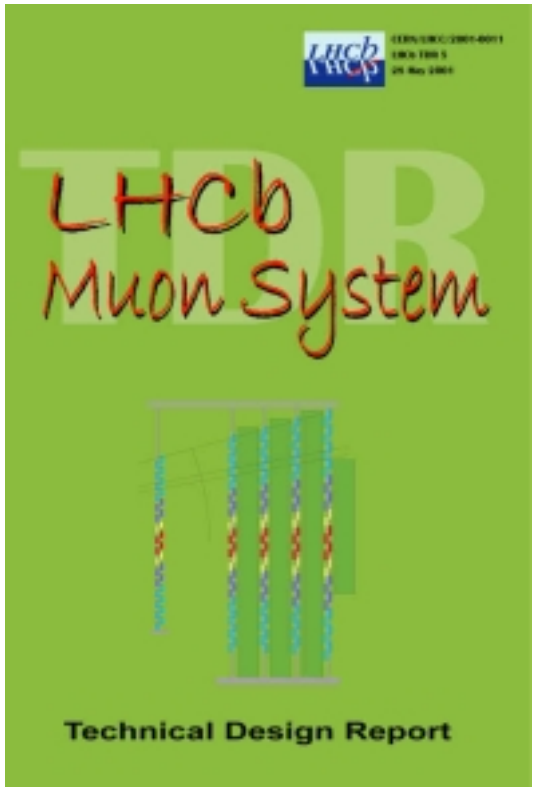
Technical Design Report for the LHCb Muon System



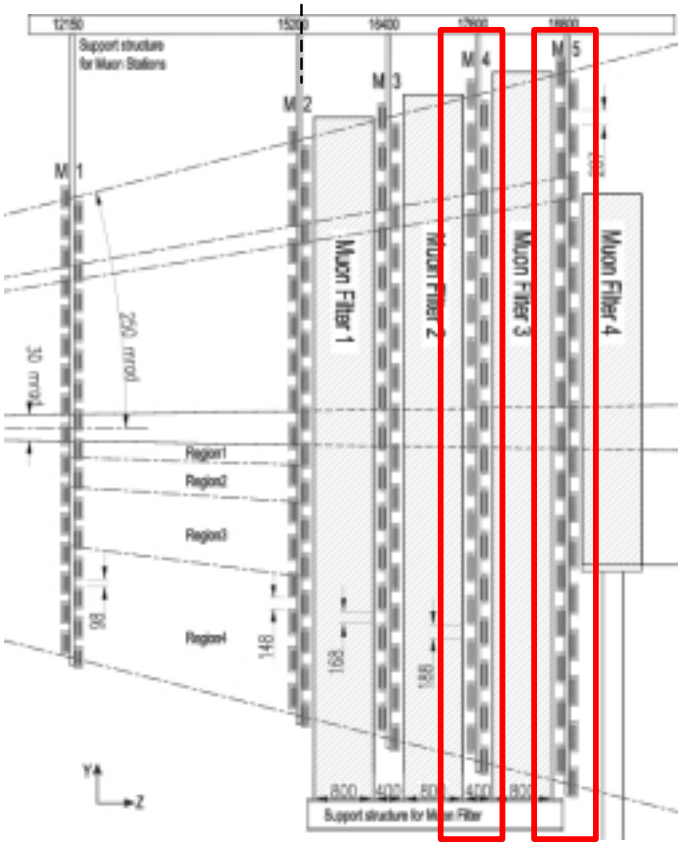
Part II: RPC Detectors, Readout Electronics, Project Organization

