Large Size Avalanche Mode RPCs for CMS

Yanlin Ye, Yong Ban, Sijin Qian, Yajun Mao

School of Physics, Peking University

CMS bulletin April 2006

The Compact Muon Solenoid Experiment

CMS Bulletin

CERN, CH-1211 GENEVA 23, Switzerland

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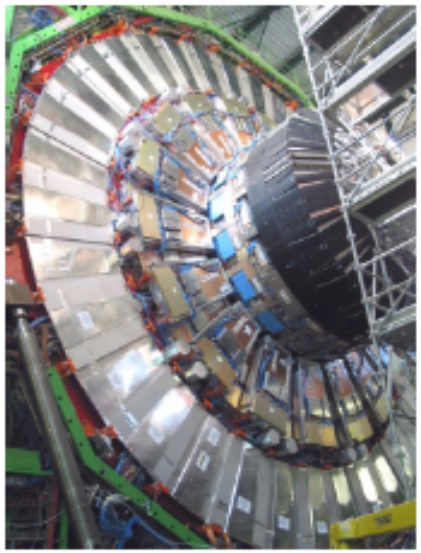
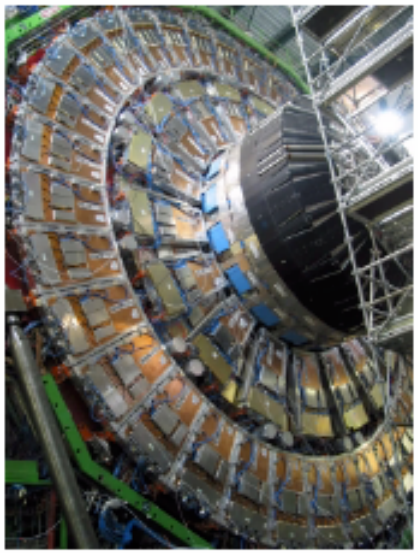
13 March 2006

Moving Forward !

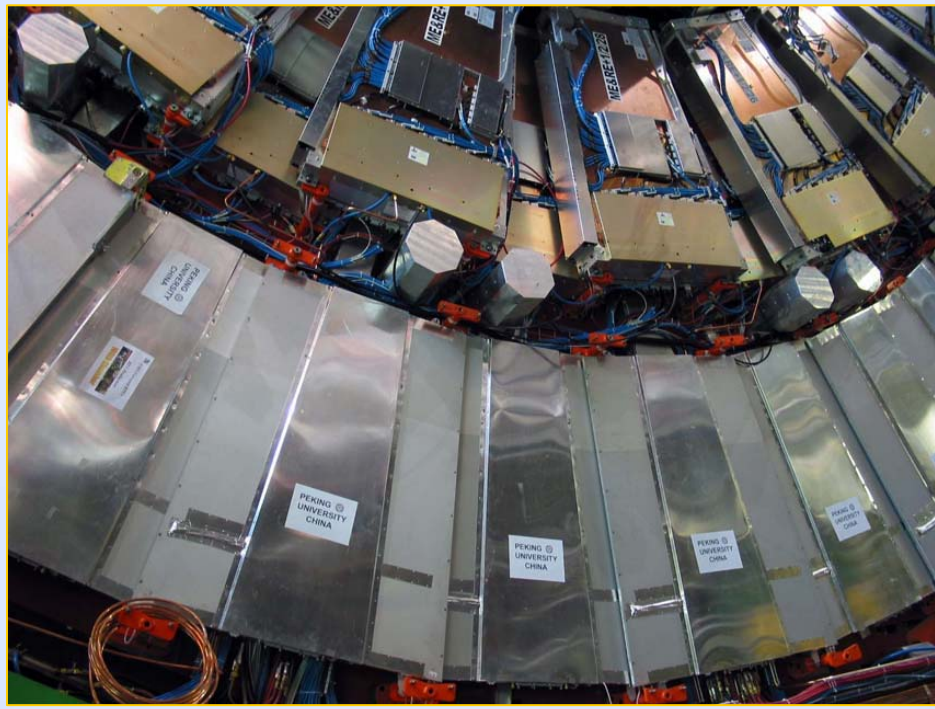


YE+1 yoke equipped with CSC/RPC packages (inner ring) and RE1/3 RPC's (outer ring).



The ME1/3 CSC's now cover the RPC outer ring and hence complete the first Muon station on YE+1.

Feb. 2006, RE1/3 installed on CMS



Outline

I. The Task

II. The R&D and prototyping

III. production and Installation

IV. Summary

I. The Task

FW-RPC: A "high priority" problem for CMS in 1996.

The Compact Muon Solenoid Experiment

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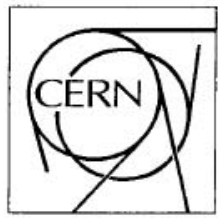

Date of publication: 06-09-96 Number 96-01

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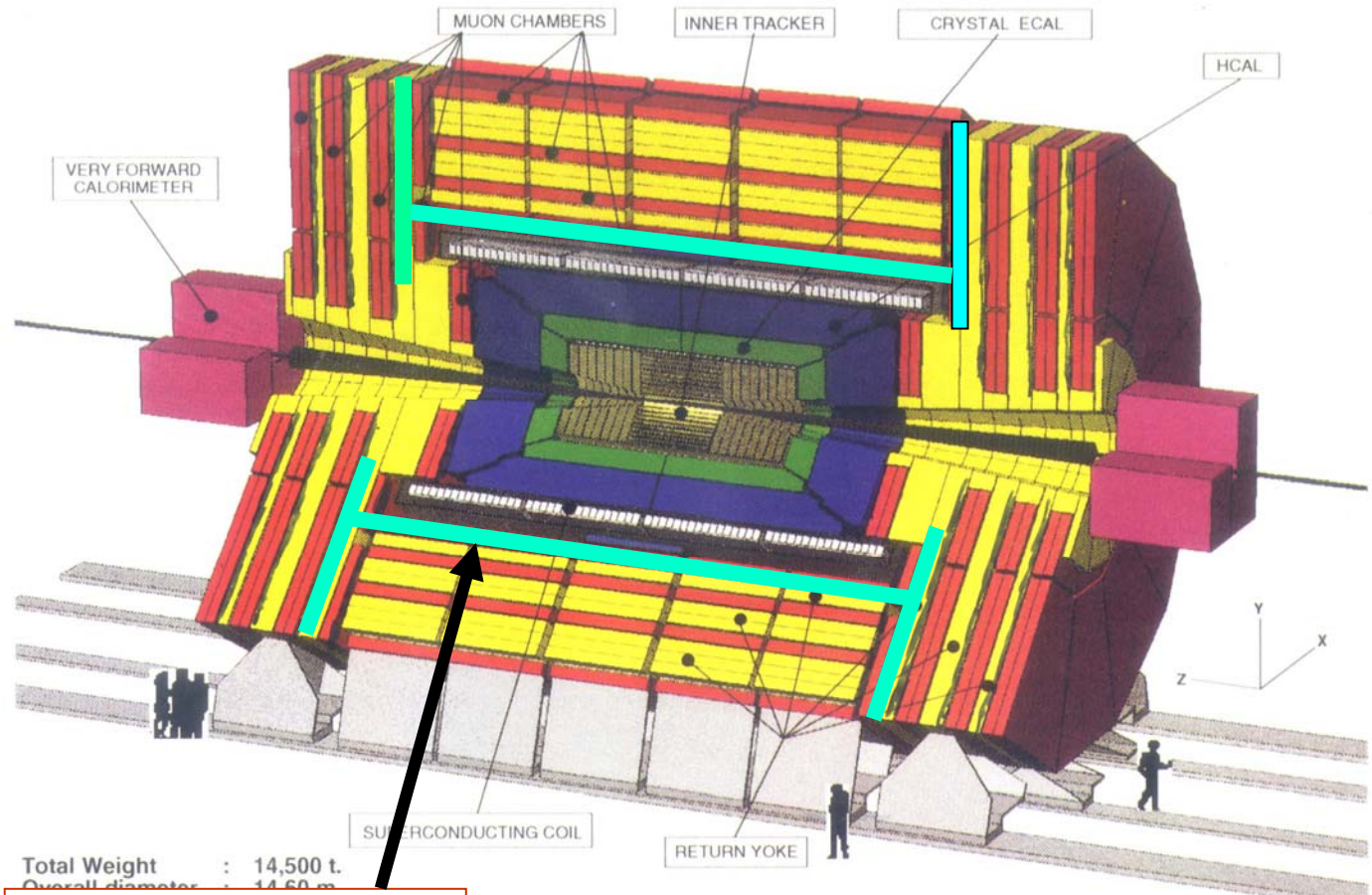
LETTER FROM THE SPOKESPERSON :

CMS Bulletin 96-01

the forward region. The natural P_t cut-off due to ranging out in the calorimeters is only ≈ 1 GeV in the forward region as opposed to ≈ 3 GeV in the barrel region. This means that the single rate in the forward region is two to three orders of magnitude higher than in the barrel, dominated by real muons from π/K decays associated to beam-beam collisions. The only way to cut down this rate in the first level trigger is to measure P_t online and apply a high P_t cut. To achieve this difficult task Cathode Strip Chambers must be complemented by pad detectors with r-ϕ segmentation such as RPCs. Design, funding and construction of the forward RPCs remains a very high priority for CMS. An important milestone for the muon system is the definition of the RPC parameters in December 96.

