Current Status of Semi-DHCAL R&D in European

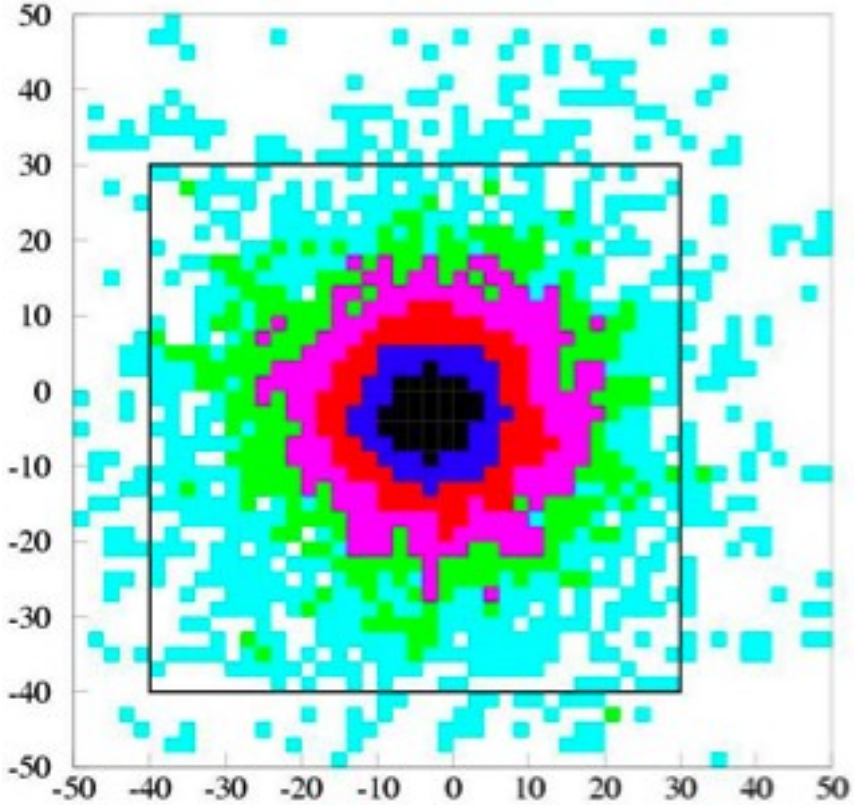
Manqi Ruan

Outline

- Introduction: Case of Semi-DHCAL;
- R & D: MiniDHCAL and 1 m^2 prototype
  - Electronic, Mechanical, Gas system;
  - DAQ and data format;
- TB: Search for the best design
  - TB setting & Statistic of different test beam period;
  - TB Performance:
    - Efficiency & Multiplicity scan with HV, Threshold, Gas;
    - Efficiency with semi conductivity glass;
    - Shower profile with 1m^2 prototype
- Next step: 1 m^3 prototype
- MC & Analysis: Integration to full detector
- Conclusion

Case for a Semi Digital HAdronic CALorimeter

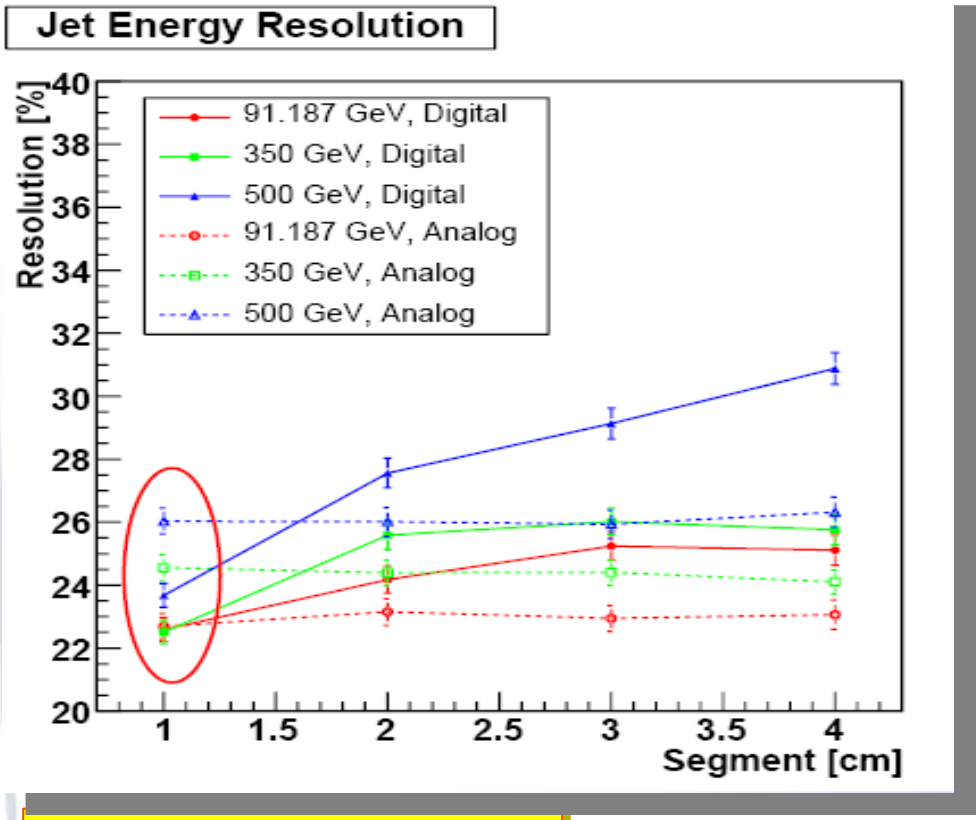
- 1 or 2 bits of information per cell
  - Finer granularity → 1×1 cm² × 48 planes
    - Ideal for a **PFA** approach
  - Cheaper, simpler, more robust detectors
    - GRPC, MGRPC, μMEGAS, GEM's
- Gaseous detectors
  - insensitivity to neutrons
    - narrower showers (99% of hits in 70×70 cm² for 100 GeV π)
    - suppression of big fluctuations
- Recovery of information
  - Counting: 3 thresholds
  - Topology: clustering

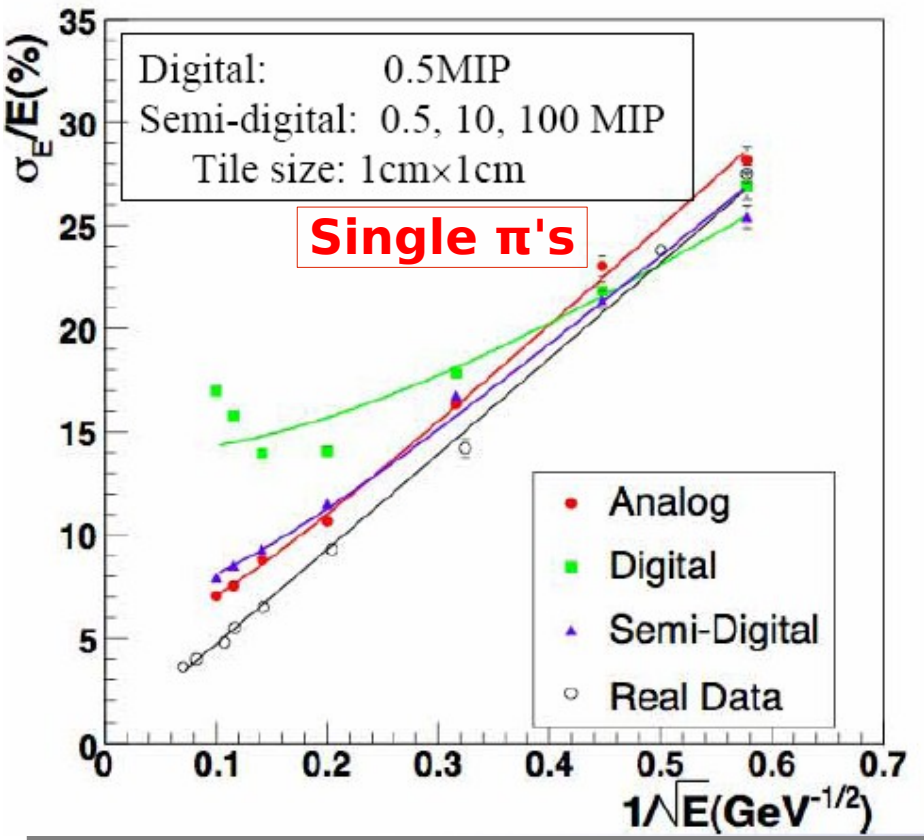


See note LC-DET-2004-029

Resolution studies

- GLD HCAL study by KEK Group
  - 3 thresholds (0.5, 10, 100 MIP's)
  - 1×1 cm² **scintillator tiles**



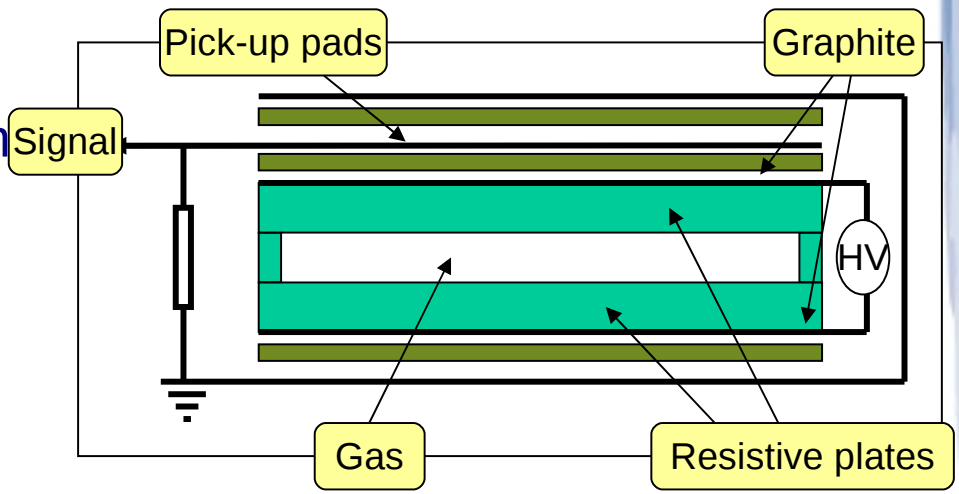


- $e^+e^- \rightarrow qq$ (uds)
  - $\sqrt{s}$ = 91, 350, 500 GeV
- Assuming Perfect PFA
  - Improved jet resolution

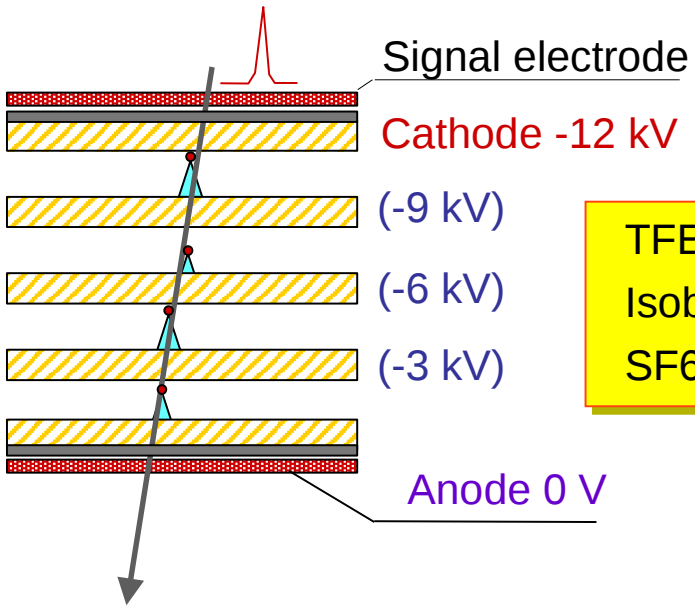
H MATSUNAGA
Pramana J. Phys., Vol. 69, No. 6, December 2007

RPC Gaseous detector prototypes

- GRPC *(IHEP+IPNL)*
  - simple, robust, rate ≤ 100 Hz/cm
    - 1.2 mm gaz gap
    - 400 µm glass plate
    - Graphite/Licron/Statguard resistive cover
    - ~ 7.4 kV