Giovanni Carboni

on behalf of the Muon Group

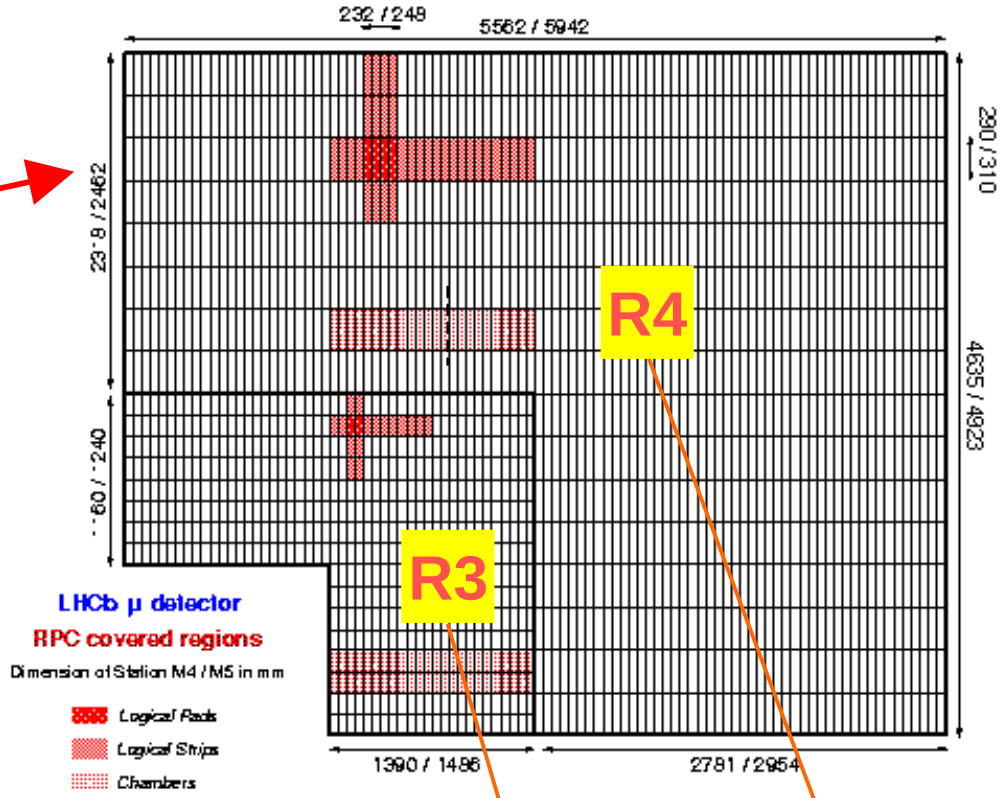
RPC Detector

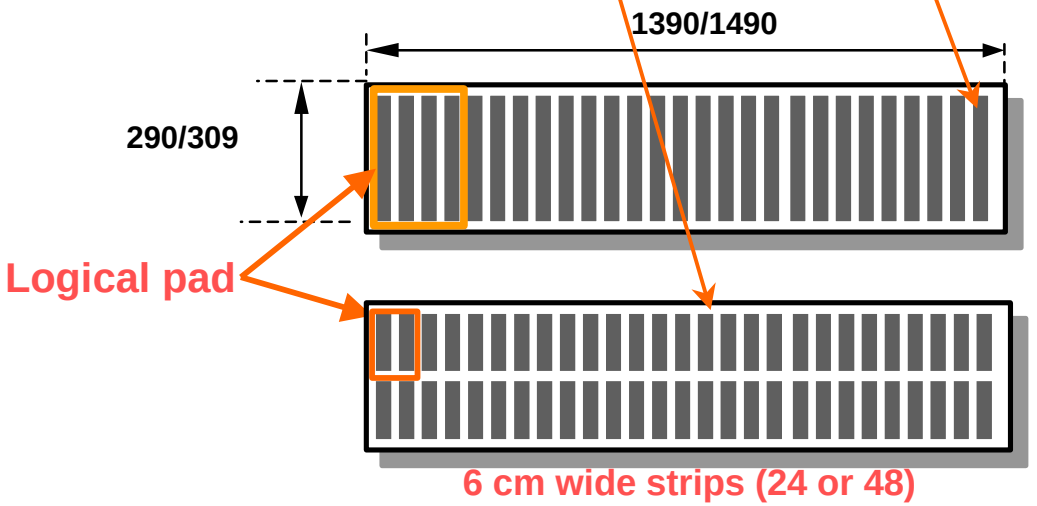
48% of total area



480 chambers
2 gaps/chamber

M4 M5



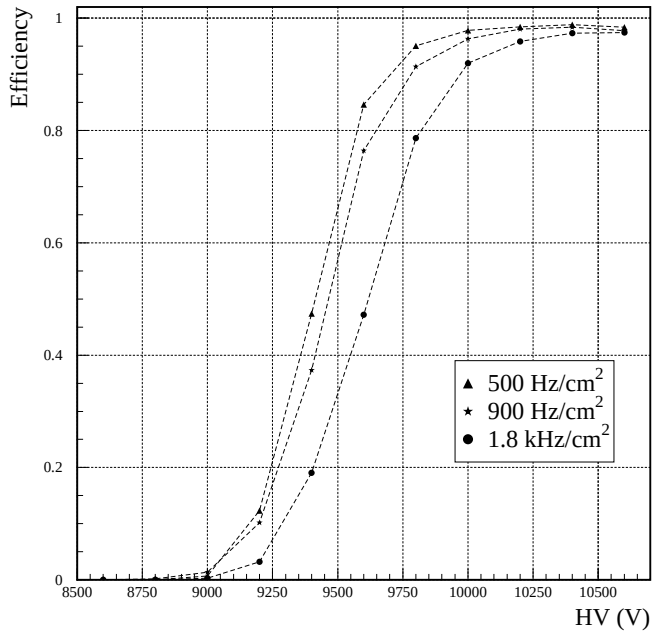


4 chamber types

RPC Performances

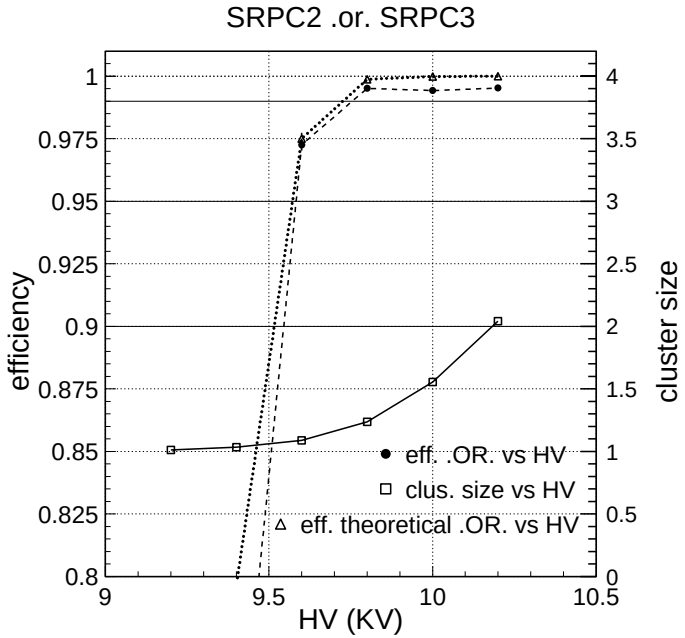
$\rho = 9\ 10^9\ \Omega$ cm (bakelite)
Gas mixture:
95% $C_2H_2F_4$, 4% i-C_4H_{10} 1% SF_6

Rate capability of single gap (GIF)