LHC-CMS Detecotr



PKU Task

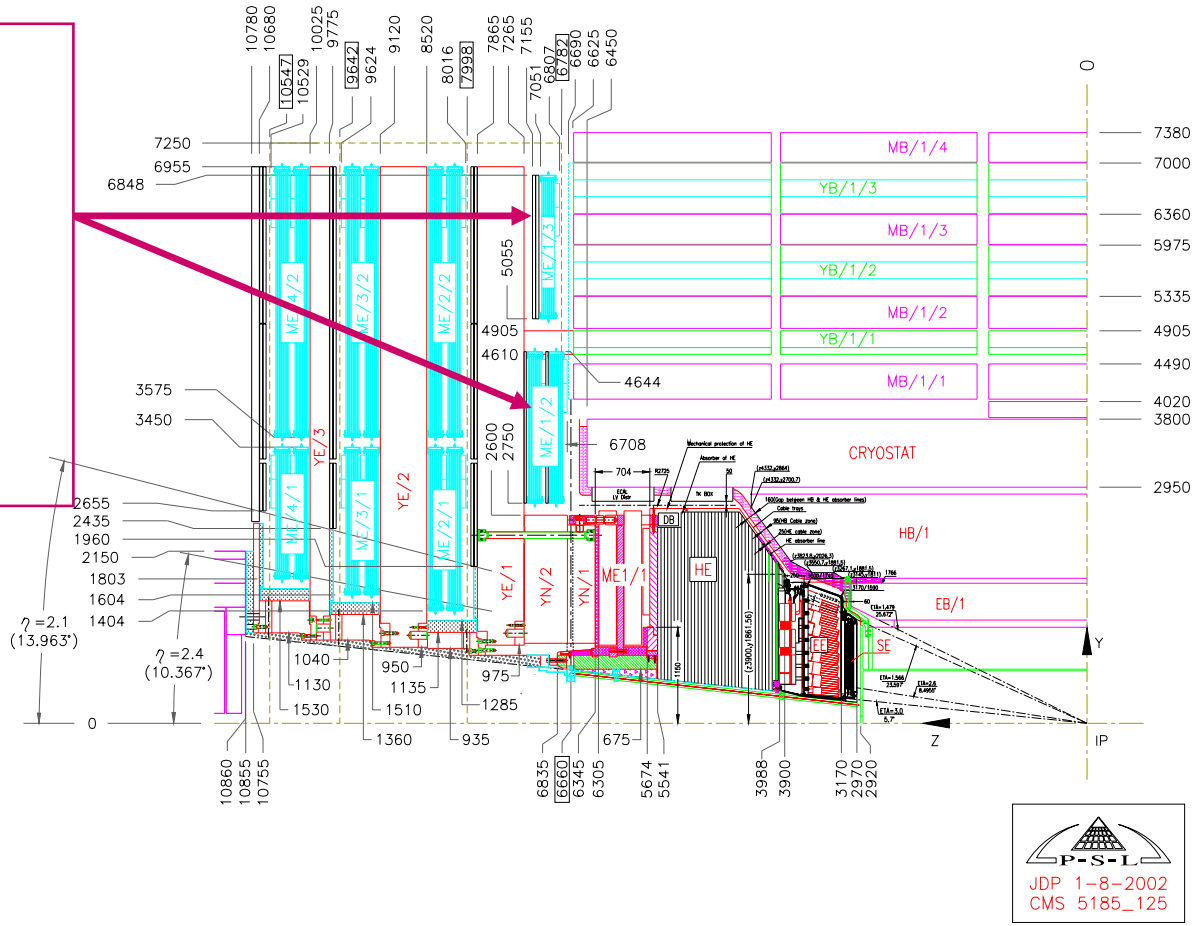
Fig. 1.1: Three-dimensional view of the CMS detector.

The End-cap RPC System

Responsibility of China:

RE1/2 and RE1/3

144 chambers



P-S-L
JDP 1-8-2002
CMS 5185_125

1999.4. MoU

¼ of Barrel RPC（RB1）and ¼ of FW RPC（RE1/2-3）

	station	size	total area	# gaps	gap area
RB1	120	5.2m^2	624 m^2	480	1248 m^2
RE1/2-3	144	~2.0 m^2	280 m^2	532	560 m^2

production 120%。

In-kind Contribution: 700 kCHF
M&O contribution: 250 kCHF

Achievable MoU deliverables

Ref.	Institutes	Achievable MoU Deliverables: 4,365 kCHF	Assigned
1.2.05	China	Magnet : Endcap Yokes : Carts Weldments (In-kind contribution , cf. 10.8 and Annex 9.1)	1,215
5.1.2	IHEP	Muon Detector : Barrel Drifttubes : Electronics Assembly and test of the high-voltage and de-coupling boards and interconnecting cables for all DT chambers (800 kCHF instead of 350 kCHF)	800
5.1.3	IHEP	Mechanical Supports for MB1 and MB4 (instead of 5.1.1: I-beams for 1,000 kCHF)	350
5.3.1	IHEP	Muon Detector : Endcap CSC : Detectors and Components Prototyping, tooling, assembly, testing and transport to CERN of the ME 1/2, and ME 1/3 chambers. Critical tooling, chamber parts and electronics will be provided to IHEP from US_CMS	1,500
5.4.3	PU	Muon Detector : Barrel RPC : Mechanical Structure and Supports Production of mechanical frames, assembly of the mechanical frames to the bakelite gaps, installation of tested electronics boards and test of the complete MB1 RPC chambers (100 kCHF instead of 350 kCHF)	350
5.5.3	PU	Muon Detector : Forward RPC : Mechanical Structure and Supports Production of mechanical frames, assembly of the mechanical frames to the bakelite gaps, installation of tested electronics boards and test of the complete ME1/2 and ME1/3 RPC chambers	150
		Total Achievable Funding	**4,365**

Cost to completion: additional deliverables

Ref.	Institutes	Cost to Completion: Addditional Deliverables for 700 kCHF	Assigned
9.2.06	IHEP	UX Steel Floor Plates	500
5.5.3	PU	Honeycomb Panels for Forward RPCs: RE1/2 a	200
		Total Additional Funding	700

M. Della Negra, Beijing, 10 April 2003

II. The R&D and Prototyping

Requirements

Large area (a few m^2);
Avalanche mode, counting rate > 1 kHz/cm^2
Resistive plate: resistivity $10^{10\sim11}\ \Omega$.cm
Surface Roughness < 0.3 μ m
cluster size < 2 strips (15mm strip)
Efficiency > 95% for a HV range wider then 1000V
Time resolution < 2ns,
Electronic noise < 2 mV;
Radiation stability > 5 years
Assembly thickness < 40 mm.

1st Prototype with Chinese Bakelite [NIM A459(2001)513]

Size: 50 X 58 X 2 mm³

Bulk material: phenolic resin with 5 x 10^{12} Ω. cm resistivity

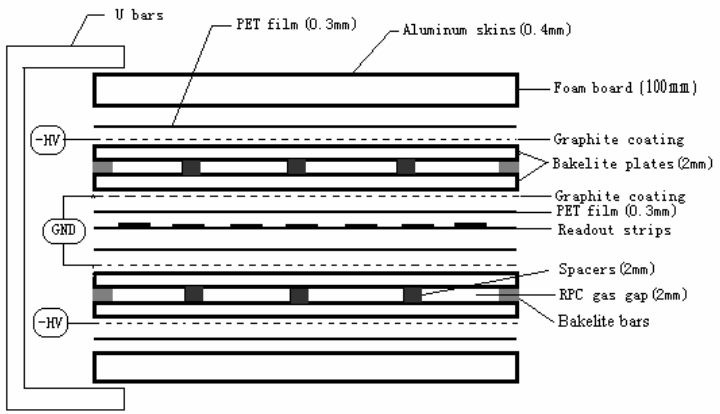
Surface: melamine film with an average surface roughness of 0.16±0.08 μ m

