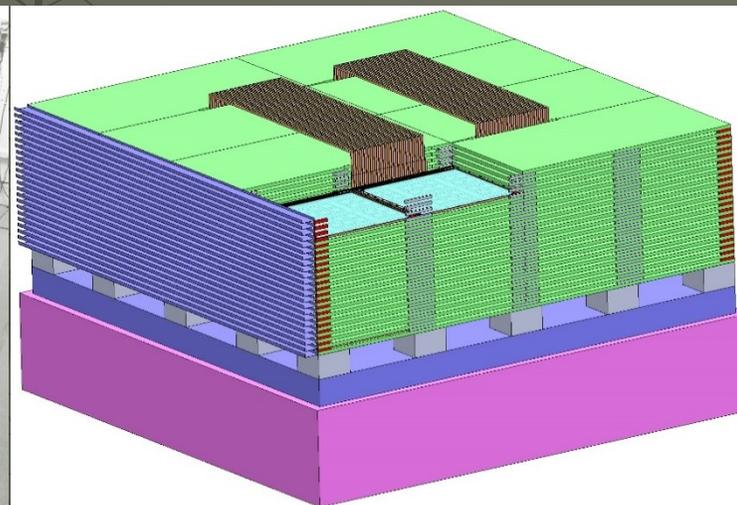
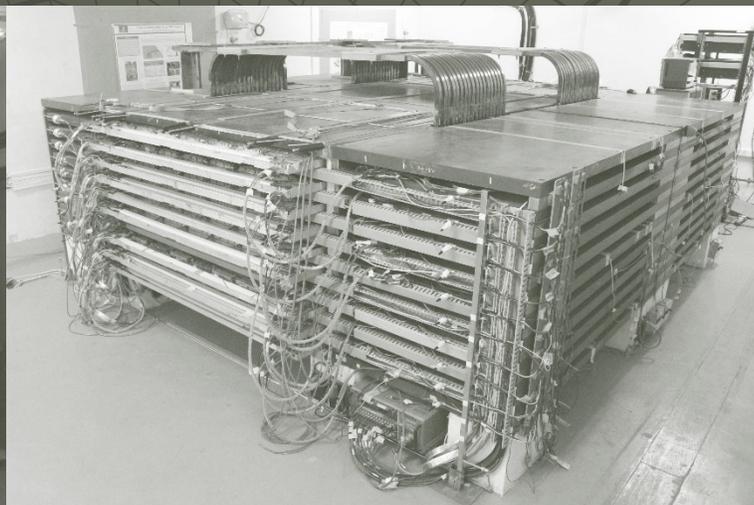
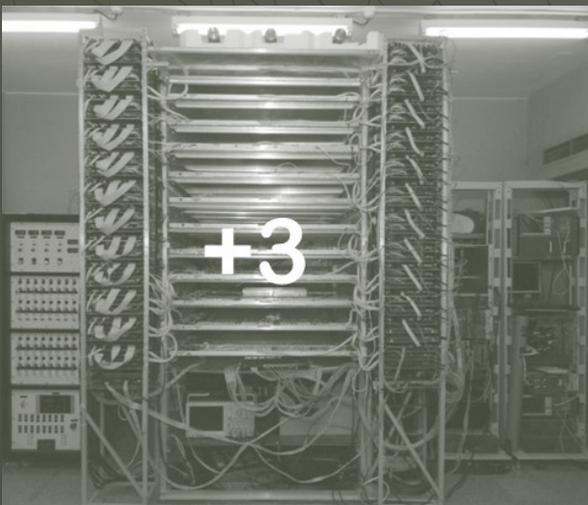


Features, and preparations for the INO's ICAL engineering module



ICAL, e-ICAL and m-ICAL

Parameter	ICAL (51kt)	e-ICAL (700t)	m-ICAL (85t)
No. of modules	3	1	1
Module dimensions	16.2m×16m×14.5m	8m×8m×2m (90:1)	4m×4m×1m (720:1)
Detector dimensions	49m×16m×14.5m	8m×8m×2m	4m×4m×1m
No. of layers	150	20	10
Iron plate thickness	56mm	56mm	56mm
Gap for RPC trays	40mm	40mm	45mm
Magnetic field	1.3Tesla	1.3Tesla	1.3Tesla
RPC dimensions	1,950mm×1,910mm×24mm	1,950mm×1,910mm×24mm	1,950mm×1,910mm×24mm
Readout strip pitch	30mm	30mm	30mm
No. of RPCs/Road/Layer	8	4	2
No. of Roads/Layer/Module	8	4	1
No. of RPC units/Layer	192	16	2
No. of RPC units	28,800 (107,266m ²)	320 (1,192m ²) (90:1)	20 (74.5m ²) (1440:1)
No. of readout strips	3,686,400	40,960 (90:1)	2,560 (1440:1) 2

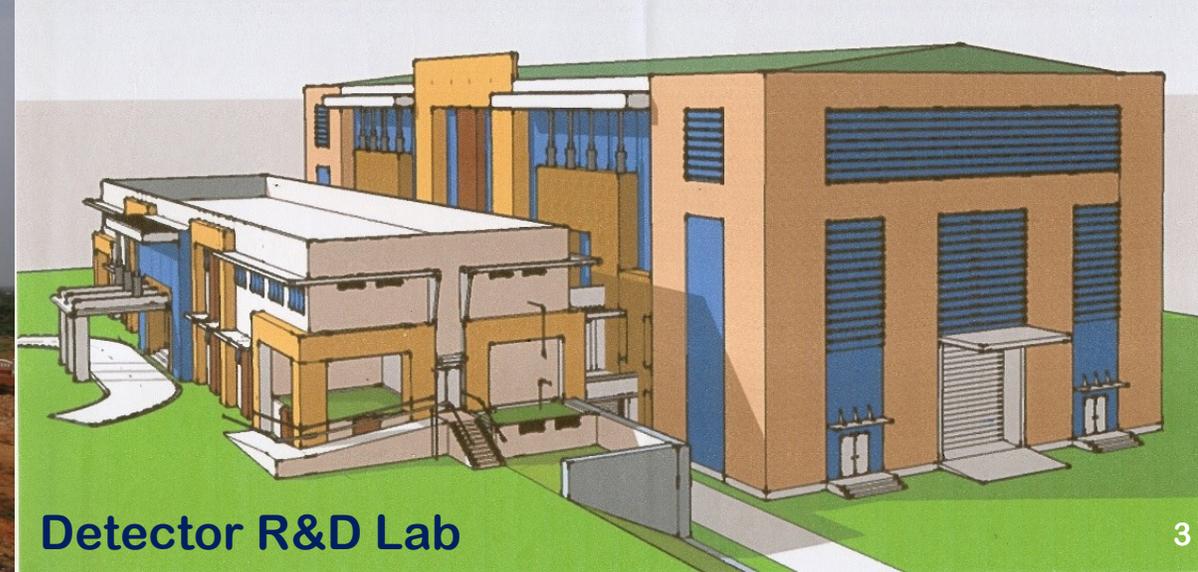
Inter-Institutional Centre for High Energy Physics (IICHEP)



12.2 hectare land close to Madurai Kamaraj University.
Centre to operate INO lab, GTP, HRD and detector R&D lab.
Geo tech investigation done, boundary wall constructed long ago.

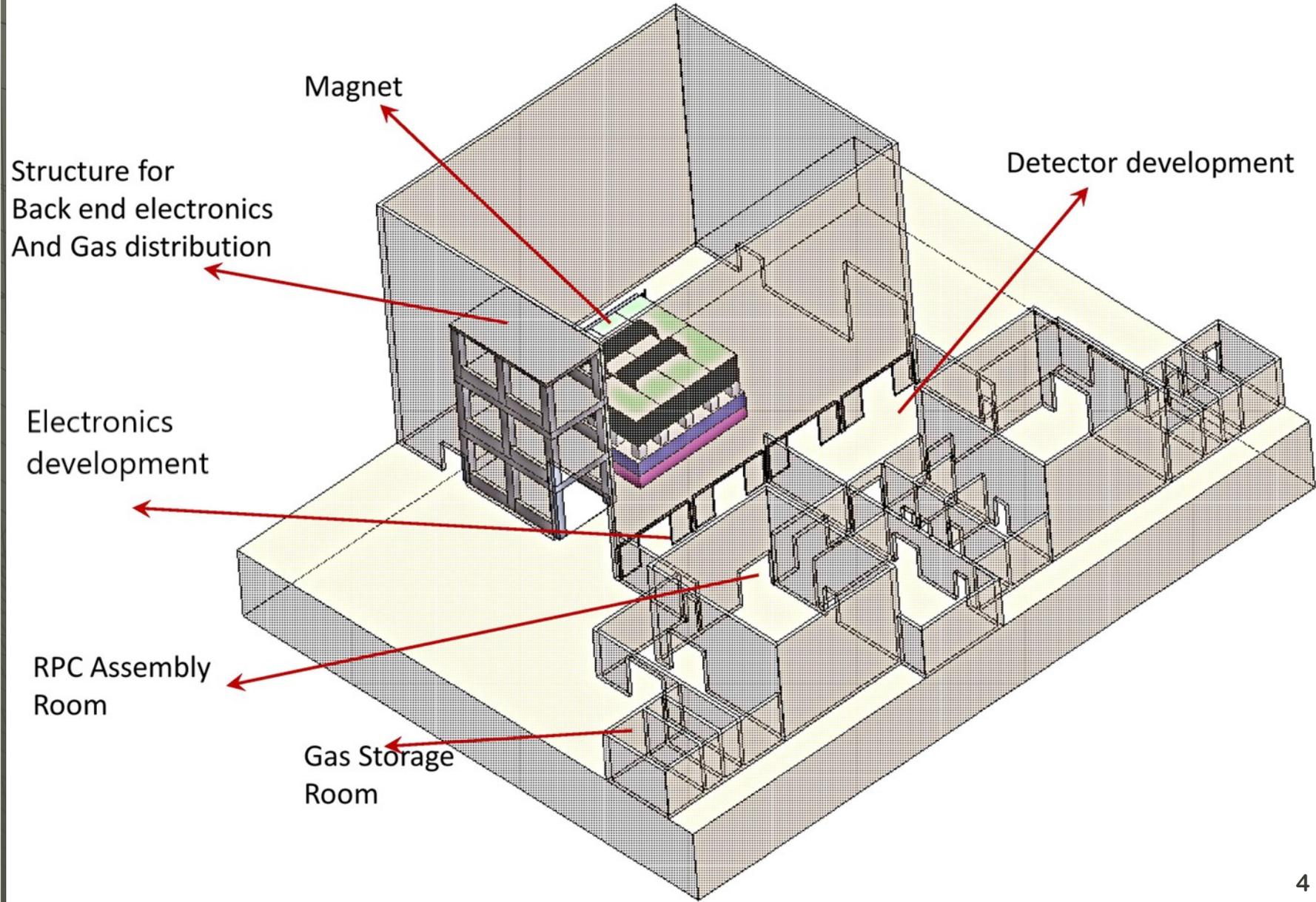
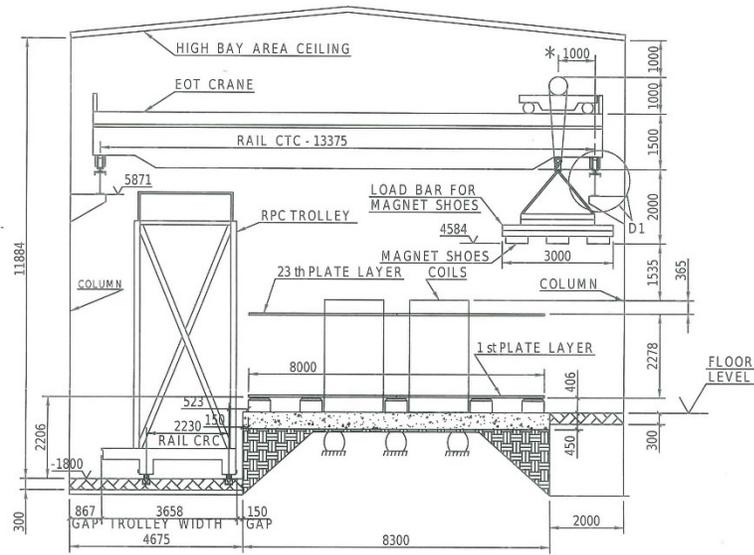


Centre Site



Detector R&D Lab

Laboratory design for e-ICAL



Low carbon steel plates and machining

ESSAR Steel (I) Pvt. Ltd., Hazira
Steel Authority of India Ltd., Bhilai
Jindal Steel & Power Ltd., Odisha
SS Engineering, Mumbai

RPC surface planarity
measurement system will
be used for qualification.



Inter-plate gap
measurement robot

Green & Green Engineering Solutions, Coimbatore

Magnet coil components and assembly



Magnet power supply and measurements



- ◆ 30V, 1500A power supply loaned from VECC for m-ICAL.
- ◆ Needed chilled water for cooling, coils too need cooling.
- ◆ The power supply is not functional now.
- ◆ 50V, 1250A air cooled, switched mode supply being procured for m-ICAL/e-ICAL.

Detector installation/maintenance trolley



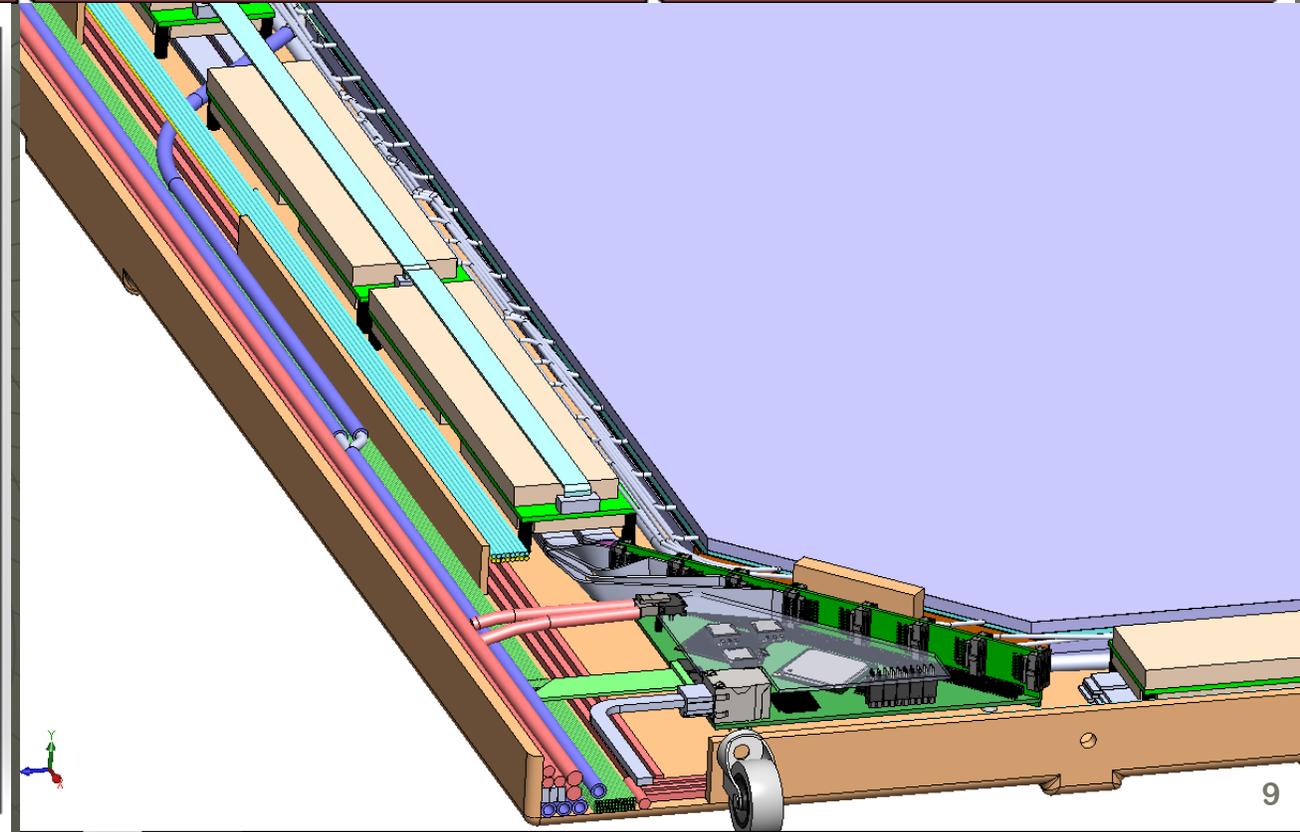
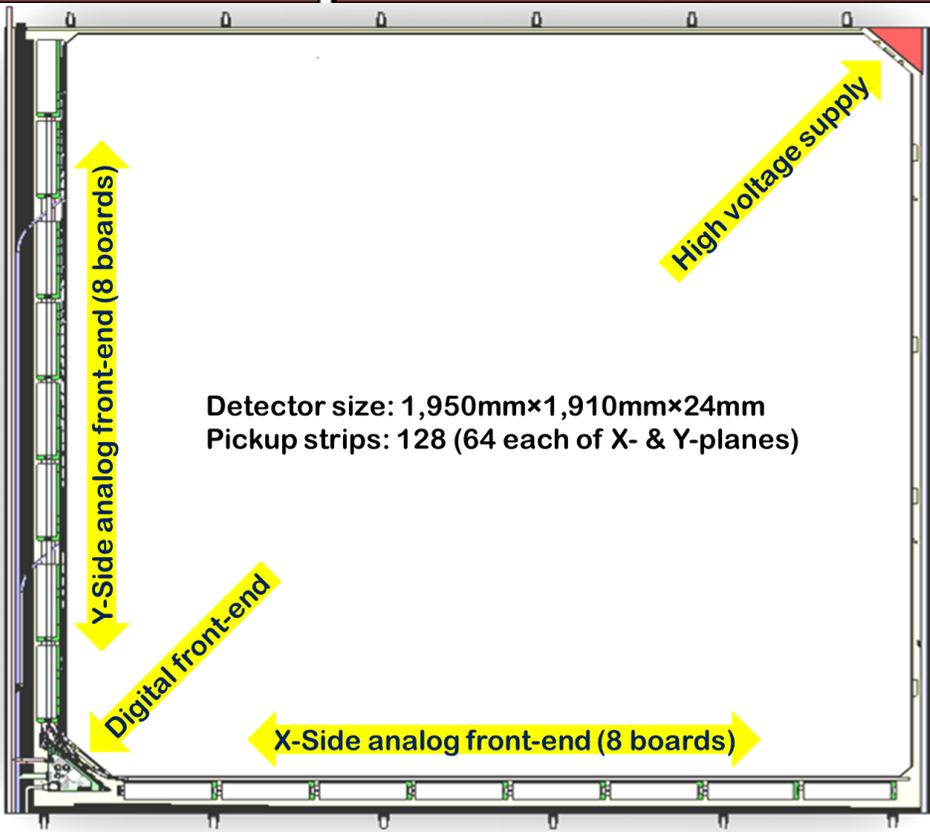
RPC insertion and extraction system is planned



