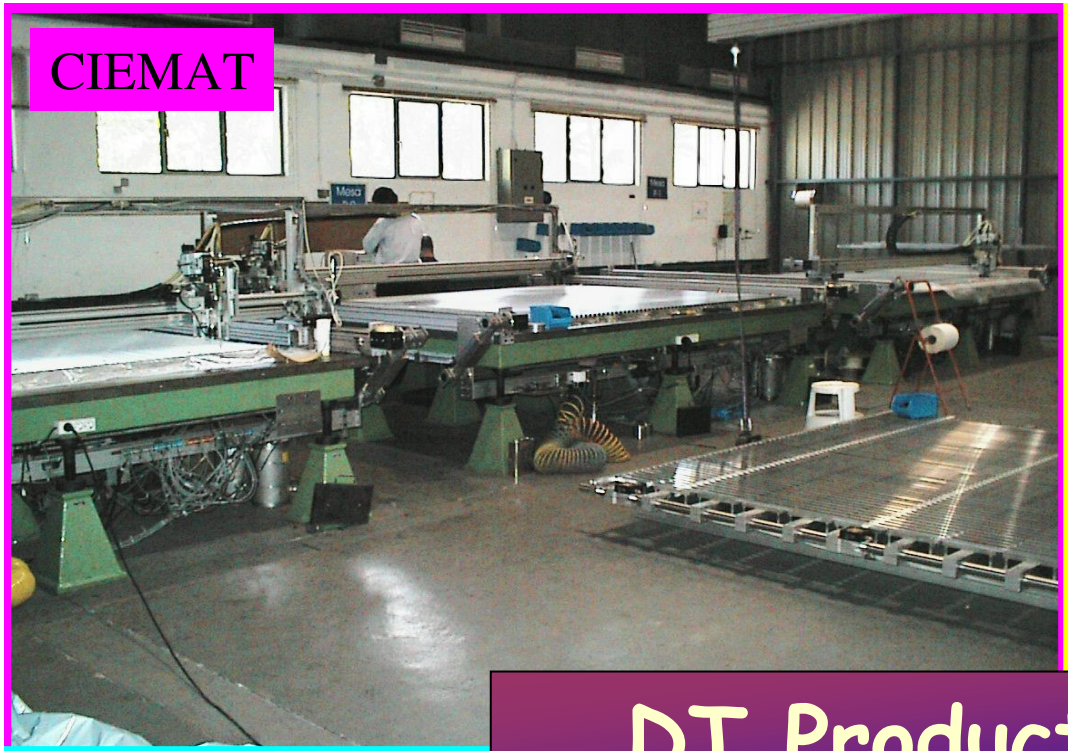
Barrel Muon DT



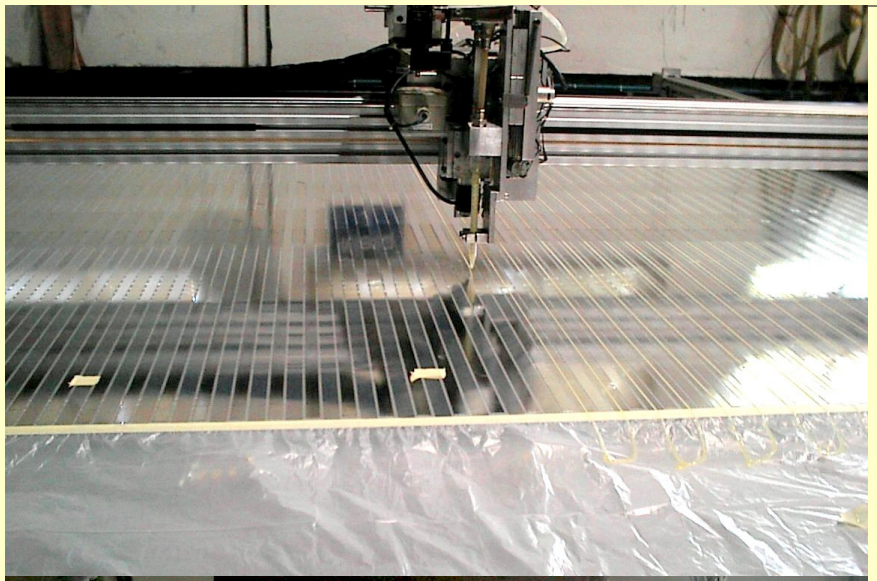
60	MB1	3SL	2 RPC ~2.0 x 2.54 m^2	960kg
60	MB2	3SL	2 RPC ~2.5 x 2.54 m^2	1200kg
60	MB3	3SL	1 RPC ~3.0 x 2.54 m^2	1300kg
40	MB4	2SL	1 RPC ~4.2 x 2.54 m^2	1800kg
10	MB1	2SL	1 RPC	
10	MB2	2SL	1 RPC	
10	MB3	2SL	1 RPC	

The Barrel Muon system comprises 250 chambers
In 7 flavors for 5 wheels
Total 1700 m^2

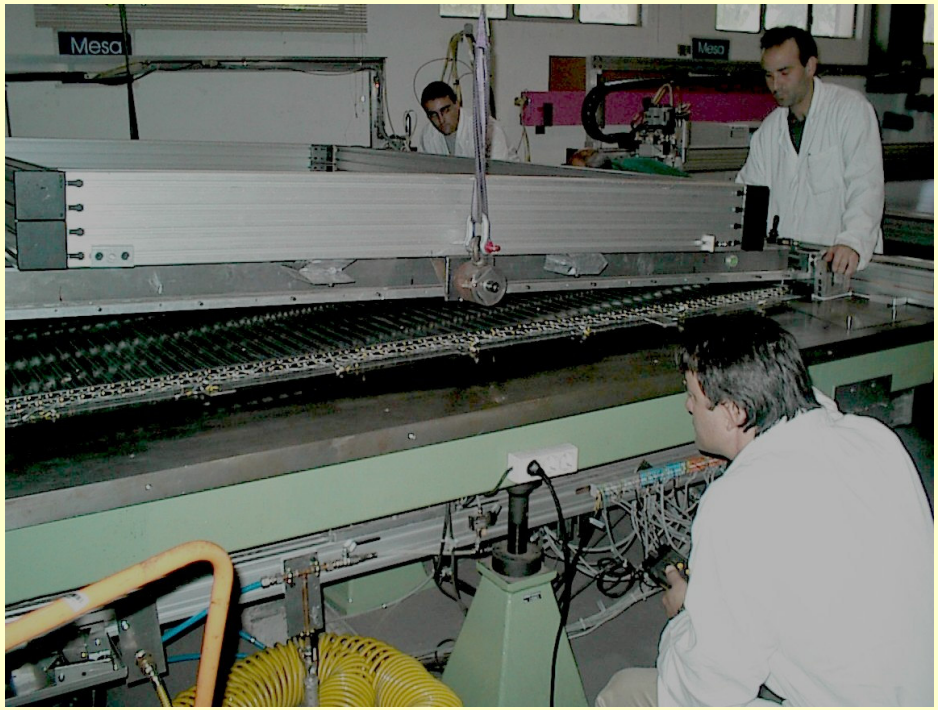
DT Production Sites



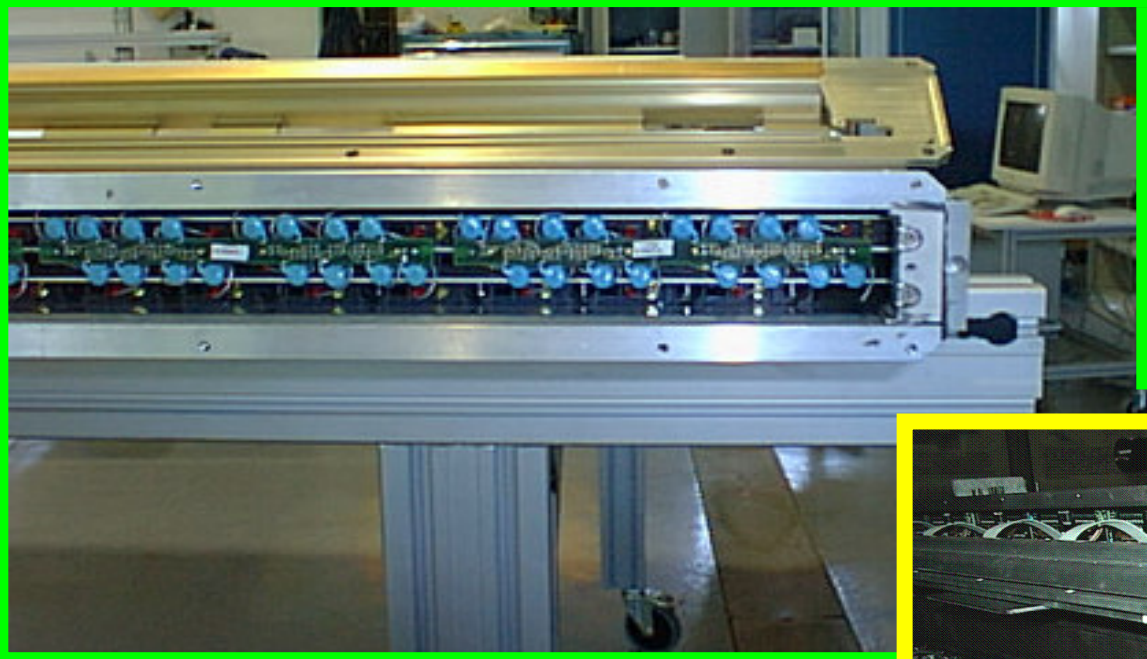
DT Assembly

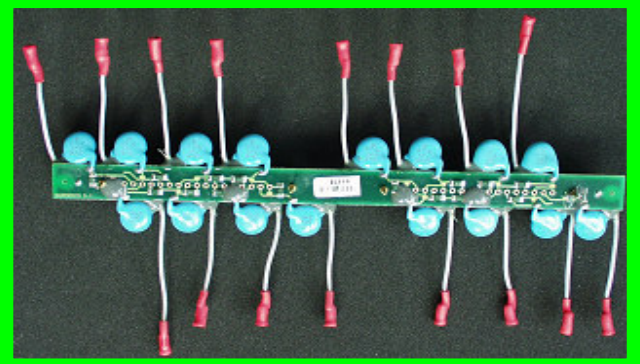


- Plates with strip electrodes
- Catode I beams
- Wires and wire fixation pieces
- Corner blocks and frames