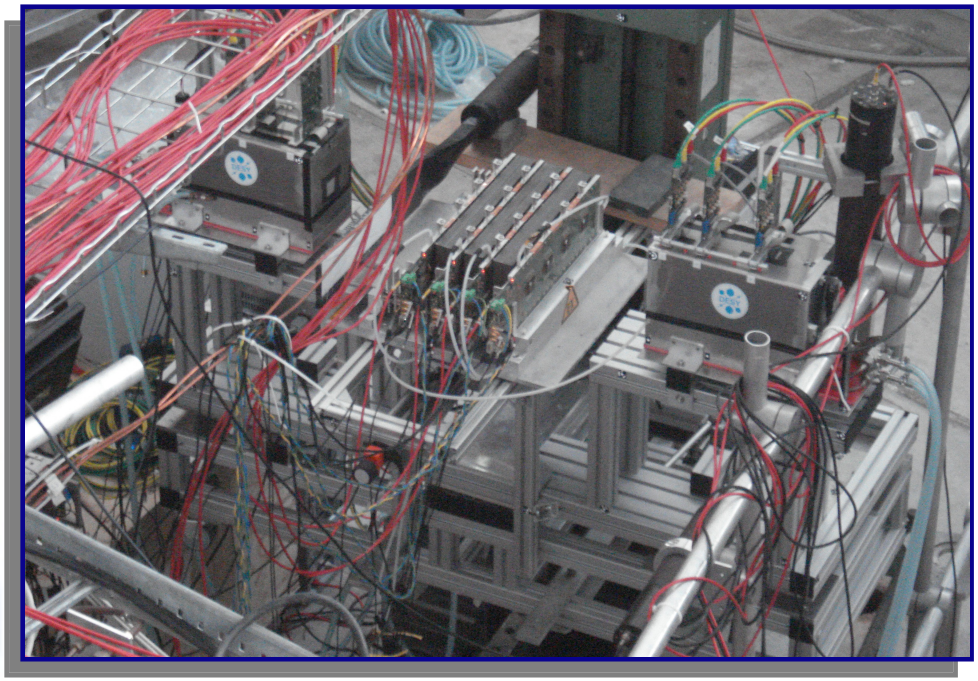
- Multi-gap RPC *(INFN Bologna-CERN)*
  - Higher rates & efficiency
  - Idem Alice ToF system
    - 4 x 250µm gaz gaps
    - 400 µm inner glass plates
    - 550 µm ext. glass plates
    - ~ 10—12 kV

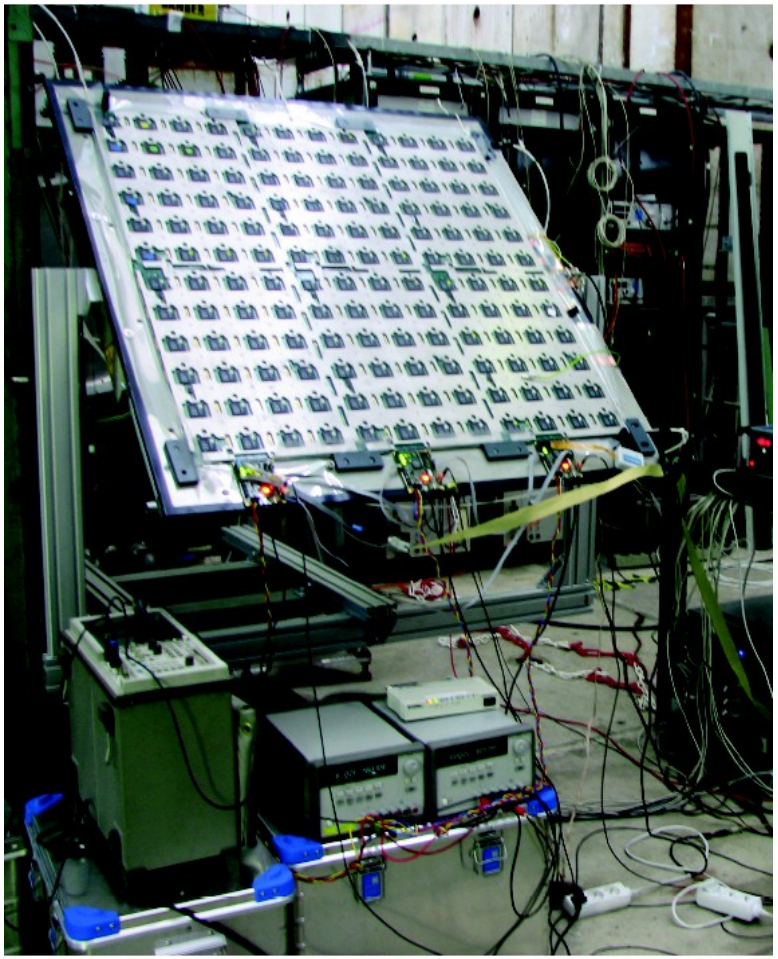


TFE	93%
Isobutene	5%
SF6	2%

Prototypes: Mini DHCAL and 1 m²

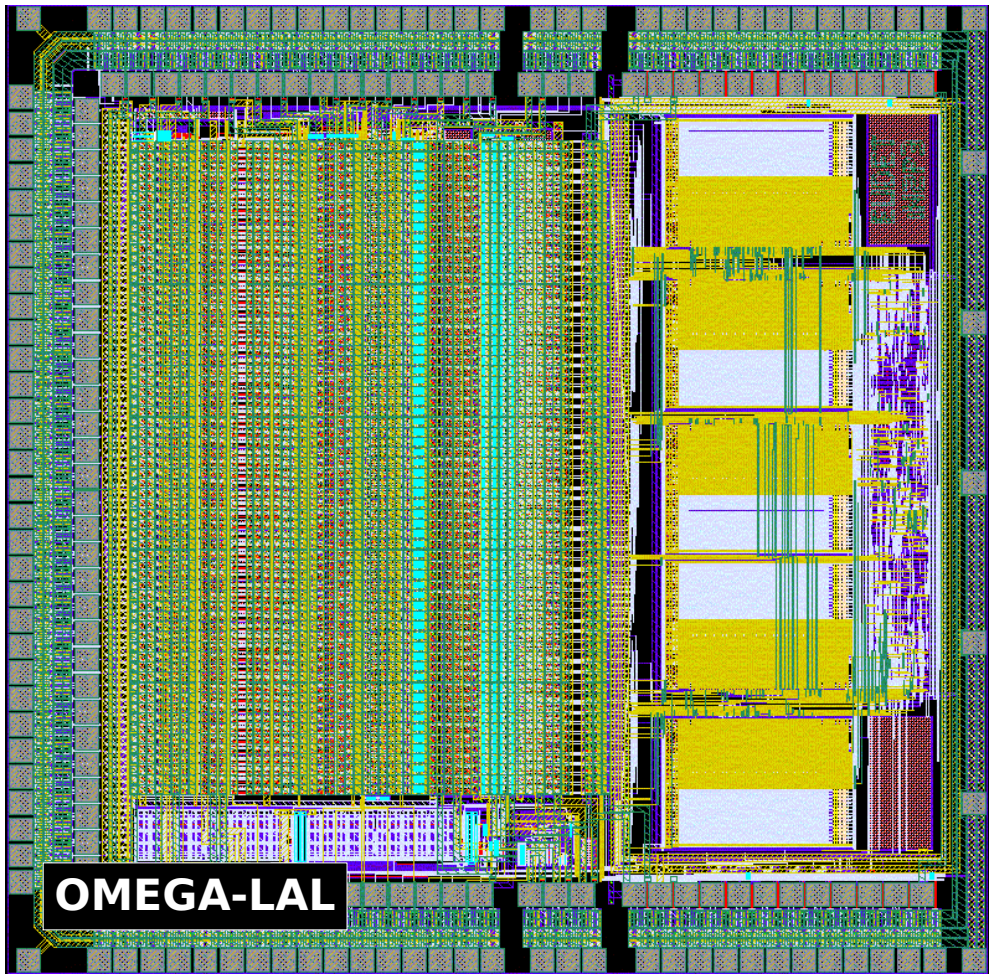
- GRPC:
  - 8×8, 32×8, 50×32, 100×32, 100×100 with 1 cm²-pad : already produced (with different option) and tested.
- MGRPC
  - 32×8, 100x100, produced & tested





Electronics: HarDROC (Hadronic Rpc Detector Read Out Chip)

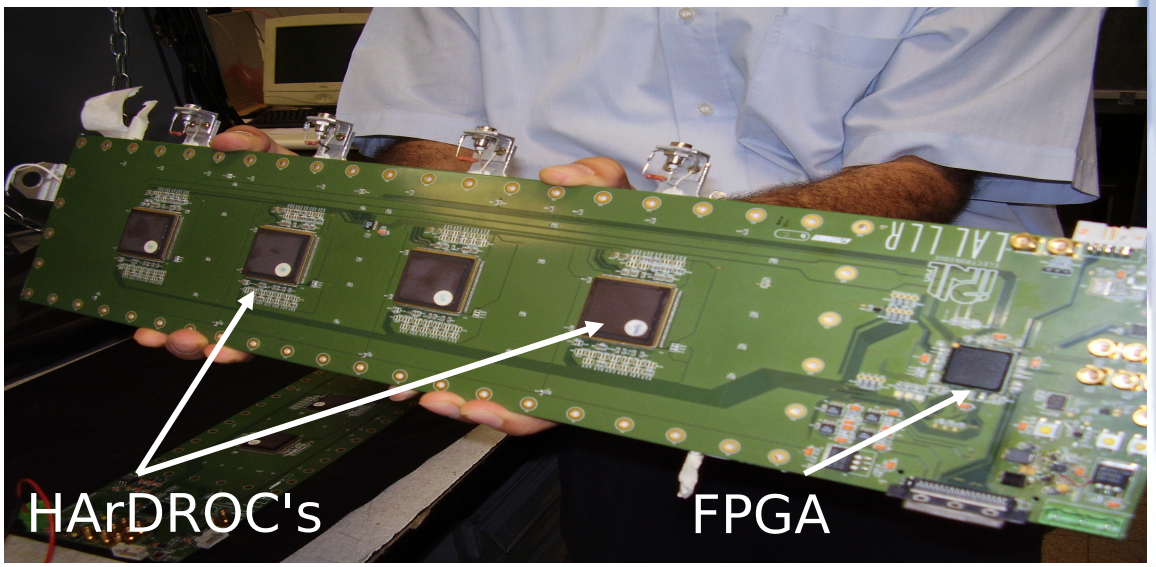
- AMS SiGe 0.35µm, 16 mm^2
- 64 channels
- Digital/analogue output
- 2 independant thresholds
- low consumption
  - < 10 µW/ch
  - Power pulsing
- Digital memory
  - 128 events
  - ASIC ID (8b), BC ID (24b), hits
- Large gain range (6bits)
  - Channel wise
- X-talks < 2%
- Threshold > 10 fC



*** DIRAC: Another ASIC developed in IPNL/LAPP aims at a threshold of 3 fC**

Mini DHCAL

- **8-layer**, **800 µ** thick PCB
  buried and blind vias
  x-talk <0.3 %
- 4 hardroc chips
- Readout **FPGA** → USB
- **8×32** pads detector

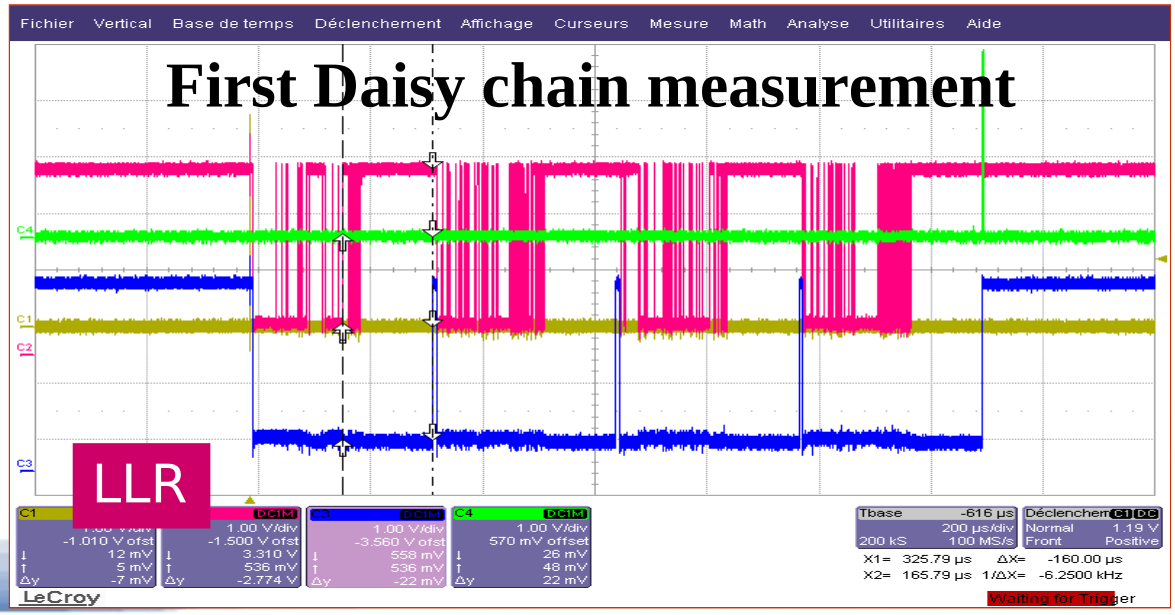


Acquisition modes : different modes are allowed:

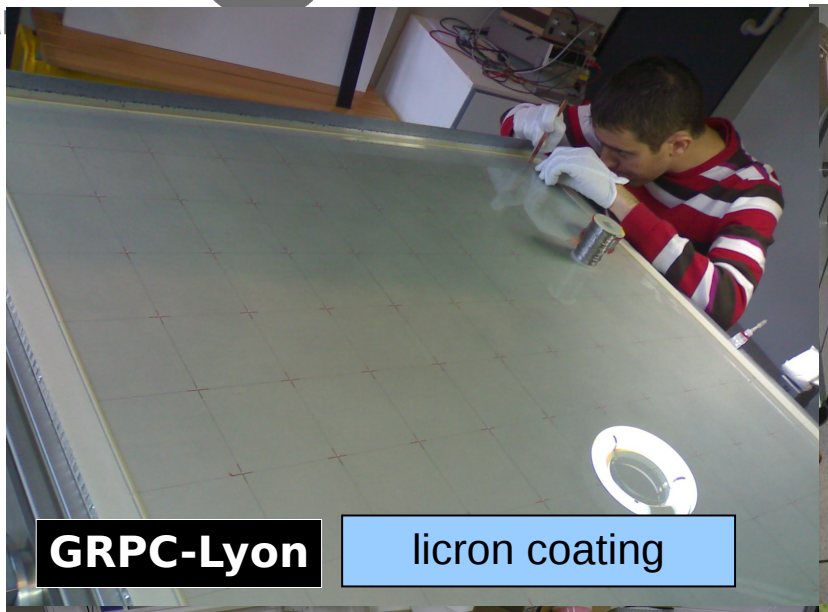
a) Train (ILC mode)

b) External trigger :
cosmic rays & test beam

Data output:
digital and analogue



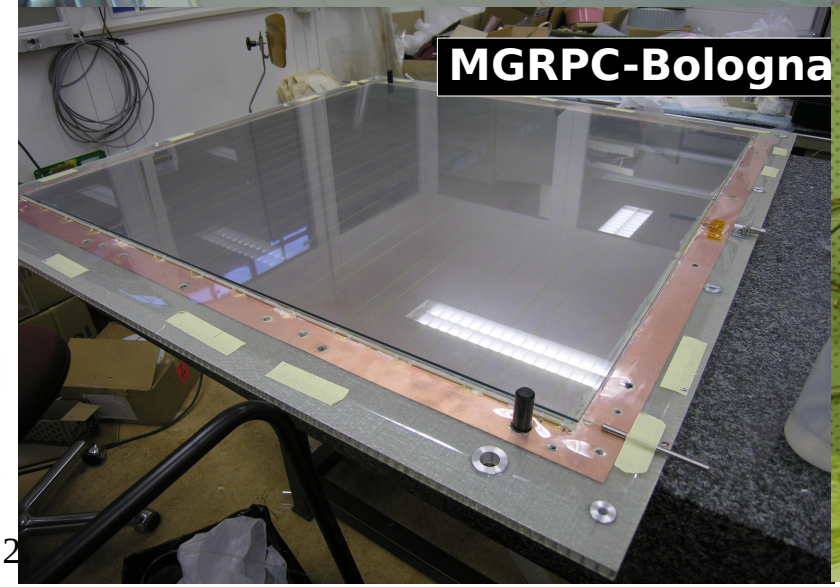
The 1 m² project



GRPC-Lyon

licron coating

Lyon GRPC (statguard coating)



MGRPC-Bologna

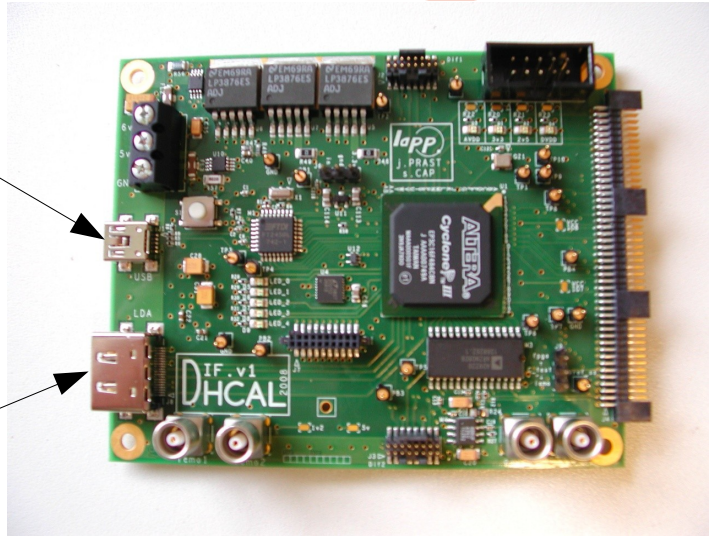
GRPC-IHEP

1 m² GRPCs were built with **different options**

The 1 m² project

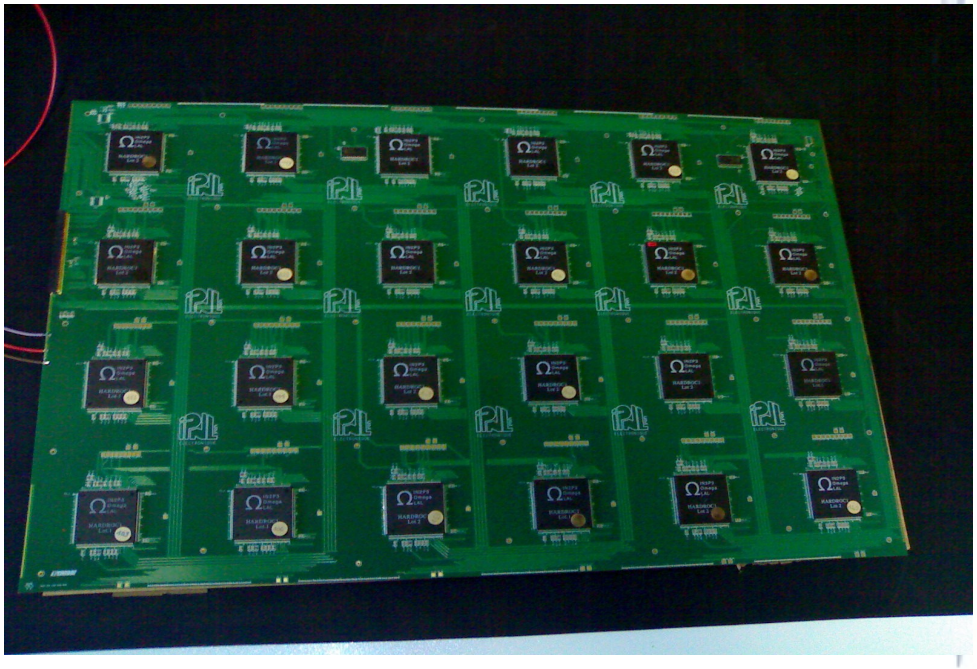
DIF

- 10-layer board (6 for signals) designed and prototype produced
- FirmWare & SoftWare operationnal and tested in beam (with 4 HR µMegas card)



ASU

- 8-layer board designed and produced
- 500×33.3×1.2 mm³
- Connections between adjacent PCB foreseen
- ASICs were tested and plugged

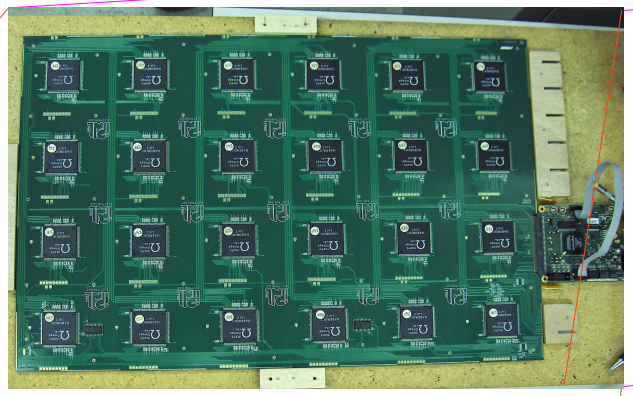


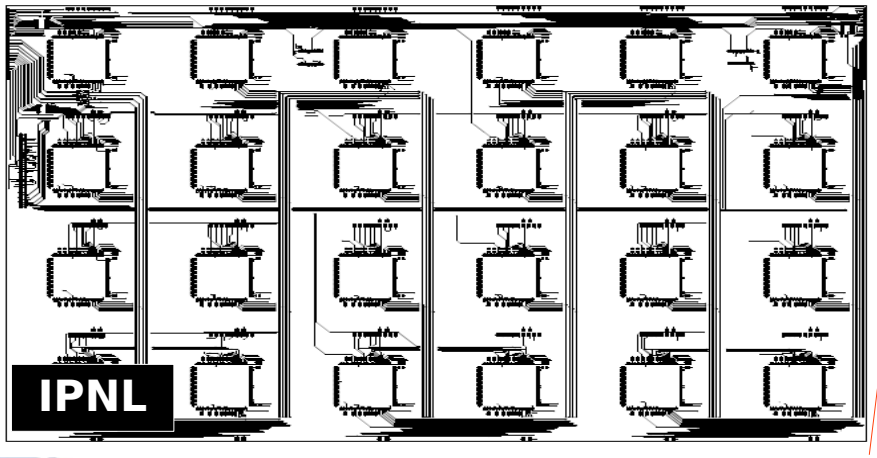
Software

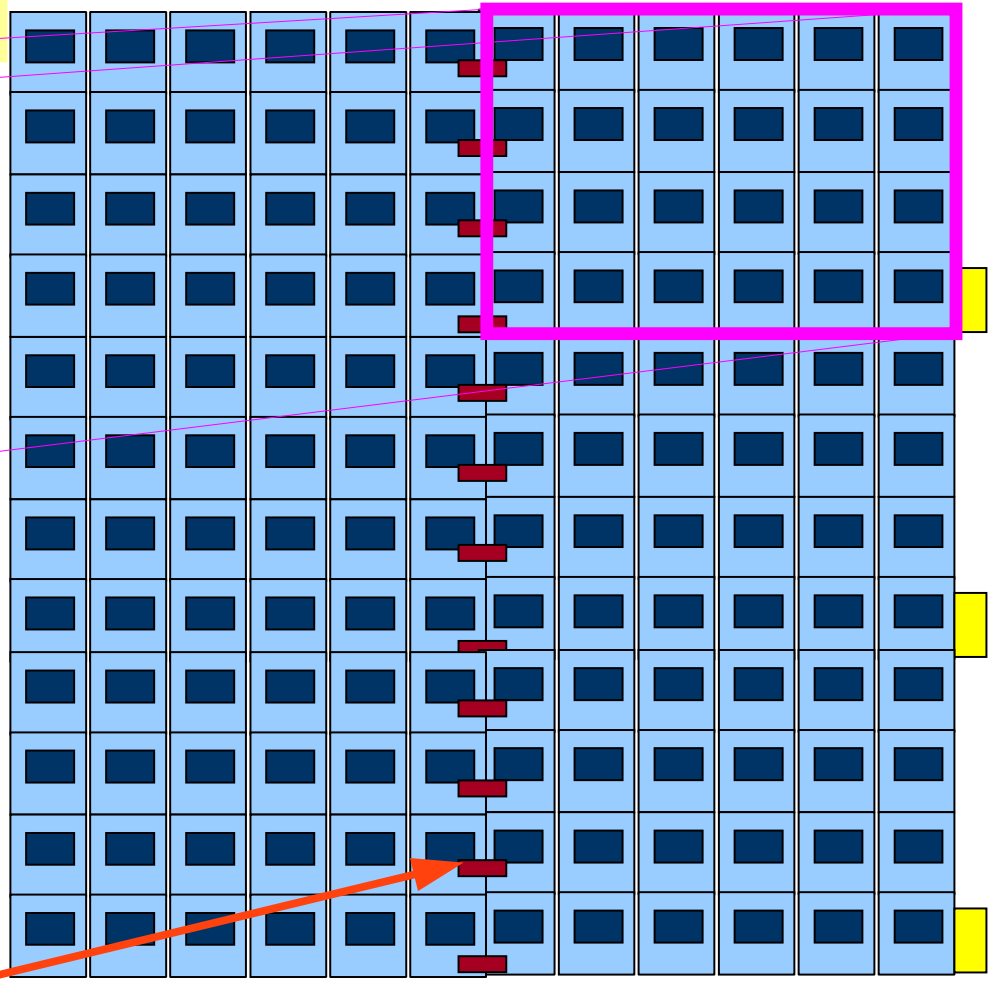
Acquisition software based on US/XDAQ developed