$$R_a = \frac{1}{l_s}\int_0^{l_s} |y| dx$$

Gas gap: 2 mm ±10 μ m

Graphite coating: about 100 k Ω.cm²

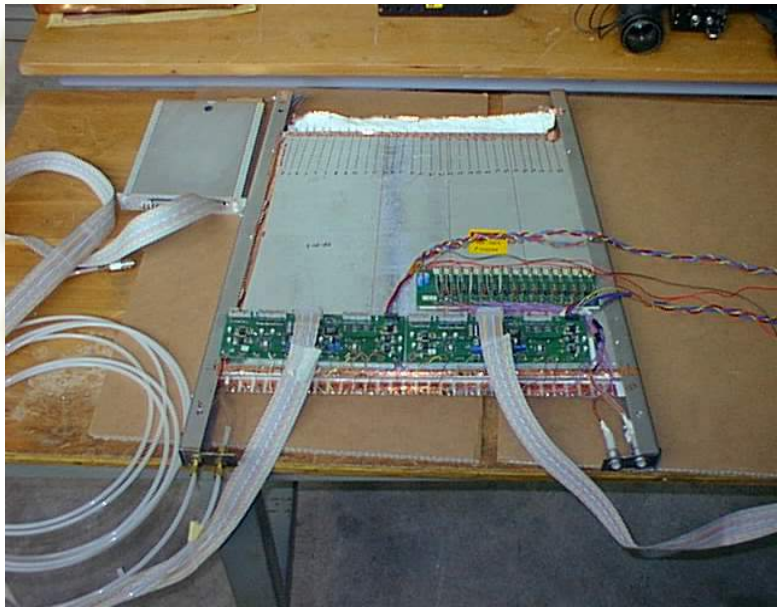
Strips: 32 strips, 1.5 cm wide each

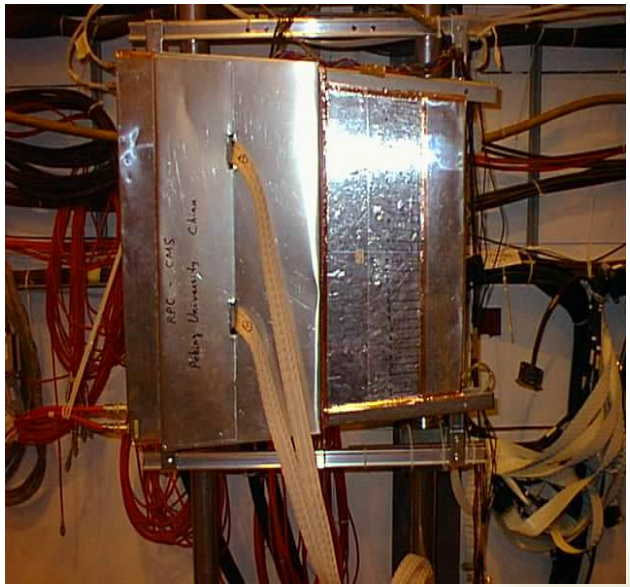


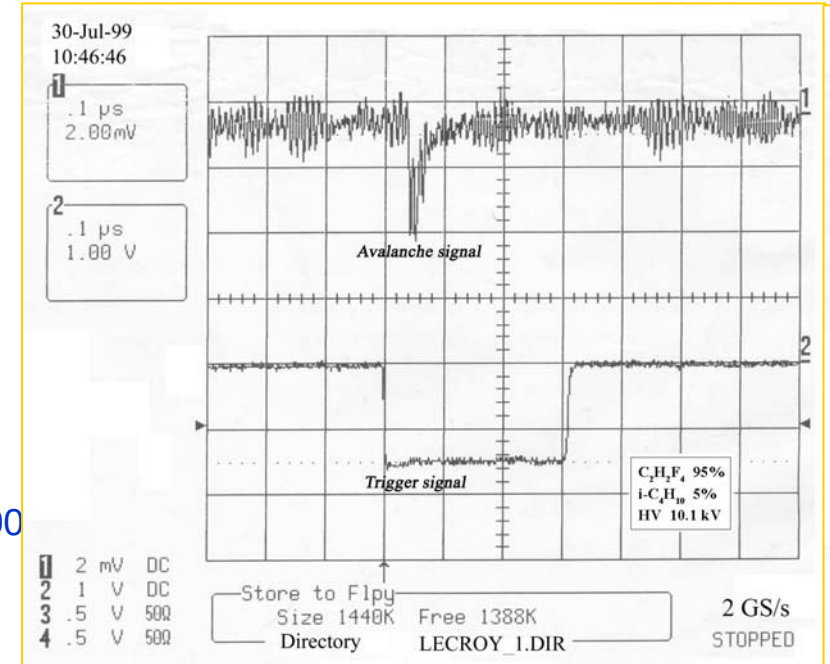
RPC流光模式与雪崩模式的比较

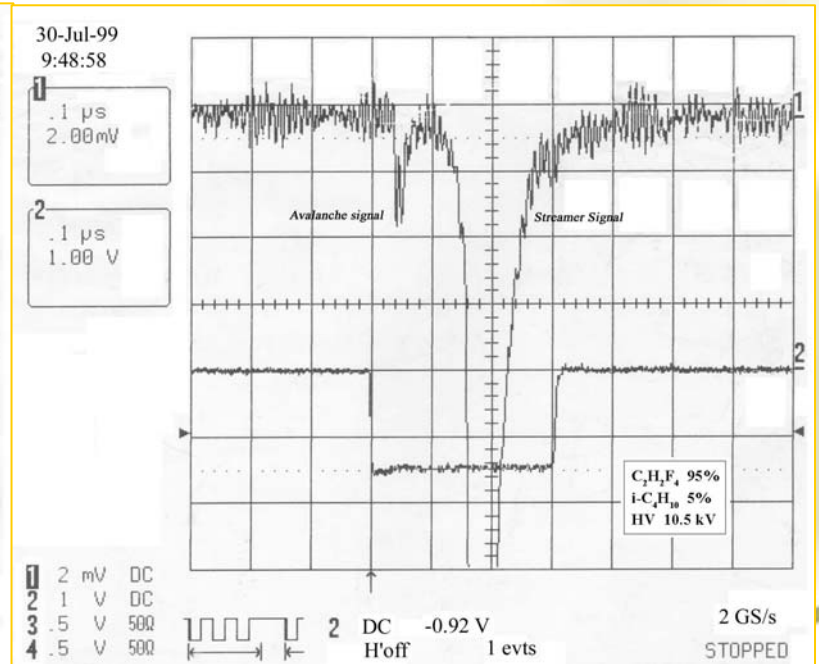
性能	流光模式	雪崩模式
输出信号幅度	几百 mV（不需放大）	几 mV（需放大）
探测效率	⩾95%	⩾95%
正常工作的计数	100 Hz/cm^2	1 KHz/cm^2
时间分辨本领	几 ns	几 ns
工作电压	较高	较低