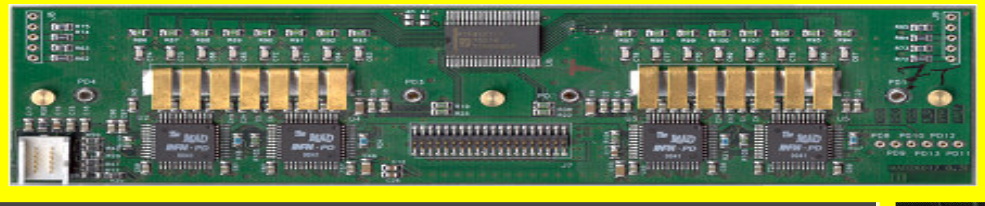


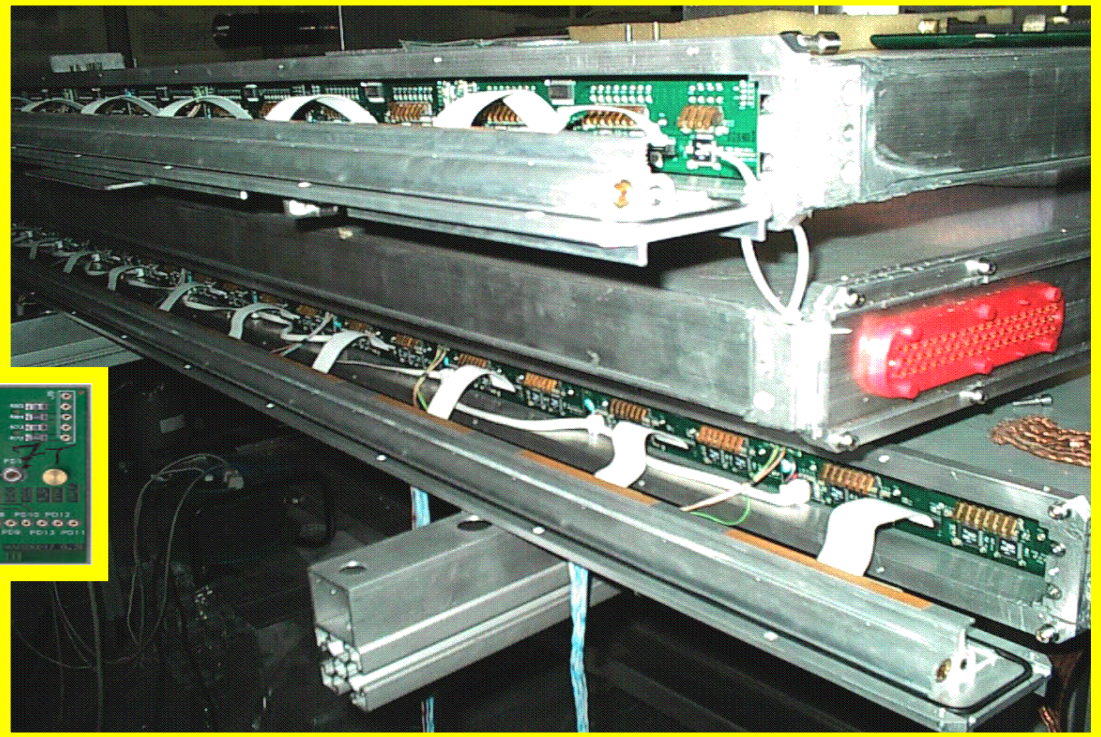
FE Electronics side



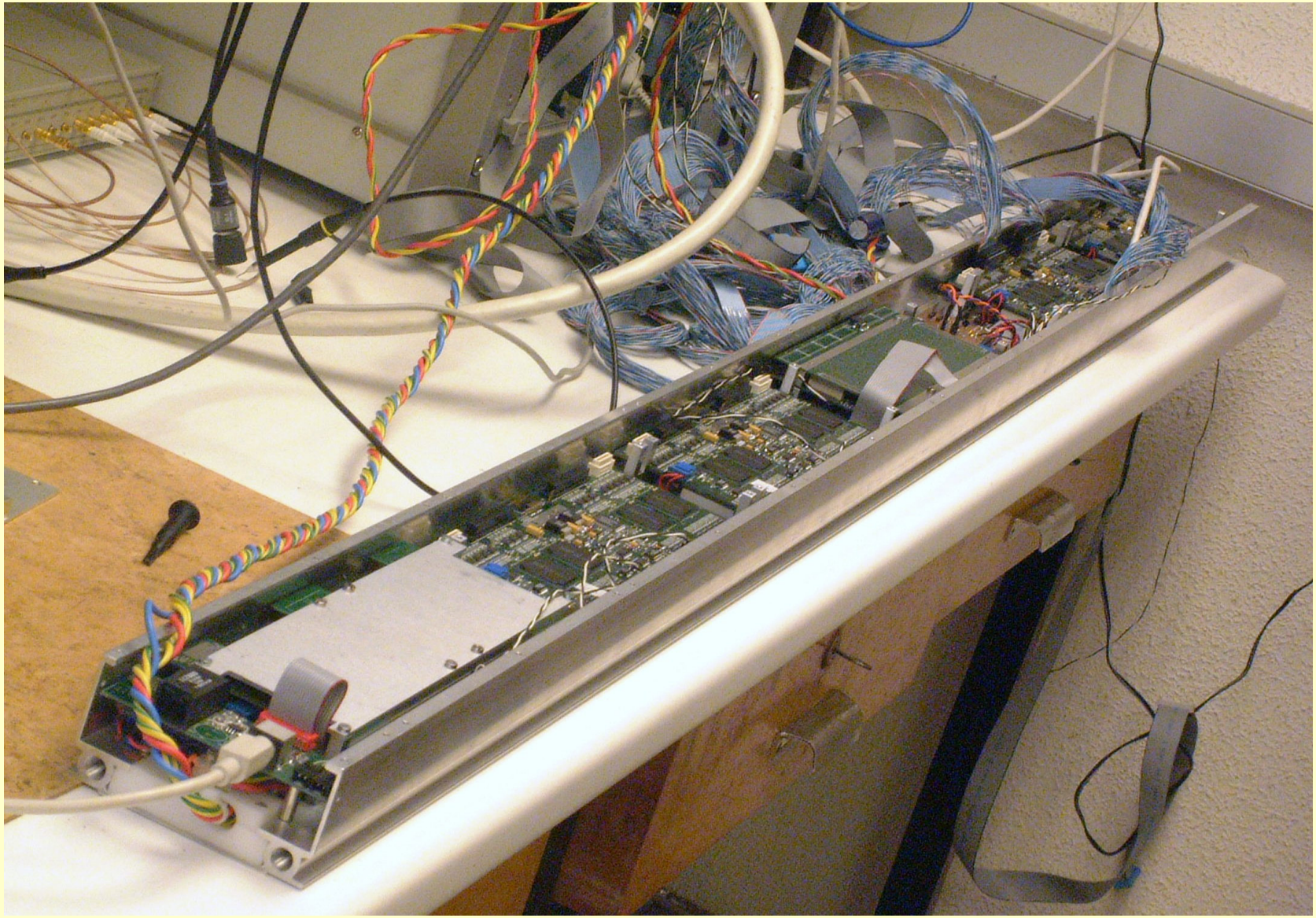


FE BOARDS





Minicrate (TE)