3 cm strips

Performance of 2 gaps in OR

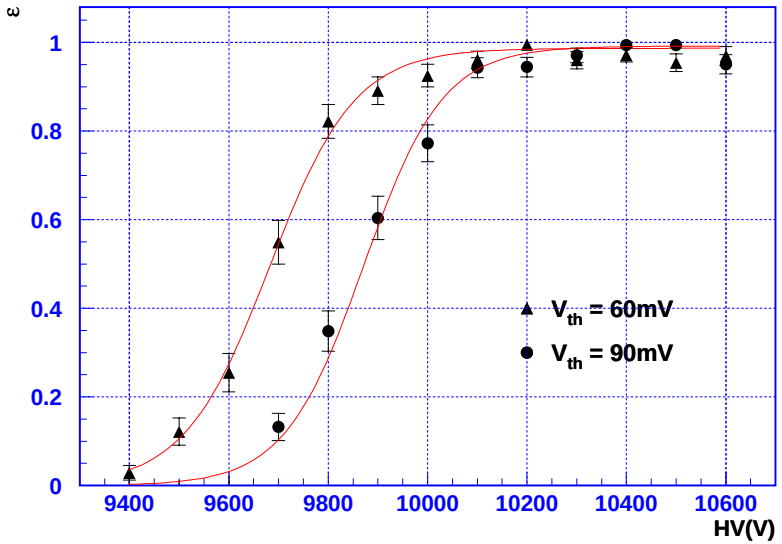


Spatial efficiency per chamber: > 99%
Time resolution < 2ns
Cluster size < 2

RPC Performances

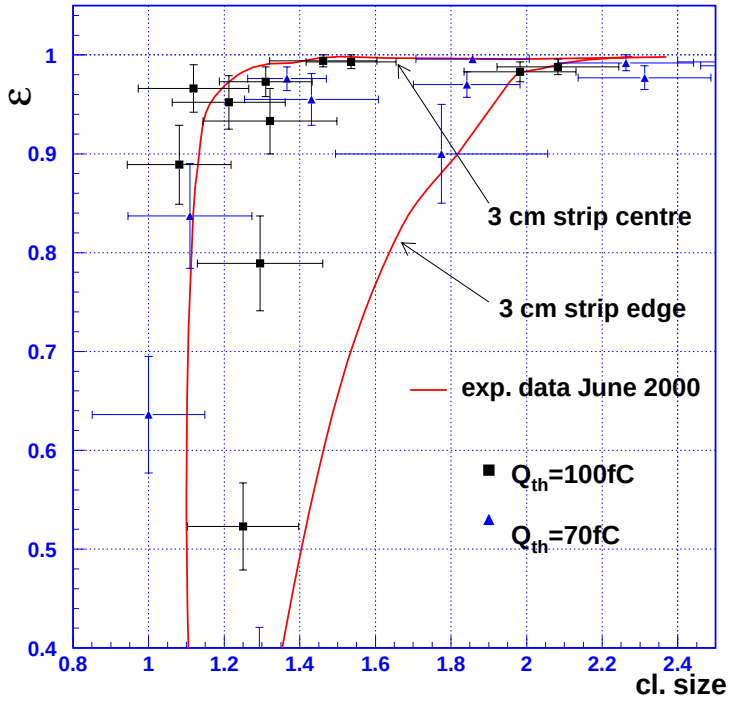
ρ = 9 10^9 Ω cm (bakelite)
Gas mixture:
95% $C_2H_2F_4$, 4% i-C_4H_{10} 1% SF_6

Efficiency



6 cm strips

Efficiency vs. cluster size



Spatial efficiency per gap: > 97%
Time resolution 1 ns
Cluster size 1.2

RPC FE Electronics

Baseline choice: CMS BiCMOS chip

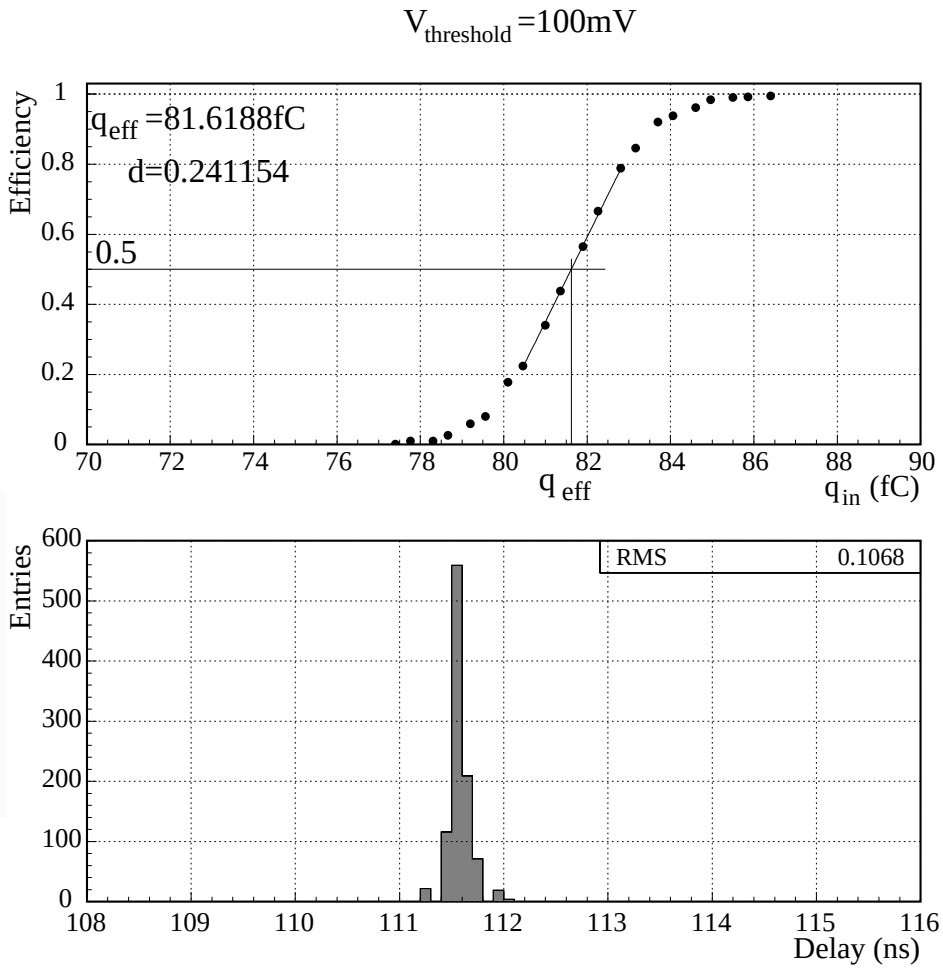
Technology	**0.8 um BiCMOS**
Dimensions	**2.9x2.6 mm**
Input impedance	**15 ohm**
Dynamic range	**20 fC - 20 pC**
Charge sensitivity	**1 mV/fC**
Equiv. Input noise	**4 fC**
Ch. to ch. time spread	**< 0.35 ns**
Dead time	**50 ns**
Power consumption	**45 mW/channel**

LVDS output

Prototype board used in beam tests (8 ch)