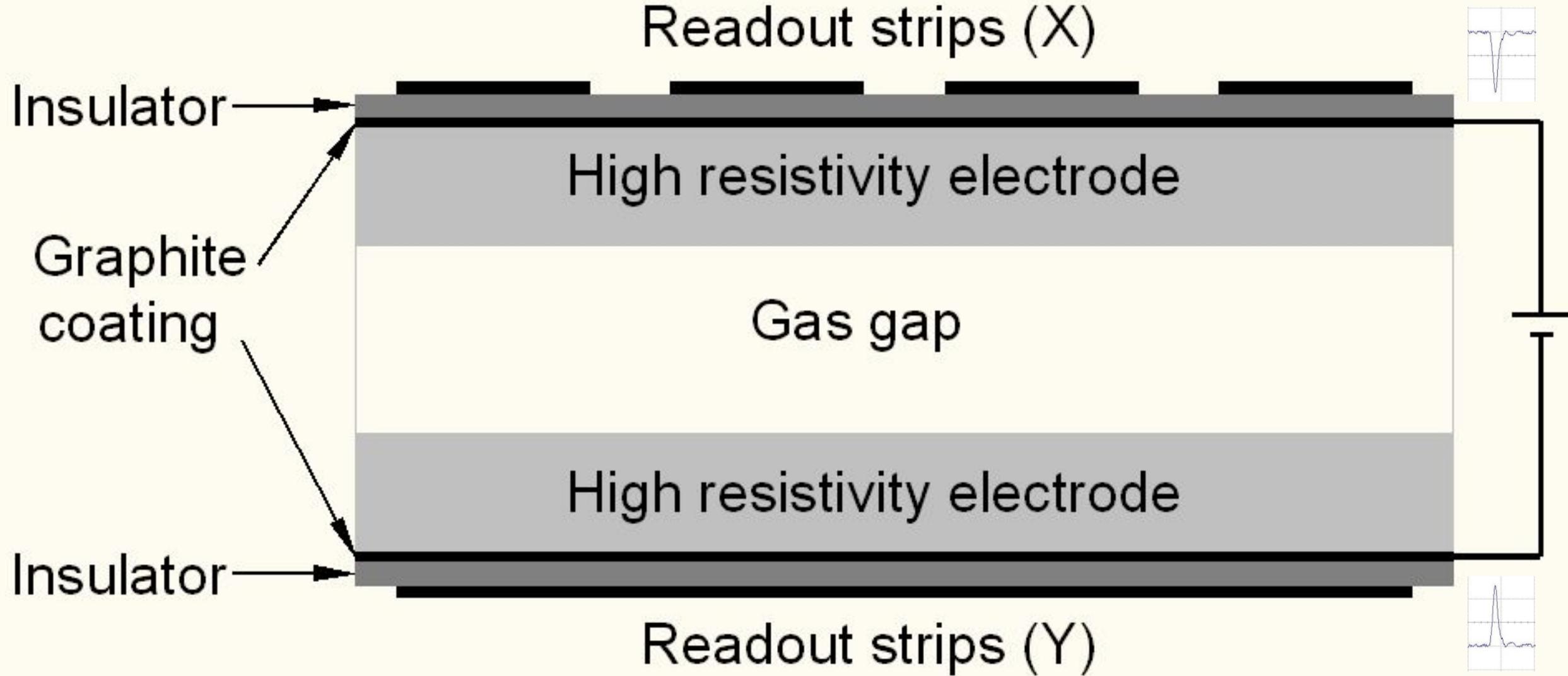
NeelKamal & Jalaram Industries

TCE (Mumbai), PCMT (Vellore) and Sunlight Automation (Bengaluru)

Integration of RPCs in e-ICAL

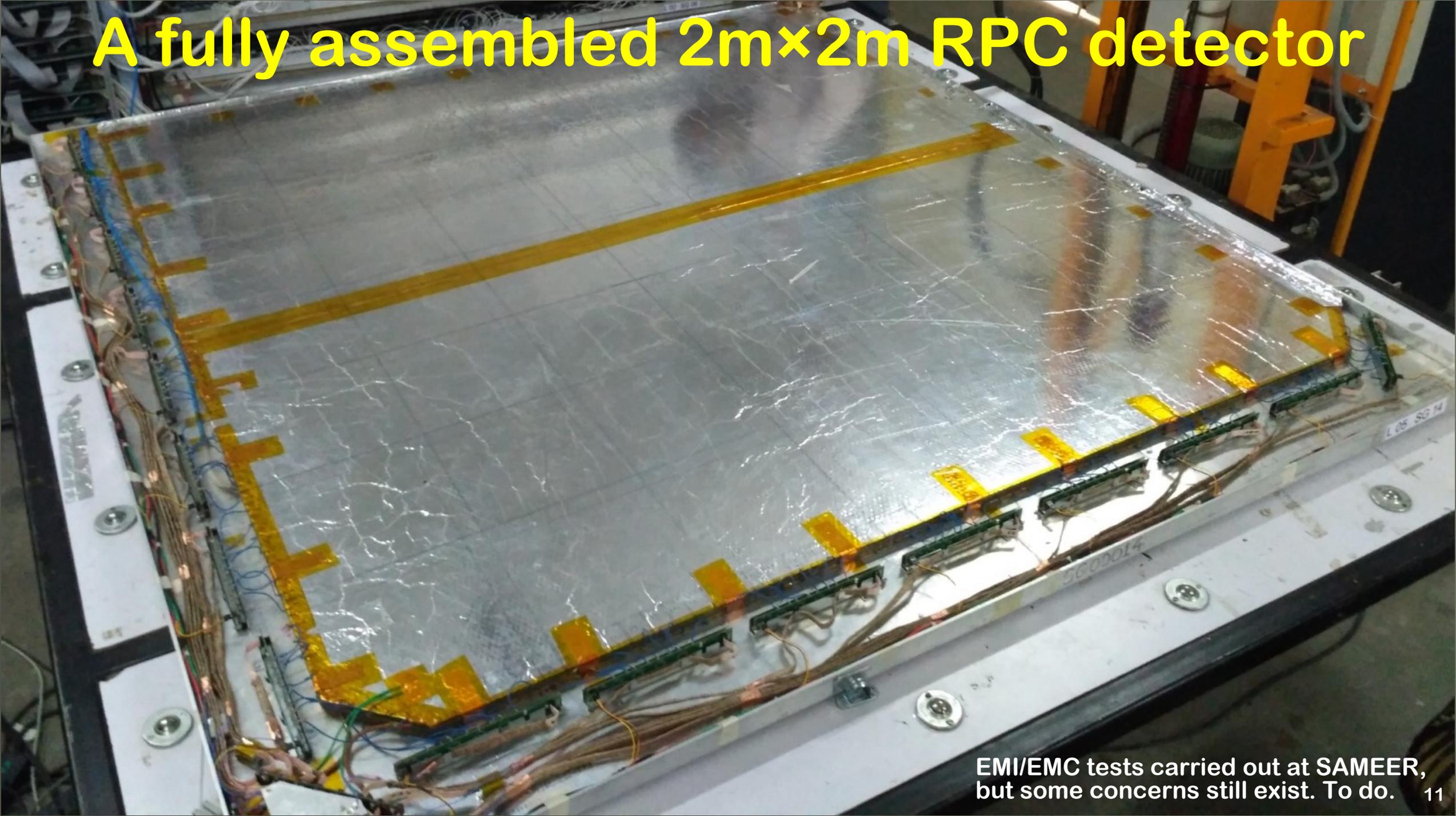


Construction of an RPC detector



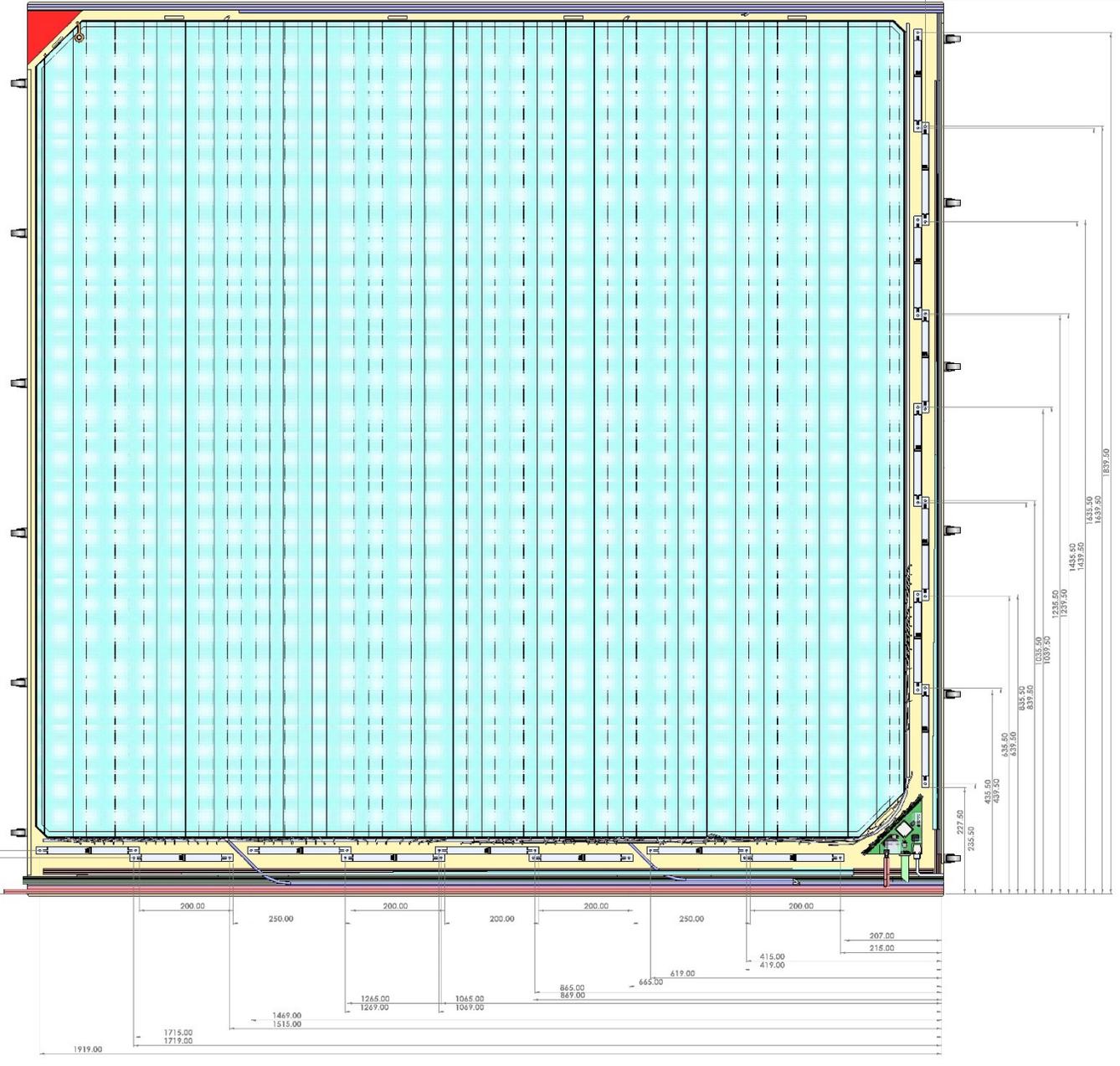
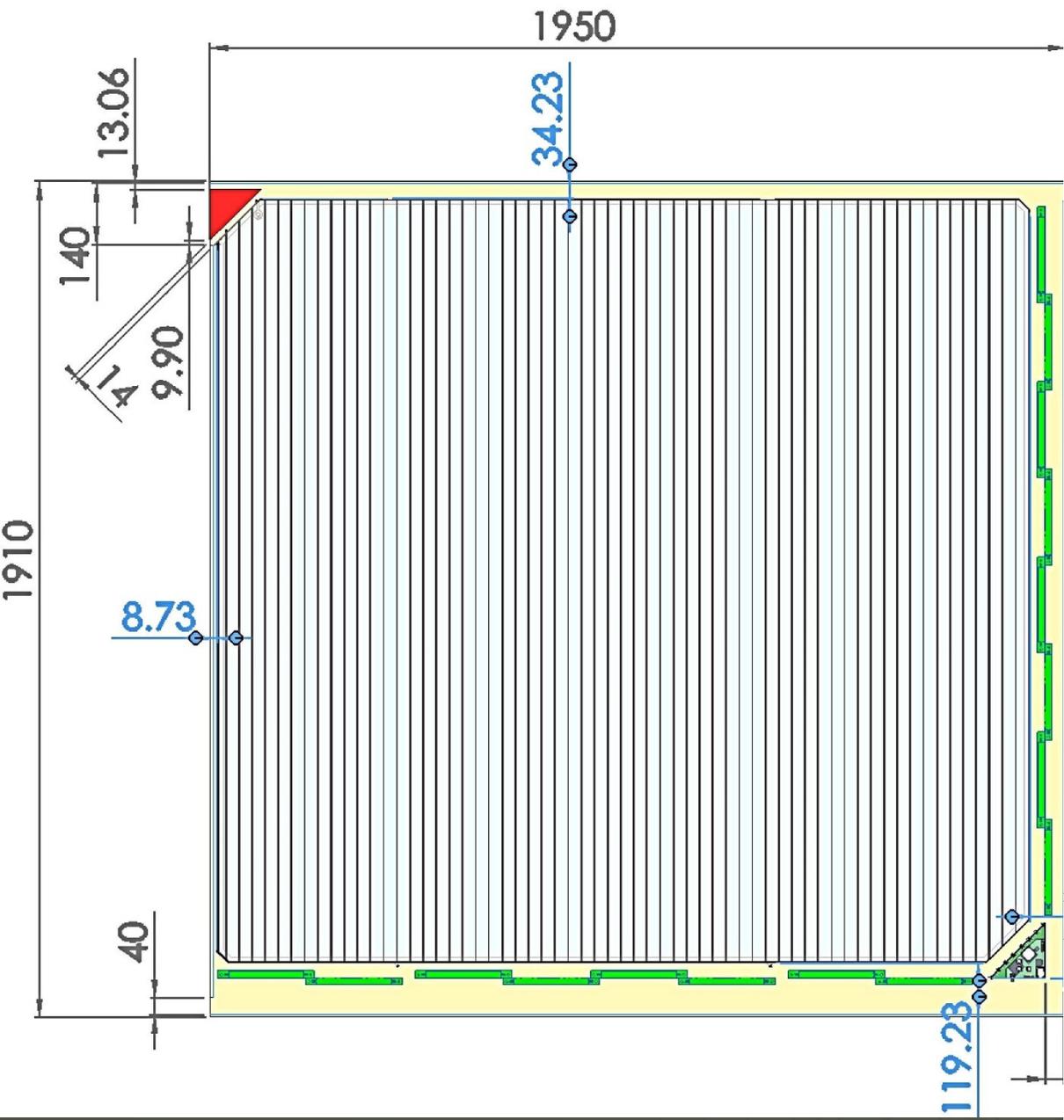
- ❖ Resistive materials like glass or bakelite for electrodes
- ❖ Special paint mixture (developed locally) for semi-resistive coating
- ❖ Plastic honey-comb laminations used as readout panel
- ❖ Avalanche mode of operation using three component gas mixture: R134a:Isobutane:SF₆ ::95.5:4.2:0.3

A fully assembled 2m×2m RPC detector



EMI/EMC tests carried out at SAMEER,
but some concerns still exist. To do.