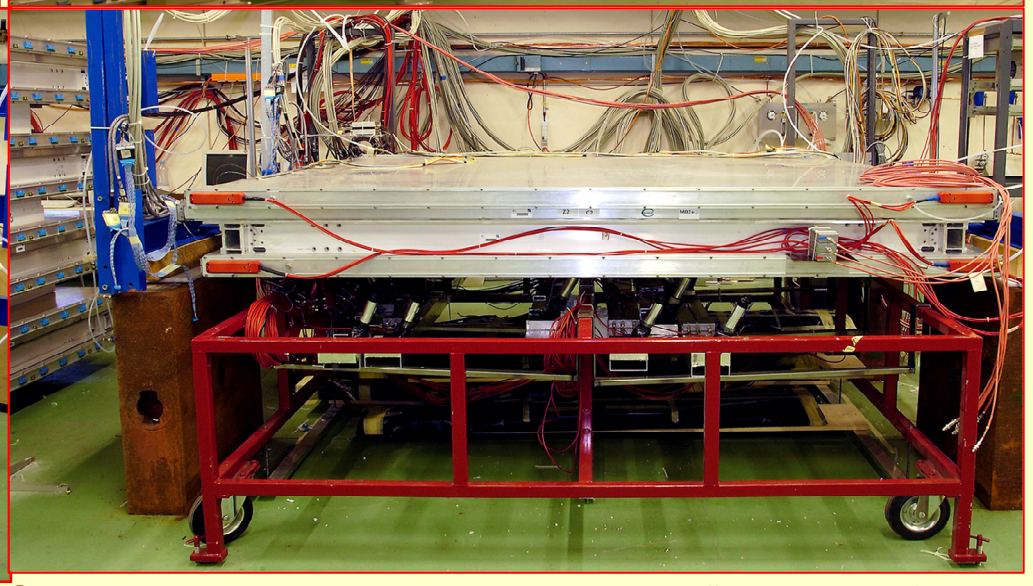


ISR Chamber preparation

DT chambers are sent to the ISR for full tests

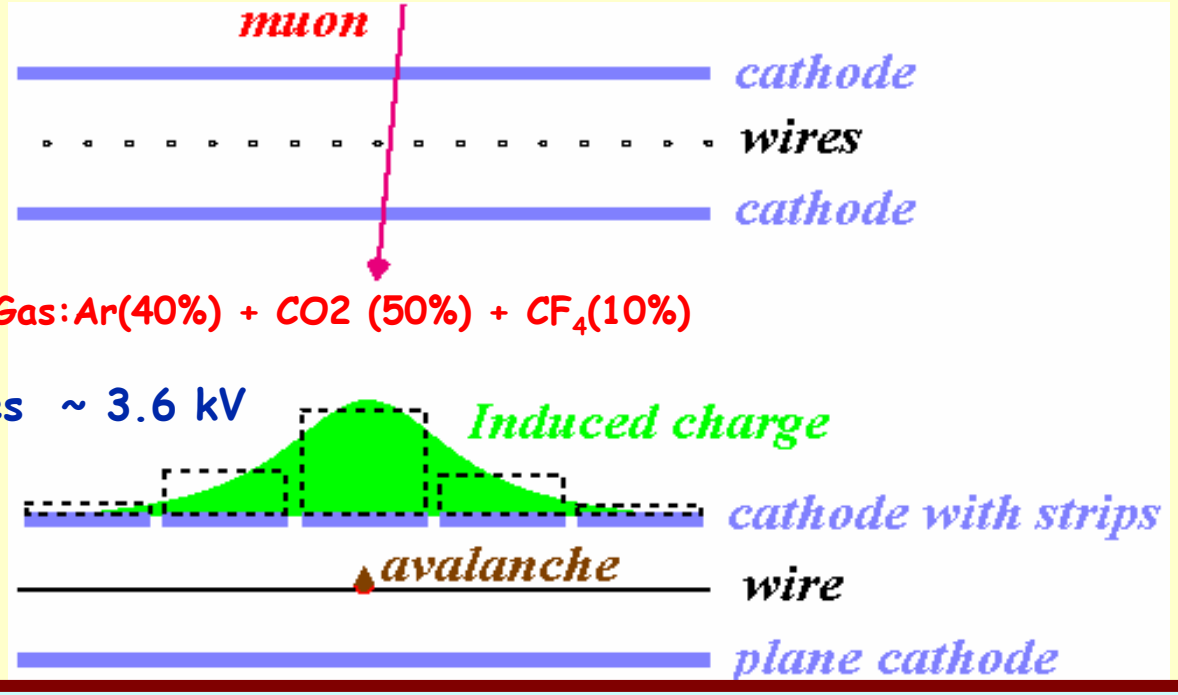
1. Acceptance tests: HV, Leak-rate,noise, cosmics
2. DT alignment calibration
3. DT cabling+services
4. DT assembly with RPCs

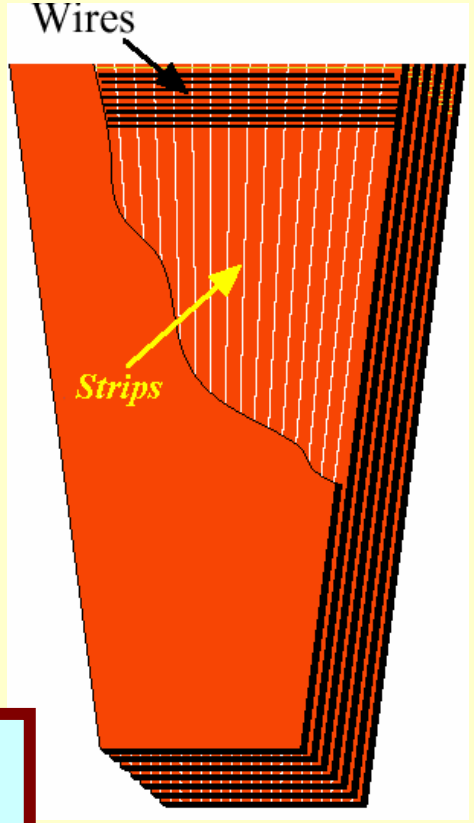
Storage in transport frames



Cathode Strip Chambers

Cathode Strip Chambers (CSC)





Trapezoidal Chambers (10^0 or 20^0 in Φ), 6 layers

Radial cathode strips – measure Φ (75-150 μm)

Wires orthogonal to strips

Precise timing measurement (BX) - ~4.5 ns

Coarse measurement of the radial position (16-54 mm)

CSC Local Trigger

Cathode trigger – Optimized to measure Φ precisely

By combining 6 layers (1 chamber) → 0.15 –strip ~1,2 mm

Anode trigger – Optimized to efficient BX identification

For each spatial pattern a low level coincidence (≥ 2 layers) is used to establish timing

A higher level coincidence

(≥ 4 layers) is required to establish a muon track

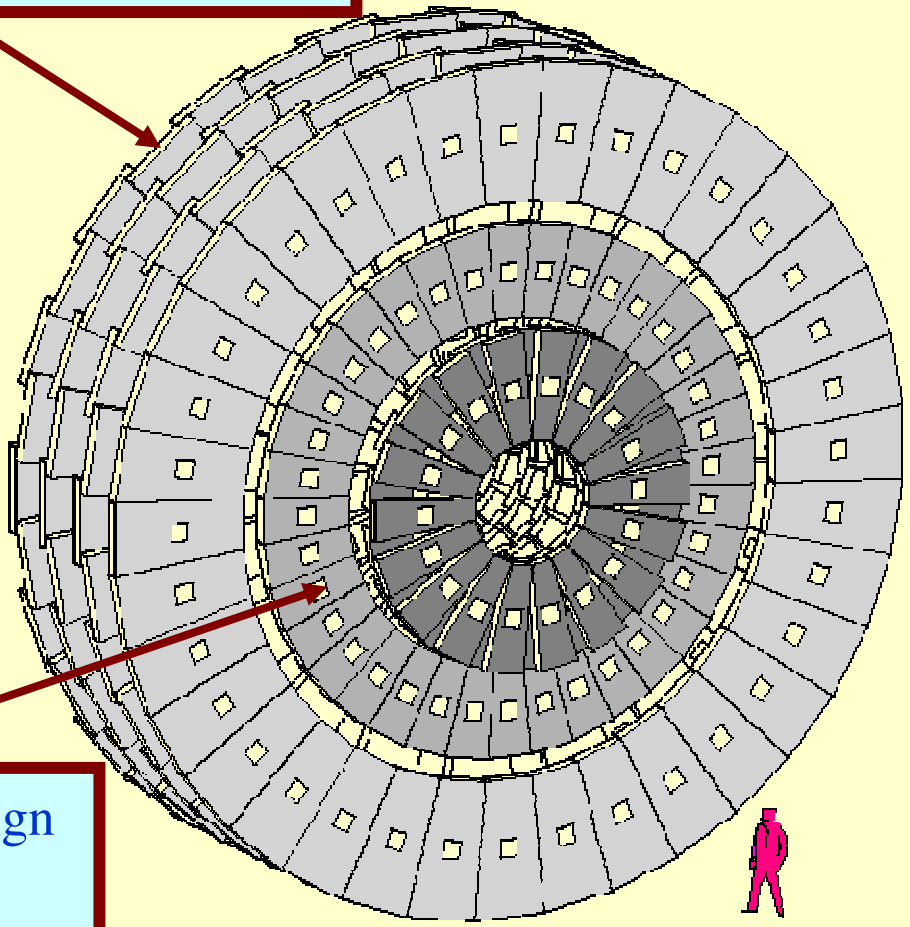
ALCT+CLCT → Time + Location+Angle are send to CSC Track Finder

Track Finder =reconstruct tracks using 3-D spatial information Assigns pt, Φ and η

Select the 4 highest quolity candidates and sends them to the **Global Muon Trigger**