Final board will be 16 ch

Chip calibration

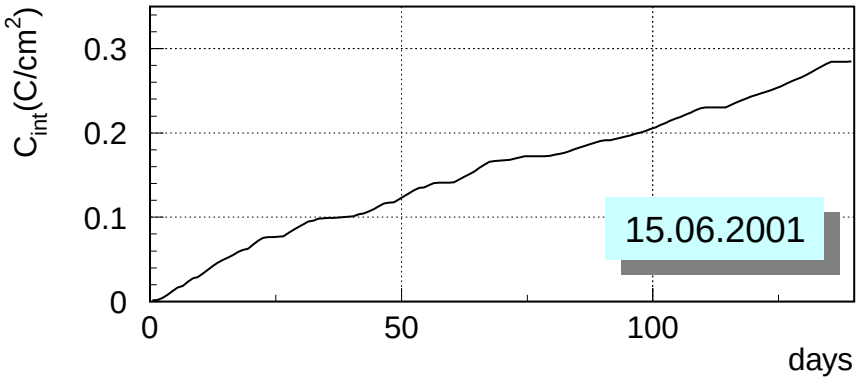


GIF Ageing Test

Ageing requirements in LHCb
(including safety factors)

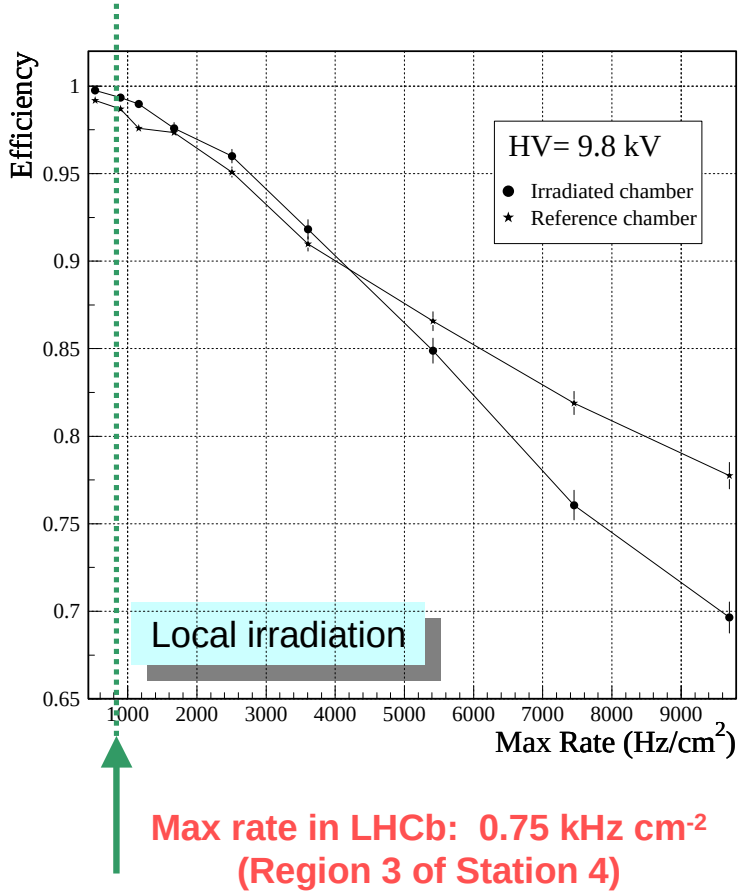
	Region 3	Region 4
J_{max}	11 nA cm^{-2}	4 nA cm^{-2}
Q (10 y)	1.1 C cm^{-2}	0.4 C cm^{-2}

GIF test: started Jan. 15



By end of year
=> 0.8 C/cm^2 (= 20 LHCb-y in R4, 7 y in R3)

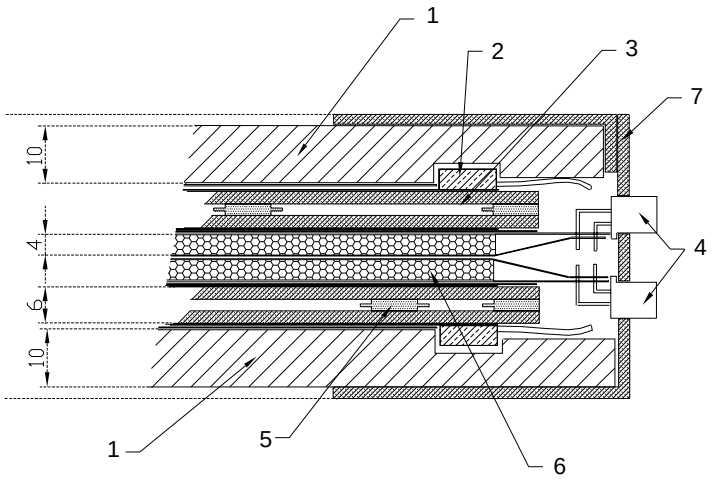
Rate capability measurement after accumulating 0.2 C cm^{-2} (≈ 5 LHCb years in Region 4)