1 m² : ASIC support Units

1 ASU → 6×4 chips



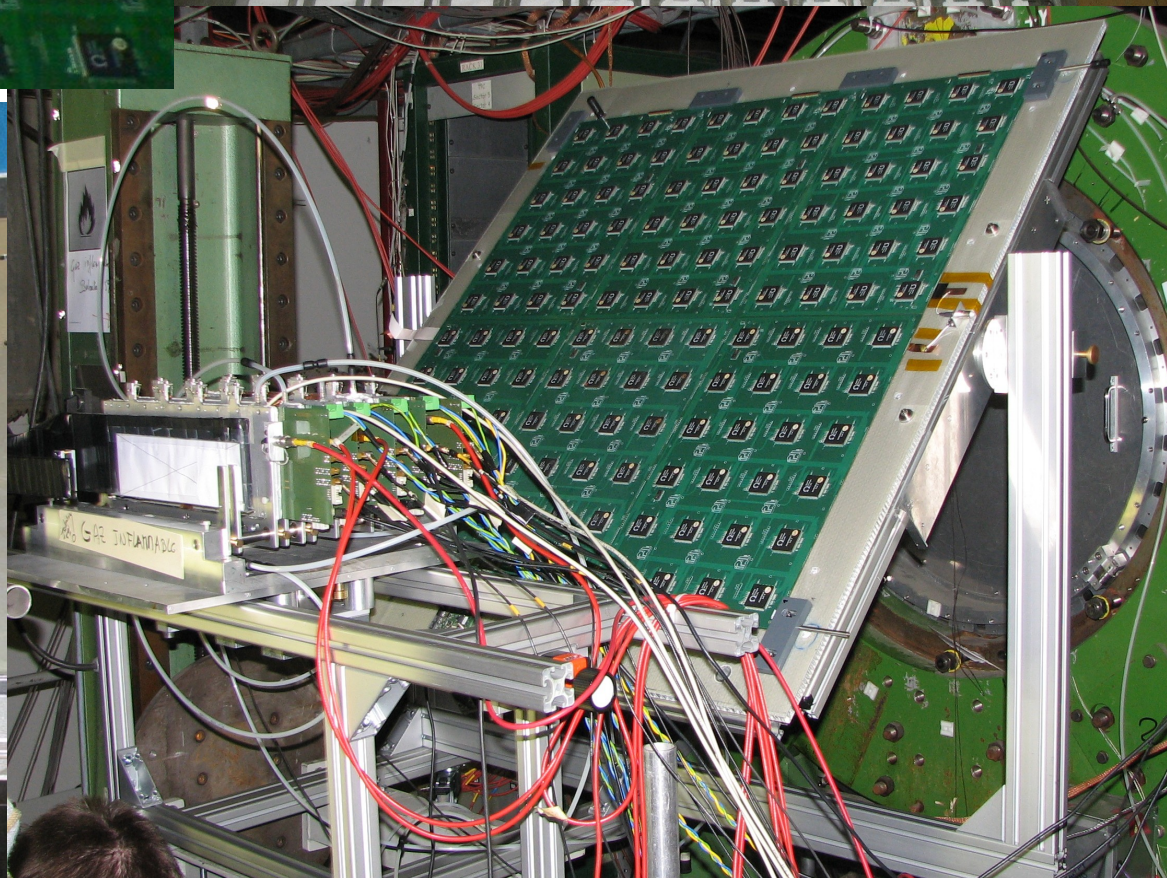




pcb-connector

ASU hosting 24 HARDROC chips produced and being tested

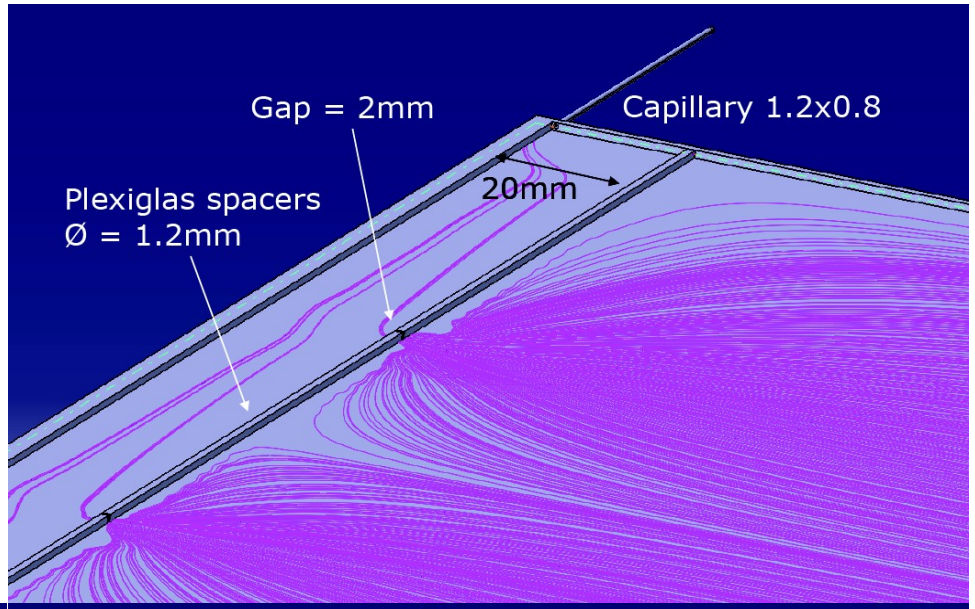
Support is being realized
CIEMAT

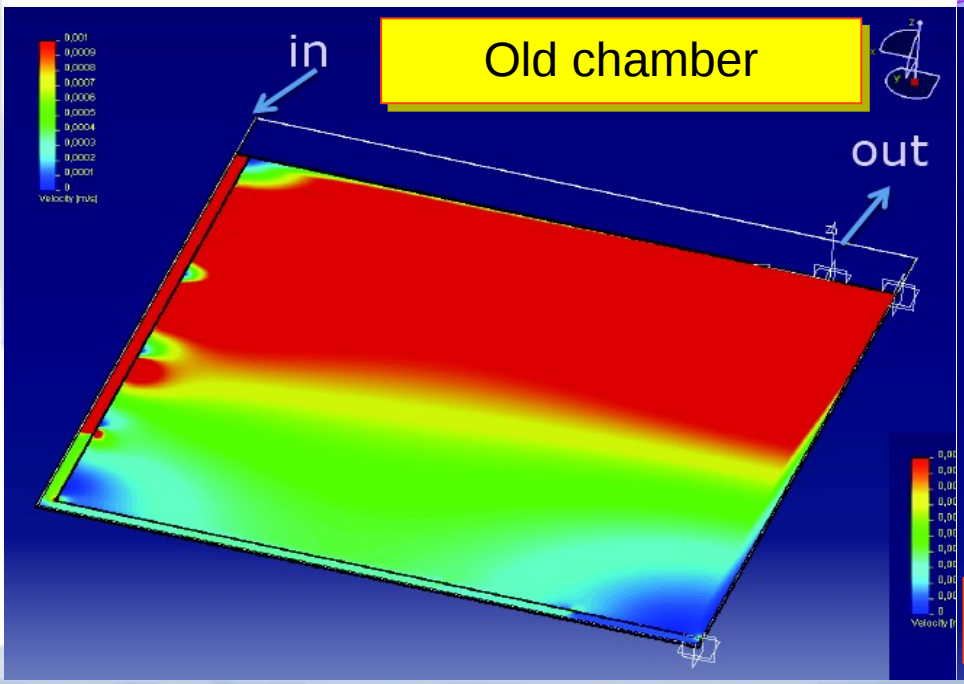


Gas circulation study

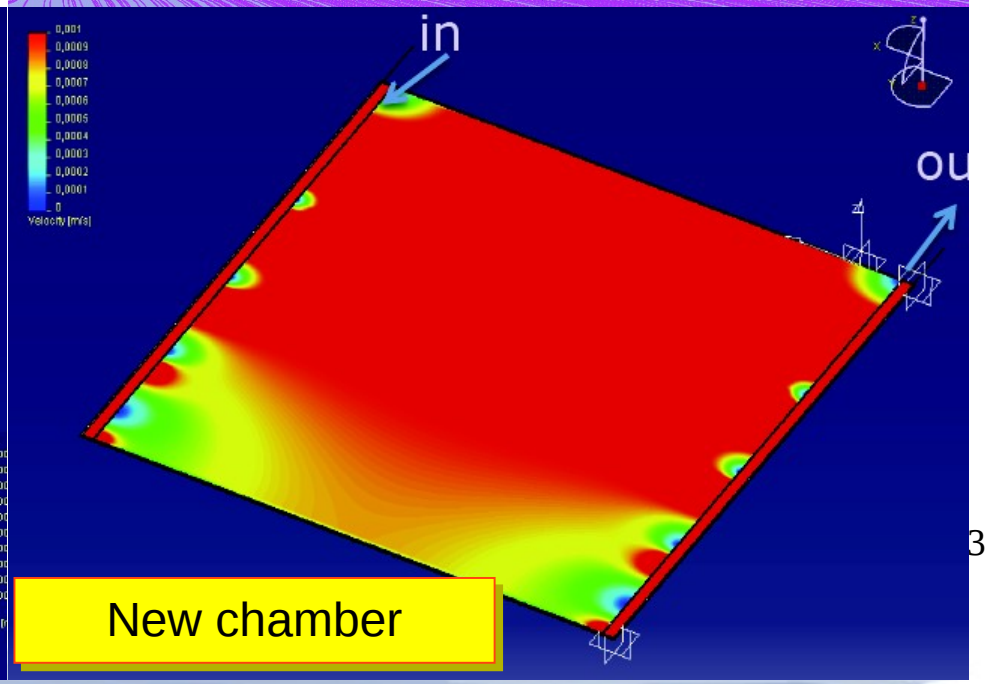
improve on gas distribution system in new chamber design

Gas velocity maximal ~ 1mm/s





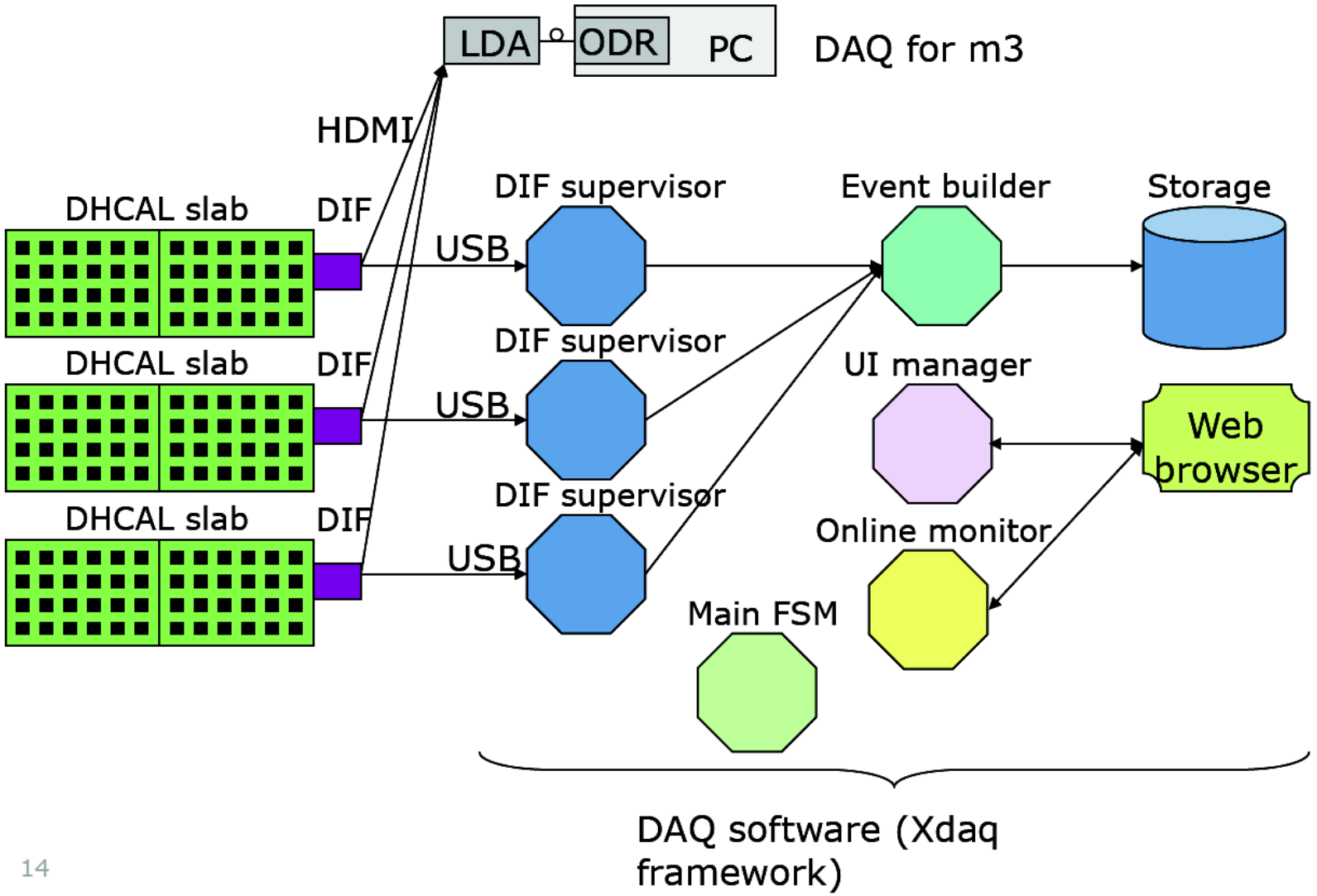
Old chamber



New chamber

DAQ & Data format

DAQ Schematic view



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LCIO format for reconstructed DHCAL Header & DIF part (proposal v0.01)

