ARE WE READY WITH RPCS FOR ICAL?

B. Satyanarayana, TIFR, Mumbai
ICAL detector and construction

Magnet coils

RPC handling trolleys

Total weight: 50Ktons

4000mm × 2000mm × 56mm low carbon iron sheets
### Factsheet of ICAL detector

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of modules</td>
<td>3</td>
</tr>
<tr>
<td>Module dimensions</td>
<td>$16m \times 16m \times 14.5m$</td>
</tr>
<tr>
<td>Detector dimensions</td>
<td>$48.4m \times 16m \times 14.5m$</td>
</tr>
<tr>
<td>No. of layers</td>
<td>150</td>
</tr>
<tr>
<td>Iron plate thickness</td>
<td>56mm</td>
</tr>
<tr>
<td>Gap for RPC trays</td>
<td>40mm</td>
</tr>
<tr>
<td>Magnetic field</td>
<td>1.3Tesla</td>
</tr>
<tr>
<td>RPC dimensions</td>
<td>$1,950mm \times 1,840mm \times 26mm$</td>
</tr>
<tr>
<td>Readout strip pitch</td>
<td>30mm</td>
</tr>
<tr>
<td>No. of RPCs/Road/Layer</td>
<td>8</td>
</tr>
<tr>
<td>No. of Roads/Layer/Module</td>
<td>8</td>
</tr>
<tr>
<td>No. of RPC units/Layer</td>
<td>192</td>
</tr>
<tr>
<td>No. of RPC units</td>
<td>$28,800 \ (97,505m^2)$</td>
</tr>
<tr>
<td>No. of readout strips</td>
<td>3,686,400</td>
</tr>
</tbody>
</table>

**B.Satyanarayana, TIFR, Mumbai**

**Are we ready with RPCs for ICAL?**

**September 22, 2011**
- Glass (bakelite) for electrodes
- Special paint mixture for semi-resistive coating
- Plastic honeycomb laminations as pick-up panel
- Special plastic films for insulation
- Avalanche (streamer) mode of operation
- Gas: R134a+Iso-butane+SF$_6$ = 95.5+4.2+0.3 (R134a+Iso-butane+Argon=56+7+37)
Construction of an RPC detector

- Signal reference plane
- Plastic honeycomb
- Copper pickup strips
- Graphite/Paint
- Top glass
- Button spacer
- Bottom glass
- Edge spacer
- Gas nozzle
- Bottom pickup panel

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Are we ready with RPCs for ICAL?

September 22, 2011
Glass cleaning

- Cleaned with *Labolene* soap solution and rinsed with distilled water
- Left to natural drying
- Wiped with iso-propyl alcohol

Spray painting

- Using auto garage compressor and paint spray gun
- Left to natural drying
- Currently scaling-up an automated paint plant used for 1m x 1m glass
**Surface resistivity measurement**

**Measurement jig**
- Developed a simple technique
- Fabricated jigs of various sizes to suit for measurements of different grid sizes

**Measurement data**
- *Reasonably* uniform
- Needs improvement at the edges
- Better uniformity obtained on sheets painted by automatic paint plant

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Are we ready with RPCs for ICAL?

September 22, 2011
Gas gap preparation-1

Bottom glass in place

- Template for button positions placed below the bottom glass
- Buttons placed on 20cm x 20cm grid

Gluing of buttons

- Currently glue dispensed manually
- Protective template placed on the glass
- Auto timer-based glue dispenser being designed
Gas gap preparation-2

Placing the top glass

- Tilting the work table for placing the top glass electrode
- Precise stoppers mounted on the table for guiding the top glass

Vacuum jig for gluing

- A simple vacuum jig designed for perfect and efficient gluing of the gas gap
- Technique suggested by Carlo Gustavino
Preparing to glue bottom-side

- Rotating the work table for gluing bottom-side spacers
- Suitable work-table design and over-head crane for easy handling of glasses and gaps

Ready to glue top-side spacers

- Last step before closing the gas gap
- Gas nozzles on all four corners of the gap – two each used for gas inlet and outlet
Leak testing the gap

- The gap pressurised marginally above atmosphere with R134a gas
- Tested for leaks with R134a leak detector
- Leaks plugged

Fully fabricated gas gap

- Gap ready to be assembled as an RPC detector chamber
RPC pulse height studies

Preamplifier pulse shots

Pulse height distribution

Mean pulse height from the RPC: 2.5-3mV

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Are we ready with RPCs for ICAL?