1999, PKU-RPC-1, test at CERN

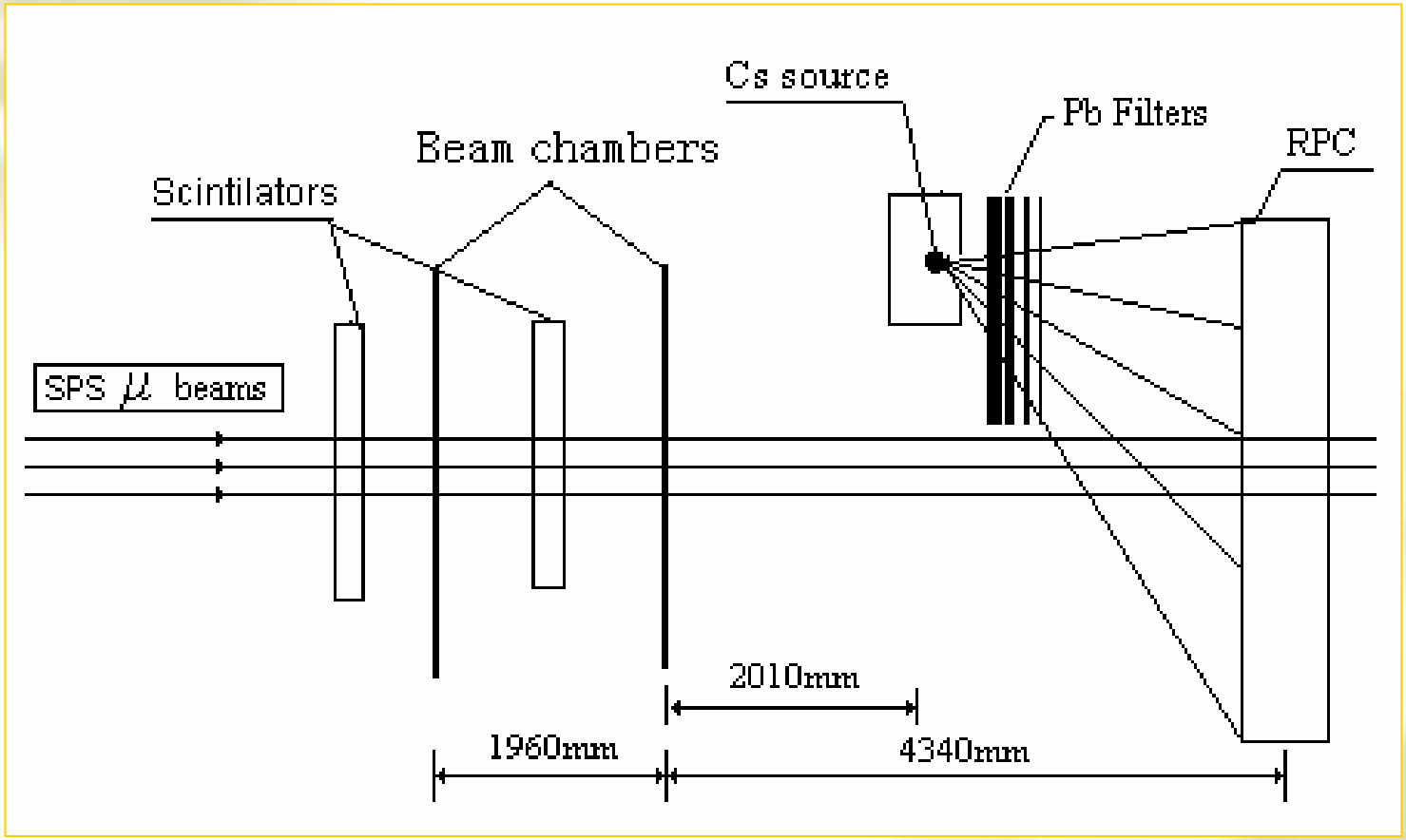


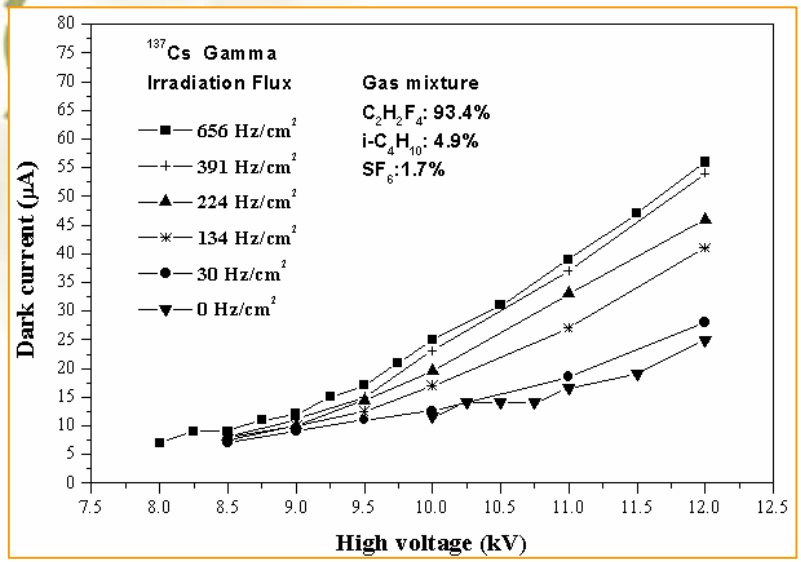


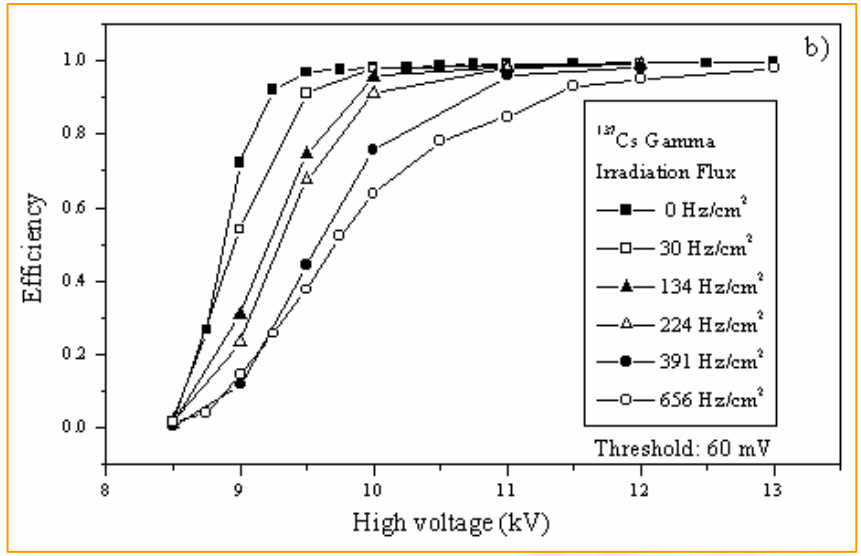


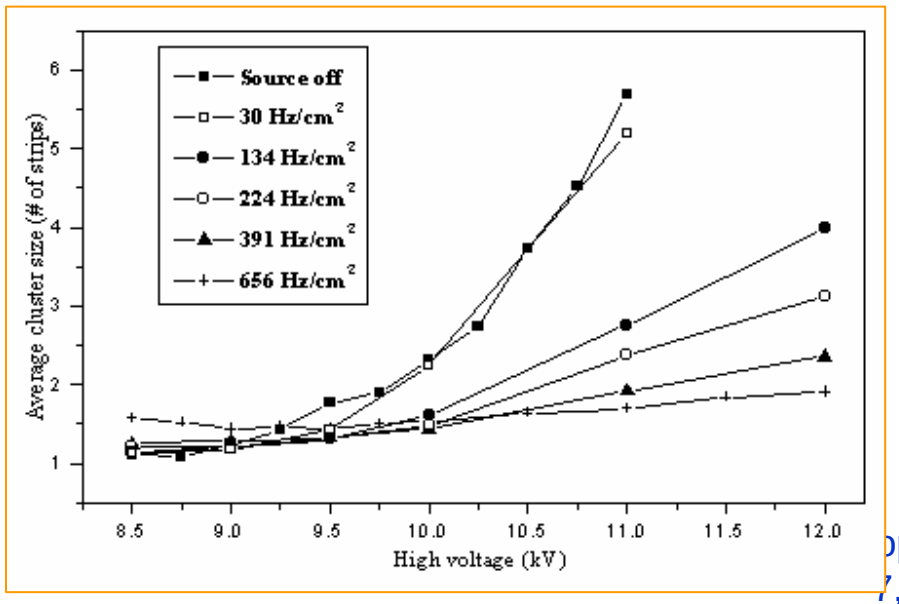


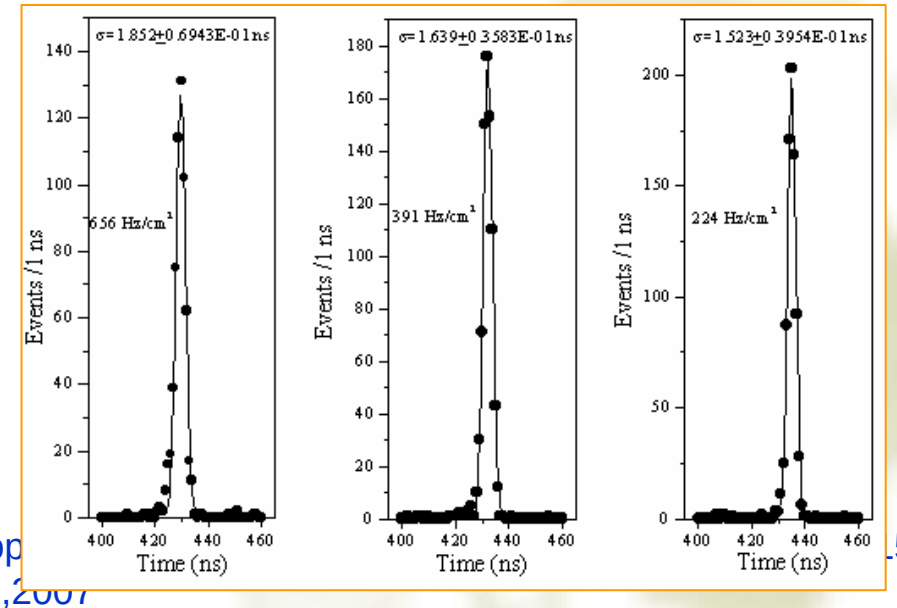
muon beam test system GIF at CERN




^{137}Cs Gamma
Irradiation Flux
Gas mixture
$C_2H_2F_4$: 93.4%
i-C_4H_{10}: 4.9%
SF_6:1.7%
656 Hz/cm^2
391 Hz/cm^2
224 Hz/cm^2
134 Hz/cm^2
30 Hz/cm^2
0 Hz/cm^2
Dark current (μA)
High voltage (kV)


b)
^{137}Cs Gamma
Irradiation Flux
0 Hz/cm^2
30 Hz/cm^2
134 Hz/cm^2
224 Hz/cm^2
391 Hz/cm^2
656 Hz/cm^2
Threshold: 60 mV
Efficiency
High voltage (kV)


Source off
30 Hz/cm^2
134 Hz/cm^2
224 Hz/cm^2
391 Hz/cm^2
656 Hz/cm^2
Average cluster size (# of strips)
High voltage (kV)


σ=1.852±0.6943E-01ns
656 Hz/cm^2
σ=1.639±0.3583E-01ns
391 Hz/cm^2
σ=1.523±0.3954E-01ns
224 Hz/cm^2
Events /1 ns
Time (ns)

For the Chinese made double gape avalanche mode RPC:

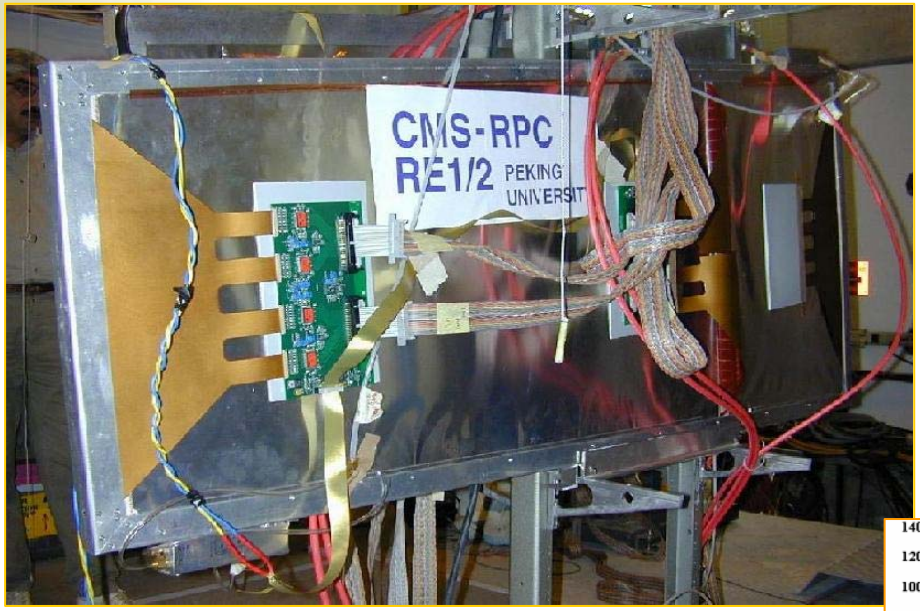
Counting rate ~ 400 $s^{-1}cm^{-2}$

time resolution <2 ns

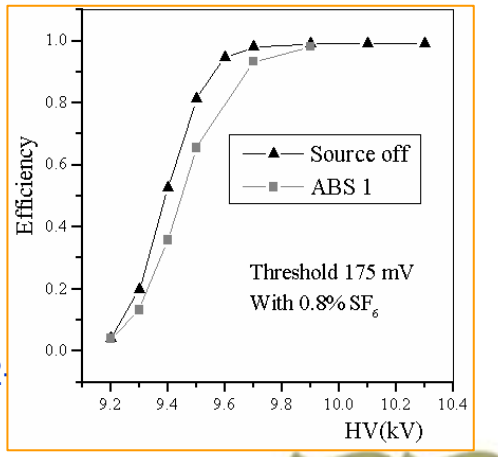
efficiency ~ 100 %

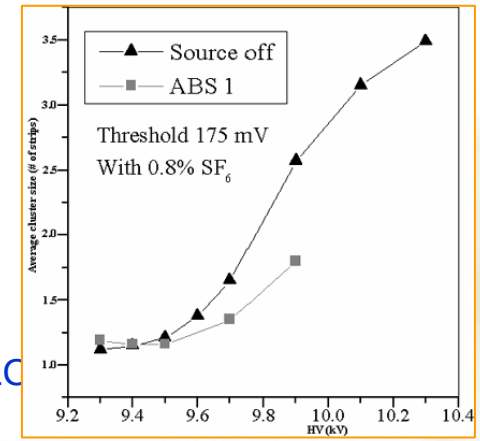
- **Ying J, Ye YL, Ban Y, et al., *Beam test results of a resistive plate chamber made of Chinese bakelites* , Nucl. Inst. and Meth. A, 459 (3) 513-522, 2001**
- **Ying J, Ye YL, Ban Y, et al., *Study of an avalanche-mode resistive plate chamber,* J. Phys. G, 26 (8) 1291-1298， 2000**