Component layout on the RPC tray



Inks for glass electrode coating



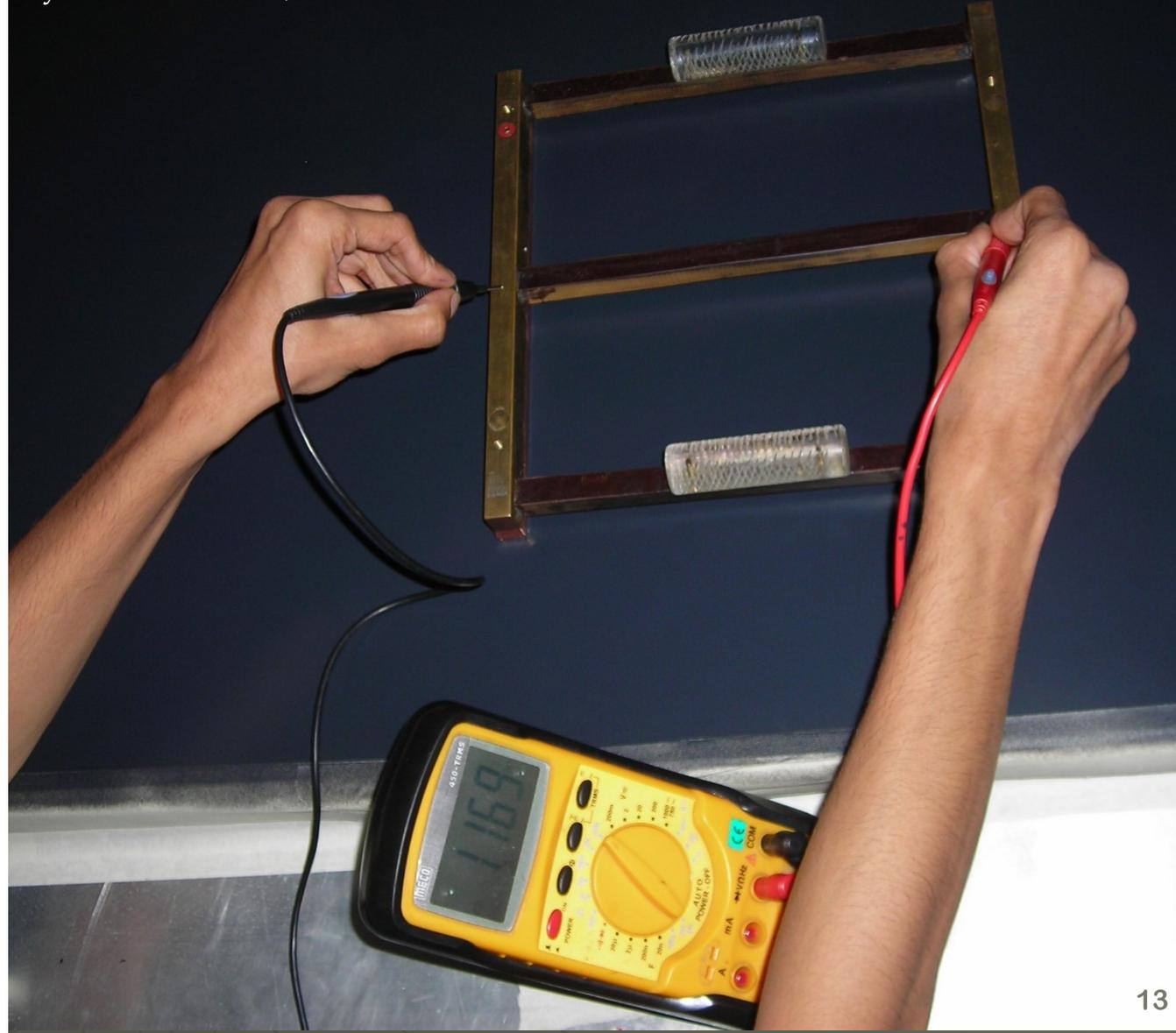
Regd office : Post Box No. 16322, Nerolac House, Ganpatrao Kadam Marg, Lower Parel, Mumbai – 400 013
Tel. : 022-2493 4001 / 2492 8008 FAX : 022-493 5742 E-Mail : gnpnet @ bom3.vsnl.net.in

PRODUCT DATA SHEET	REF. NO.	REVISION	DATE	PAGE
	1026040	00	09.12.2020	1/1

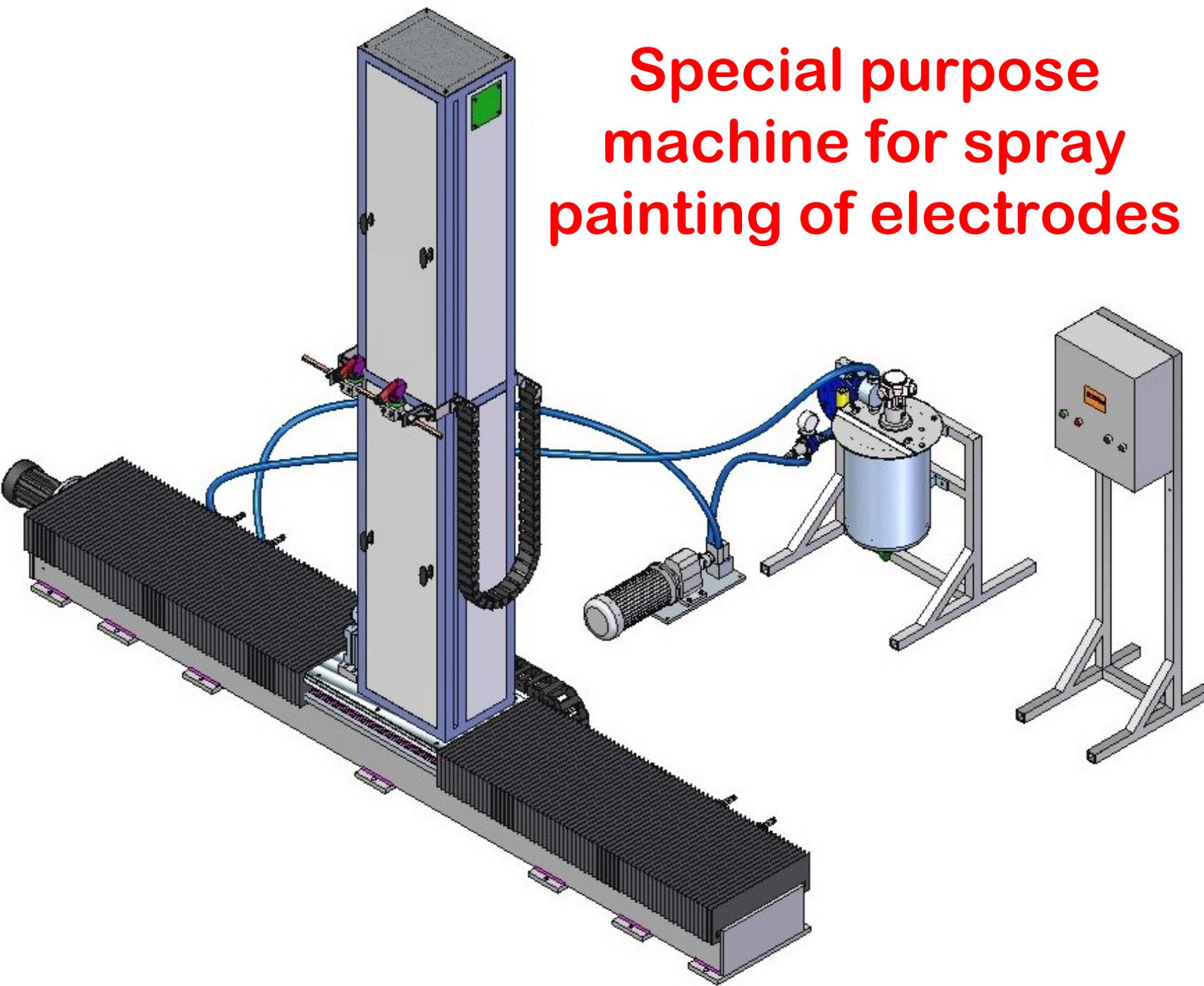
PRODUCT: CONDUCTIVE COATINGS BLACK FOR GLASS

01	Supply Weight / 10 L	11.05 Kg ± 3 %
02	Supply Viscosity	25 ± 05 Sec by F/C B-4 @ 30°C
03	Total Solids by wt (Comp A)	40 ± 3 % by Kg
04	Recommended Thinner	1000052
05	Thinner Intake	15 ± 5 % by wt
06	Application	By spraying at 18±2 sec viscosity by F/C.B-4 @ 30°C
07	Recommended DFT	25 μ
08	Comp B	HARDNER for Conductive Coatings Black for Glass
09	Mixing Ratio	Comp. A : Comp. B =100 : 05 by wt
10	Pot Life	5 hrs
11	Stoving Schedule	Air Dry
12	Color	Grey
13	Finish	Smooth & Glossy
14	Shelf Life	Six months from the date of manufacturing under normal storage conditions at 27-30°C when both the components are stored separately and away from contact of water and moisture. Thinner intake should not be more than the double of the original after six month of storage.

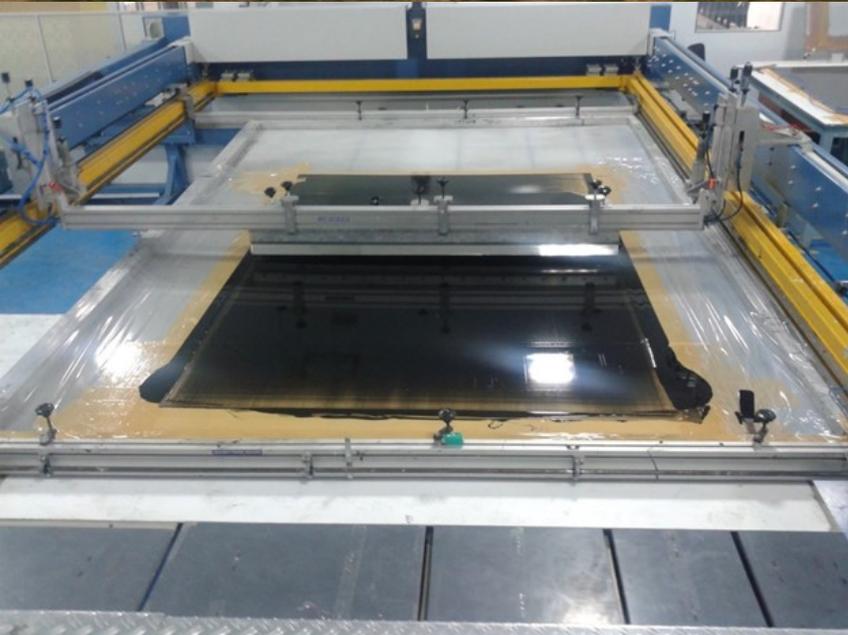
Screen printing ink Carbon Heat DC-1000M and DC-20 by M/s Dozentech, Korea



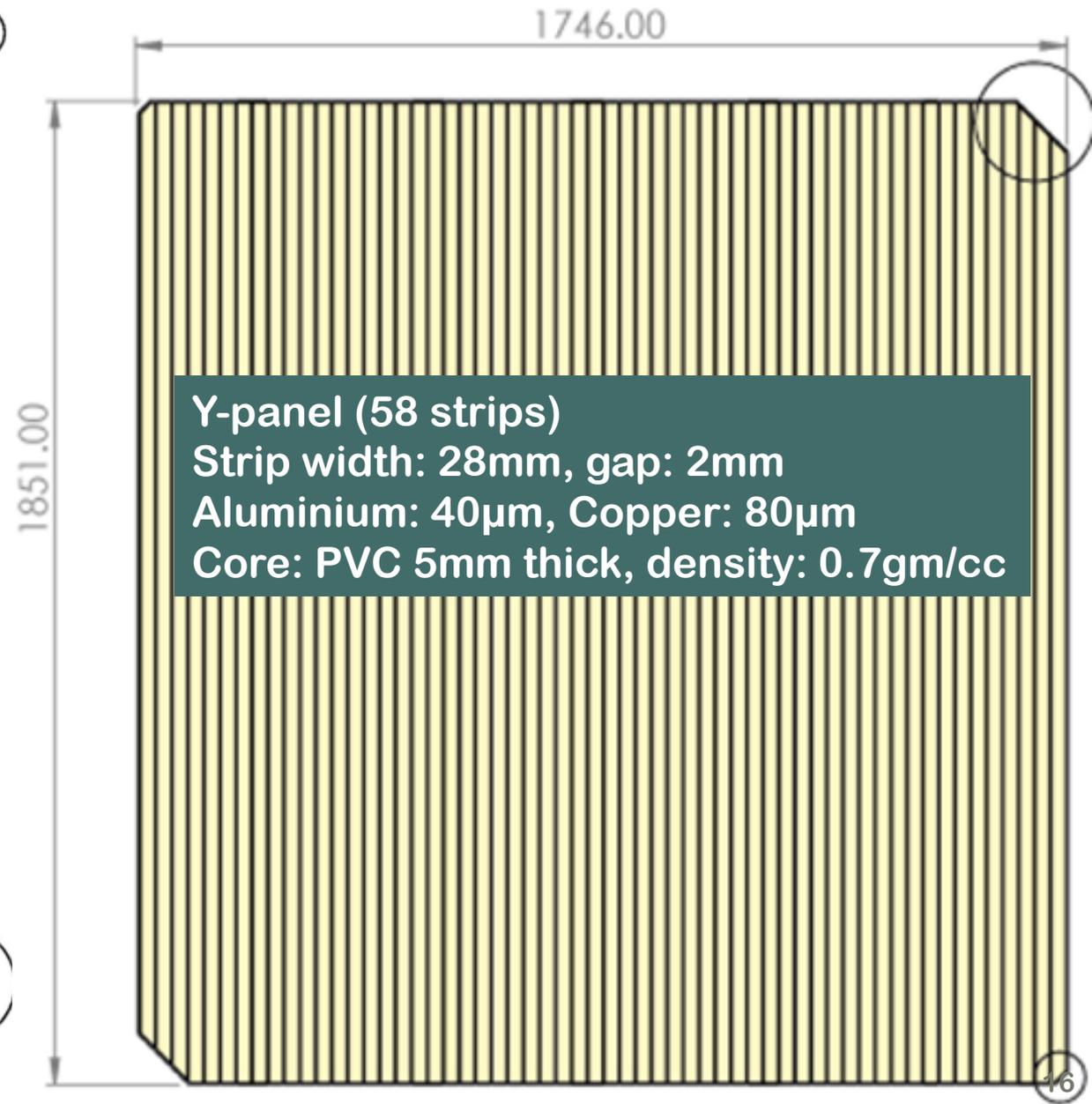
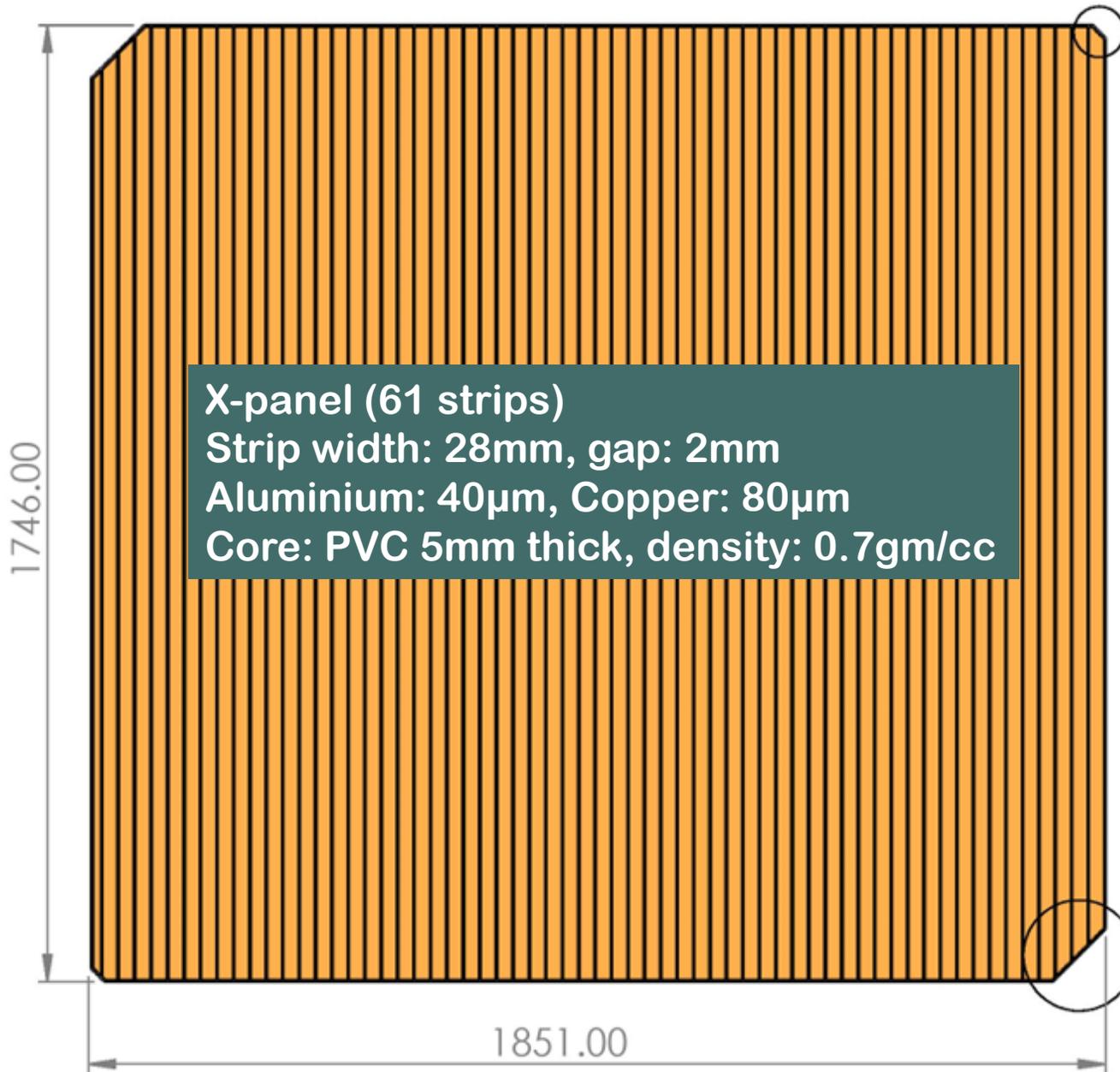
Special purpose machine for spray painting of electrodes