September 22, 2011
Charge and time distributions

Charge

Timing

<table>
<thead>
<tr>
<th>Parameter</th>
<th>tdc1</th>
<th>qdc1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entries</td>
<td>5997</td>
<td>7426</td>
</tr>
<tr>
<td>Mean</td>
<td>601.1</td>
<td>55.78</td>
</tr>
<tr>
<td>RMS</td>
<td>21.48</td>
<td>30.58</td>
</tr>
<tr>
<td>$\chi^2 / \text{ndf}$</td>
<td>543.1 / 168</td>
<td>1322 / 235</td>
</tr>
<tr>
<td>Prob</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Constant</td>
<td>121.1</td>
<td>157.4</td>
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<tr>
<td>Mean</td>
<td>602.2</td>
<td>50.26</td>
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<tr>
<td>Sigma</td>
<td>17.98</td>
<td>15.55</td>
</tr>
</tbody>
</table>

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Are we ready with RPCs for ICAL?

September 22, 2011
Efficiency plateau

Noise rate profile

Monitoring operating parameters

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SF₆ studies: Chamber current

V-I characteristics

Chamber current

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SF$_6$ studies: Collected signal charge

Charge distributions

Charge parameters
Efficiency

Noise Rate

SF₆ studies: Important operating parameters

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SF$_6$ studies: Timing characteristics

Time response

Time resolution

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Are we ready with RPCs for ICAL?

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Prototyping of ICAL detector

1mx1m RPC prototype stack

2mx2m RPC test stand

Industrial production of RPC

1mx1m ICAL prototype
Results from prototype stack

A muon track

Position residue plot

Tomography of RPC

Zenith angle distribution

Velocity plot

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Are we ready with RPCs for ICAL?

September 22, 2011
Features of ICAL FE ASIC

- IC Service: Europractice (MPW), Belgium
- Service agent: IMEC, Belgium
- Foundry: austriamicrosystems
- Process: AMSc35b4c3 (0.35μm CMOS)
- Input dynamic range: 18fC – 1.36pC
- Input impedance: 45Ω @350MHz
- Amplifier gain: 8mV/μA
- 3-dB Bandwidth: 274MHz
- Rise time: 1.2ns
- Comparator’s sensitivity: 2mV
- LVDS drive: 4mA
- Power per channel: < 20mW
- Package: CLCC48(48-pin)
- Chip area: 13mm²
High voltage for RPCs
- **Voltage:** 10kV (nominal for Glass, less for Bakelite)
- **Current:** 6mA (approx., 200nA per chamber)
- **Ramp up/down, on/off, monitoring**

Low voltage for electronics
- Voltages and current budgets still not available

Commercial and/or semi-commercial solutions
- **Buy supplies, design distribution (and control)?**

DC-DC and DC-HVDC converters; cost considerations
Cables and interconnects

- RPC to front-end boards – *the toughest*
  - Integration with pickup panel fabrication
- Front-end boards to RPC-DAQ board
  - LVDS signals (any alternatives?, prefer differential)
  - Channel address
  - Analog pulse
  - Power
- RPC-DAQ boards to trigger sub-systems
  - Four pairs, Copper, multi-line, flat cable?
- RPC-DAQ boards to back-end
  - Master trigger
  - Central clock
  - Data cable (Ethernet: copper/fibre, …)
Total number of RPCs in ICAL = \(3 \times 150 \times 64 = 28,800\)
Total gas volume = \(28,800 \times 184\text{cm} \times 184\text{cm} \times 0.2\text{cm} = 195,010\) litres

For example:
One volume change/day with 10% gas top-up in a re-circulating scheme
Approximate running gas cost = Rs 30,000/day (R134a from Mafron)