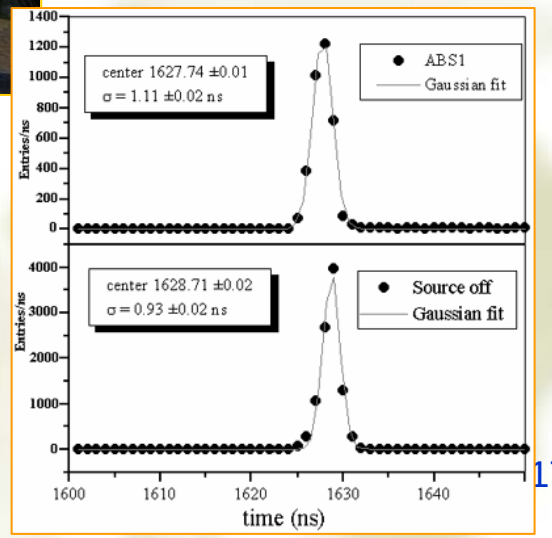
PKU-RPC2: Full size RE1/2,
Italian bakelite a resistivity of $5 \times 10^{10}\ \Omega \cdot cm$.
can work at 1kHz/cm^2

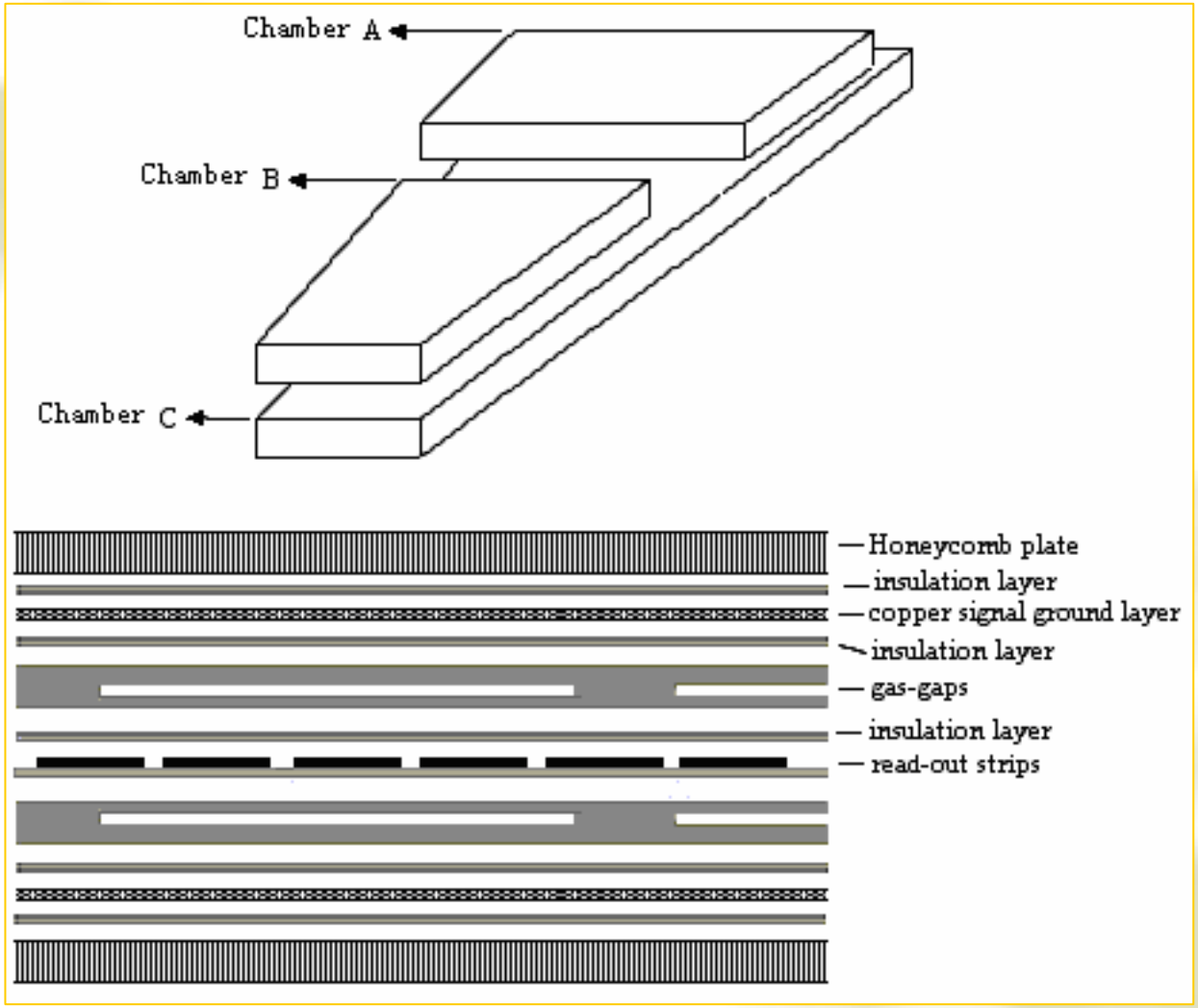


HEP&NP, 2005,29(2):175-170








Chamber A
Chamber B
Chamber C
Honeycomb plate
insulation layer
copper signal ground layer
insulation layer
gas-gaps
insulation layer
read-out strips

PKU-RPC3: Study of new assembly technique with honeycomb panel

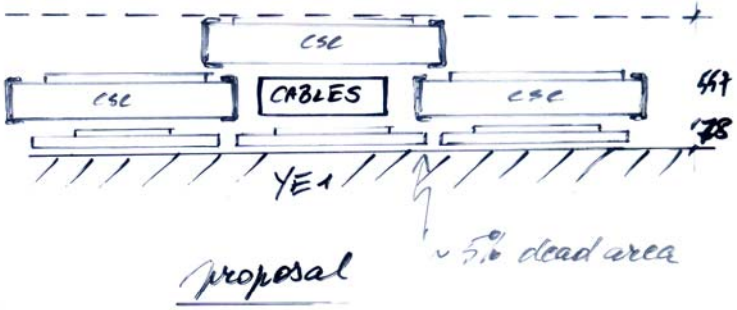
Due to the change of the space available, CMS require to reduce the total thickness of the FW-RPC from 40 mm to < 30 mm.

The solution with honeycomb panel had been studied and accepted. The thickness of 28 mm was achieved.

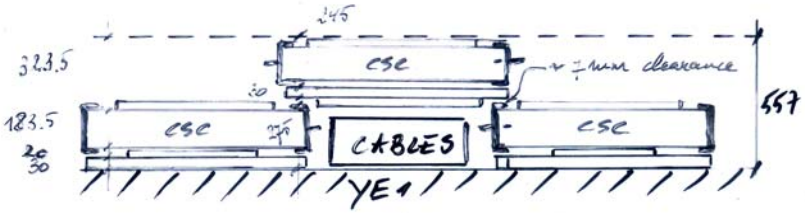
RE 1/2

present

≡ BASELINE (SC)

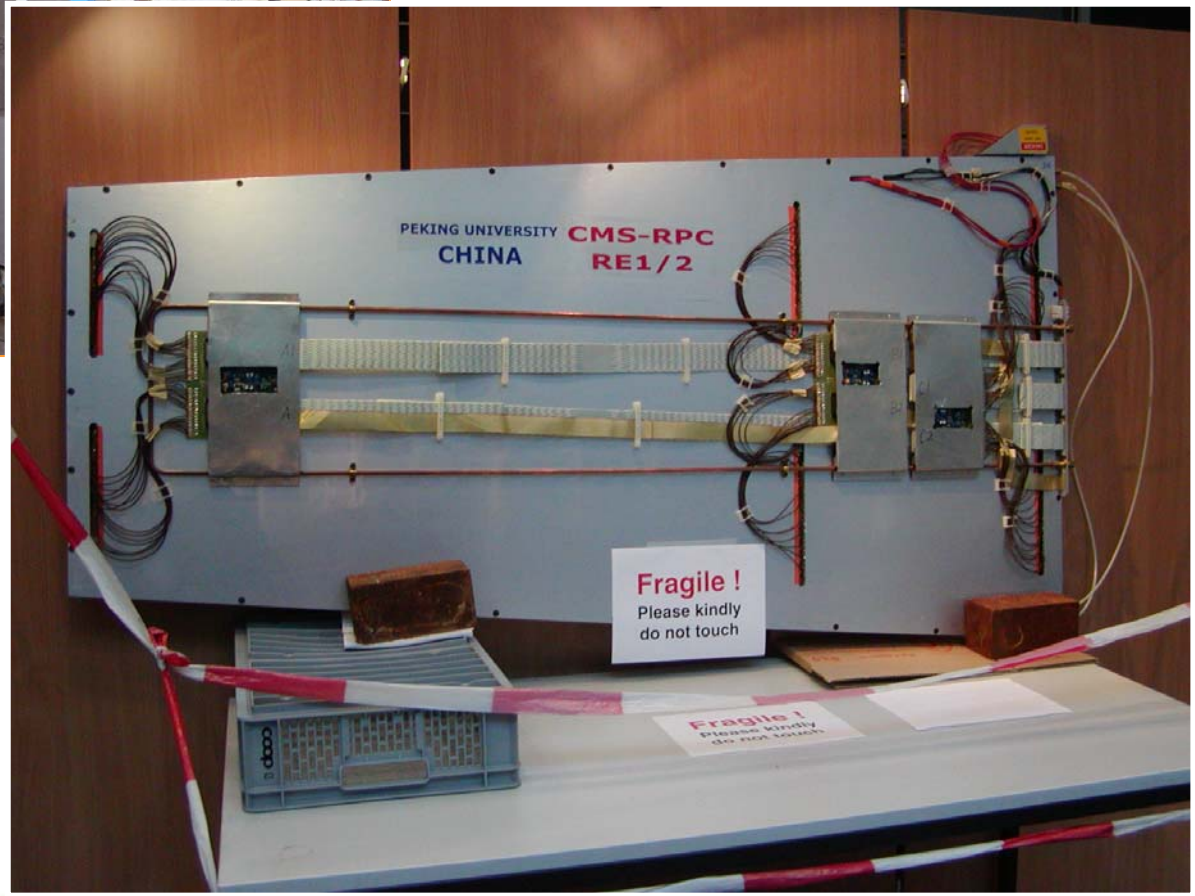


proposal



- Decouple cabling from RE1/2 installation
- Easier maintenance RE1/2
- Faster installation
- Overlap covers as beams