Screen printing and RPC gap fabrication



Pickup panels for RPC detector readout



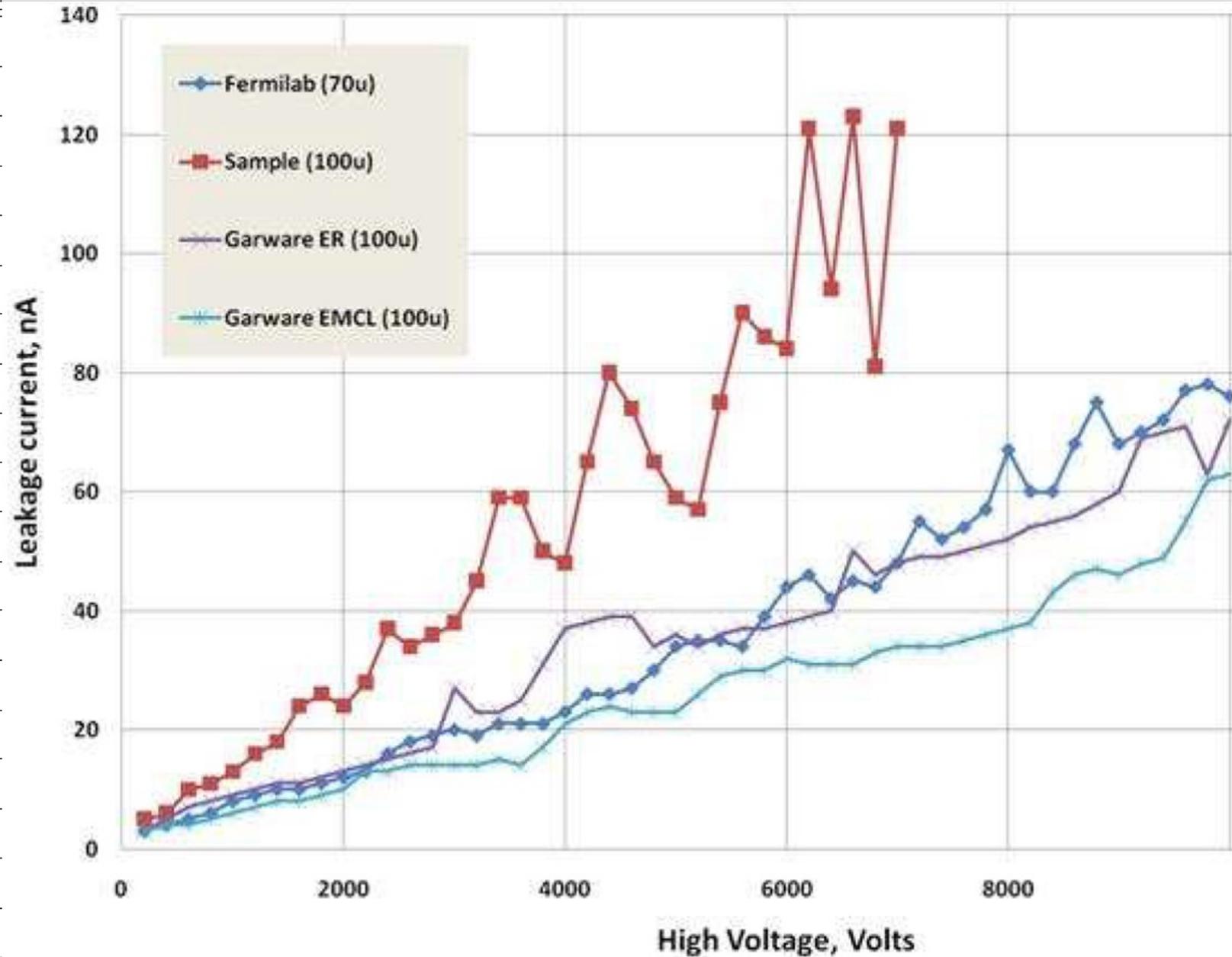
Pickup panels produced in industry



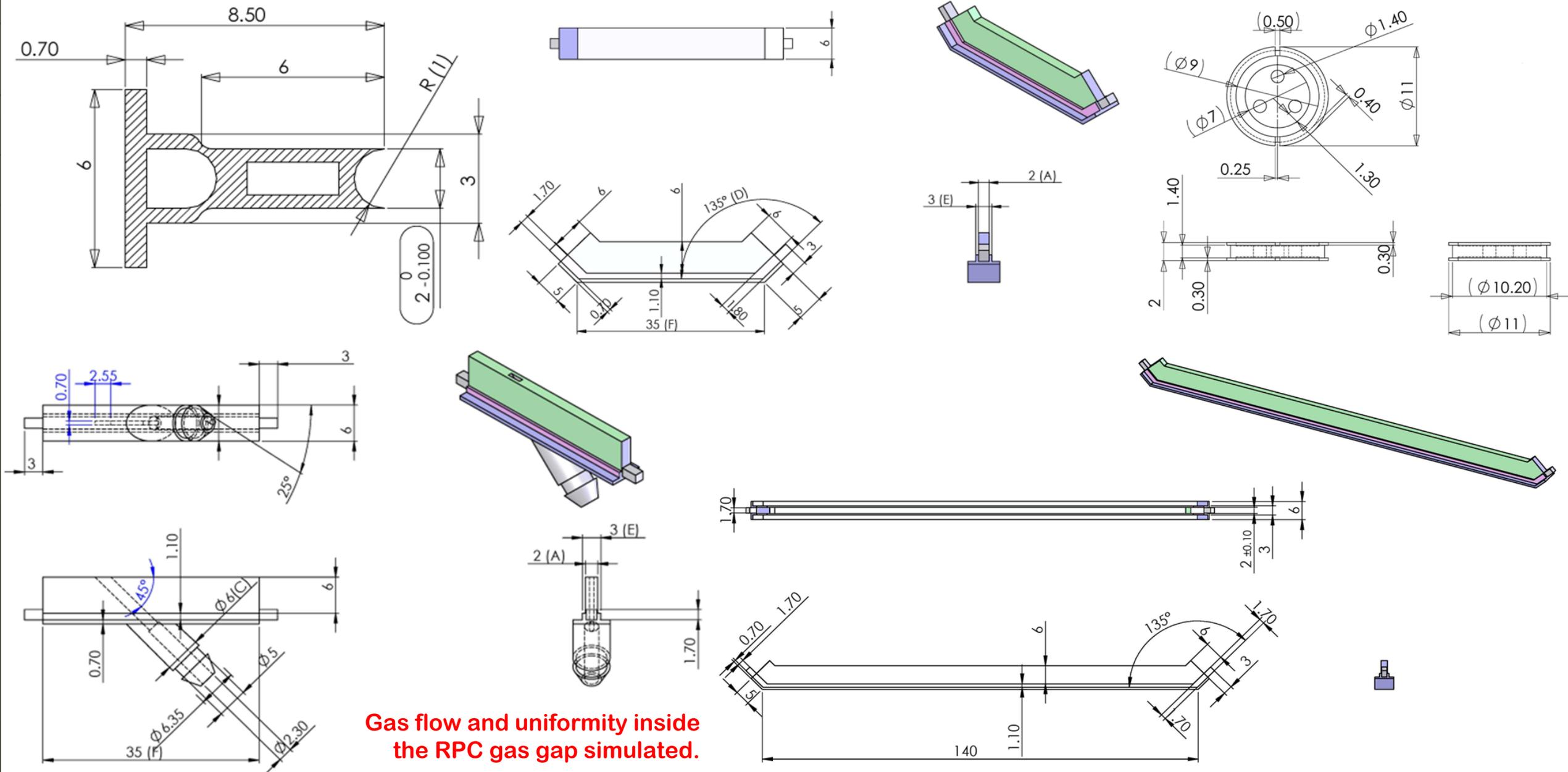
Mechanised mounting of terminations and soldering of cables planned.

Mylar sheet for insulating RPC bias

Property	Unit	Target
Thickness	μm	100.0
Yield	m^2/kg	7.1
Tensile strength	kg/cm^2	
MD		2000
TD		2000
Elongation	%	
MD		135
TD		120
Shrinkage @150°C	%	
MD		1.1
TD		0.4
Shrinkage @190°C	%	
MD		2.0
TD		1.0
Haze	%	2.0
Coeff. of friction		0.45
Standard length	m	1500
Width tolerance	mm	± 2



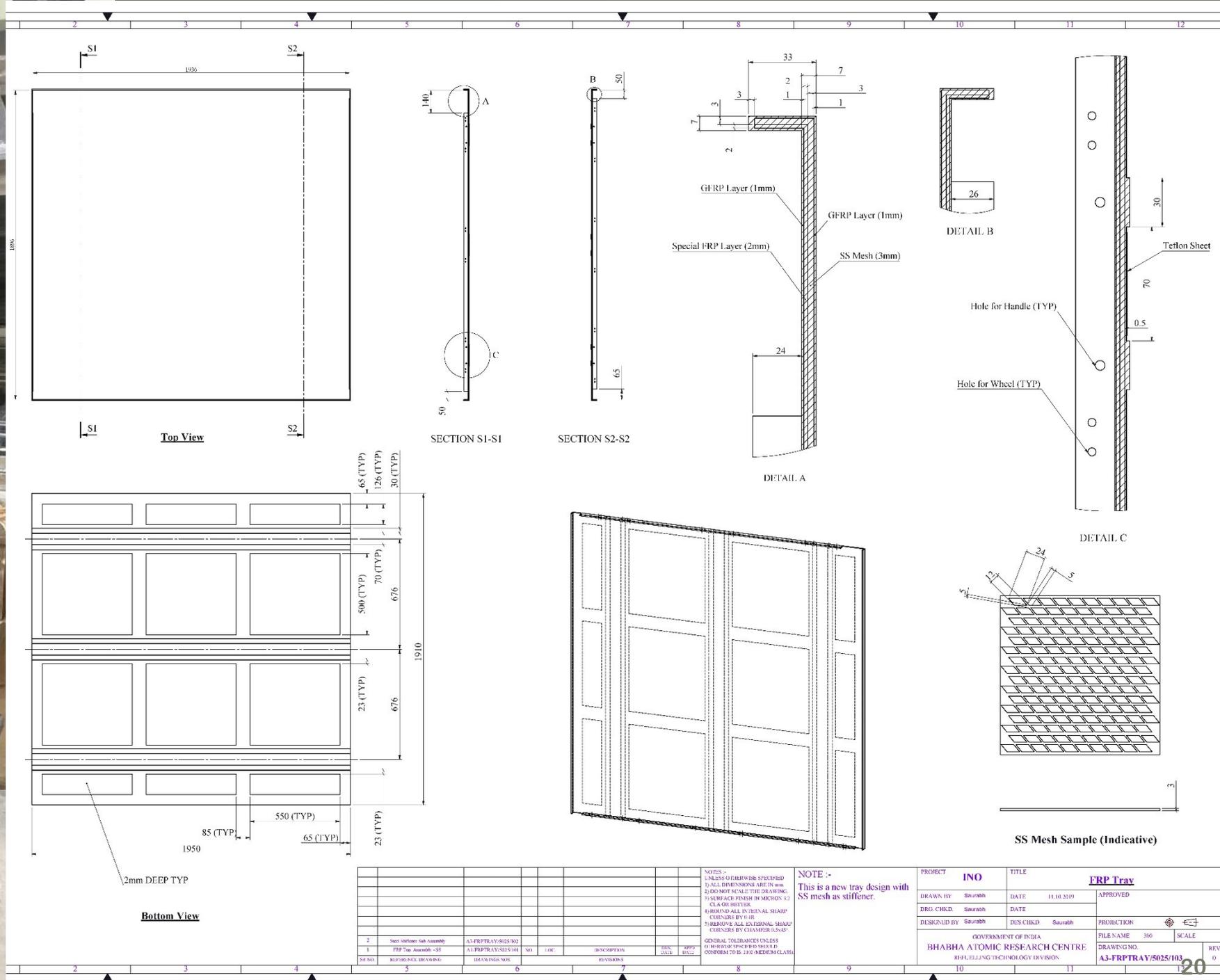
Polycarbonate parts for gas gap fabrication



Gas flow and uniformity inside the RPC gas gap simulated.