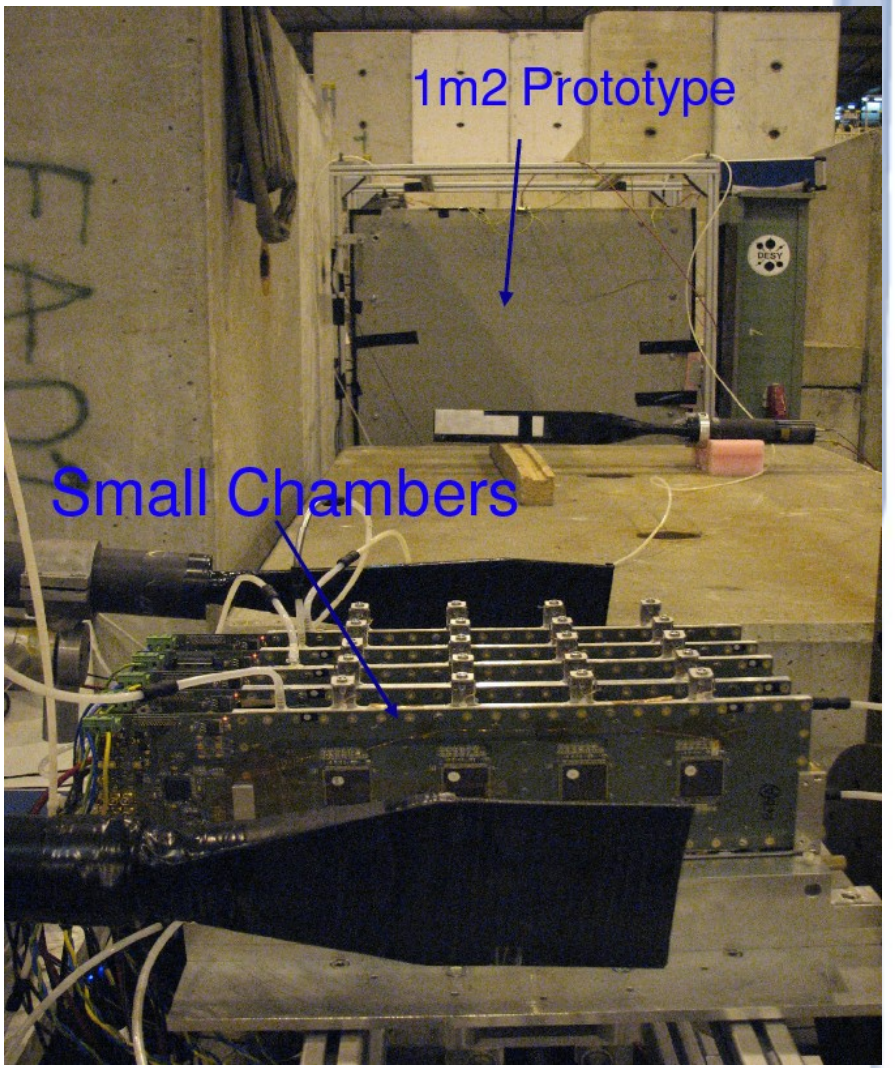
back of envelop discussion
V. Boudry, G. Grenier, R. Kieffer

```
EVENT::LCEvent
{
    int  _runNumber;          //
    int  _eventNumber;        // Global Trig Count == # evt
    EVENT::long64 _timeStamp; // Mean timestamp from Hit/DIF
                              // TB: Large BC
                              // For ILC: Large BC since run start.
    std::string   _detectorName; // Detector version ??
    LCCollectionMap    _colMap; // List of collections
    std::vector< std::string >  _colNames; // Name of collections
    LCParametersImpl   _params; //
    LCCollectionSet    _notOwned; //
}

EVENT::LCGenericObject
{
// ->DIF Collection
//    - int DIF_ID+Module_ID        // DIF_ID (48-144 ==> 7-8b)
//                                  // + Module_ID (40 barrel + 24 Endcap ==> 6b)
//    - int ATC                     // delta GTC / DTC
//    - int DTC                     // Diff Trig Counter == #evt vu par la DIF
//(    - float TimeDiff              // Time2Previous event )
//    - int LargeBC                 // BC from run start.(32b)
}
```

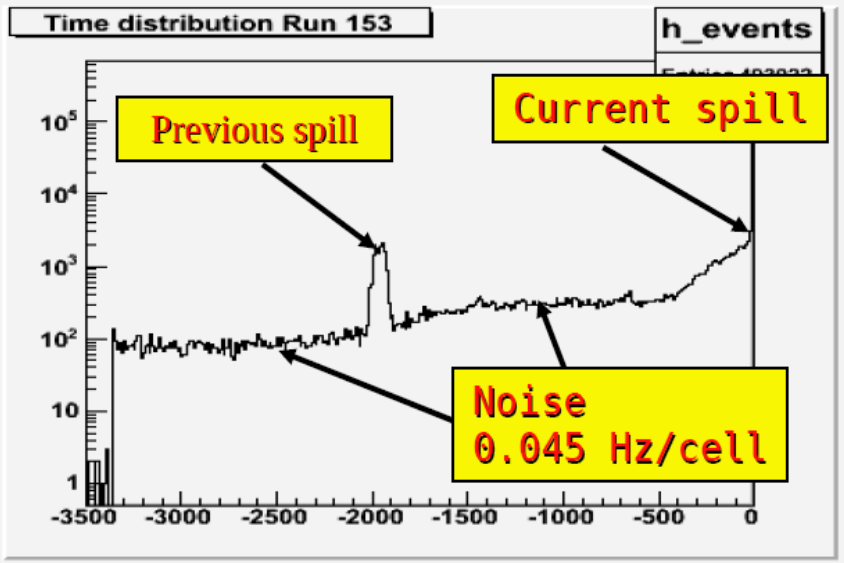
TB Performances:

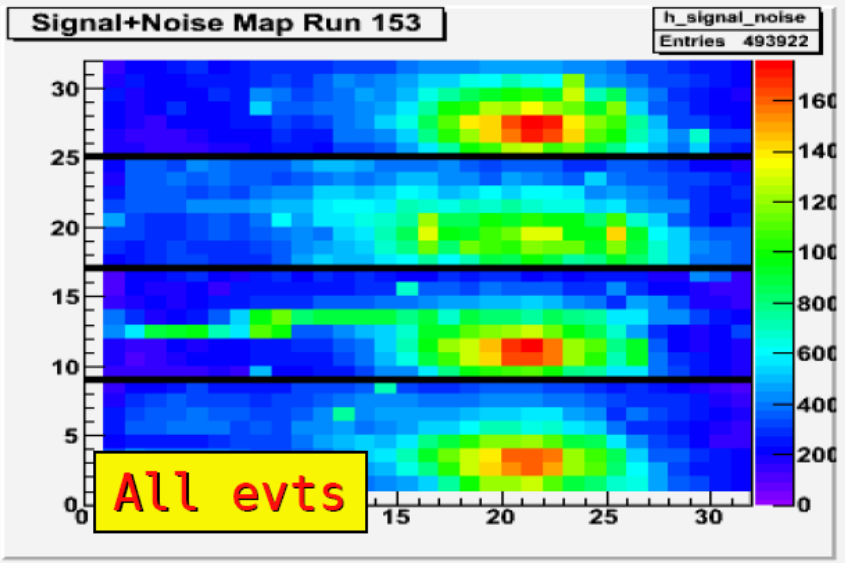
	Time	Statistic	Detector
PS T10	17-24 July, 2008	260k	Mini DHCAL
PS T9	28 Jul - 4 Aug, 2008	80k	Mini DHCAL
PS T9	7-12 Nov, 2008	65k	Mini DHCAL + 1m2
PS T9	18 Jun - 8 Jul, 2009		Mini DHCAL + 1m2
SPS H4	31 Jul - 8 Aug, 2009		Mini DHCAL + 1m2