CSC

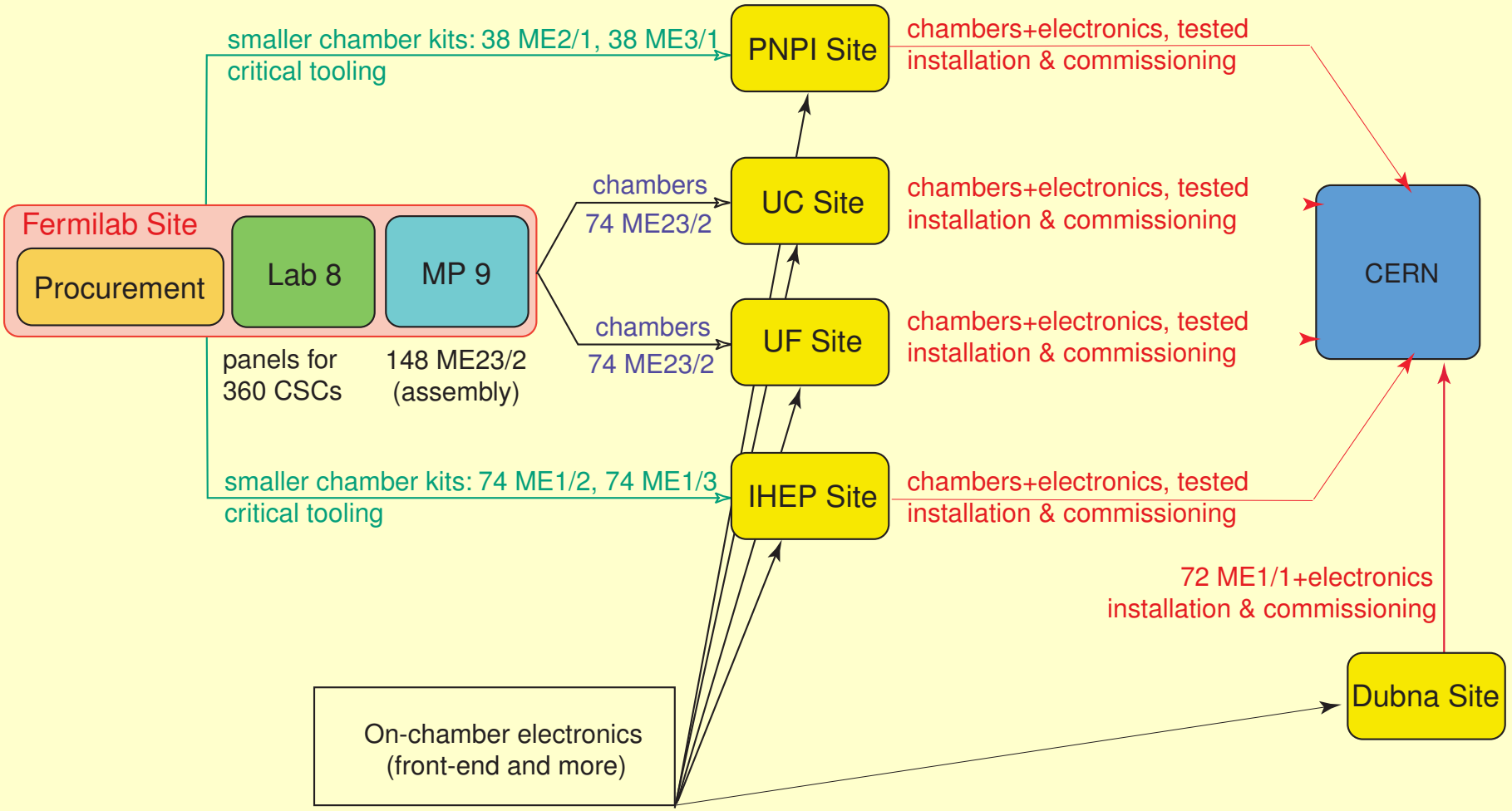
Outer section of 4'th station staged



6 planes per chamber
468 chambers
6000 m^2 sensitive area
2 Million wires
220 K cathode channels
1 chamber ~ 1000 readout chanels

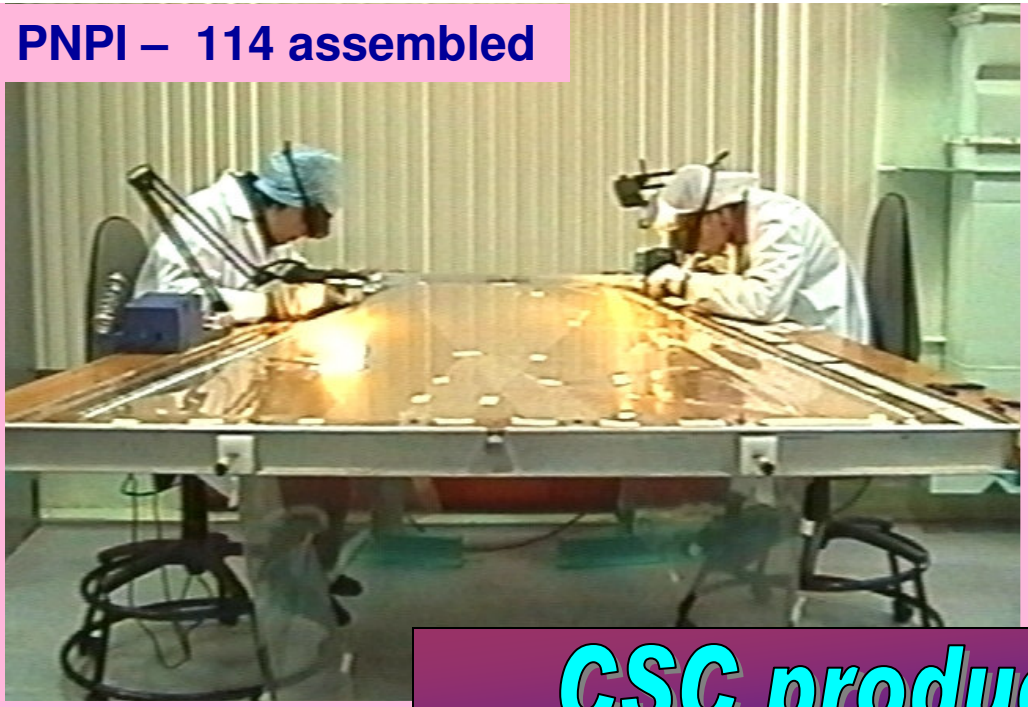
ME1/1 –special design
Inserted in endcap
Calorimeter support