**FRP tray drawing
and RPC tray
manufacturing unit**

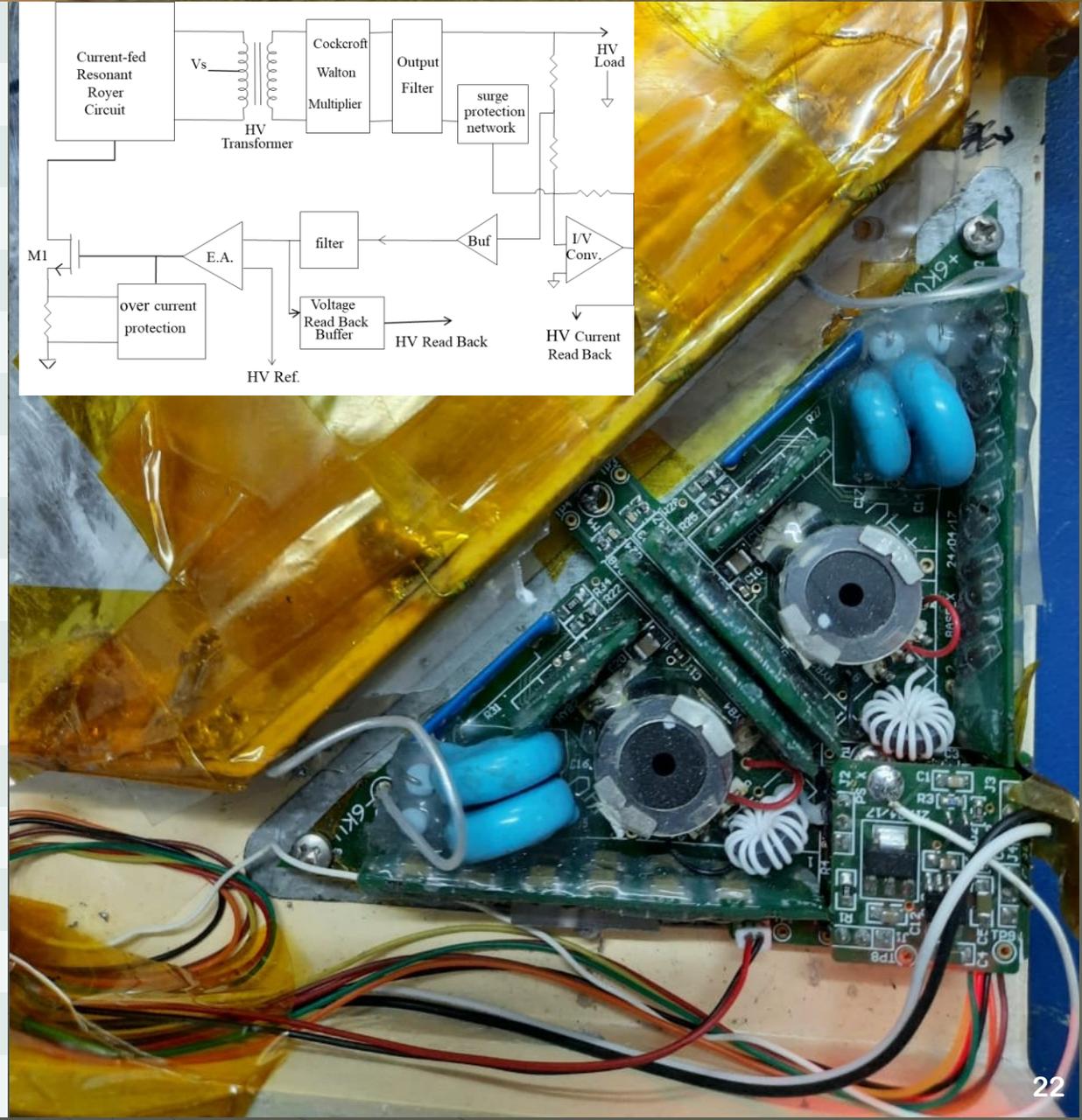
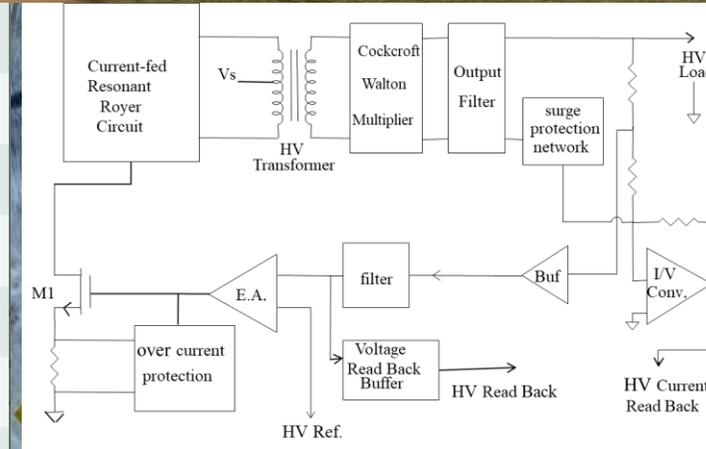


A fabricated FRP tray to host the RPC



High voltage power supply for RPC bias

1. No of HV channels	2 channels one +ve and one -ve HV
2. O/P voltage	Adjustable from 0 to ± 6 kV.
3. O/P voltage setting and monitoring resolution	2V
4. O/P voltage setting vs. monitoring accuracy	$\pm 0.7\%$ of F.S.
5. Max. O/P current	$2\mu\text{A}$
6. O/P current monitoring resolution	5nA
7. O/P current monitoring accuracy	$\pm 0.5\%$ of F.S.
8. Programmable overvoltage limit	0 to 6200V
9. Programmable over-current limit	$0.5\mu\text{A}$ to $10\mu\text{A}$
10. HV Ramp-up/down rate	0.5V - 200 V/ sec in 9 discrete steps
11. Output-ripple and noise voltage	within 200mV (p-p)
12. HV load regulation	Better than 0.05% F.S
13. HV output connection	Through 6" long flying HV leads
14. Remote voltage programming interface	Through SPI / RS-232 links
15. LV Input supply requirement	12V ($\pm 5\%$) @ 250mA (max)
16. Mechanical size	11x11 cm triangular, 26 mm (H)
17. Ambient operating temperature range	5°C to 50°C
18. Allowed ambient magnetic field	50 mT (max)



Low voltage power supply and distribution

◆ High Voltage Supply

- ❖ Voltage rail: +12V
- ❖ Voltage regulation: $\pm 5\%$
- ❖ Maximum current: 200mA
- ❖ Maximum ripple: 20 mV (p-p)
- ❖ Monitoring: Input Voltage and Current

◆ Analog Front-end

- ❖ Voltage rails: $\pm 5V$
- ❖ Maximum current: 1280 mA $\pm 10\%$ per rail
- ❖ Monitoring: Input Voltage and Current

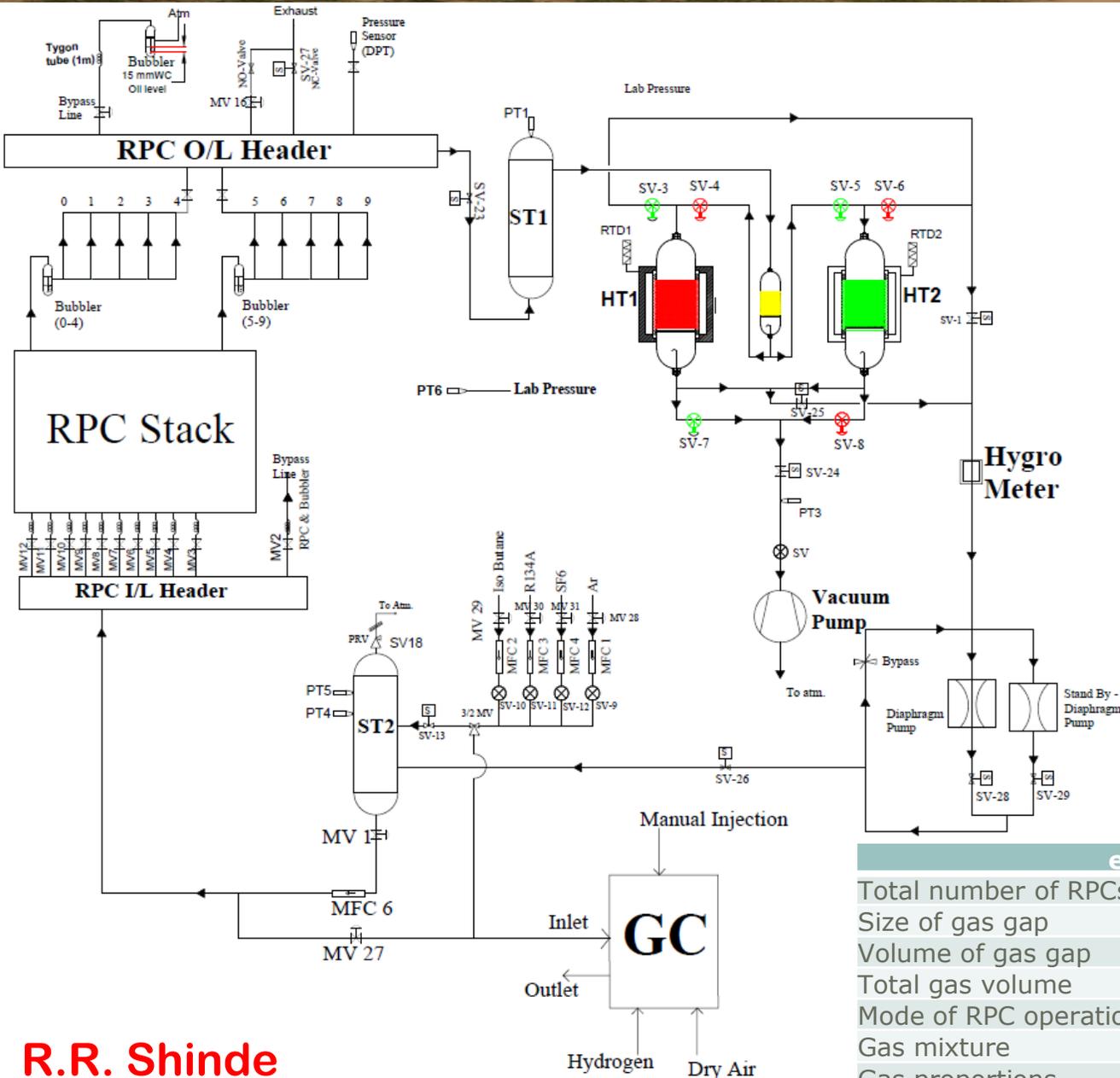
◆ Digital Front-end

- ❖ Voltage rail: +5V to +6V
- ❖ Maximum current: 1500mA
- ❖ Maximum ripple: 50mV (p-p)
- ❖ Monitoring: Input Voltage and Current
- ❖ Protection:
 - Overvoltage: Input voltage shouldn't cross +10V
 - Short Circuit: Current supplied shouldn't not exceed 1800mA



For representation purpose only

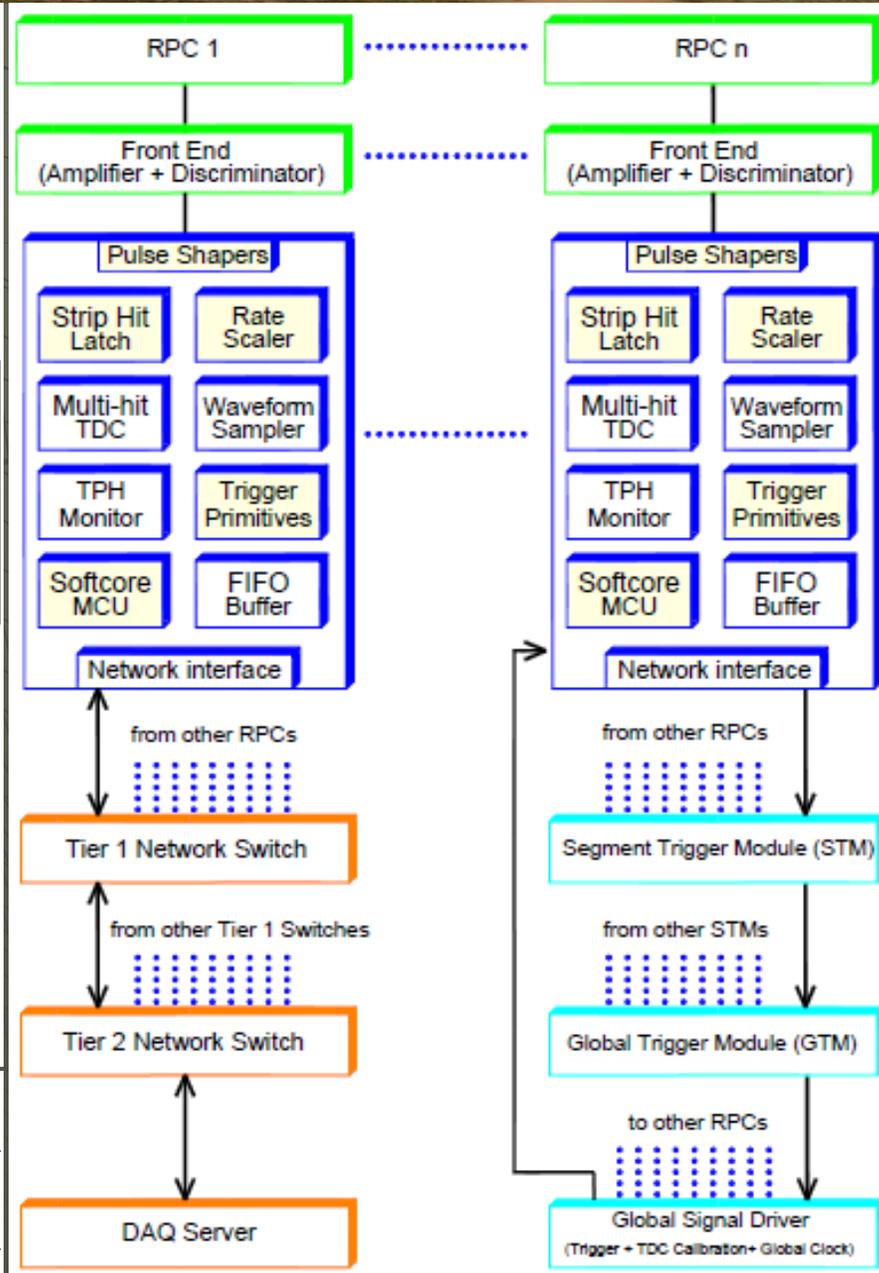
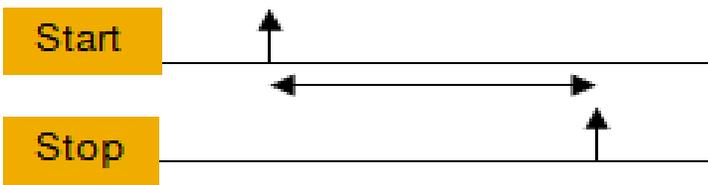
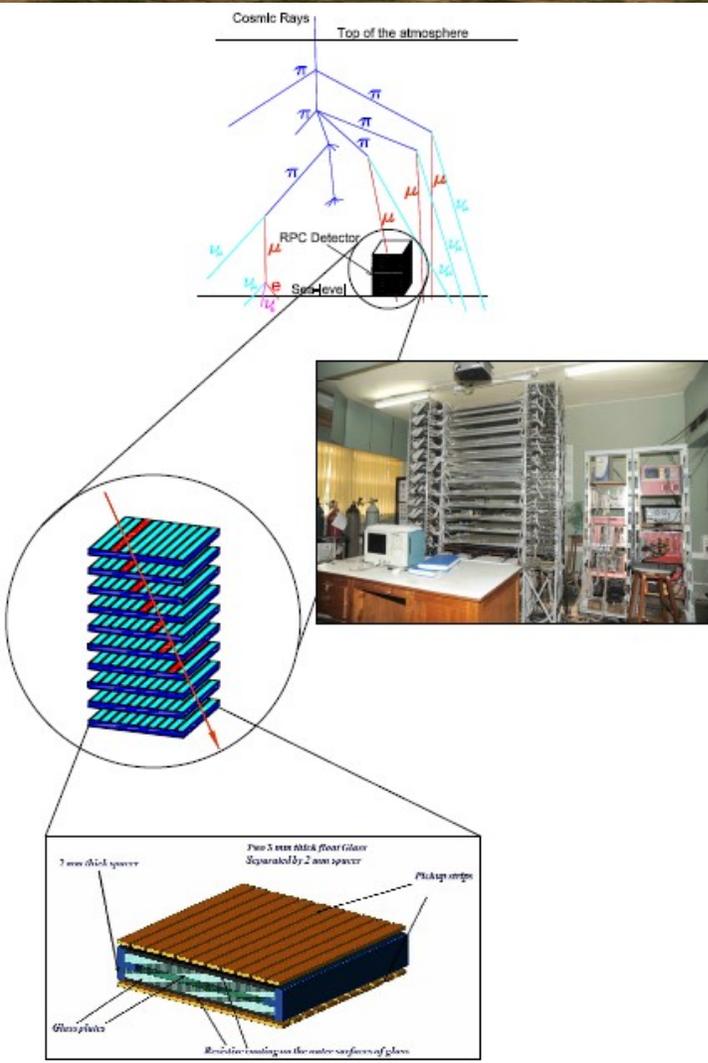
Closed loop gas system



e-ICAL requirements

Total number of RPCs	320
Size of gas gap	184.5×174×0.2 mm ³
Volume of gas gap	6.5 Litres
Total gas volume	2054 Litres
Mode of RPC operation	Avalanche
Gas mixture	R134a:Iso Butane:SF ₆
Gas proportions	95.2%:4.5%:0.3%