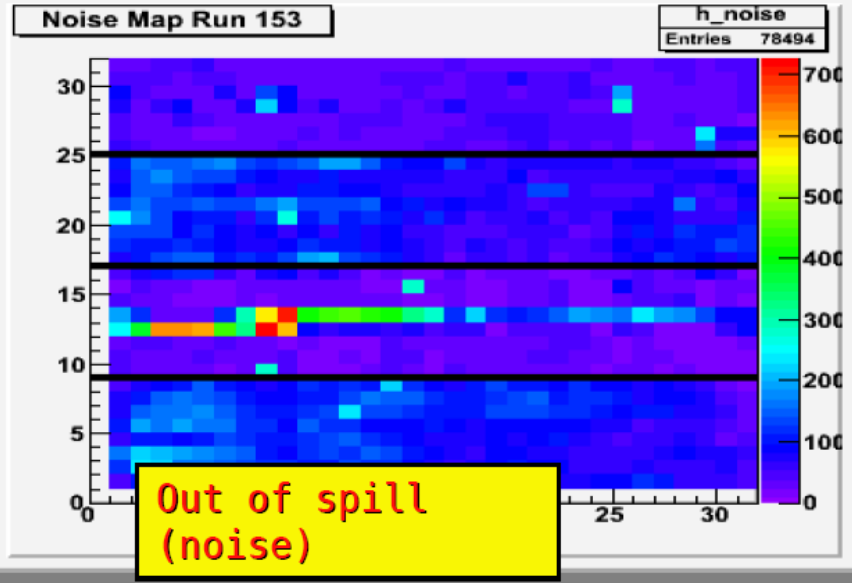


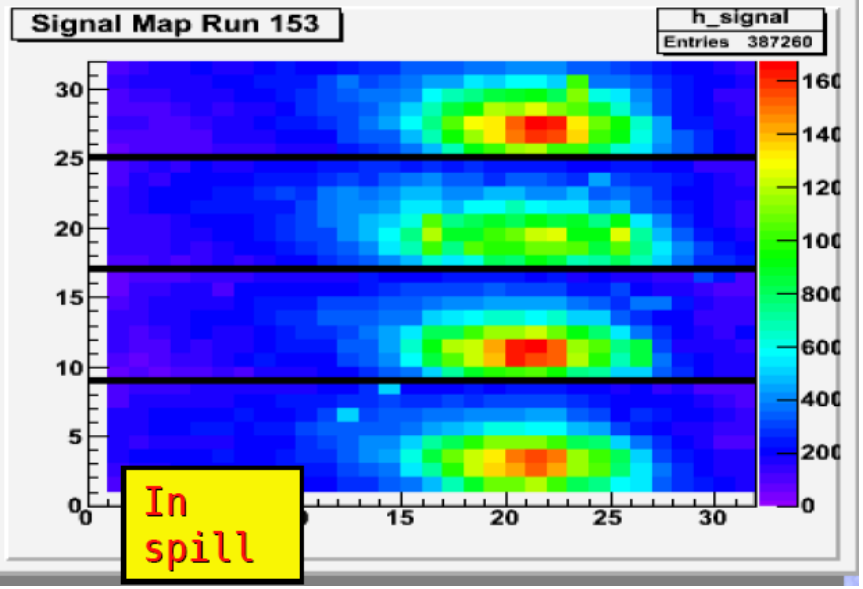
2009 SPS CERN TB Setting

Mini DHCAL: Event Selection

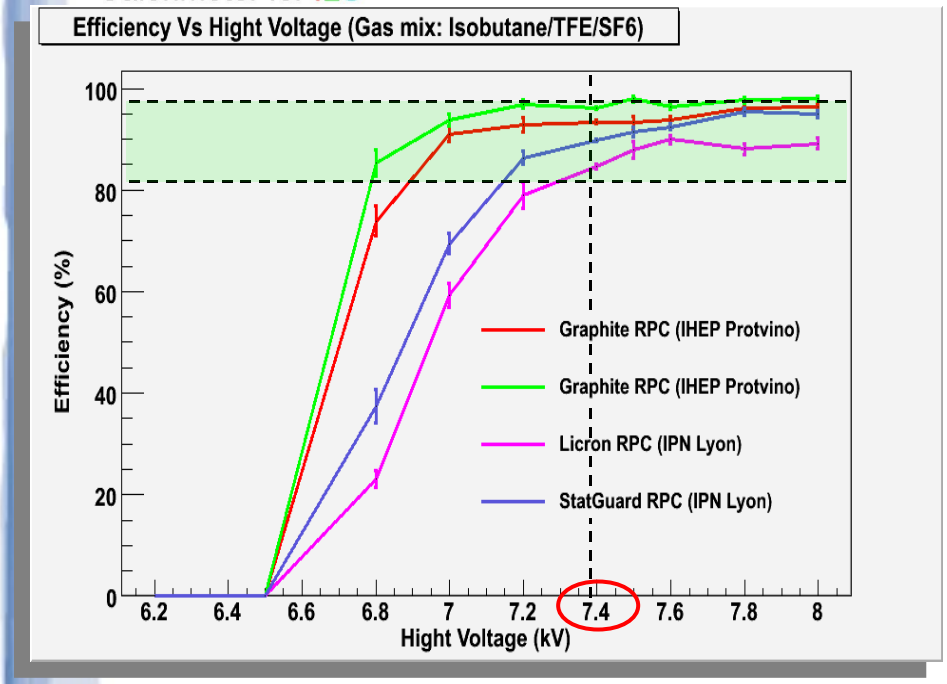


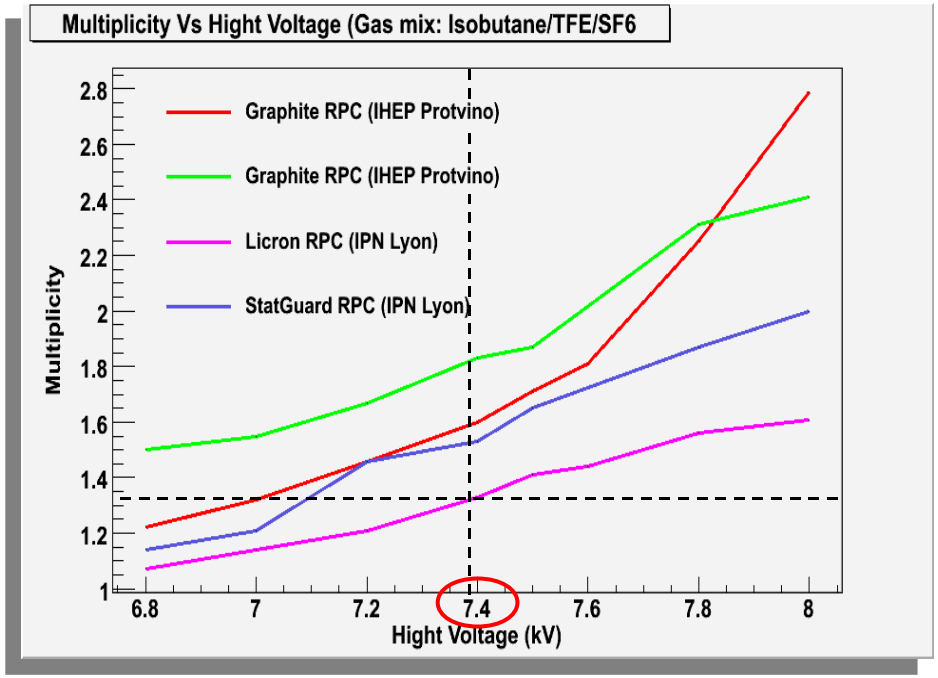






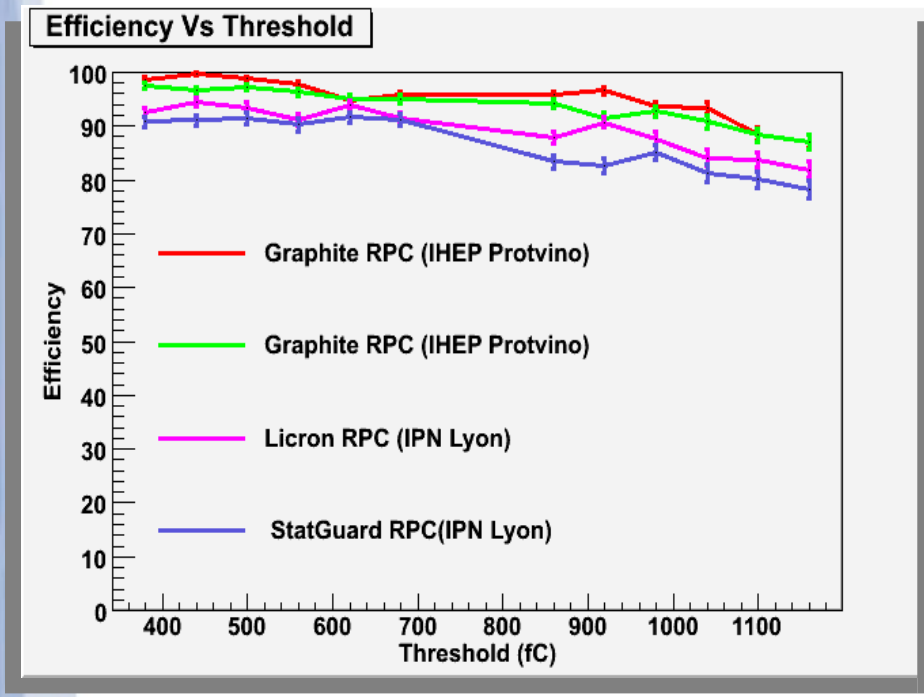
Mini DHCAL: HV Scan

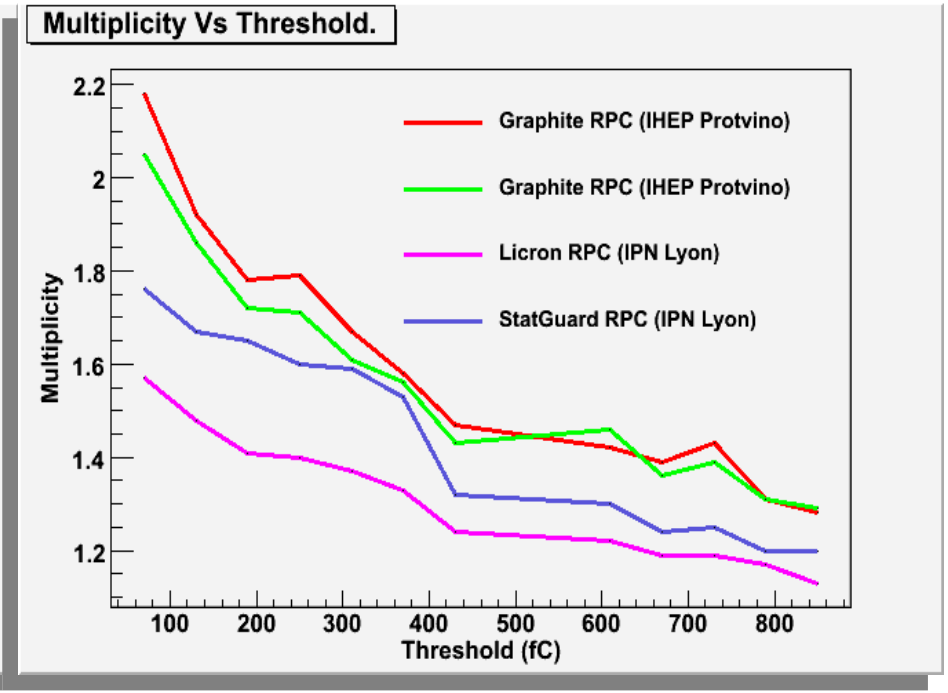




- DAC's **Thresholds**: lower 120 fC / higher 450fC
- **Plateau:** 7.2 to 8 kV
  -> Efficiency between 80 and 98%
- Lower multiplicity is preferred.
  -> Best ratio multiplicity/efficiency: around 7.4 kV
- Until now the licron coated detector seems to be **the best candidate**:
  -> it has the **lowest multiplicity** and shows **very good efficiency** performance.

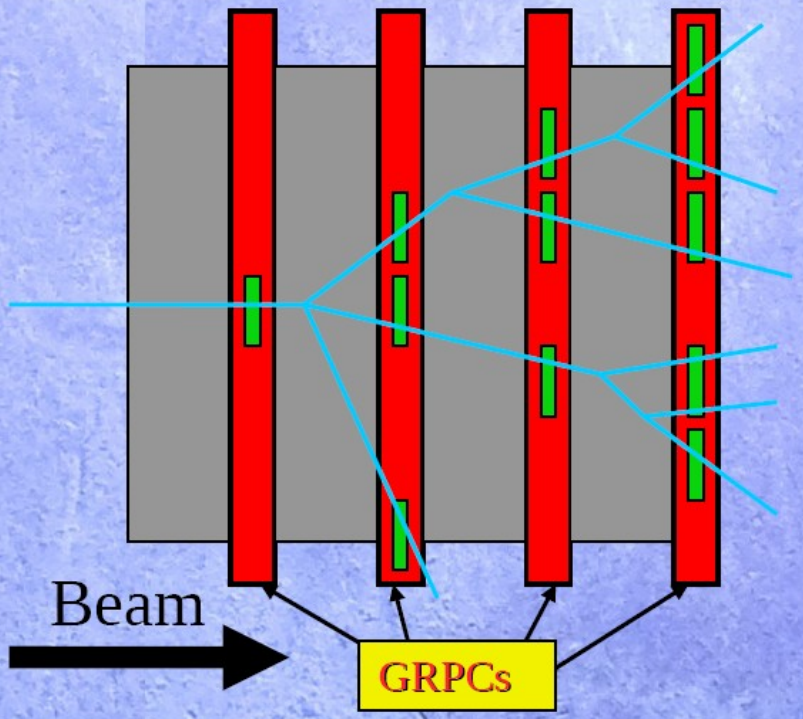
Mini DHCAL: Threshold Scan

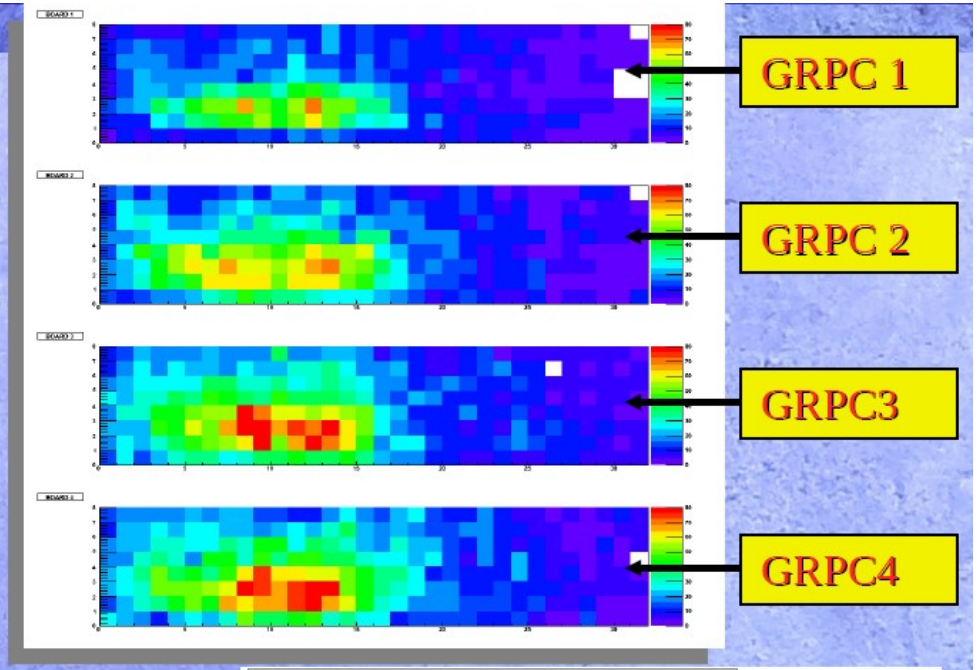


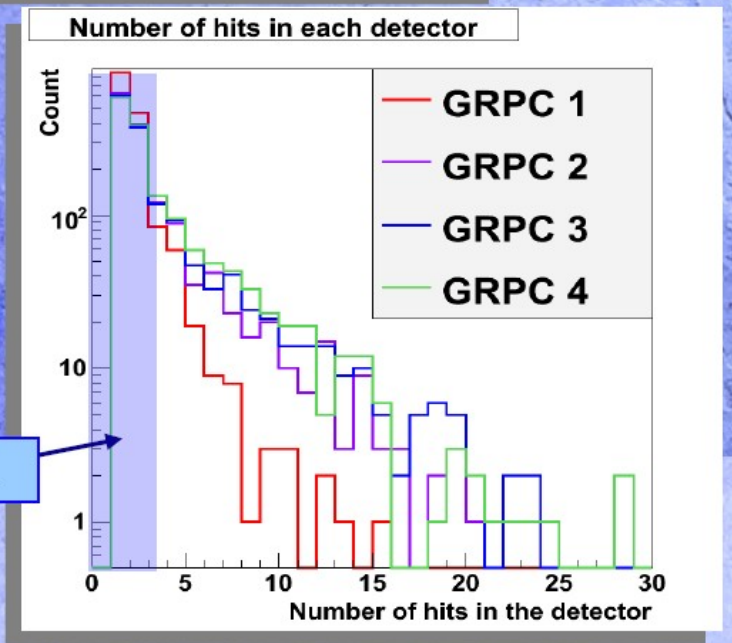


- Multiplicity moving as expected => **lowering as threshold increases**.
- Efficiency **decreasing** down to 80% at 1.1 pC threshold.

Mini DHCAL: Hadronic shower







Hadronic showers are mostly uncontained in Mini DHCAL but these profiles give a first idea of shower development, and energy deposition.