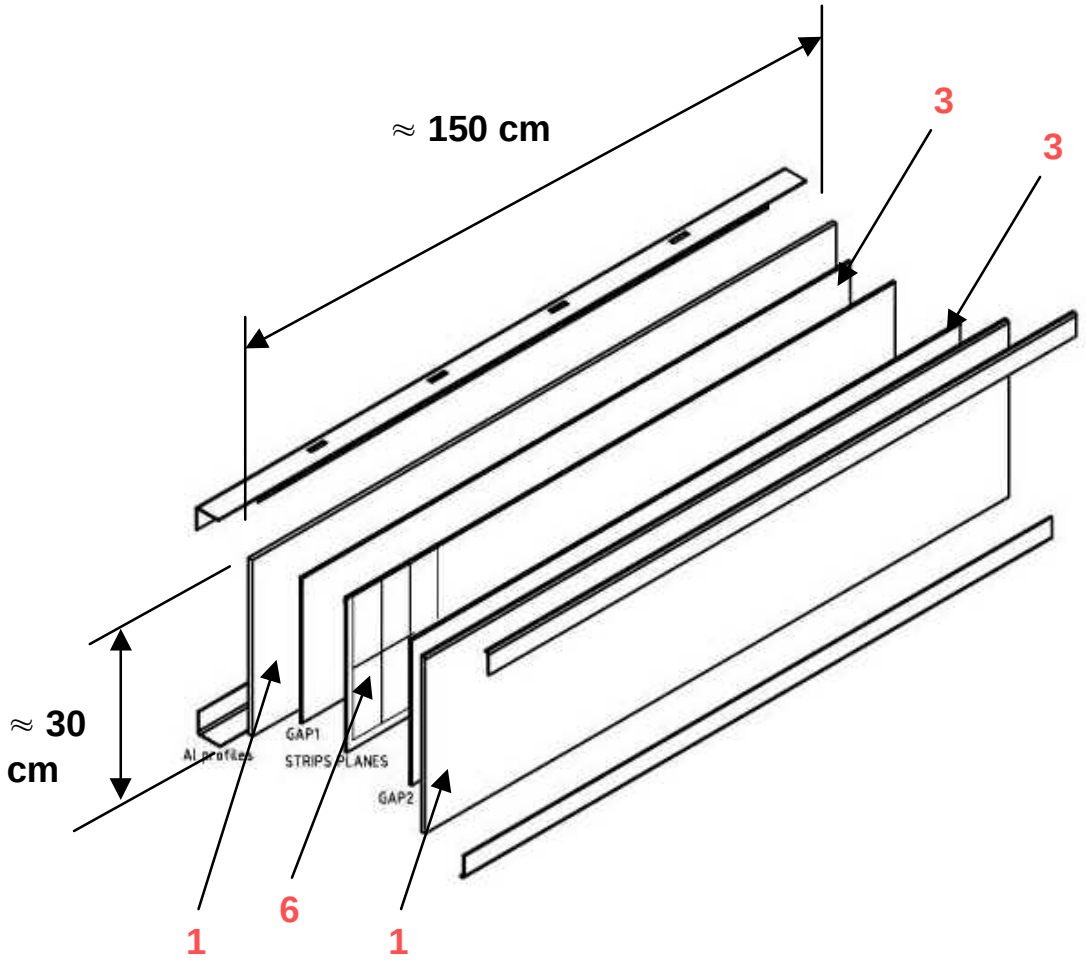
Max rate in LHCb: 0.75 kHz cm^{-2} (Region 3 of Station 4)

RPC Chamber Design

1. Al-poly sandwich
2. HV connection
3. Gas-gap
4. Output connectors
5. Spacing button
6. Strip planes
7. Al box



All gas-gaps same size

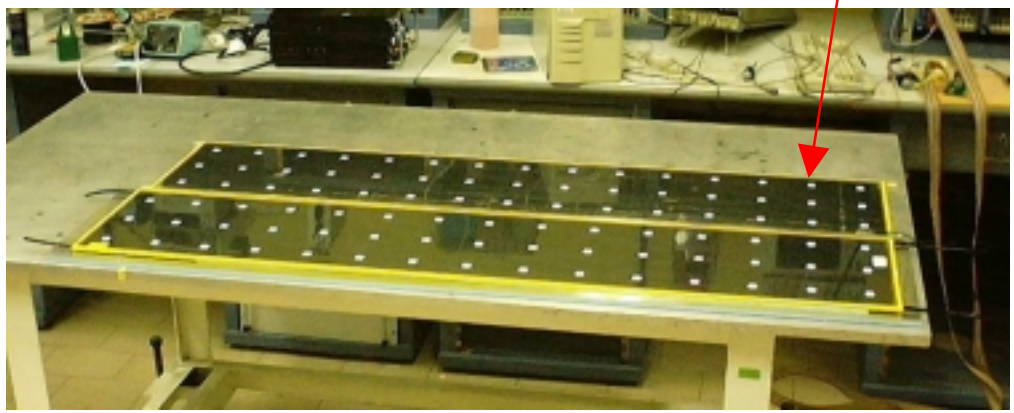


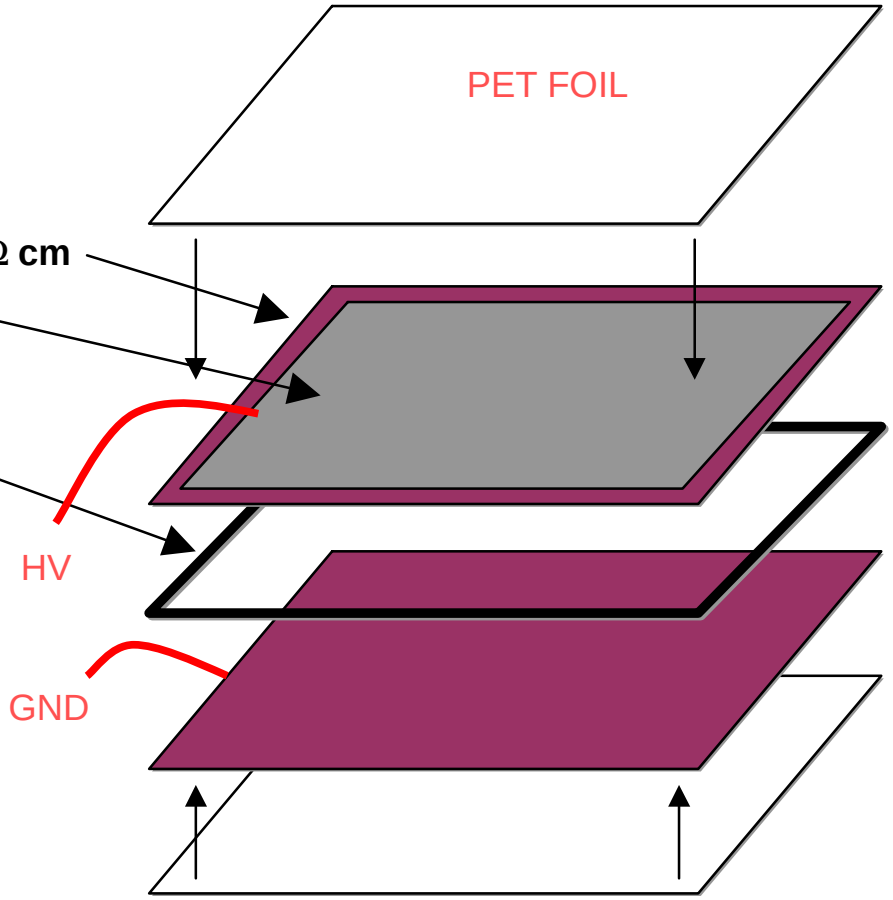
RPC Gas Gap

960 required
all same size: 150 x 31 cm²

Gas gap thickness: 2 ± 0.01 mm
Plates: melaminic-phenolic bakelite, 2 mm thick, ρ = (8±2) 10⁹ Ω cm
Graphite paint (external side)
Insulating PET foil (200 micron) glued on graphite
Spacers: 10 mm dia x 2 mm height buttons on 10x10 cm² grid
Frame: 2 mm thick polycarbonate