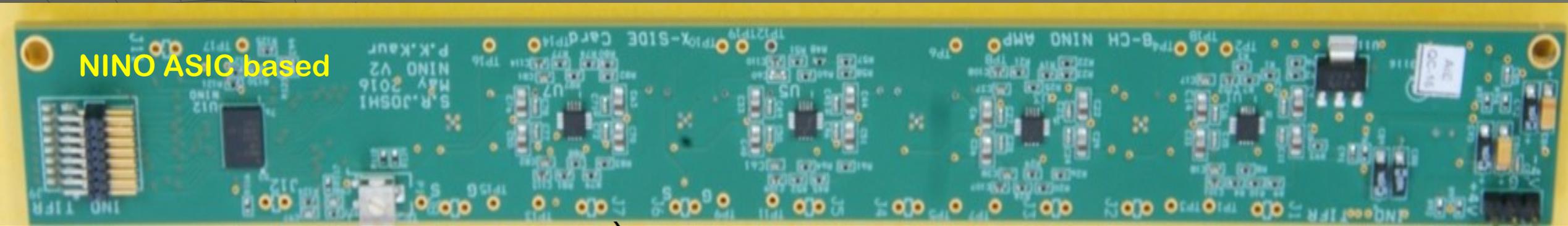
Electronics and DAQ systems



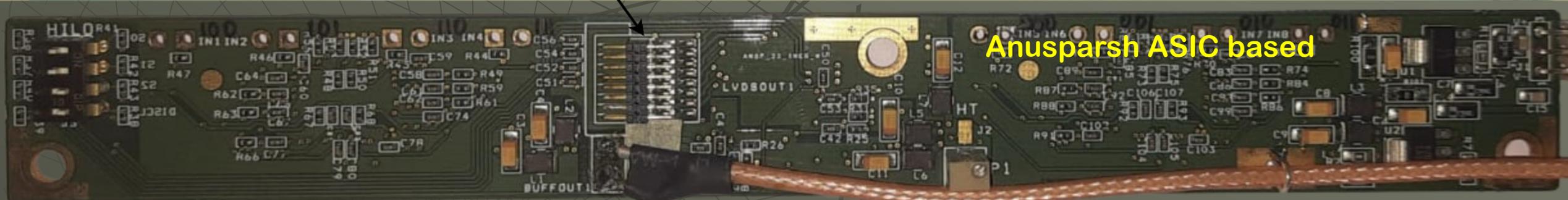
- ◆ Signal pickup and analog front-end
- ◆ **Strip hit latch (1-bit ADC)**
- ◆ Pulse shapers, timing units
- ◆ **Background noise rate monitor**
- ◆ Digital front-end and controller
- ◆ **Data network interface and architecture**
- ◆ Multilevel trigger system
- ◆ **Backend data concentrators**
- ◆ Event building, data storage systems
- ◆ **On-line data quality monitors**
- ◆ Slow control and monitoring
 - Gas system, magnet, power supplies
 - Ambient parameters (T, P and H)
 - Safety and interlocks
- ◆ **Voice and video communications**
- ◆ Remote access to detector sub-systems and data

Analog Front End solutions

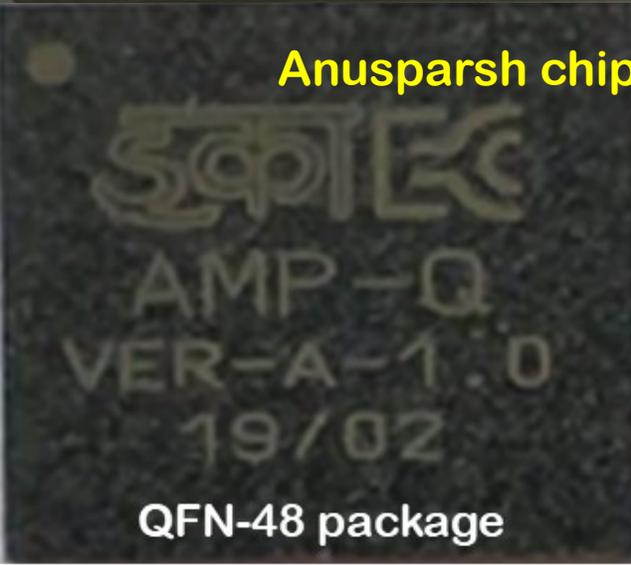
NINO ASIC based



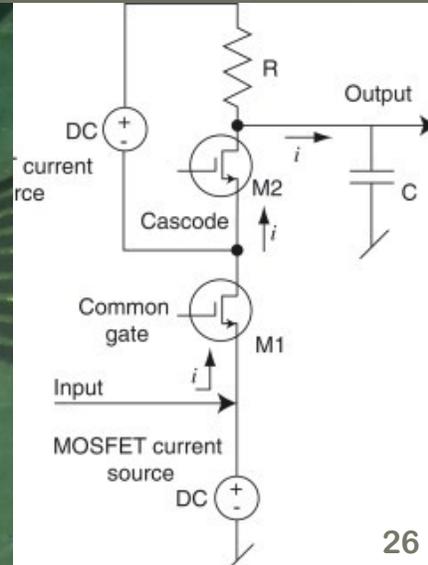
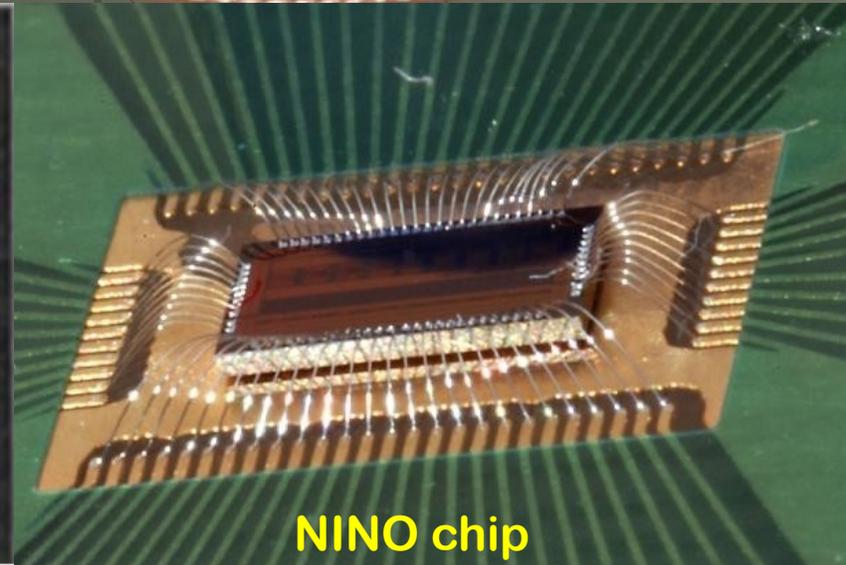
Anusparsh ASIC based



Anusparsh chip set

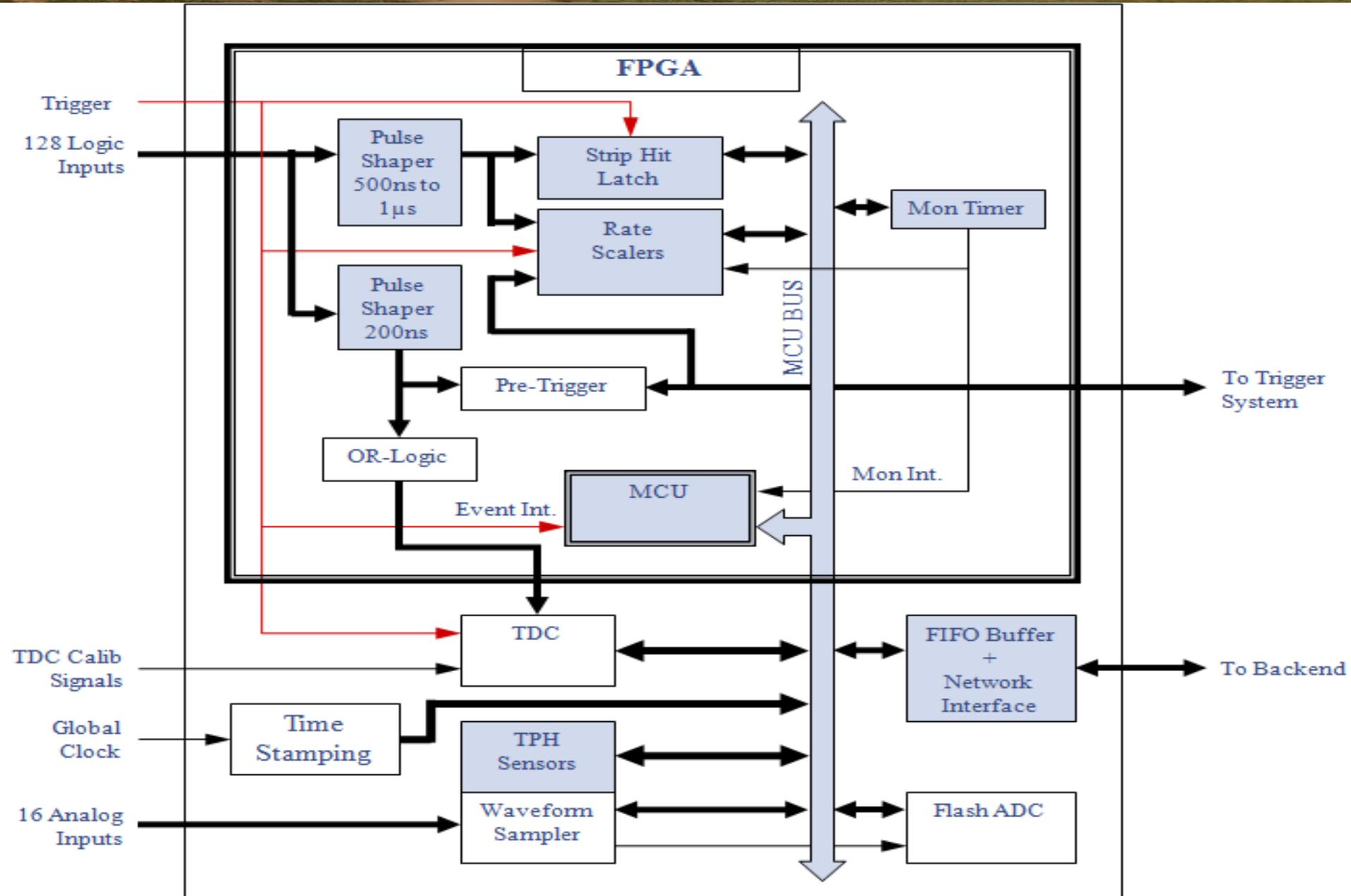


NINO chip



Digital Front End module

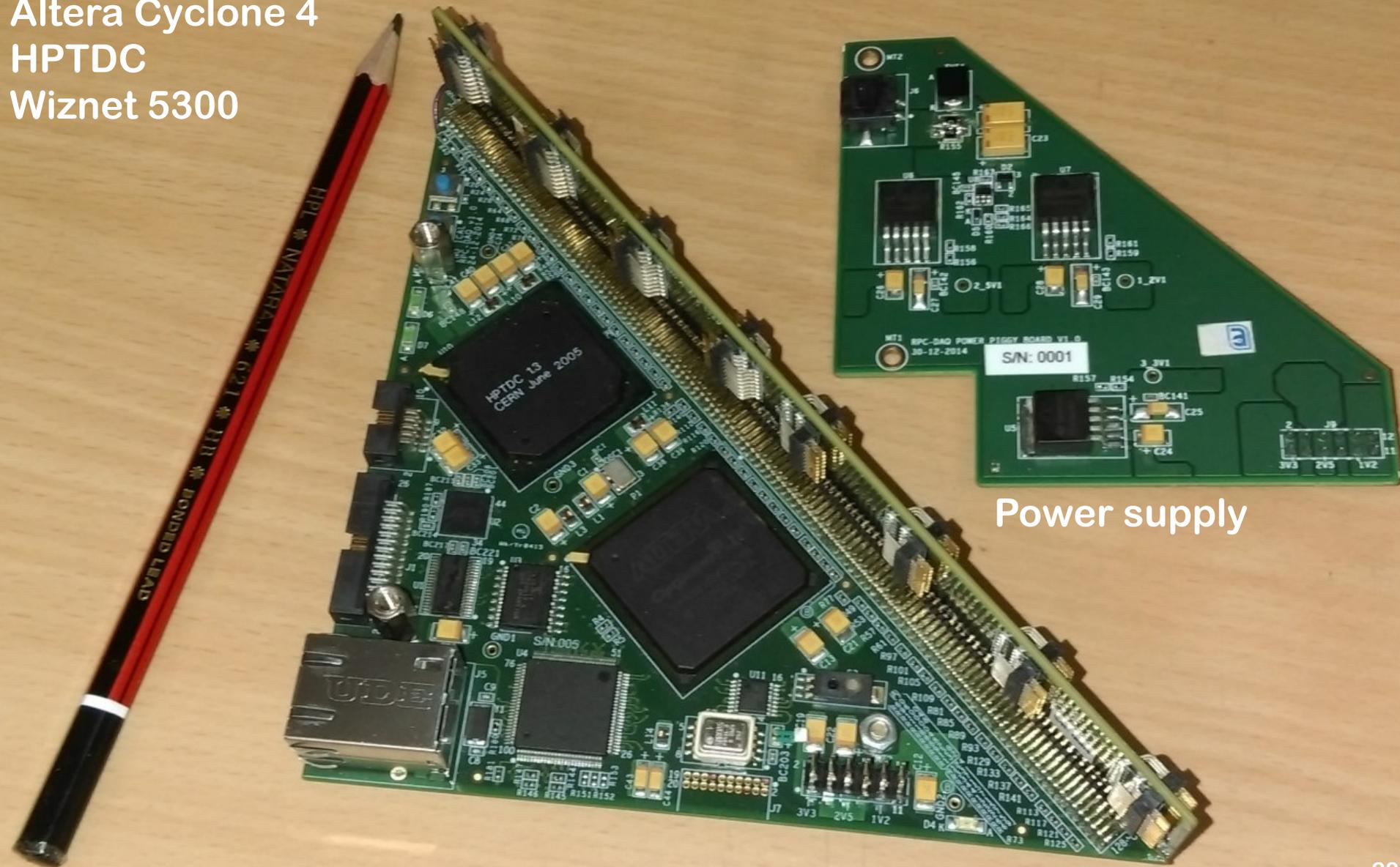
- Unshaped, digitized, LVDS RPC signals from 128 strips (max) (64x + 64y)
- 16 analog RPC signals, each signal is a summed or multiplexed output of 8 RPC amplified signals.
- Global trigger
- TDC calibration signals
- TCP/IP connection to backend for command and data transfer.



Digital Front End module

- Unshaped, digitized, LVDS RPC signals from 128 strips (max) (64x + 64y)
- 16 analog RPC signals, each signal is a summed or multiplexed output of 8 RPC amplified signals.
- Global trigger
- TDC calibration signals
- TCP/IP connection to backend for command and data transfer.