2002.08. The final prototype was tested and approved, and demonstrated by CMS for two months.

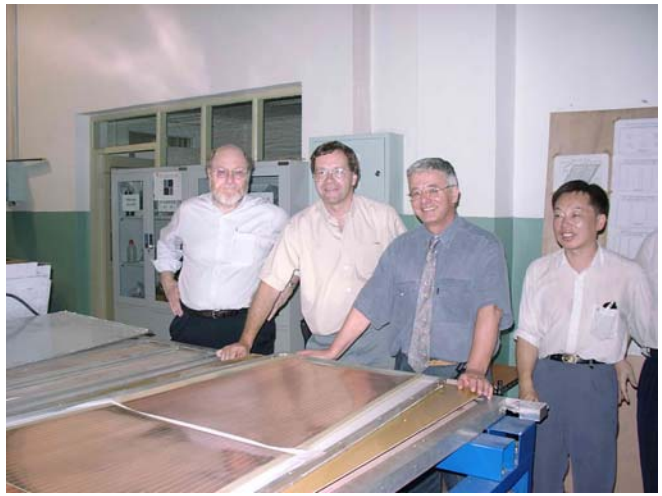


III. Production and Installation

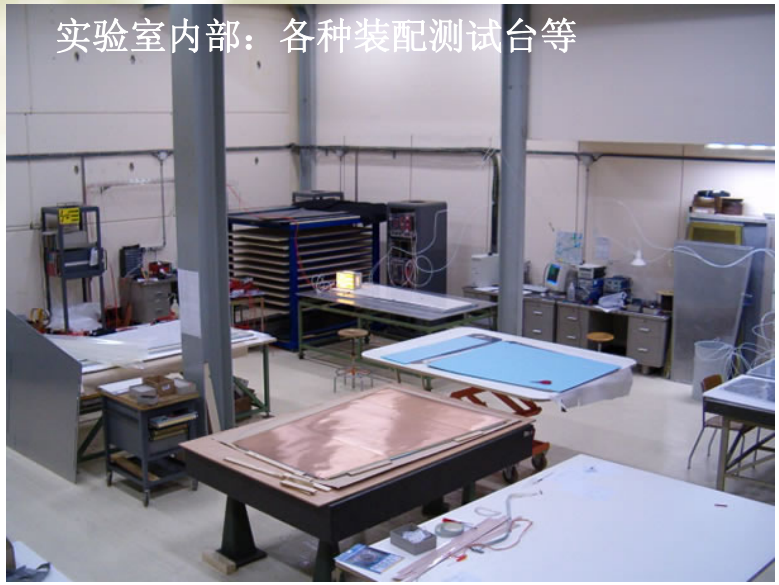
A new workshop at PKU was established for the production of materials and for the preassembly with the model gas-gaps.