CSC Production



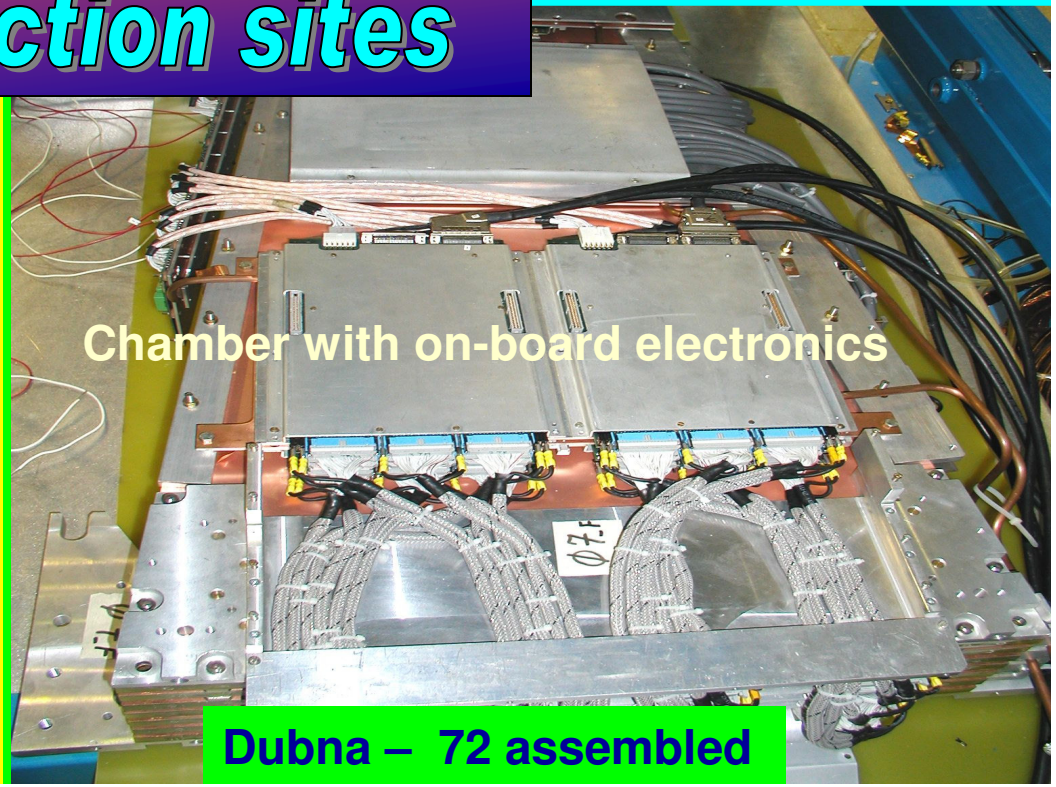
CSC production sites

PNPI – 114 assembled



IHEP – 148 assembled

FNAL – 148 assembled

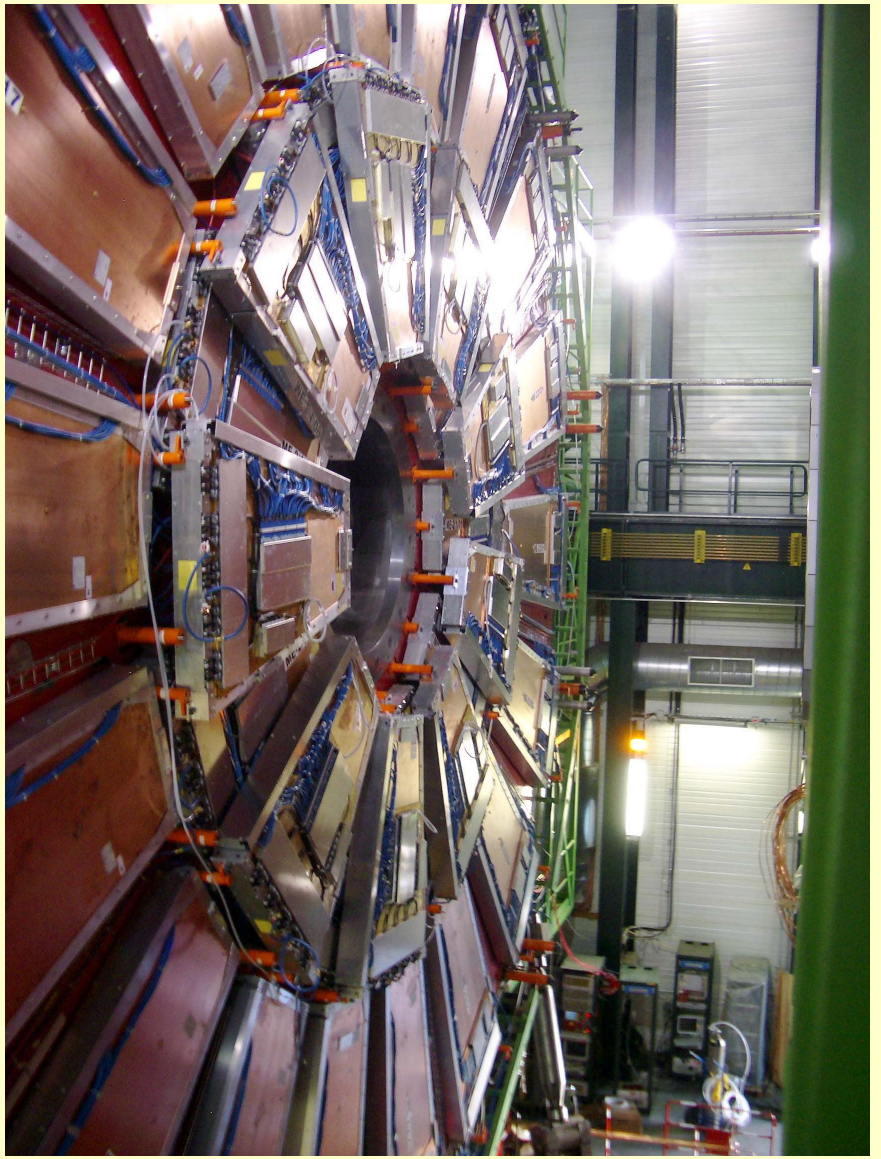


Dubna – 72 assembled

ISR FAST Site

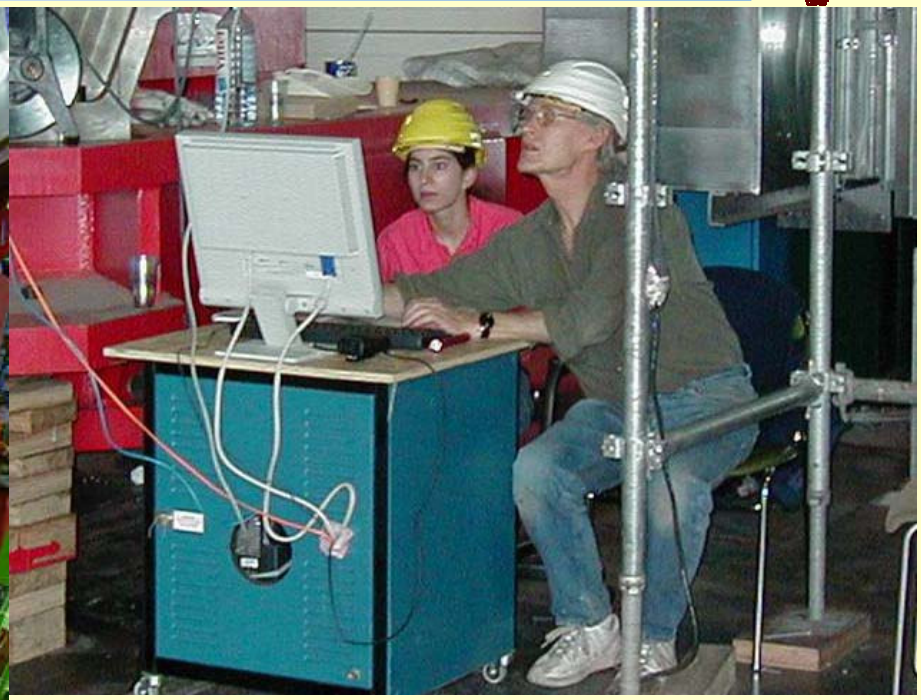
Final Testing before installation at SX5

CSC Installation



Readout cables & Walkway

Chamber commissioning at SX5



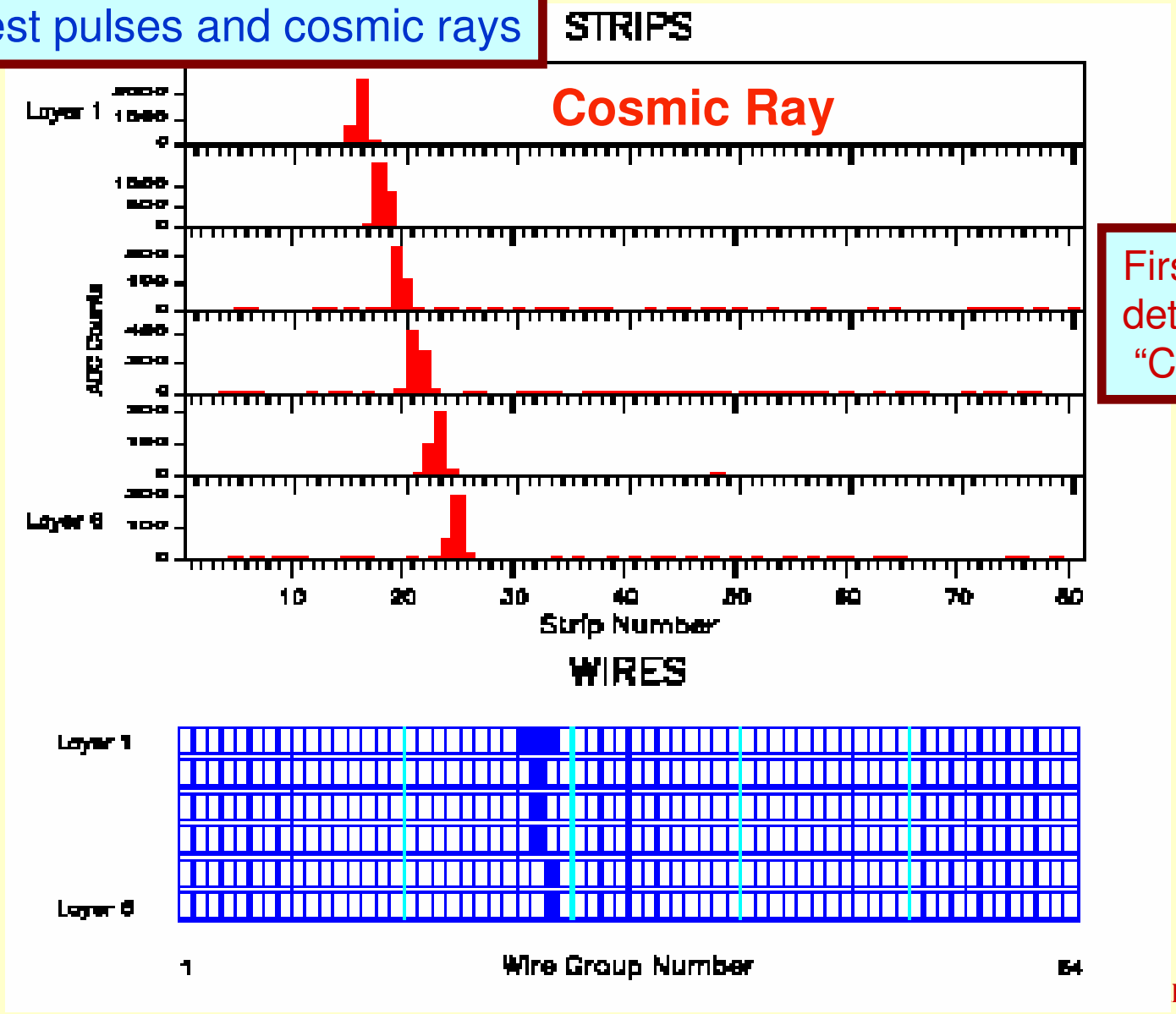
Commissioning of CSCs+on chamber electronics follows installation

Use a subset of FAST site tests

Some additional tests: e.g. skew-clear cable delays, long term tests under LV

Chamber commissioning at SX5

using test pulses and cosmic rays



First particles detected by installed "CMS" subsystem!!

Resistive Plate Chambers

Resistive Plate Chambers

Resistive Plates – bakelite with bulk resistivity $(2 \pm 1).10^{10}\Omega$cm

Gas gap (2mm ± 20μm wide)

Gas mixture, containing

96% $C_2H_2F_4$(Freon),

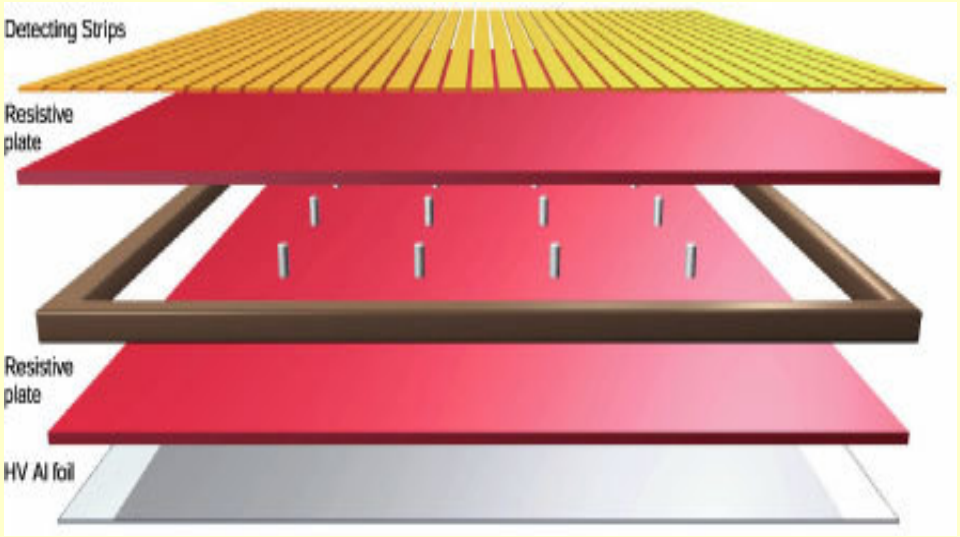
3,5 % isobutan, SF_6 – 0.5 %

Graphite electrodes with resistivity 300 kΩ / cm

Insulating PET film (0.3 mm thick)