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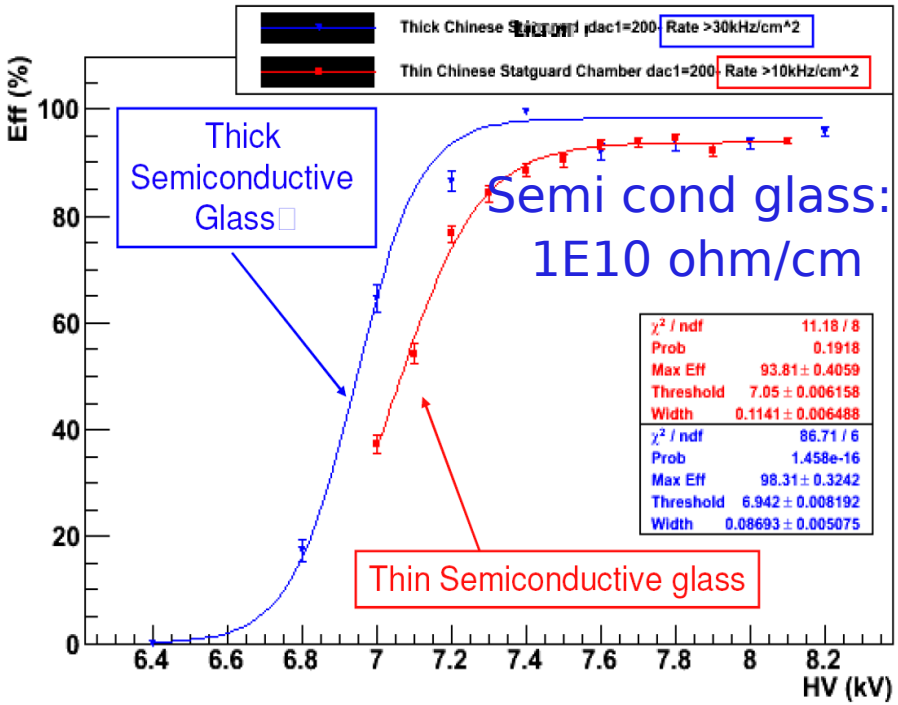
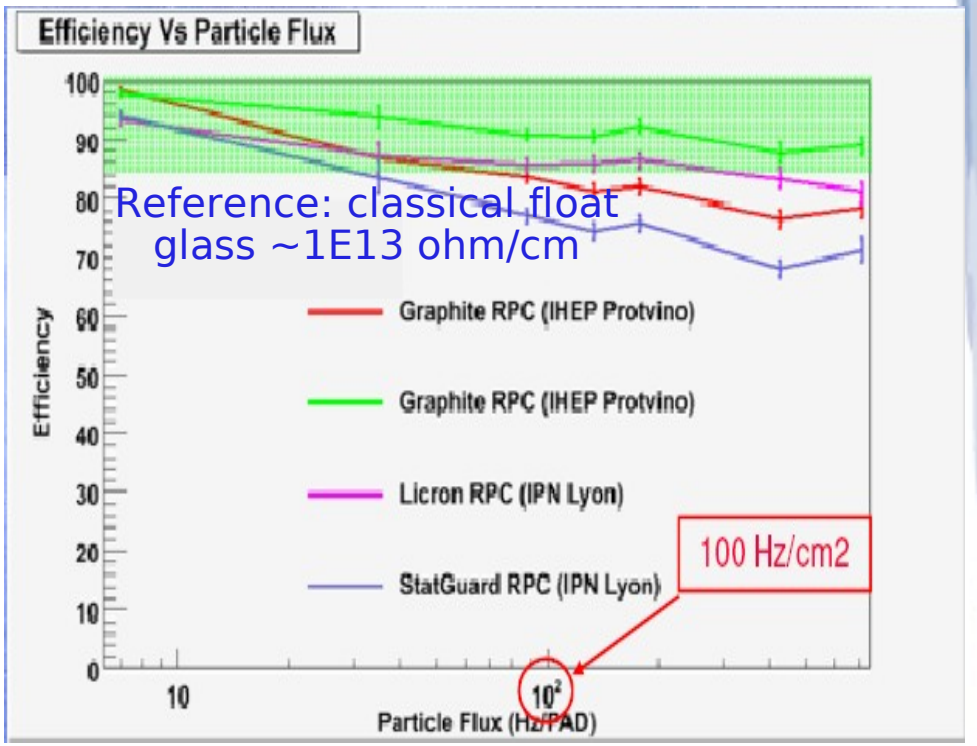
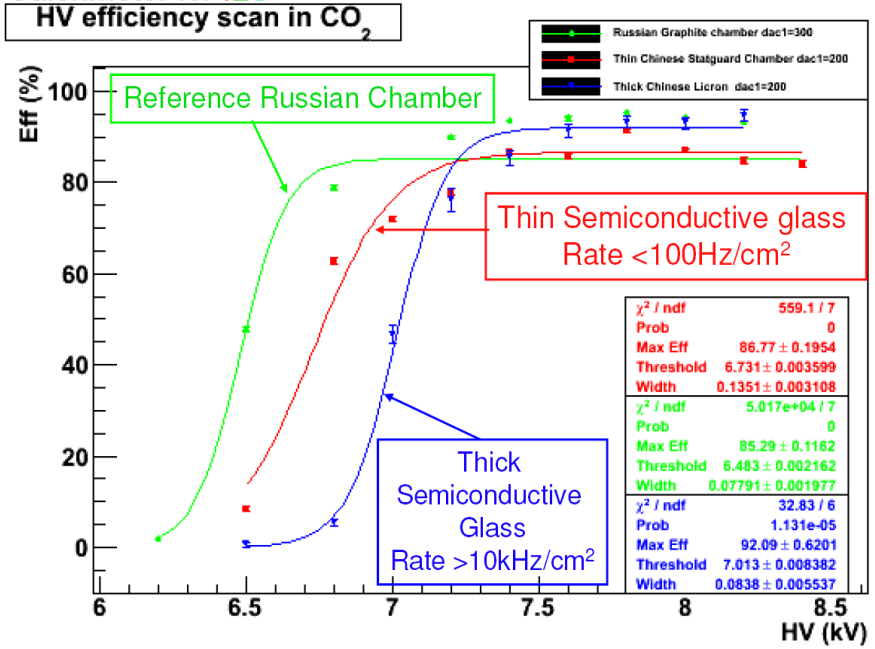
Mini DHCAL: with Semi conductive glass

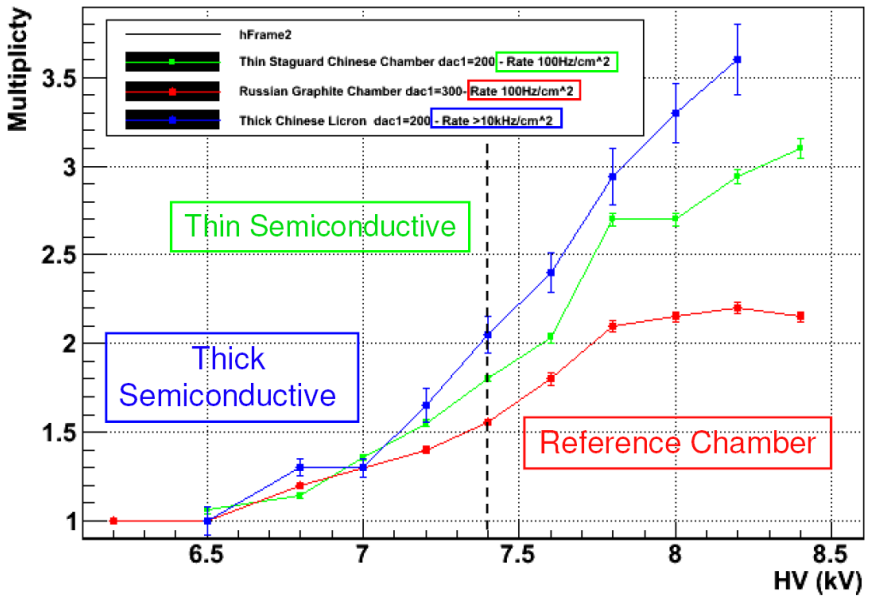




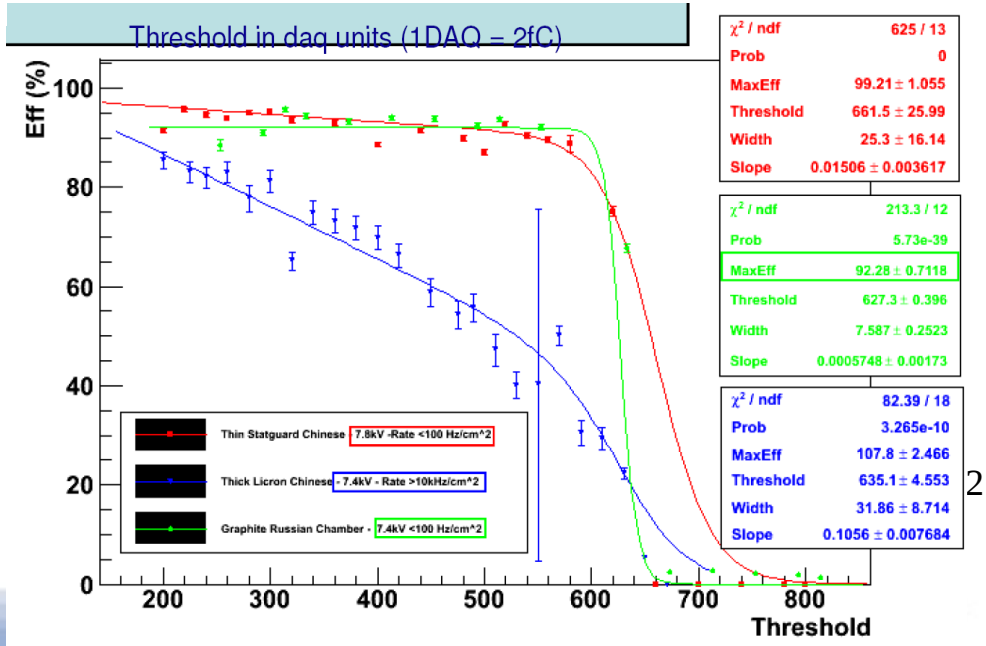
- Cooperation with Tsinghua University: Provide us with semi-conductivity glass 1.0^10 ohm/cm;
- 2 chambers with 32*8 pads: *1.1mm at both side + licorn coating & 1.1mm on cathode + 0.83 mm at readout + statguard coating*
- Semi conductivity glass has good efficiency at high event rate (>10kHz/cm^2), while classical glass has significant efficiency drop when event rate exceed 100Hz/cm^2