<table>
<thead>
<tr>
<th>Gas</th>
<th>Avalanche (%)</th>
<th>Streamer (%)</th>
<th>Maximum (%)</th>
<th>Volume (L)</th>
<th>Density (g/L)</th>
<th>Weight (Kg)</th>
<th>Cost (Rs/Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon</td>
<td>0.0</td>
<td>30.0</td>
<td>30.0</td>
<td>58,503</td>
<td>1.784</td>
<td>104.4</td>
<td></td>
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<tr>
<td>R134a</td>
<td>95.5</td>
<td>62.0</td>
<td>95.5</td>
<td>186,234.6</td>
<td>4.25</td>
<td>791.5</td>
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<tr>
<td>Isobutane</td>
<td>4.3</td>
<td>8.0</td>
<td>8.0</td>
<td>15,600.8</td>
<td>2.51</td>
<td>39.16</td>
<td></td>
</tr>
<tr>
<td>SF(_6)</td>
<td>0.2</td>
<td>0.0</td>
<td>0.2</td>
<td>390</td>
<td>6.164</td>
<td>2.40</td>
<td></td>
</tr>
</tbody>
</table>
Sealed gas test for C217 stack

- Stack of 12 1m×1m RPCs
- L0, L4 and L11 were used as reference
- Other RPCs sealed on April 27, 2010

Summary of the study

<table>
<thead>
<tr>
<th>Sl. no</th>
<th>Layer No</th>
<th>RPC Name</th>
<th>Sealing date</th>
<th>Gas flow restarted</th>
<th>No of days sealed</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>L00</td>
<td>AB06</td>
<td>--------------</td>
<td>--------------------</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>L01</td>
<td>AB07</td>
<td>27-Apr-10</td>
<td>19-Jul-10</td>
<td>83</td>
</tr>
<tr>
<td>3</td>
<td>L02</td>
<td>AB10</td>
<td>27-Apr-10</td>
<td>19-Jul-10</td>
<td>83</td>
</tr>
<tr>
<td>4</td>
<td>L03</td>
<td>AB11</td>
<td>27-Apr-10</td>
<td>31-May-10</td>
<td>34</td>
</tr>
<tr>
<td>5</td>
<td>L04</td>
<td>AB09</td>
<td>--------------</td>
<td>--------------------</td>
<td>--</td>
</tr>
<tr>
<td>6</td>
<td>L05</td>
<td>IB02</td>
<td>27-Apr-10</td>
<td>19-Jul-10</td>
<td>83</td>
</tr>
<tr>
<td>7</td>
<td>L06</td>
<td>AB02</td>
<td>27-Apr-10</td>
<td>29-May-10</td>
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<tr>
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<td>AB01</td>
<td>27-Apr-10</td>
<td>29-May-10</td>
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<tr>
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<tr>
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<td>28-May-10</td>
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<tr>
<td>12</td>
<td>L11</td>
<td>AB08</td>
<td>--------------</td>
<td>--------------------</td>
<td>--</td>
</tr>
</tbody>
</table>
A = Sealed (L05, L06)  B = Flow started (L06)  C = Flow started (L05)
Closed loop recirculation system

SECTION (A)
- P1-Bellow pump
- Vacuum & flow controller Valve
- Receiver Tank 5L

SECTION (B)
- Continuous duty Purifier for removal of Moisture, Fluorocarbon radicals
- Precision Vacuum Sensor
- Buffer Tank 15L

SECTION (C)
- Calibration Bypass Valve

SECTION (D)
- Compound digital Pressure gauge
- Pressure and flow controller
- Electropneumatic Isolation Valves
- Flow Direction
- Safety Bypass line with Isolation valves
- RPC Detector stack, 2m x 2m, 12 nos

SECTION (E)
- Backpressure Pressure controller Valve
- Vent flow & pressure controller valve
- Vent (Exhaust)

B. Satyanarayana, TIFR, Mumbai
Are we ready with RPCs for ICAL?
September 22, 2011
Issues on RPC gap production
- Size, glass coating technique, high voltage contact

Pickup panel optimisation
- Cost, thickness, fire safety issue

RPC unit integration issues
- Electronics, gas, cooling, support structure

Industrial procedure optimisation
- Spacer & button gluing, curing, QC scheme

Large scale industrial production
- Many local industries are interested and getting involved

Gas system/flow optimisation
- Recycling system, flow control, optimisation, monitoring