Sensitive area defined by graphite paint and readout strips





Oil vs. No-Oil

Linseed oil on bakelite

improves ✔

- **Noise (less load on trigger)**
- **Dark current (less ageing)**

could introduce problems (Babar)

- **Polymerization critical**

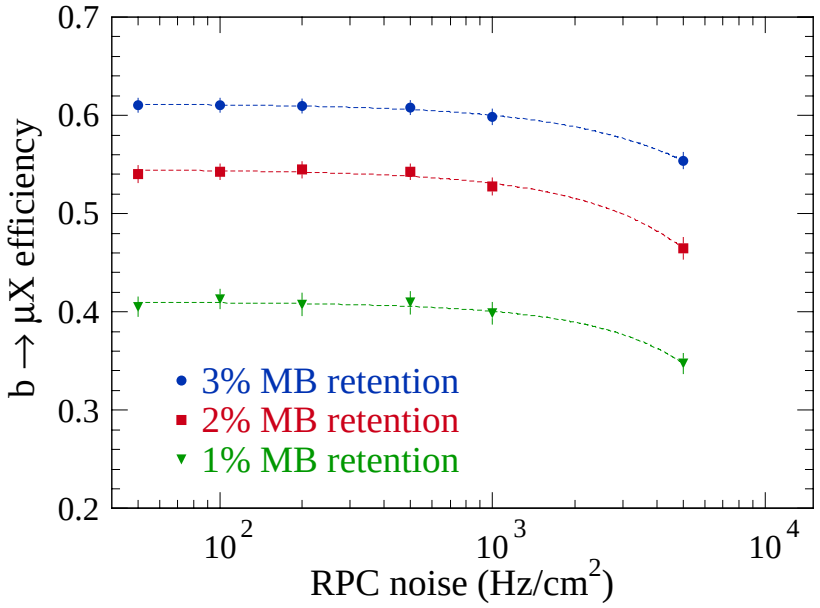
is an additional variable ⚠

- **construction more delicate**
- **extra quality control req'd**

We favor a solution without oil, provided we can meet two milestones by December 2001:

Dark rate < 100 Hz/cm^2 **(“Trigger”)** ➡

I_{DARK} < 3 nA/cm^2 (30 μA/m^2) **(“Ageing”)**



RPC Quality Control and Testing

Bakelite

Measurement of volume resistivity
Measurement of surface roughness

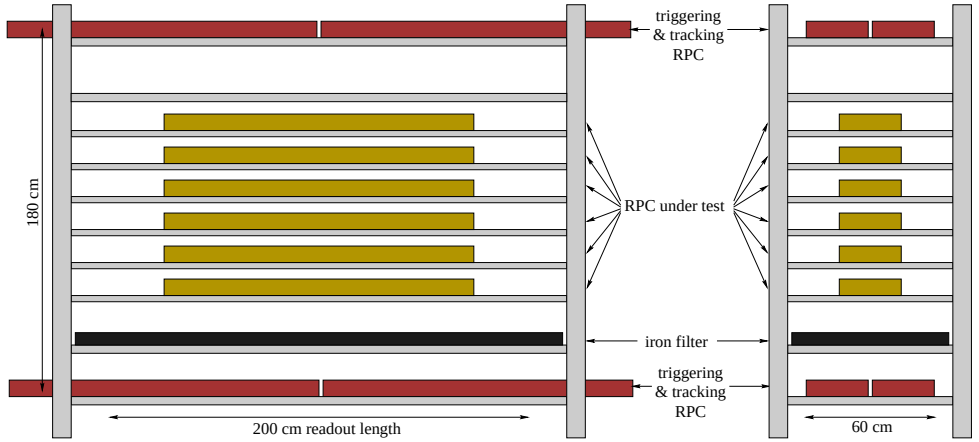
⇐ **Performed at bakelite factory**

Gas Gaps

Check of oil layer (If used. Statistical test by opening and inspecting samples?)
Check of gas tightness and HV leaks (at the factory)
Measurement of I vs. HV curve, reject gaps with too high dark currents
Pairing of similar gaps

Chambers & Electronics

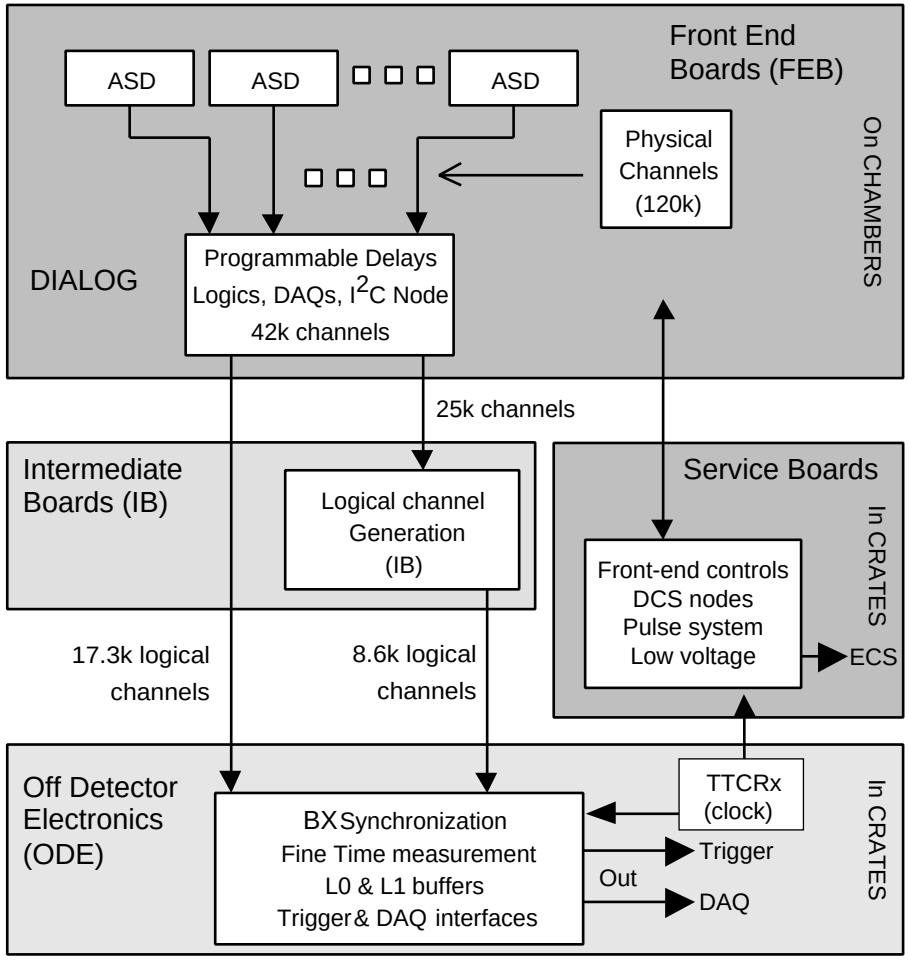
Cosmic ray test of the assembled chambers