Detecting copper strips

40μm thick,2–4 cm wide and 1250 mm long

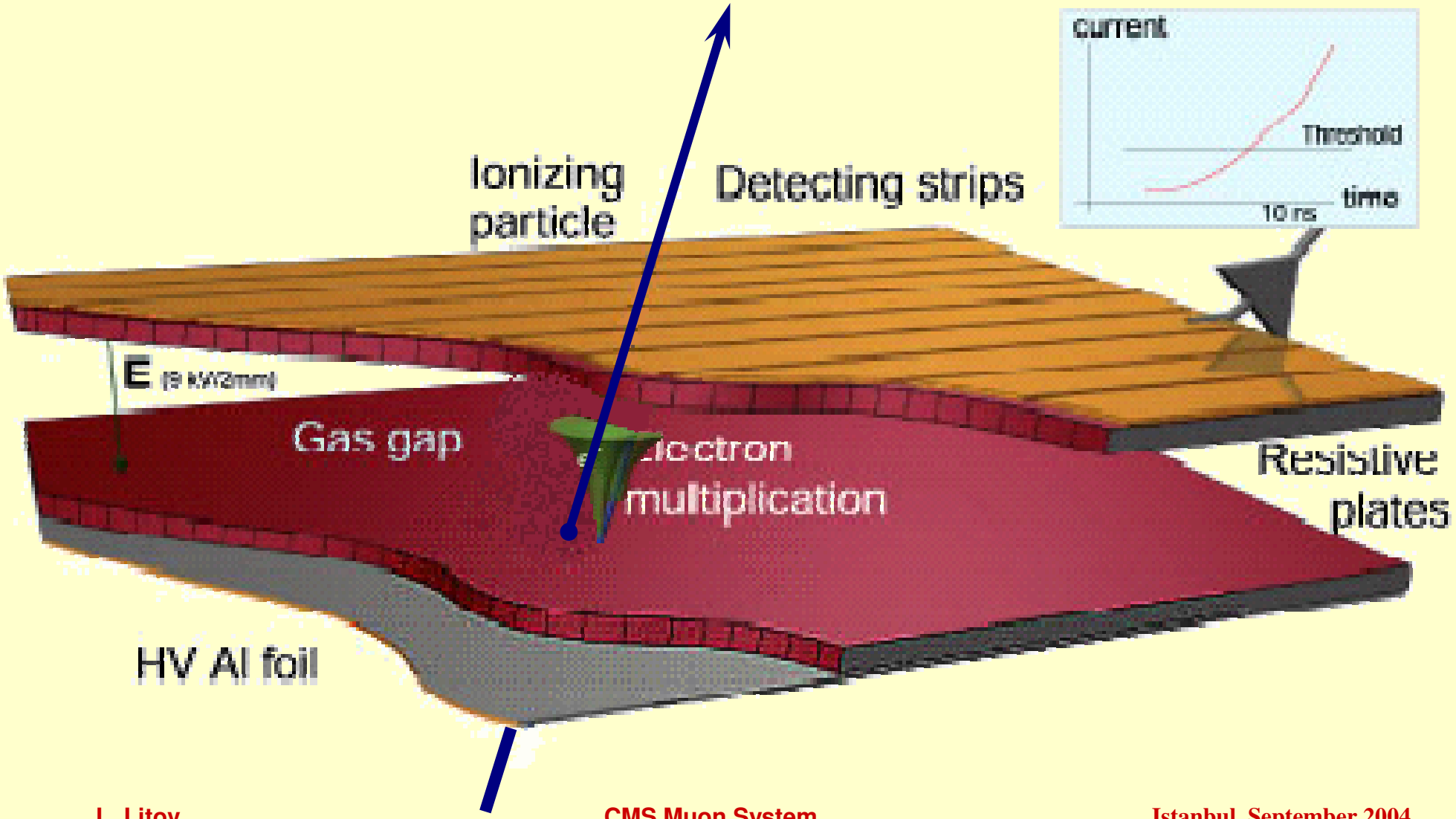


Spacers (cylinders with diameter 10 mm and height 2mm)

Copper shielding

Linseed oil treatment

RPC - Principle of Action



CMS RPC

Fast detectors for the first level trigger of the experiment

Considerably good space resolution

Able to work in areas with background ~ 10^3 Hz/cm^2

Price – as low as possible

Requirements

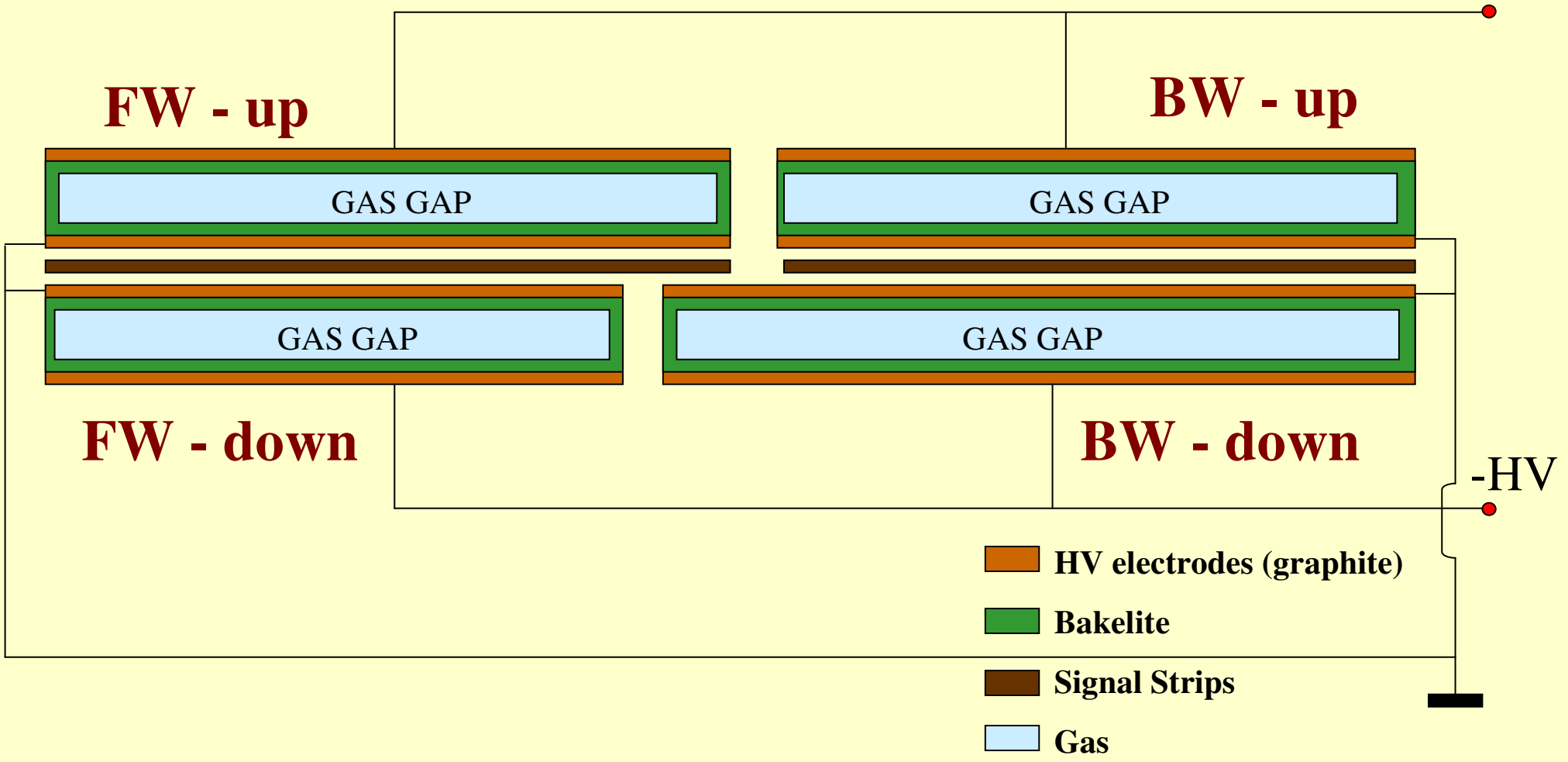
Time resolution ≤ 1.8 ns
(98 % within 20 ns)

Efficiency > 95 %

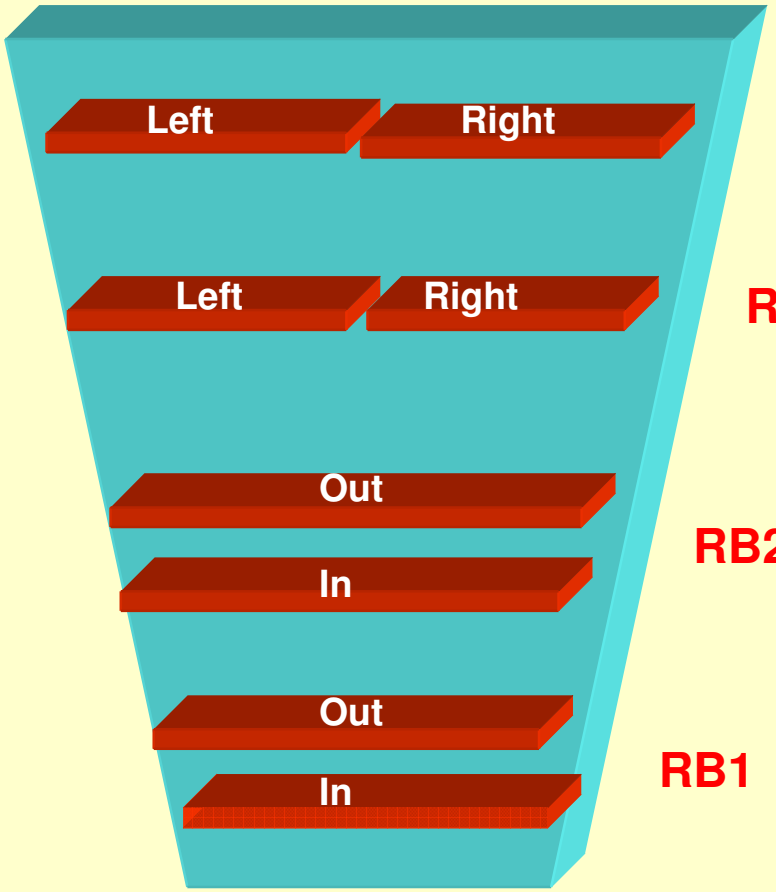
Rate capability ≤ 1kHz/cm2

- Average cluster size < 2 strips
- Number of streamers < 10%
- Operation plateau > 300V
- Power consumption 2-3 W/m^2
- Operational voltage 8.5 –10 kV