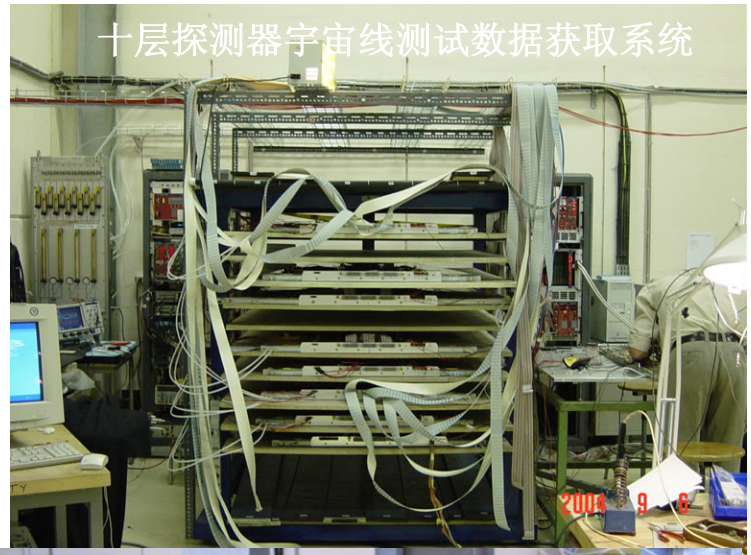

2000/12/20 12:35pm

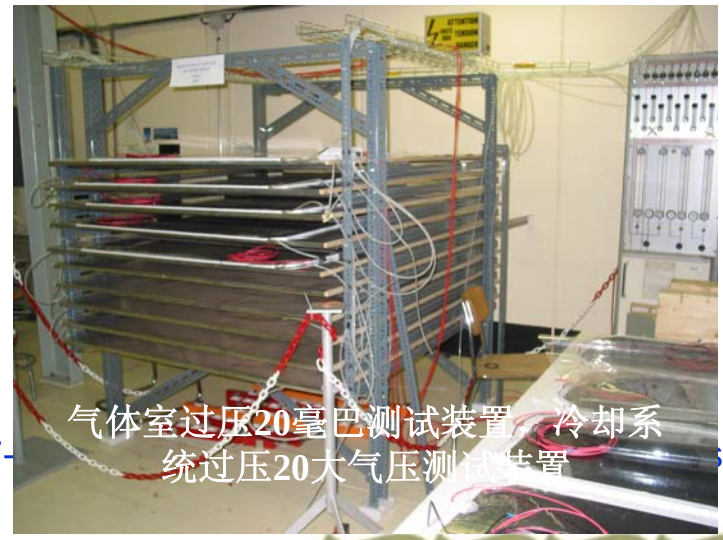

2000/12/20 12:36pm

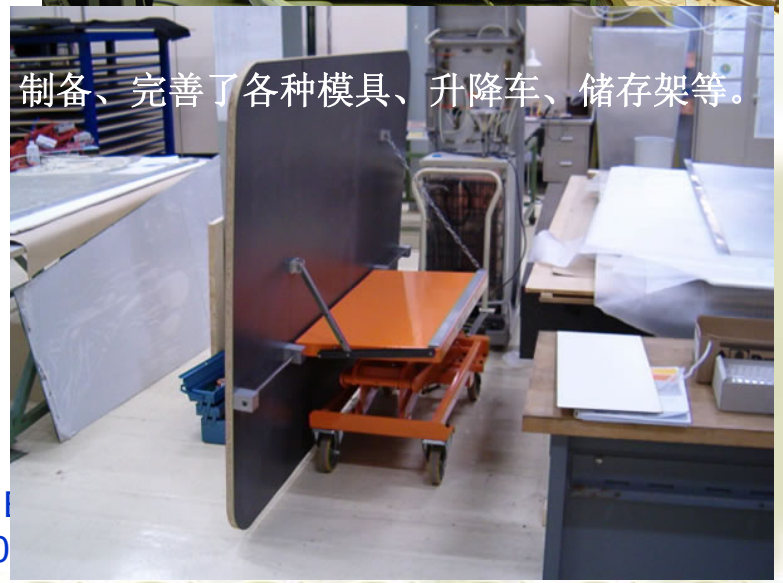


Another workshop was established at CERN for final assembly and testing



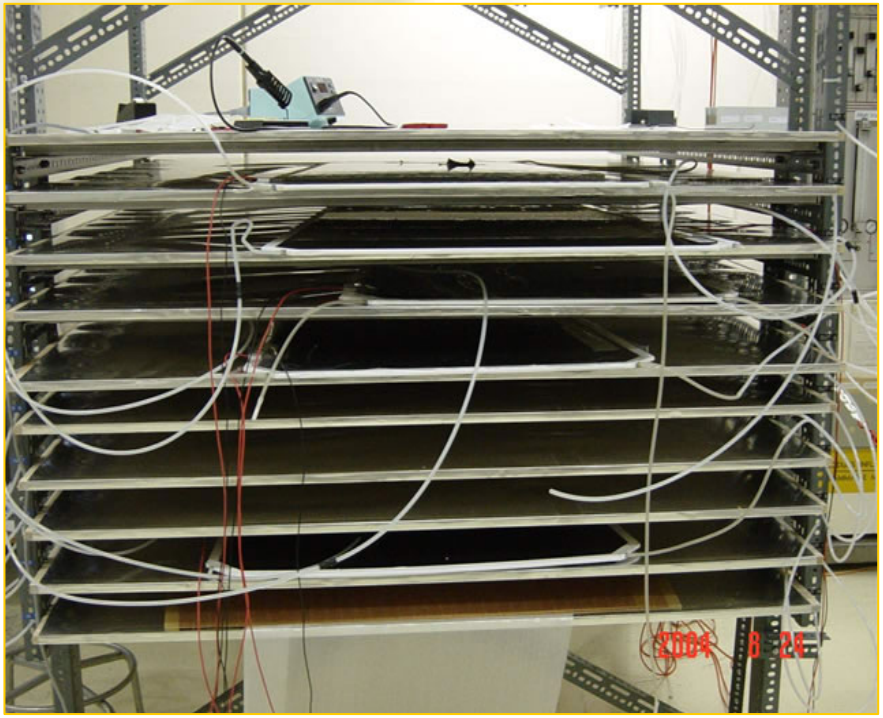


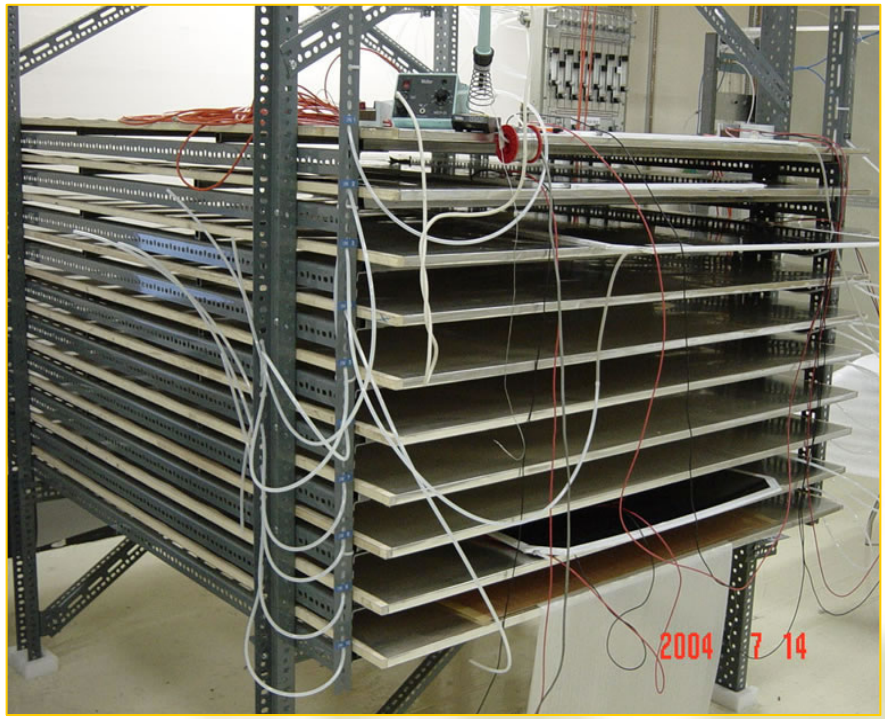




Gas leakage and spacer tests

HV test





Assembly for various components

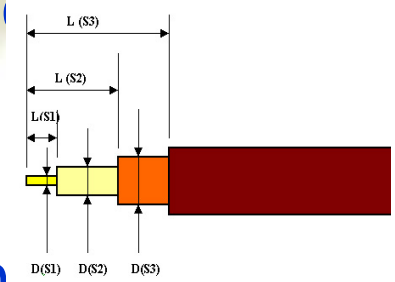
- Co-axial signal cable preparation (96 pieces, 192 ferrules) (1 day) → 0.7
- Honeycomb panel modification (2 panels and 1 Al bar) (0.5 day) → 0.3
- 40-pin flat cable preparation (6 pieces, 12 connectors) (2 hours) → 1.5
- Screen box modification (cutting 8 big holes and 1 HV port) (2 h.) → 0.5
- L-shape gap fixation bracket preparation (1.5 hour) → 1
- Mylar sheet preparation (2 pieces) (1.5 hour) → 1
- Gas pipe bending (6 types of shape) (1 hour) → 0.5
- FEB cooling plate modification and pre-assembly (1 hour) →
- Read-out strips preparation (testing any short circuit, etc.) (1 h.) → 0.5
- Soldering PCB strips on copper ground sheet (6 pieces) (1 h.) →
- Multiple-hole gas gap locator preparation (6 pieces) (1 hour) →