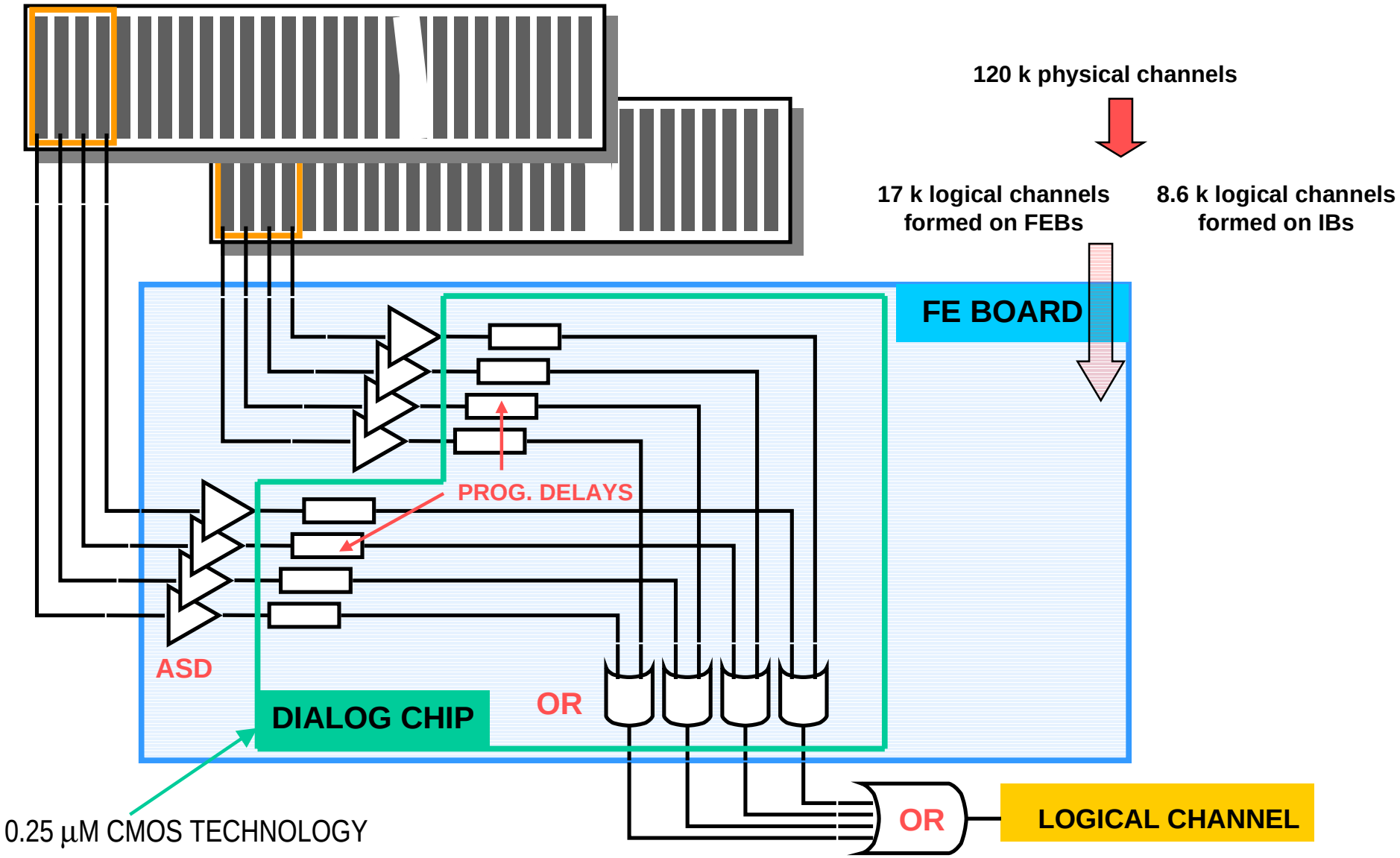
Muon System Readout Electronics

SYSTEM ARCHITECTURE

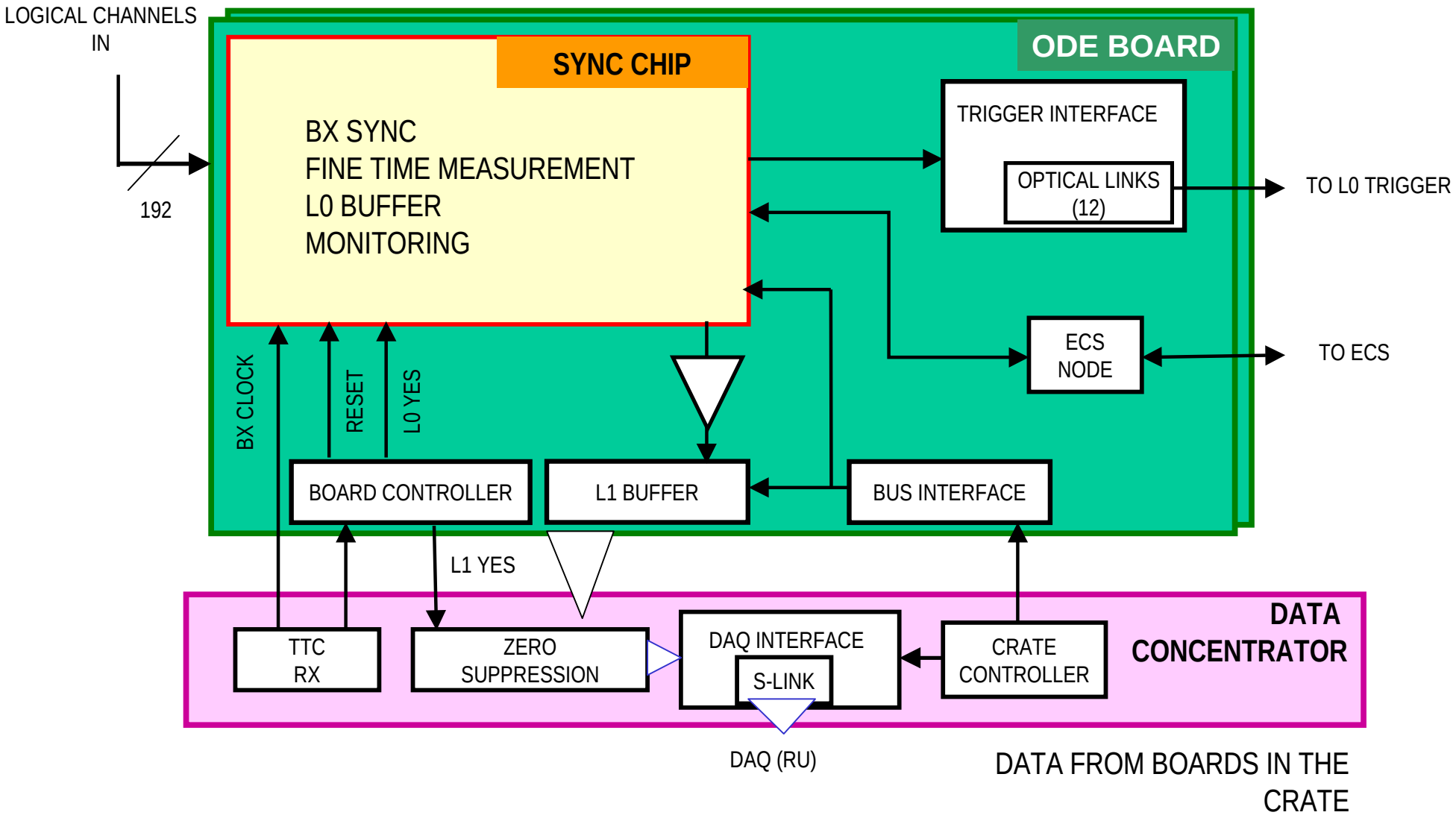
- **FE Boards: 7536**
  (with ASD and DIALOG chips)
  120 k Physical Channels
  42 k Logical Channels
- **Service Boards: 144**
  (with CAN-ELMB nodes)
- **Intermediate Boards: 168**
  26 k Logical Channels
- **Off Detector Electronics Boards: 168**



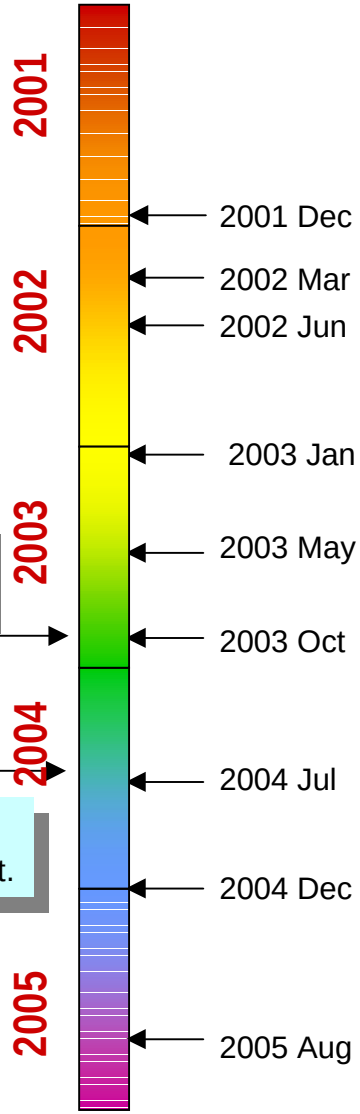
Forming the Logical Channels
(simplified scheme)



OFF Detector Electronics



Muon Detector Major Milestones



2001 Dec

2002 Mar

2002 Jun

2003 Jan

2003 May

2003 Oct

2004 Jul

2004 Dec

2005 Aug

2003 Oct
Muon filter inst.

2004 Jun
Support structure inst.

MWPC Detectors **RPC Detectors** **Electronics**

Engineering design completed

CARIOCA+DIALOG chip design and test completed

SYNC chip design and test completed

2002 Jul-Oct
Full chain electronics test

Start FE-board production

Start chamber construction

Start chamber construction