Altera Cyclone 4
HPTDC
Wiznet 5300



Development of TDC ASIC at IITM

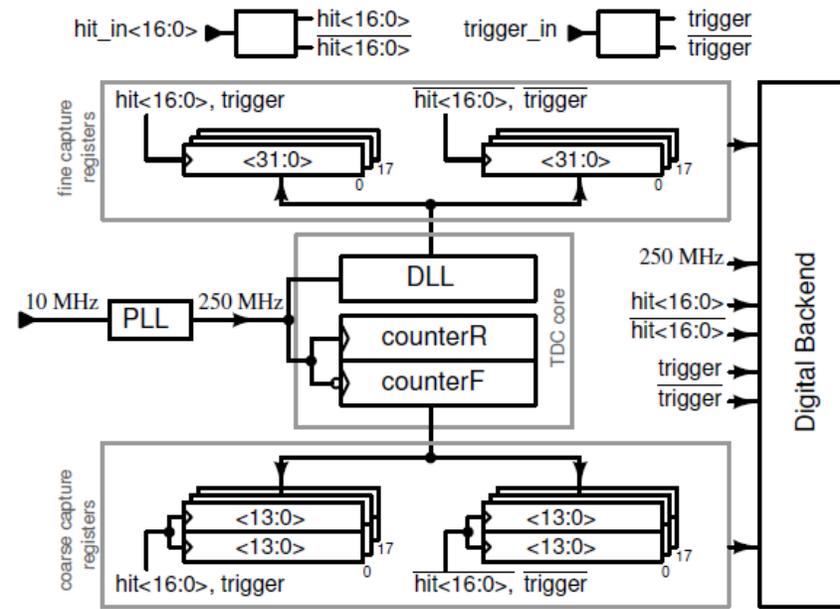
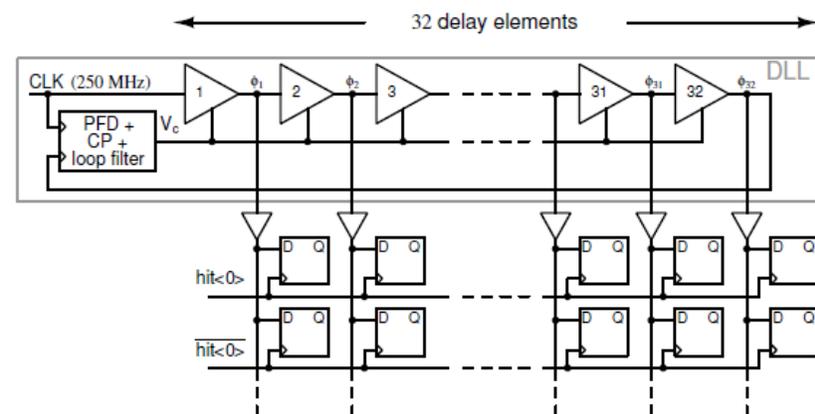
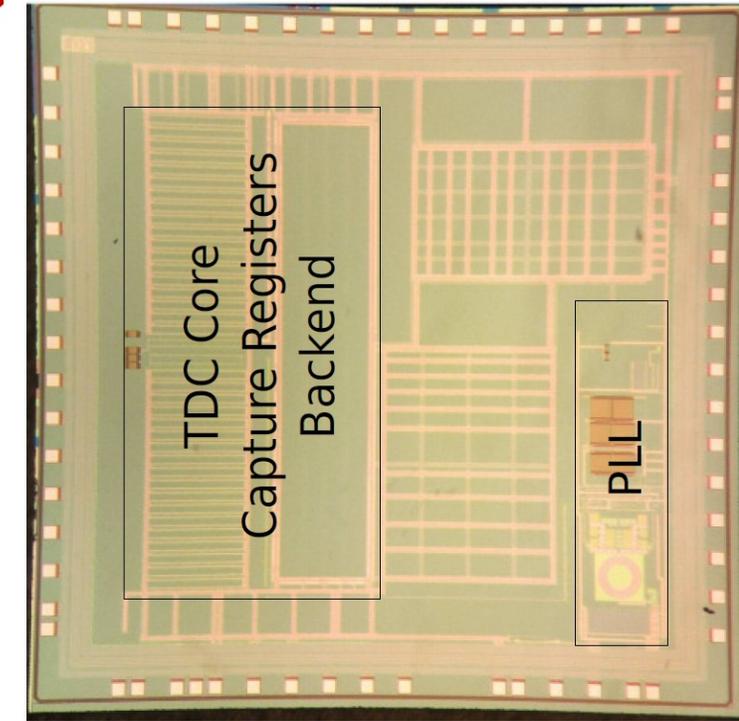
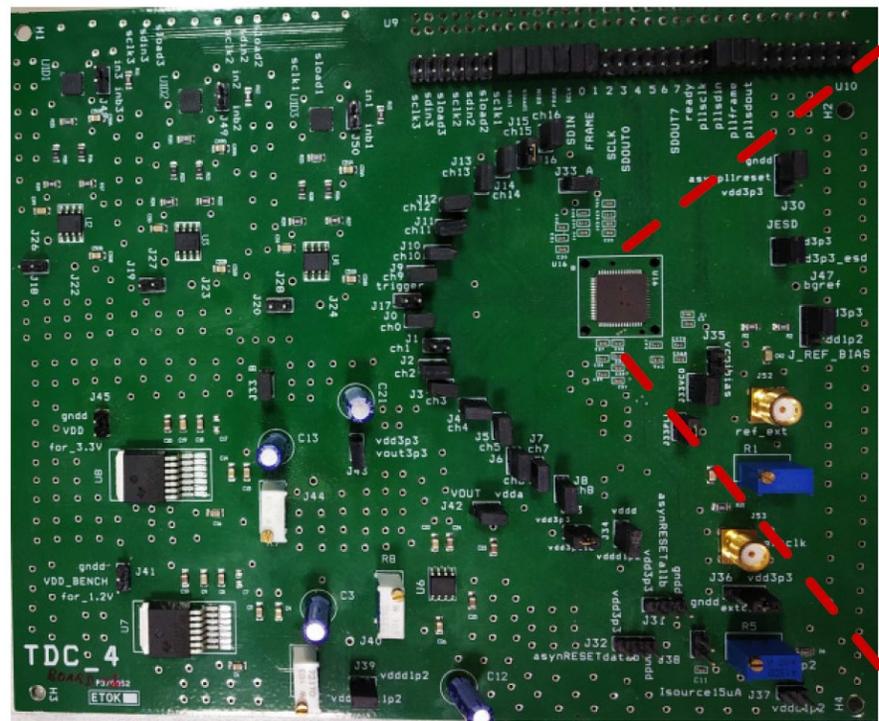


Figure 3: Top-level architecture.



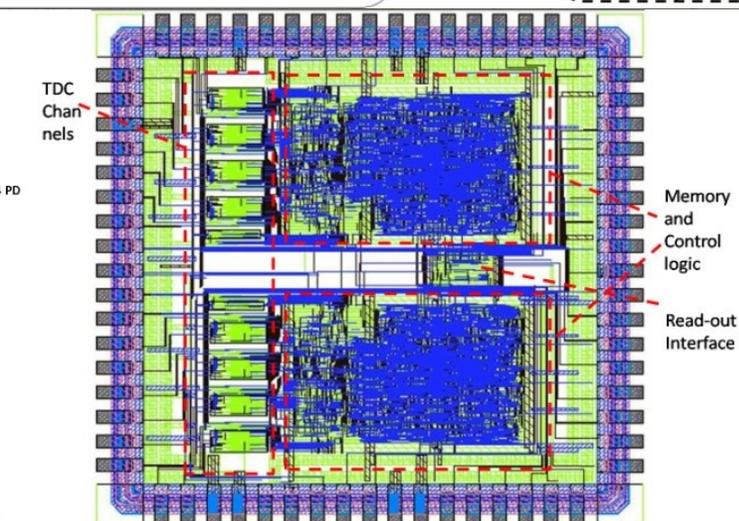
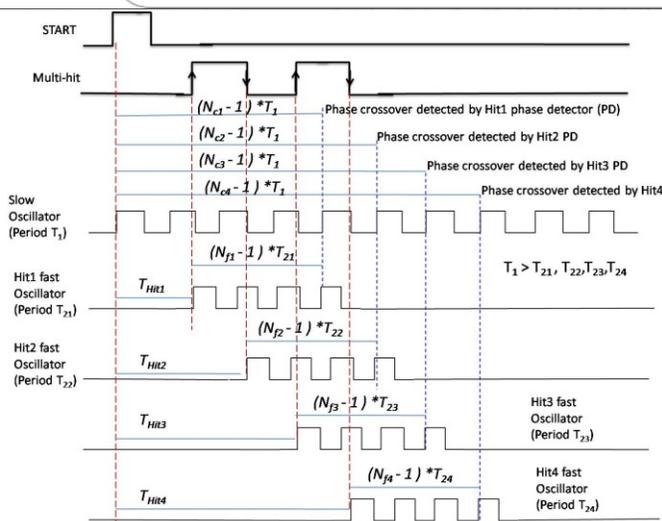
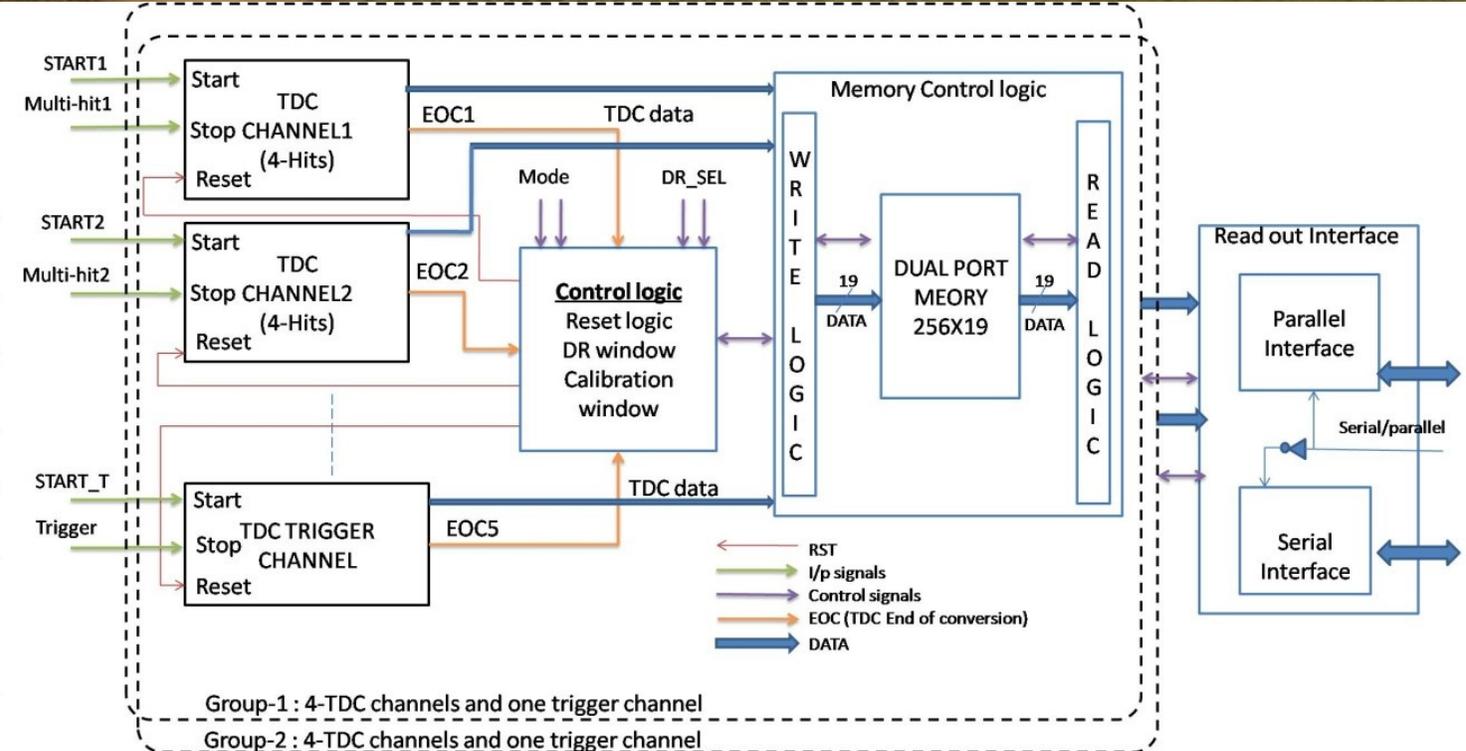
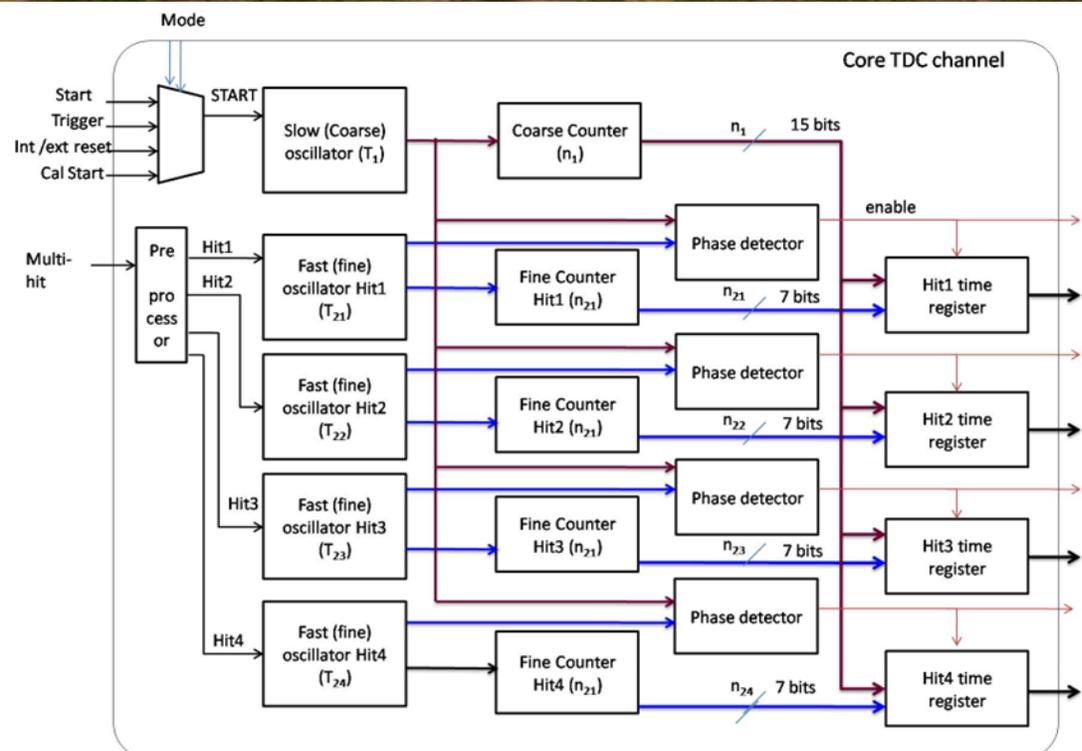
+ 34 capture registers for $hit<1>$, $hit<1>$ to $hit<16>$, $hit<16>$ and trigger, trigger

Figure 4: Fine TDC and corresponding capture registers.



Parameter	This work	[8] ^a	[5]	[20]	[3]	[27]	[28] ^b
Process (nm)	130	250	65	130	350	130	45
Channels	18	32	8	8	7	8	1
Multi-hit depth	4	dynamic	NA ^c	NA ^c	3	NA ^c	dynamic
LSB (ps)	125	98	102	5	8.88	74	25
Single-shot Precision (ps) ^d	65.34	90 ^e	95 ^f	3.45 ^e	9.8	75 ^e	-
Range (μ s)	65.5	51.38	0.418	0.0006	74	0.038	0.0008
Clock (MHz)	10	40	NA ^g	1562.5	20	NA ^g	1250
Power/channel(mW)	3.4	25	29	34 - 42	12.14	0.237	16
Area (mm ²)	3.72	-	0.3	1.2	8.88	0.163	0.36 29