Double gap design



Main Barrel RPC Types



Length: 2.455 m

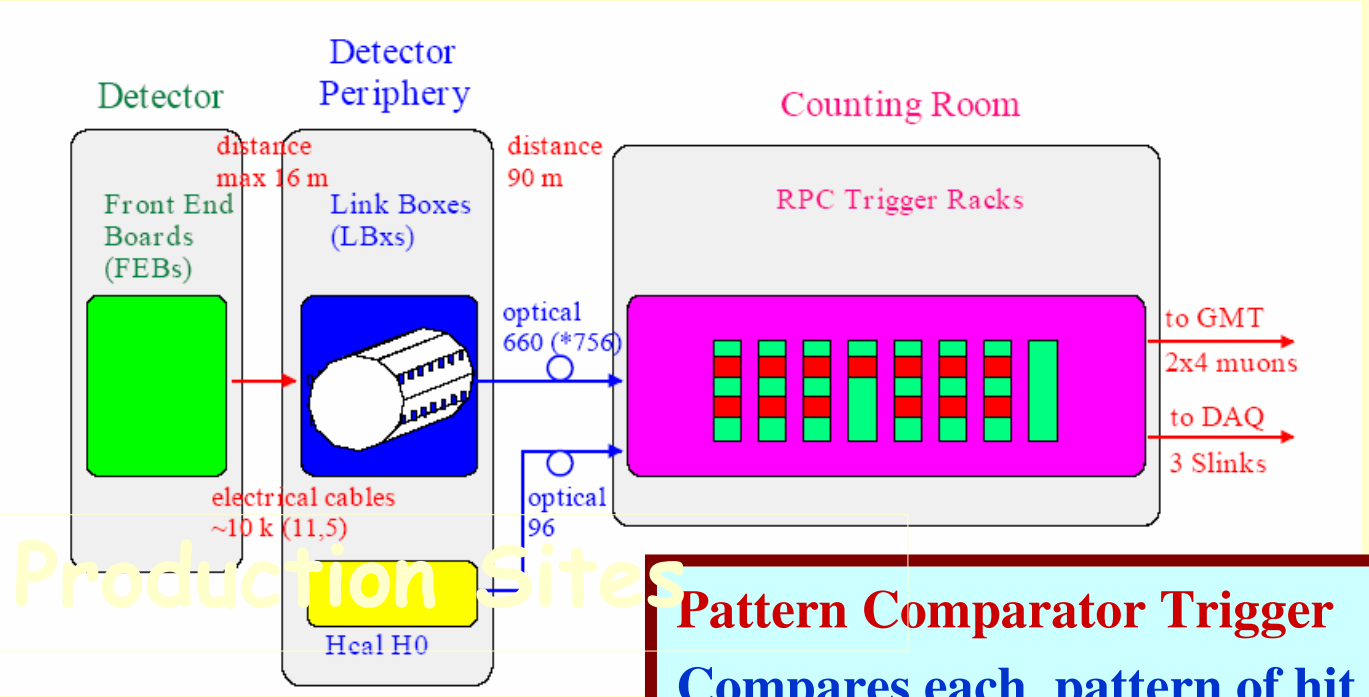
Width: 1.5, 2.0 , 2.5 m
Pitch: 40.8, 40.6, 41.0 mm
 # Strips for Gap: 48, 36, 48, 60

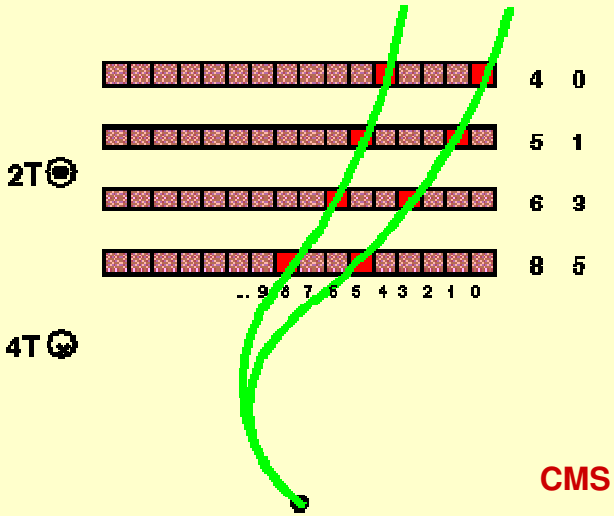
Width: 1.48 m
Pitch: 34.8 mm
 # Strips for Gap: 42

Width: 1.5, 2.0 , 2.5 m
Pitch: 27.3, 29.3 mm
 # Strips for Gap: 84, 90

Width: 1.5, 2.0 , 2.5 m
Pitch: 22.7, 24.3 mm
 # Strips for Gap: 84, 90

RPC data flow and trigger





Pattern Comparator Trigger

Compares each pattern of hit strips to predefined patterns corresponding to various pt

RPC Muon sorter

Selects 4 highest pt muons from the barrel and 4 from the endcaps and sends them to the Global Muon Trigger

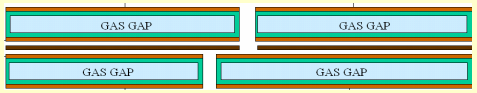
Barrel RPC Production

Chambers production and quality certification involve several steps.