Co-axial signal cable preparation

Co-ax cable Prepared

striping cables

machine chamb

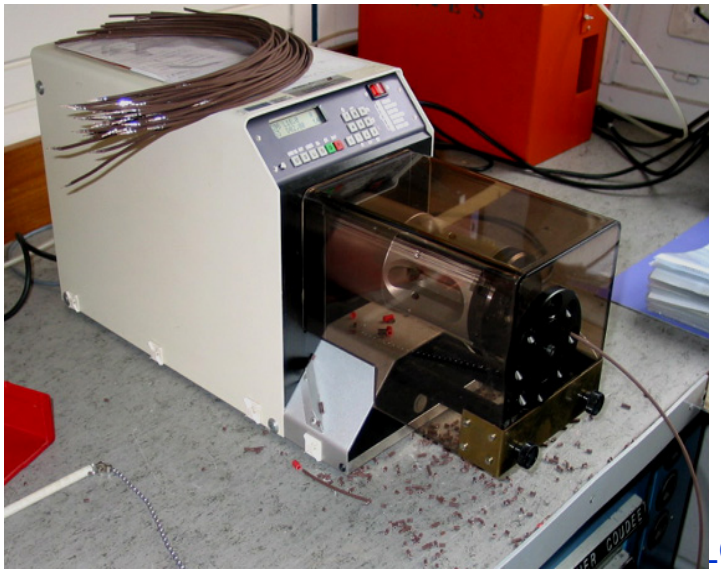


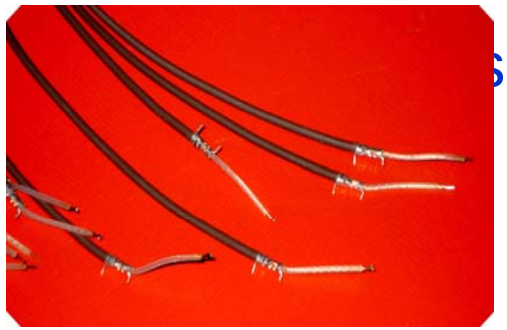
Co-ax cables with ferrules

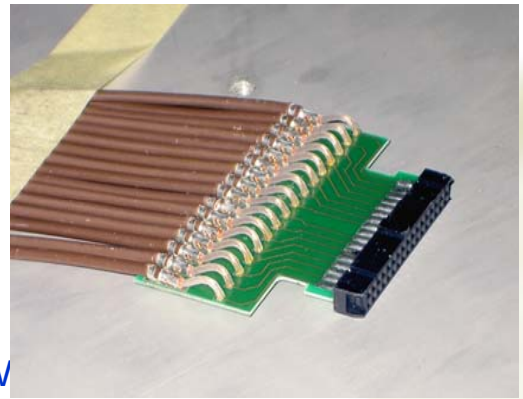
then soldered on

s

co-ax



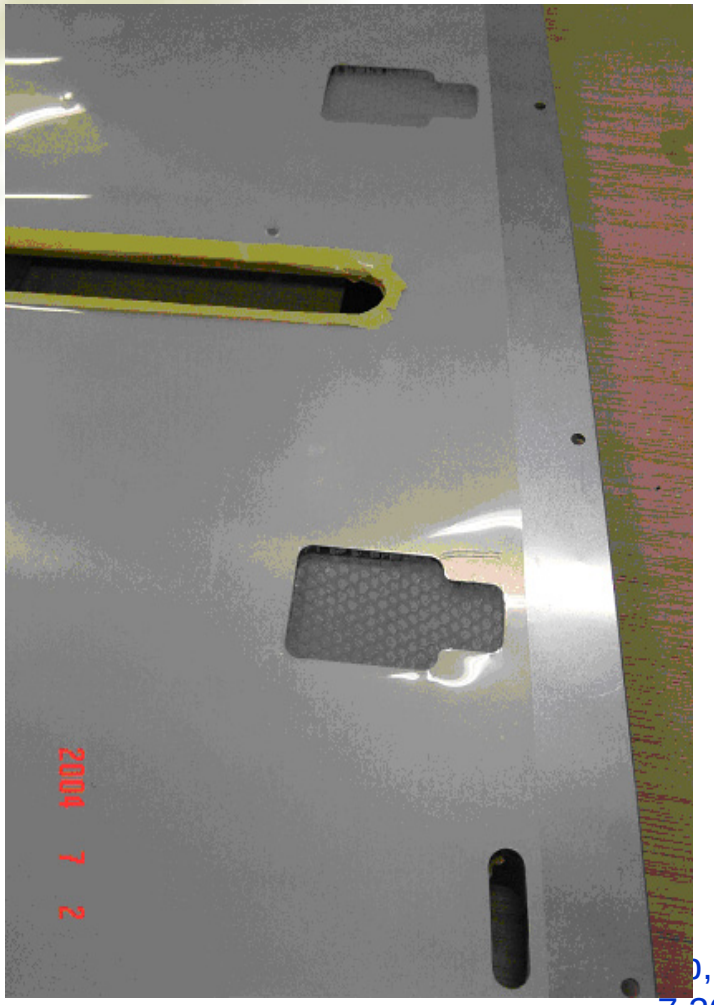


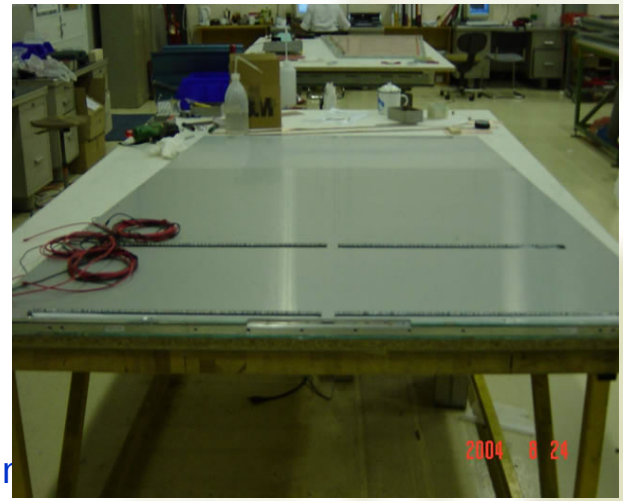


LC W

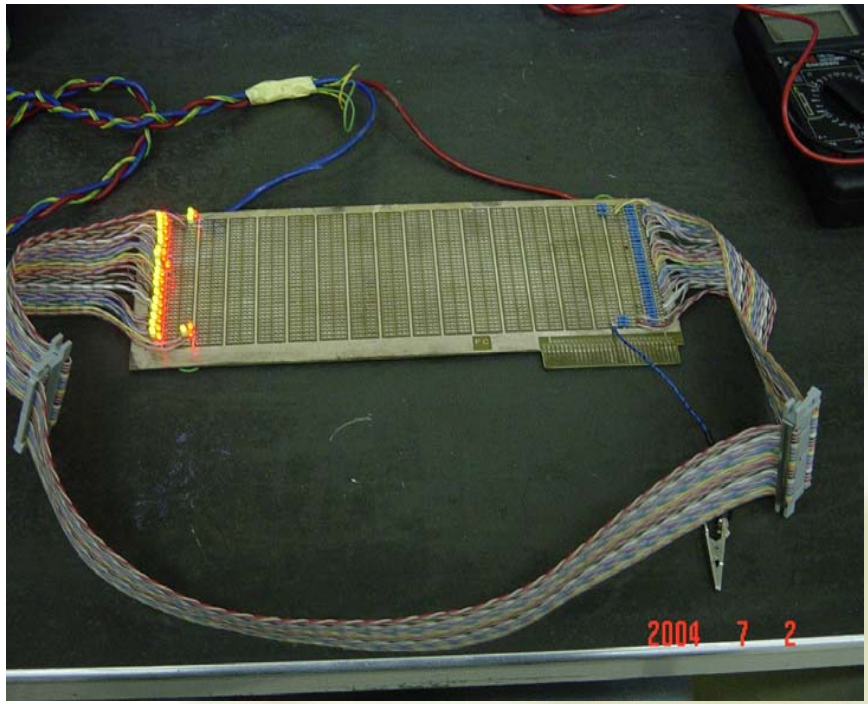
7,2007

Honeycomb panel modification



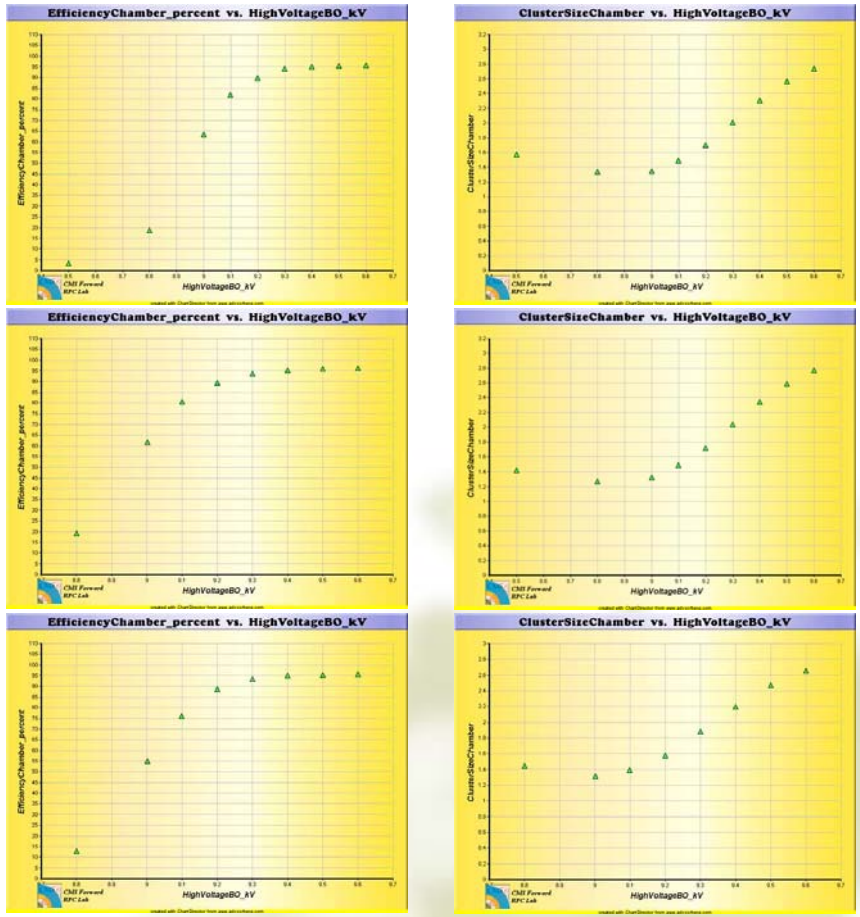


40-pin flat cable preparation



● cosmic test results: efficiency and cluster size

Storage frame



Schedule in 2005

一月 二月 三月 四月 五月 六月 七月 八月 九月 十月 十一月 十二月

组装测试10个RE1/3探测器，制备大量同轴电缆、扁平线及其他组装部件

安装18个RE1/2探测器到-z位置的CMS端部铁基座上

组装测试40个RE1/2探测器

安装18个RE1/2探测器到-z位置的CMS端部铁基座上

组装测试40个RE1/3探测器

安装18个RE1/3到-z CMS端部铁基座上

组装测试17个RE1/2探测器

安装18个RE1/2探测器到+z CMS端部铁基座上

组装测试9个RE1/3探测器

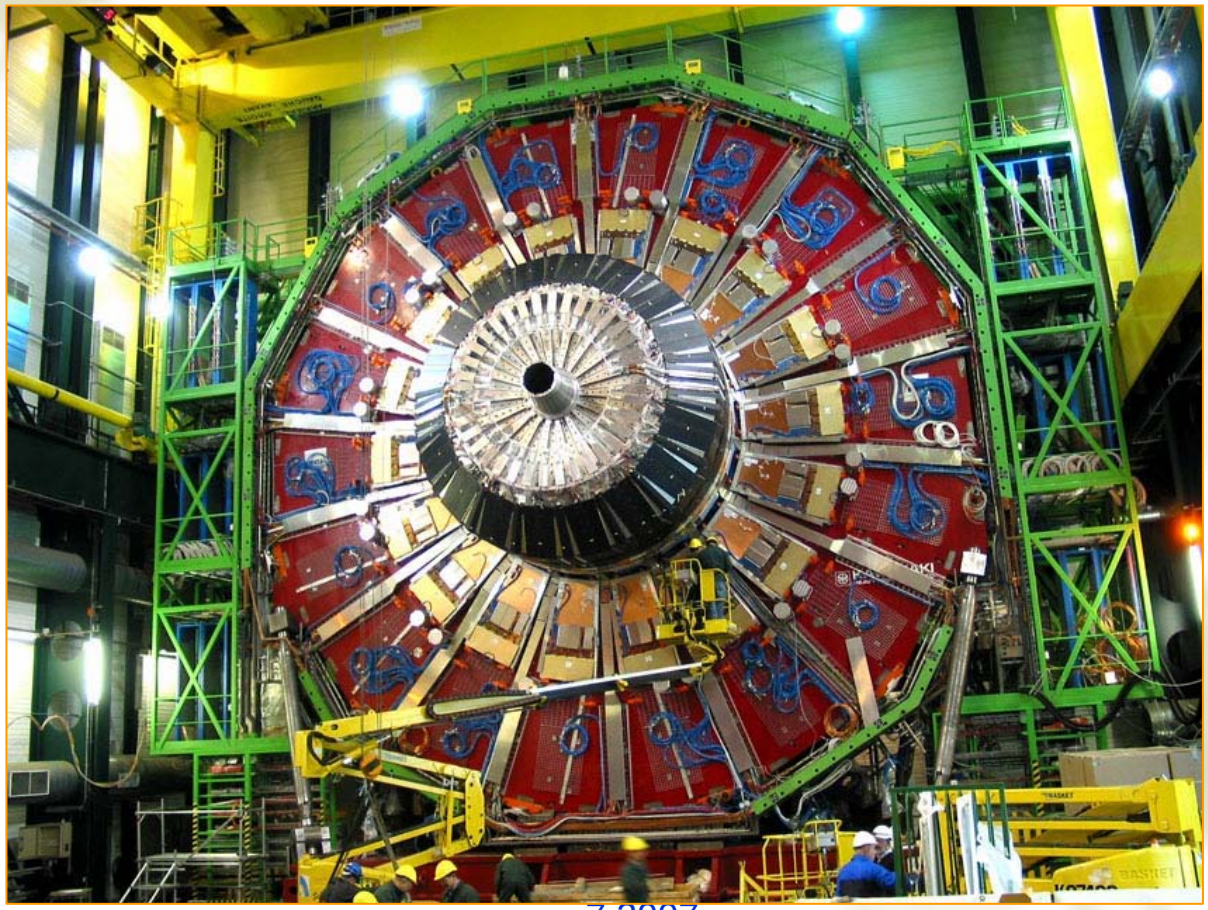
安装18个RE1/3到-z CMS端部铁基座上

2006年：

安装54个RE1/3到+z CMS端部铁基座上

开始进行整体探测器的运行调试

2005.12.19 18 RE1/2 installed at –z direction



CMS bulletin April 2006

The Compact Muon Solenoid Experiment

CMS Bulletin

CERN, CH-1211 GENEVA 23, Switzerland

Bulletins are available on CMS internal information server: http://cmsdoc.cern.ch/cms.html

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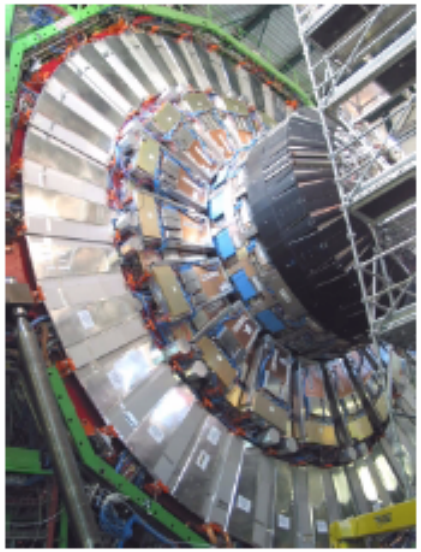
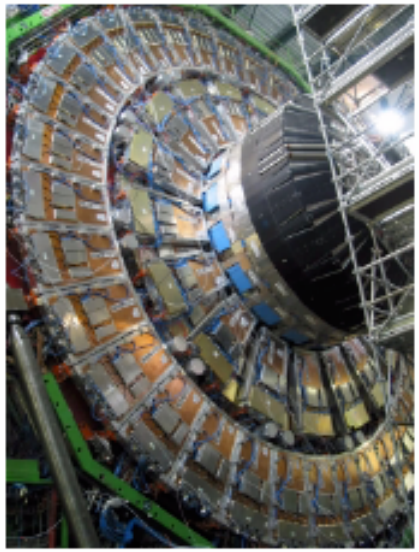
13 March 2006

Moving Forward !



YE+1 yoke equipped with CSC/RPC packages (inner ring) and RE1/3 RPC's (outer ring).



The ME1/3 CSC's now cover the RPC outer ring and hence complete the first Muon station on YE+1.

Feb. 2006, RE1/3 installed on CMS

PKU-RPC will join the first run of LHC-CMS scheduled by the end of this year!!

Summary

- The large size avalanche mode RPC made of the Chinese bakelite can be used for a counting rate < 400 Hz/cm^2
- The assembly with Honeycomb panel is a good solution for the“thin”RPC.
- Experiences with detector R&D, assembly and mass production have been accumulated and are valuable for future development and applications