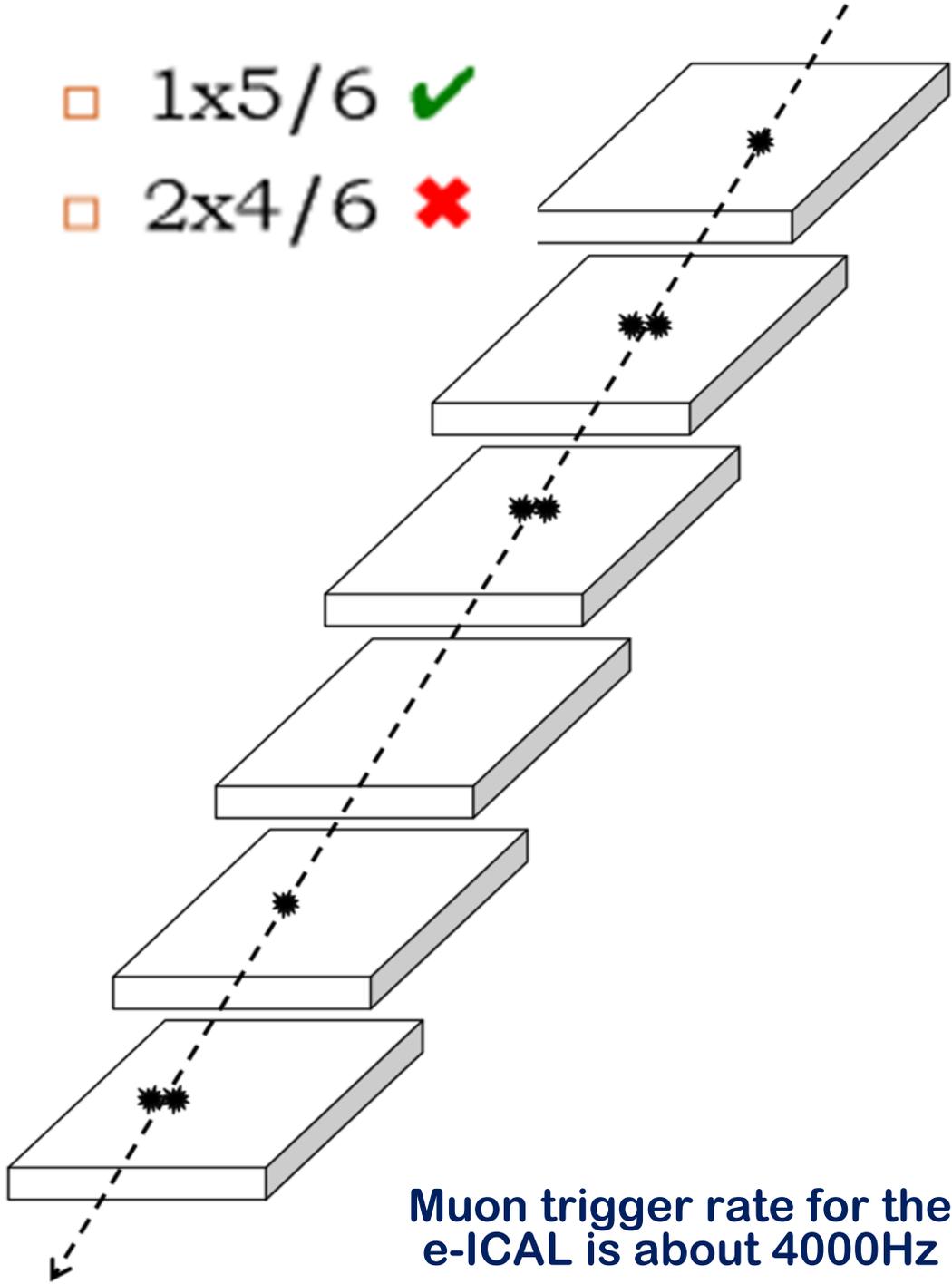
Development of TDCs BARC



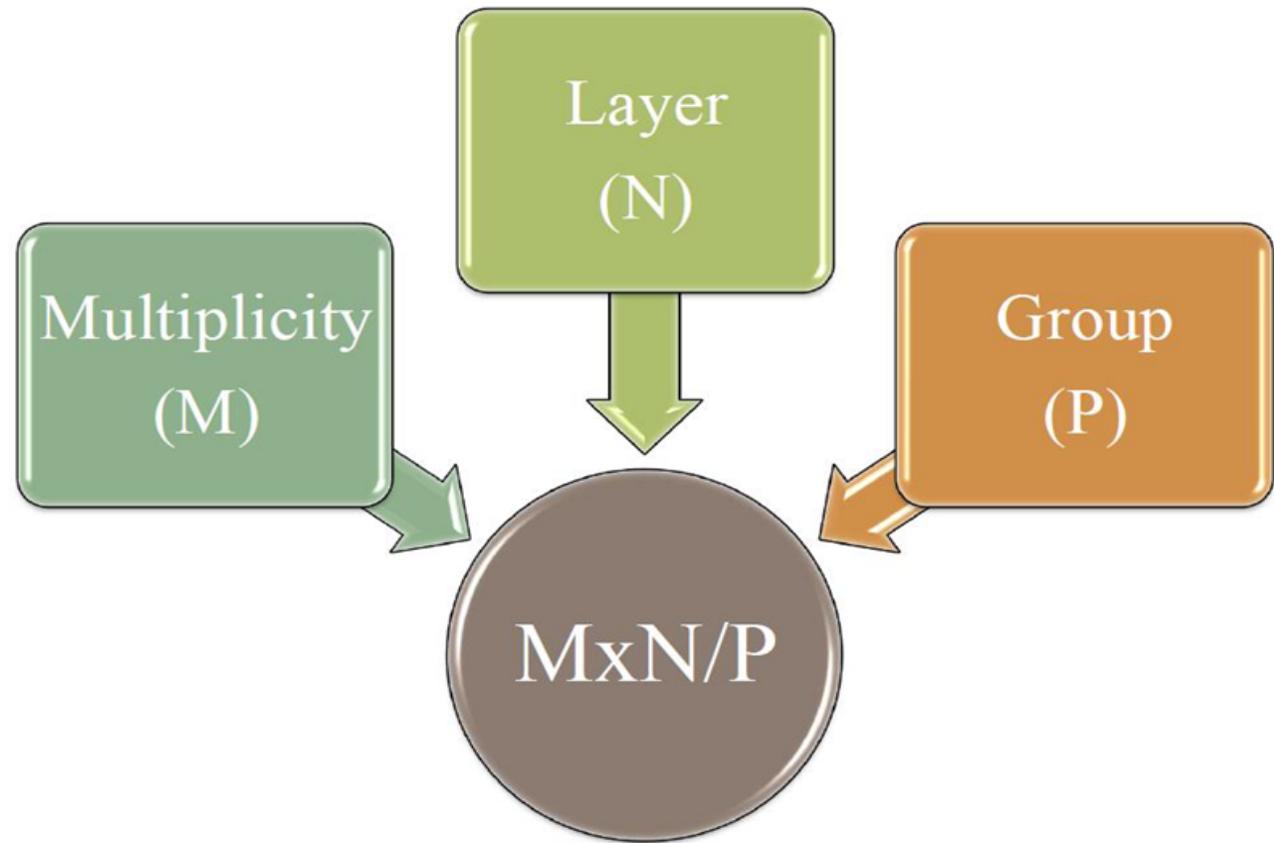
- 8-channel, 4-hit, TDC ASIC in 0.35 μ m CMOS technology.
- Vernier ring oscillator for high resolution and large dynamic range.
- In-built calibration of oscillators with an accuracy of a few ps.
- Both serial and parallel interfaces.
- Dynamic range of 4 μ s/ 16 μ s/ 32 μ s / 64 μ s.
- Resolution of 80 to 140 ps (LSB), precision of 70 ps.
- DNL and INL are 156 ps and 250 ps.

Trigger criteria

- 1x5/6 ✓
- 2x4/6 ✗

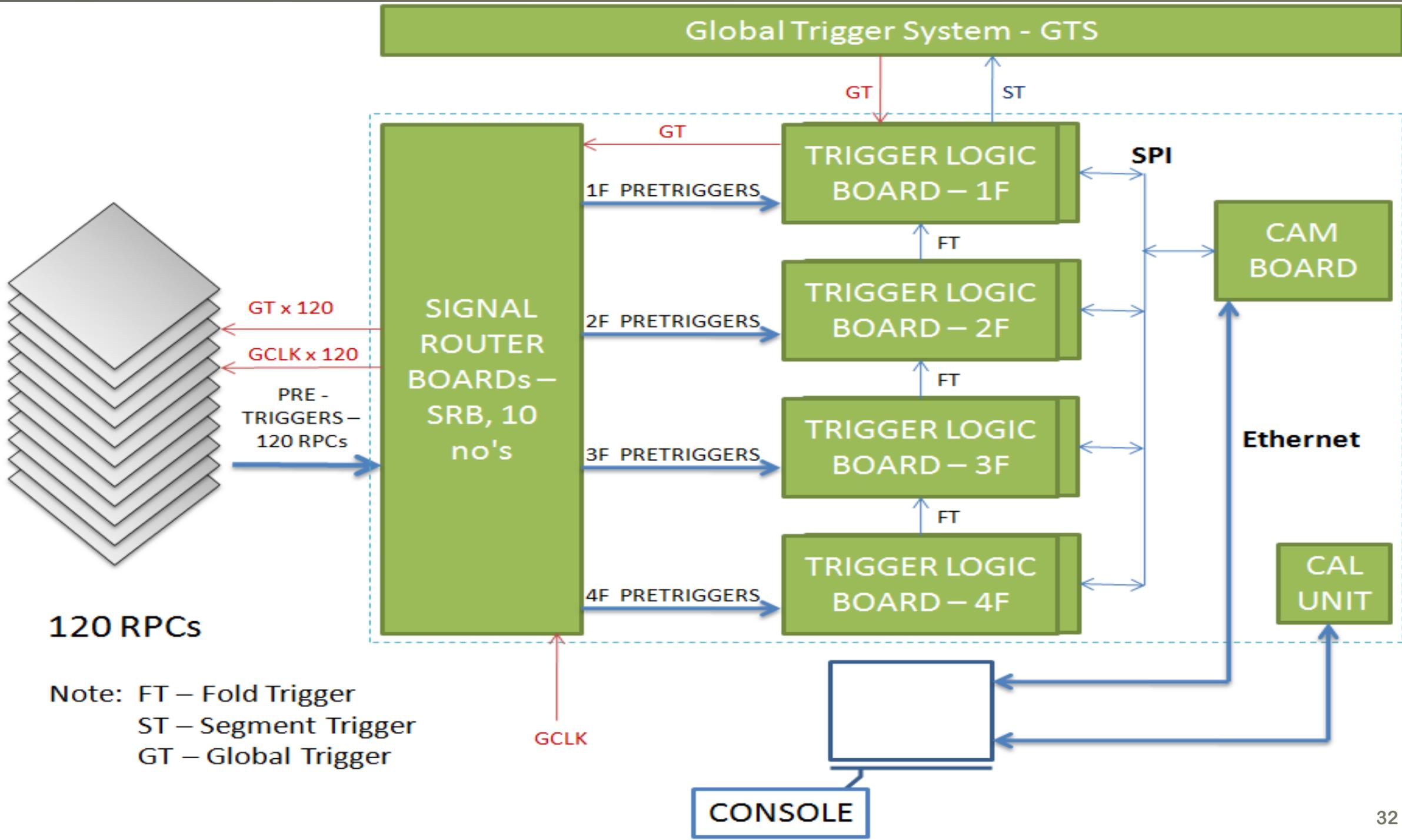


Muon trigger rate for the e-ICAL is about 4000Hz

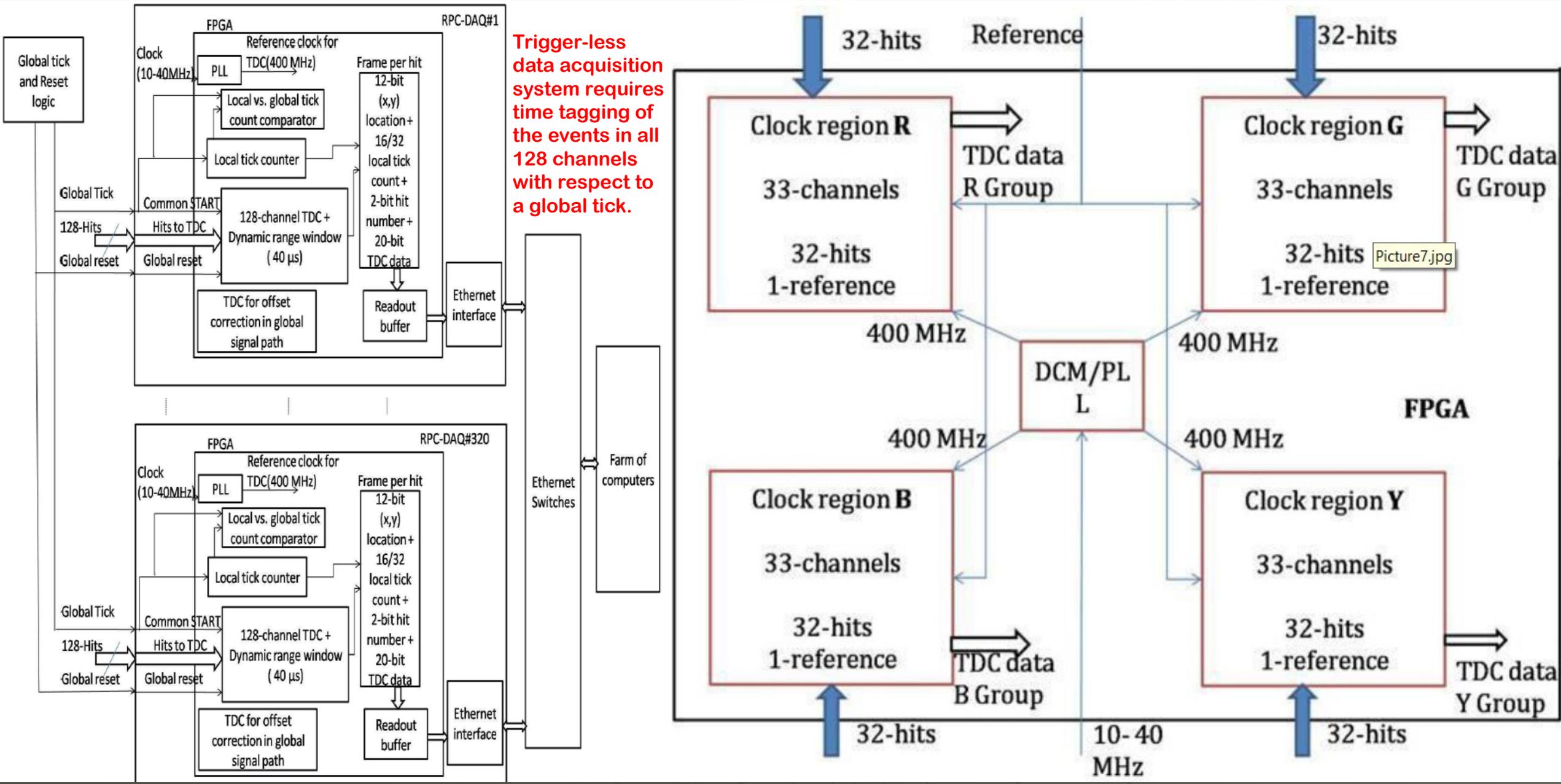


	Non-overlapped		Overlapped	
RPC Strip Rate	Chance Rate for Full Trigger	Chance Rate for Partial Trigger	Total Chance Coincidence Rate	Total Chance Coincidence Rate
250 Hz	71 Hz	841 Hz	912 Hz	319 Hz
50 Hz	0.023 Hz	0.269 Hz	0.292 Hz	0.102 Hz

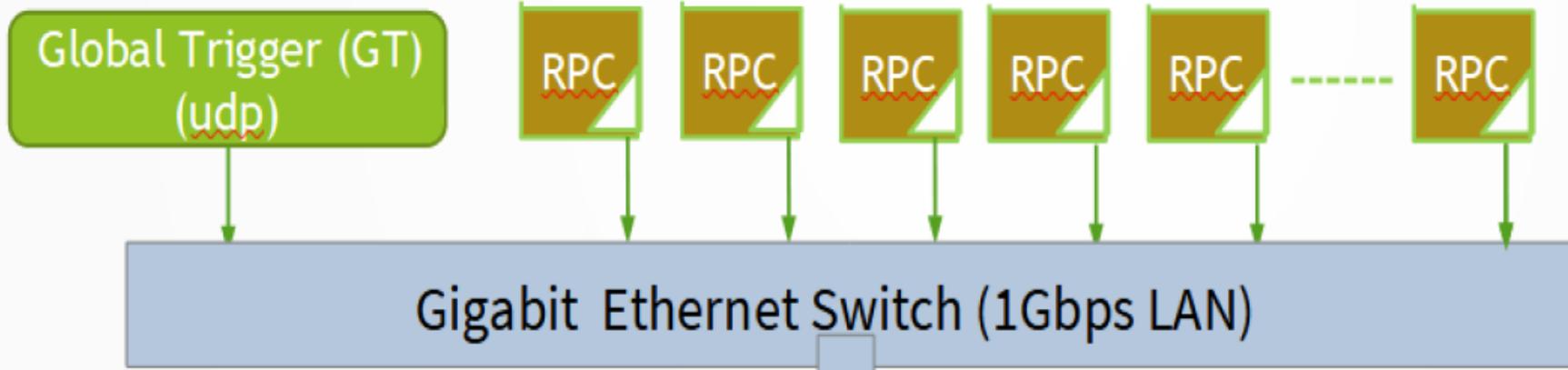
Trigger system for e-ICAL



Towards trigger-less system

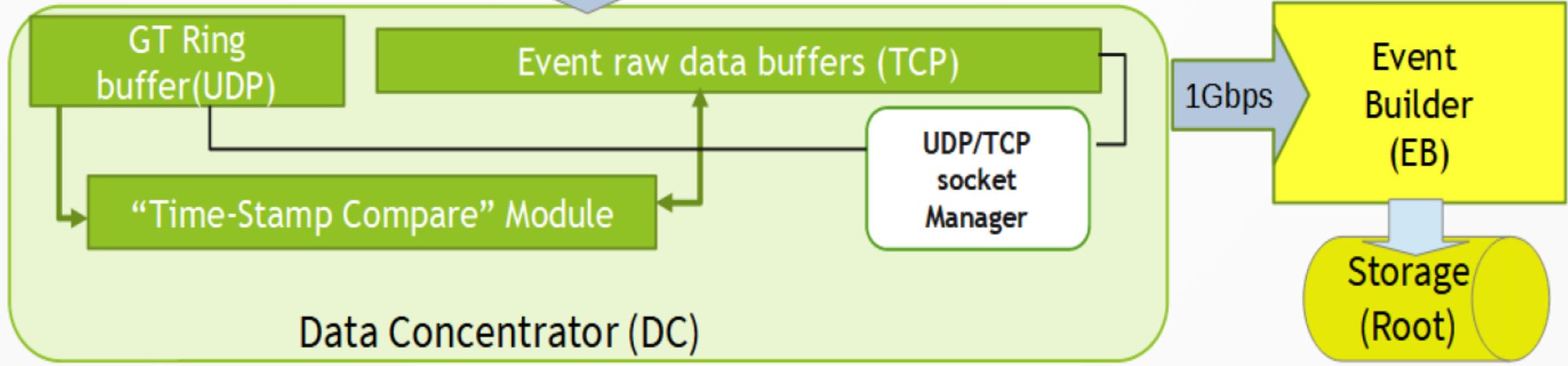


FrontEnd



Ethernet enabled FrontEnd DAQs

Back End



- DC and EB are multithreaded, lock-free applications
- All three are scalable : DC, EB & LAN
- Commodity products and technologies

Mini-ICAL	: 2.5K ch	: 400 Hz evt rate
EM-ICAL	: 51K ch	: 4000 Hz evt rate
ICAL	: 4M ch	: 40 Hz evt rate

Back-end data concentrator

Conclusions and future plans

- ◆ Most of the magnet, detector, gas system and electronics related components and systems were developed.
- ◆ They are also being tested in the mini-ICAL detector for about four years. Good experience gained.
- ◆ RPC production by the industry is a bit of concern; operation too, especially at the scale envisaged for ICAL.
- ◆ Industrial production of components not yet started.
- ◆ All the approvals for the IICHEP site obtained, but project site's approval is stuck in legal and political tangles.
- ◆ Therefore, an air of uncertainty continues to prevail about the e-ICAL at the IICHEP, Madurai site too 😞.