Start IMB, SB and ODE production

Start installation at CERN

Chamber construction completed

Electronics assembled and tested

Commissioning completed

Sharing of Responsibilities

Task	Institutes
MWPC Detectors	
M1-M3 outer part	Ferrara, LNF, PNPI, Rome I/Potenza
M2-M5 inner part	CBPF, CERN, Ferrara, LNF, UFRJ
RPC Detectors	
M4-M5 outer part	Firenze, Roma II
Inner part of M1	
	Cagliari, LNF
Electronics	
CARIOCA chip	CERN, UFRJ
DIALOG chip	Cagliari
MWPC FE Boards	CBPF, PNPI, Rome I/Potenza, UFRJ
RPC FE Boards	Firenze, Roma II
IM Boards	LNF
Service Boards	LNF
ODE Boards (+SYNC chip)	Cagliari, LNF
Services	
Gas system (design)	CERN
Monitoring, control (ECS)	Roma I
Experimental area infrastructures	
Chamber supports	CERN, LNF
Muon filter	CERN

Project Costs (kCHF)

Item	Cost
MWPC Detectors	1220
RPC Detectors	260
Electronics	4040
Services (*)	1310
Muon filter	4000
TOTAL COSTS (incl. Spares & Contingency)	**10830**

(*) Gas and HV systems + support structures