Single gap

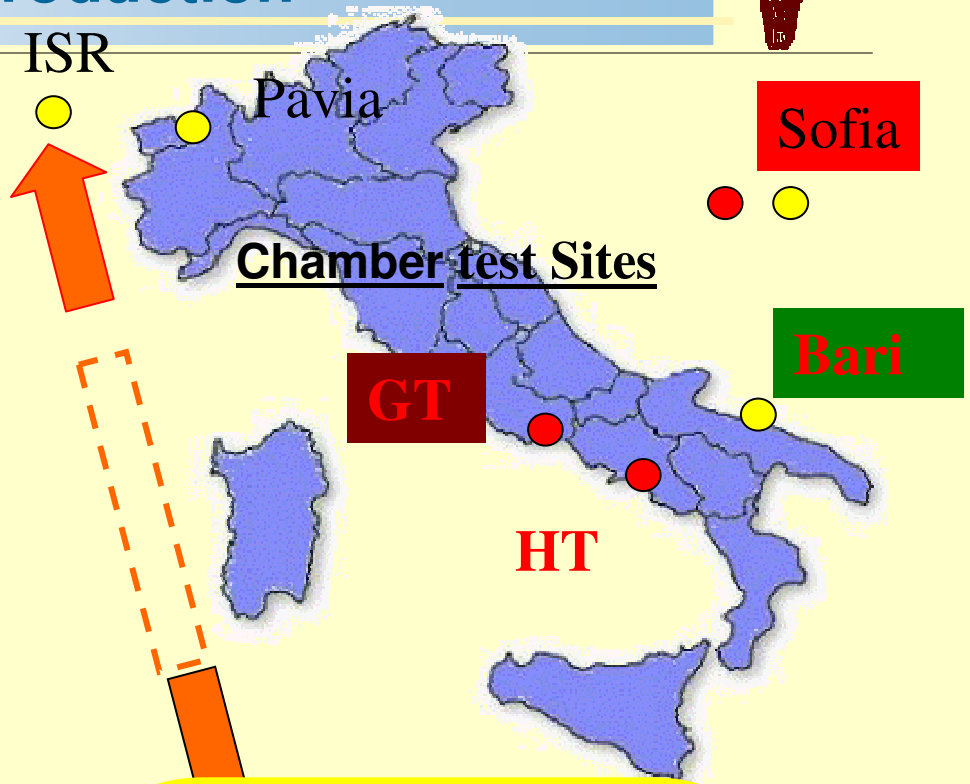
GT

Double gap



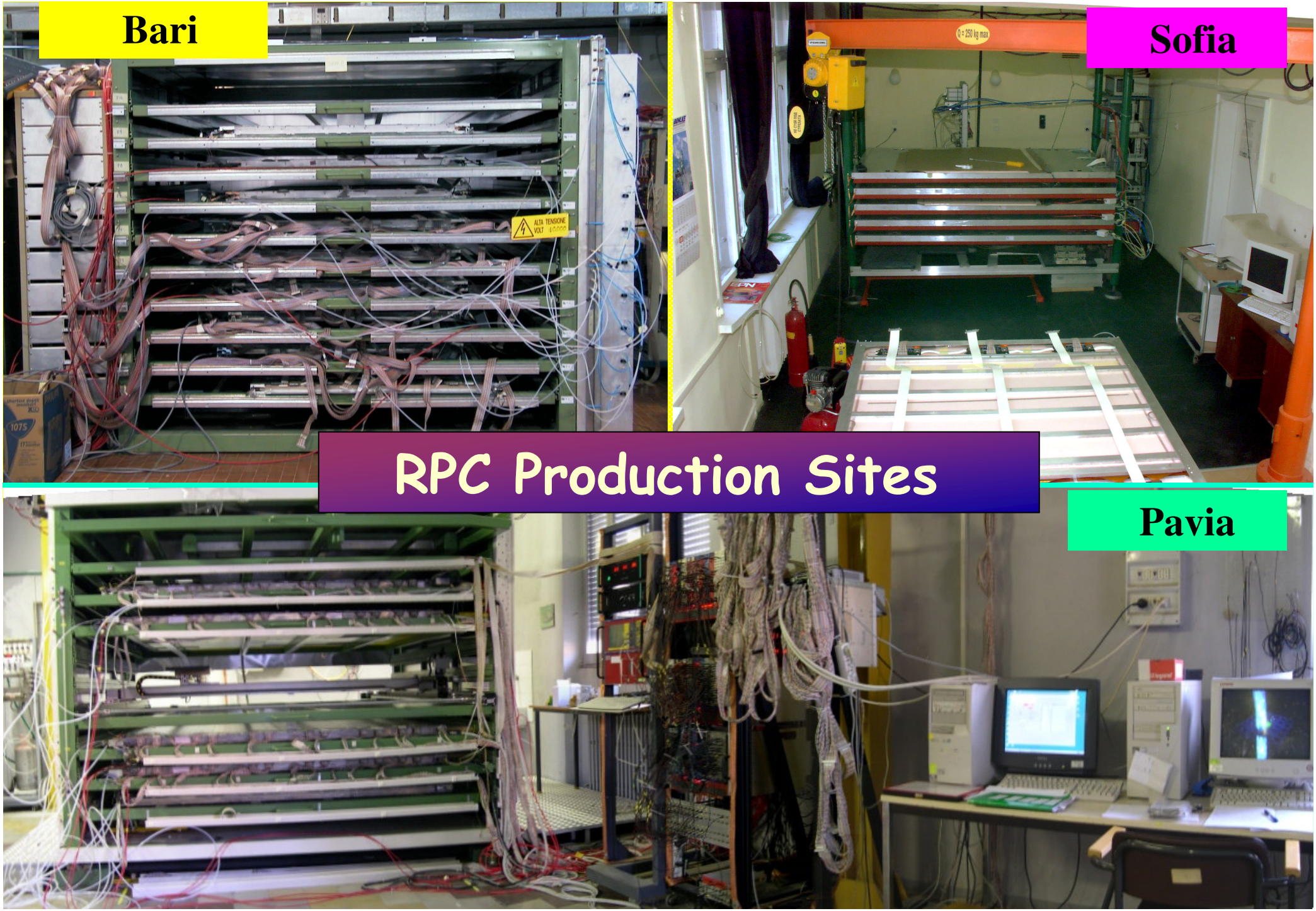
Chamber assembling Sites

120 RB1 at HT
240 RB2 and RB4 at GT
120 RB3 in Sofia (& Bari)



Chamber test Sites

RB1 in Pavia
RB2 & RB4 in Bari
RB3 in Sofia (& Bari)


Bari
Sofia
RPC Production Sites
Pavia


ISR RPC storage and test area

Installation of DT and RPC

At ISR

Coupling RPC to DT

Fast test

Transportation to SX5(CMS surface hall)

At SX5

Installation in the CMS Detector

Started in June

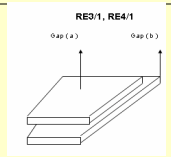

20 chambers installed in two weeks

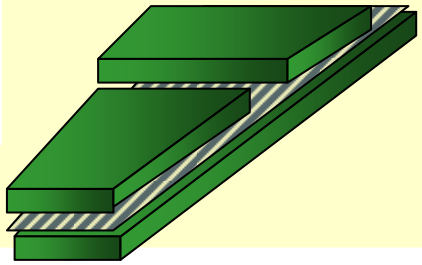
Endcap RPC

China

Korea

Pakistan





CERN

Project Co-ordination

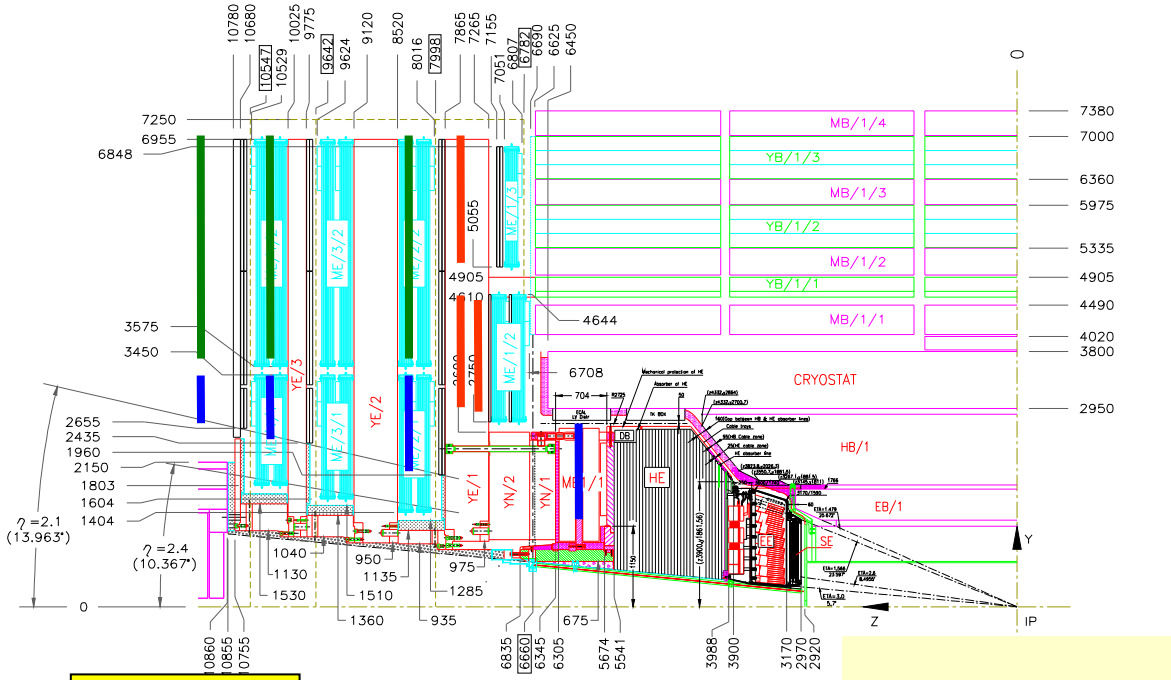
ISR Assembly Station

Gap production

Korea

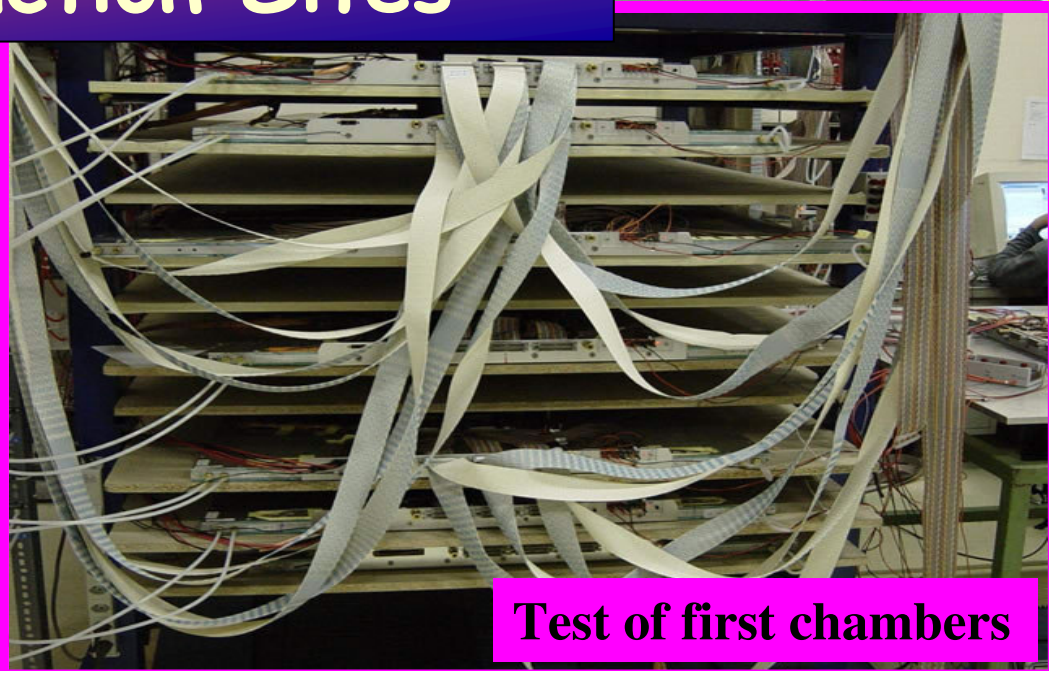
Front-end electronics

Pakistan



	RE 1/1		RE 2/1		RE 3/1	RE 3/2	RE 3/3	RE 4/1	RE 4/2
No. of chambers	36*2		18*2		18*2	36*2	36*2	18*2	36*2

RPC Production Sites



Summary

CMS Muon System – big international project - 3 Continents

DT Chambers

136/250 DT chambers produced.

Delivered to CERN -115

Installed -20

End production around mid 2005

Few months delay due to problem with HV distribution boards

CSC Chambers

Production finished (482 chambers)

Tested - 80%

Delivered at CERN – 65%

Installed 25% .

RPC Chambers

232 chambers have been assembled (out of 480)

Production is going smothly. Two months delay on schedule.

192 chambers have been accepted after the cosmics test.

Endcap RPC – production started