Mini DHCAL: with CO_2 gas

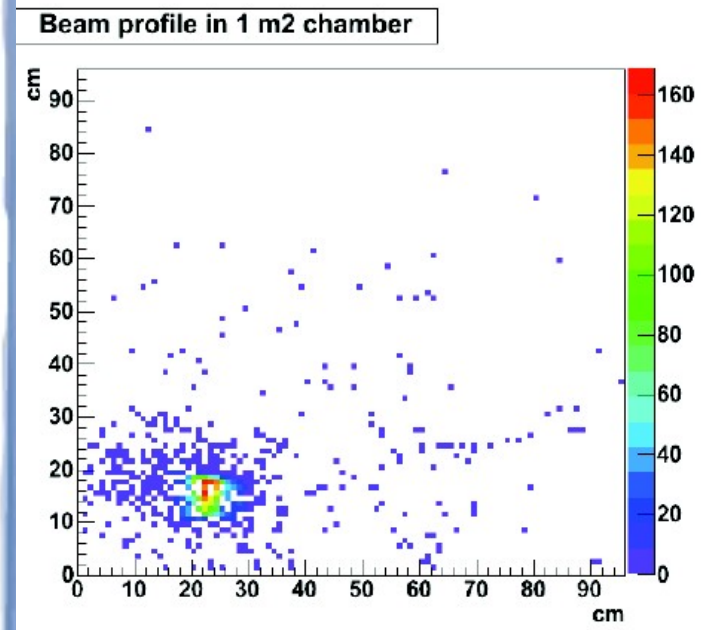


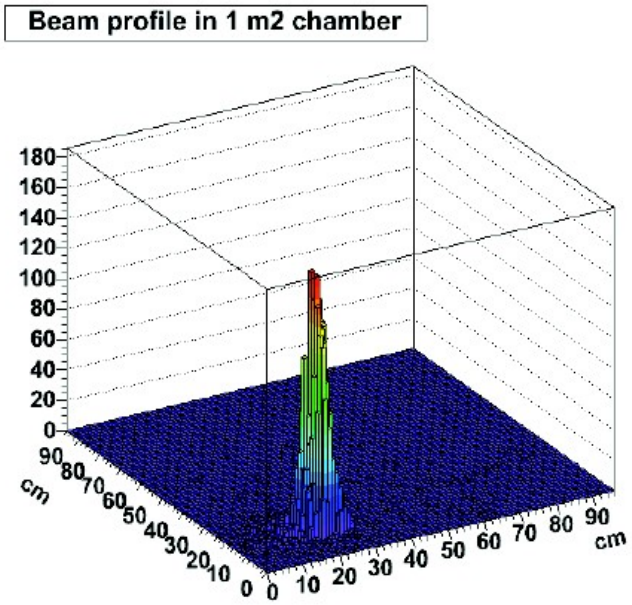


Avoid the flammable gas: replace Isobutane with CO_2



1 m² : beam profile

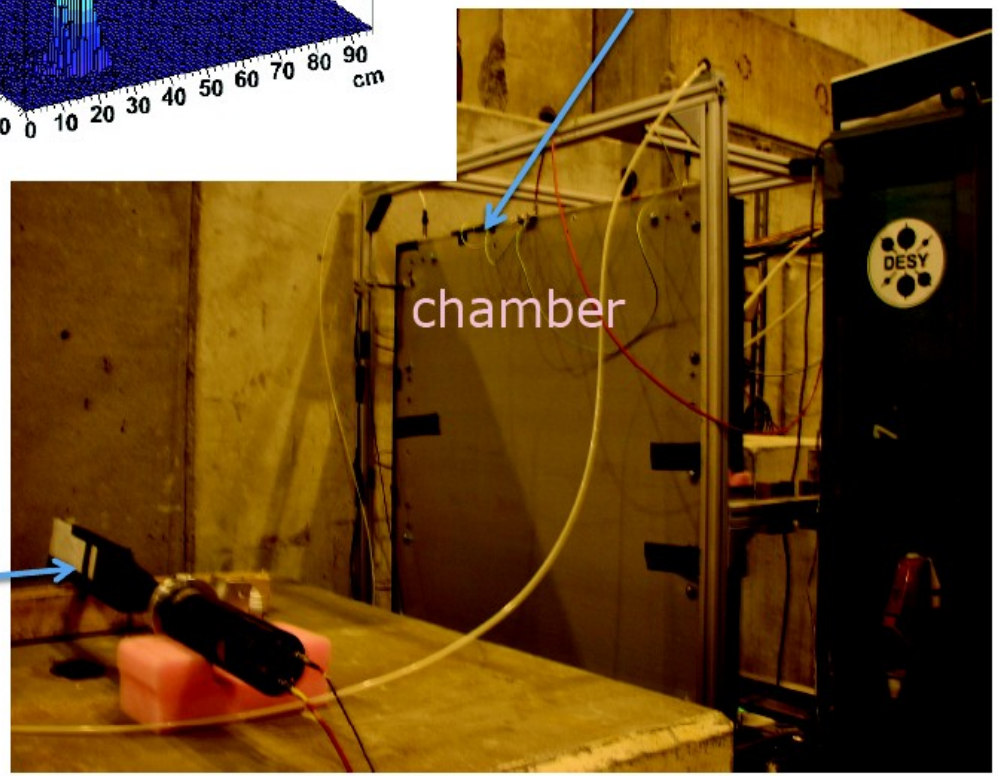




Pads over (low) threshold

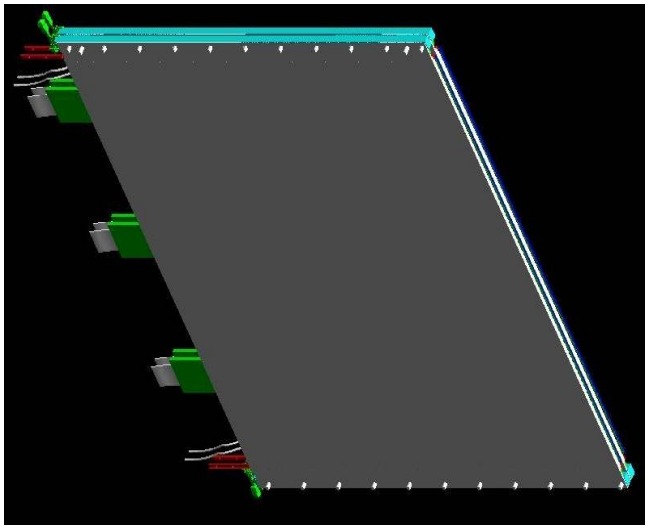
DAQ successful in testbeam mode
With 3 DIFs synchronised
Up to 93% efficiency

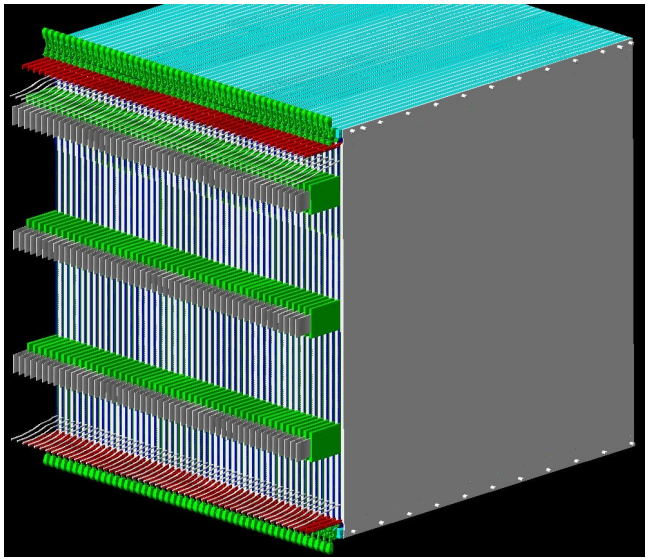
HV connection



Next step: 1 m³ prototype

The aim is to build a realistic prototype, validating the technological solution we propose for the ILD concept.





Technological prototype is made with:

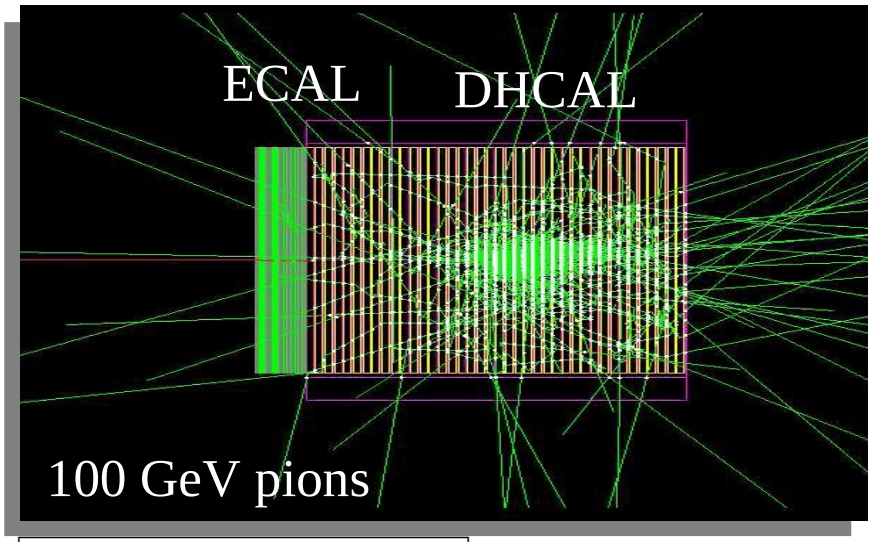
- 40 planes of 1m²
- One plane composed by:
  20 mm s.steel absorber + 6 mm GRPC/PCB
- A mechanical structure supporting the planes.
- A parallel gas distribution system.

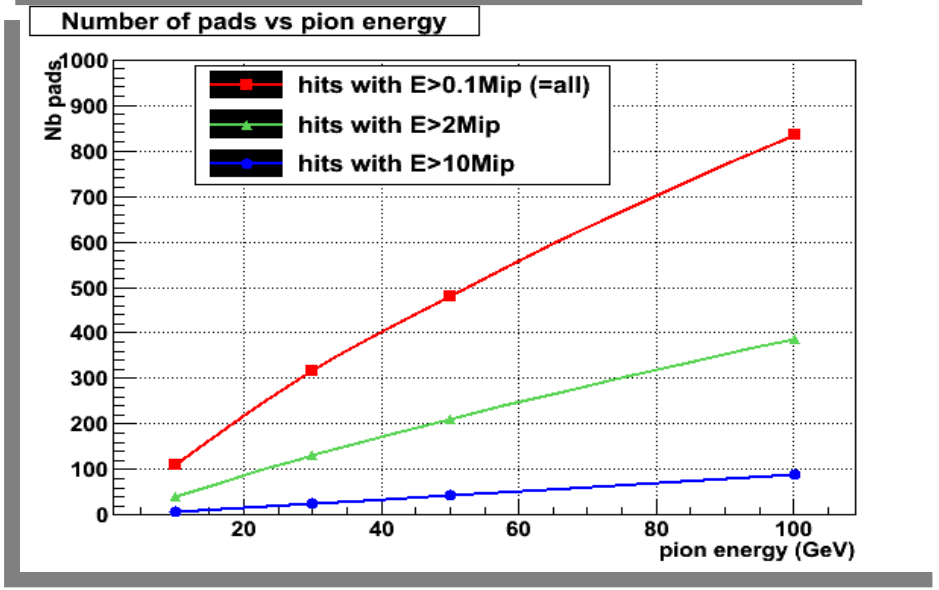
Important points:

- Mechanical structure development:
  1m³ of (Absorber+GRPC) is about **6 ton** weight.
- Use of gas system with re-cycling option.
- Semi Digital readout of 368.640 channels **:**
  DAQ, event buiding, & data storage.

1 m³: shower containment

- With a **1m³ DHCAL**, hadronic shower could be mainly contained, even for high energy pions (about 100 GeV).
- We already try to evaluate the **energy deposition** to help the 1m³ design.
- The 40 planes of 9216 channels each, will permit us to have the complete profile of the showers, with a very high granularity.
- As the **HARDROC2** will have 3 thresholds, we try to evaluate the number of fired pads for different thresholds values, to better reconstruct the energy.





MC: Full Detector Occupancy study

	Barrel N_{hits}	Barrel N_{asic}	EndCap N_{hits}	EndCap N_{asic}	Ring N_{hits}	Ring N_{asic}
$e^+e^-\rightarrow qq$ GigaZ,30evt/s	207.6 6.2k/s 0.1/s	124.6 3.7k/s 0.05/s	117.8 3.5k/s 0.1/s	77.8 2.3k/s 0.06/s	6.7 201/s 0.036/s	4.5 135/s 0.02/s
Minimal bias GigaZ,10evt/s	0.78 7.8/s	0.64 6.4/s	20.2 202/s 0.06/s	17.0 170/s 0.05/s	0.038 0.38/s	0.033 0.33/s
Minimal bias Nominal 660evt/s	1.06 700/s	0.91 600/s	29.7 19.6k/s 4.6/s	25.1 16.6k/s 4/s	0.058 38.3/s	0.05 33/s

Black: expected N_{hits}/N_{asic} per event;

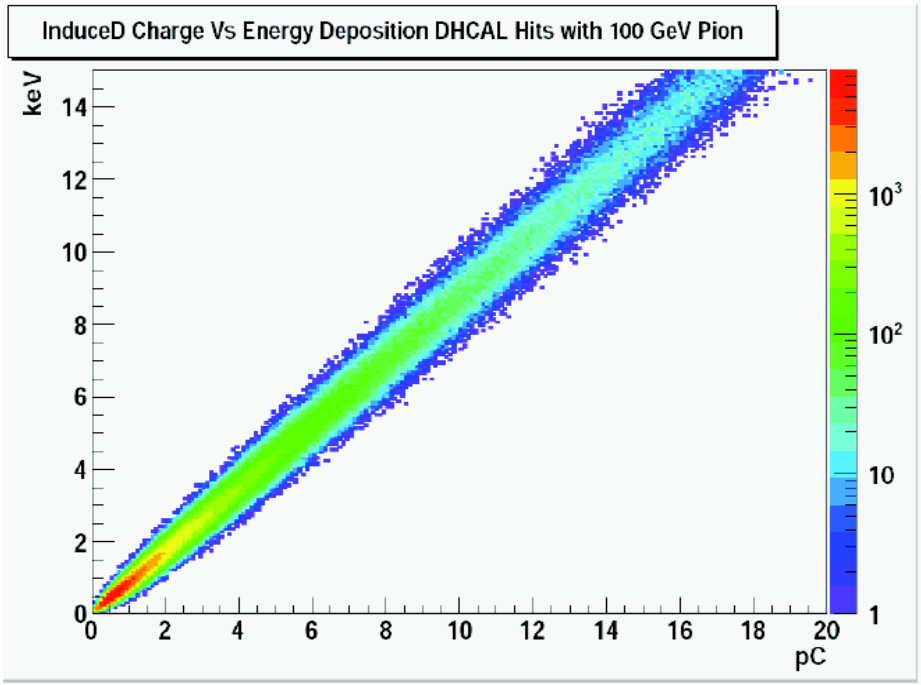
Blue: expected N_{hits}/N_{asic} per second;

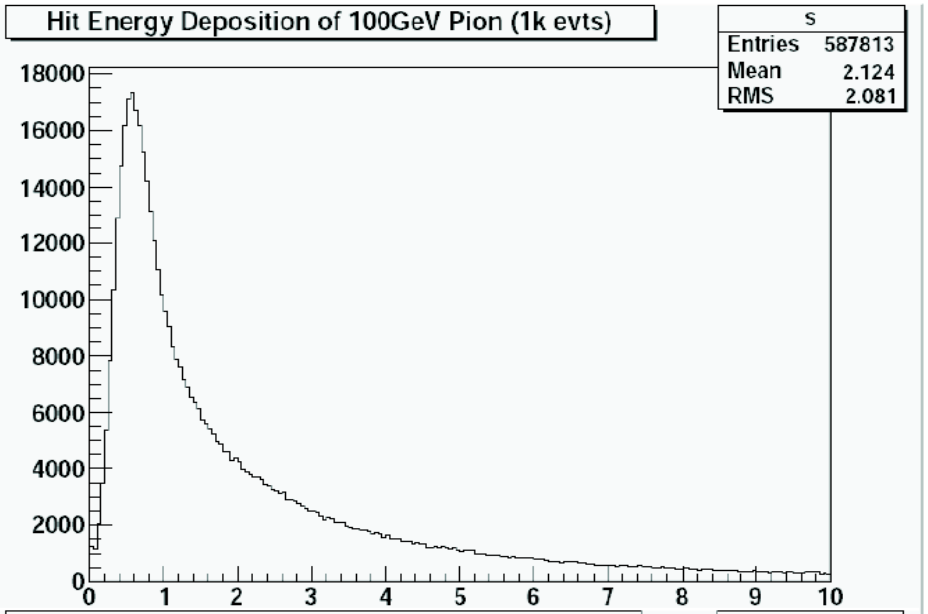
Red: N_{hits}/N_{asic} per second on the hottest Asic

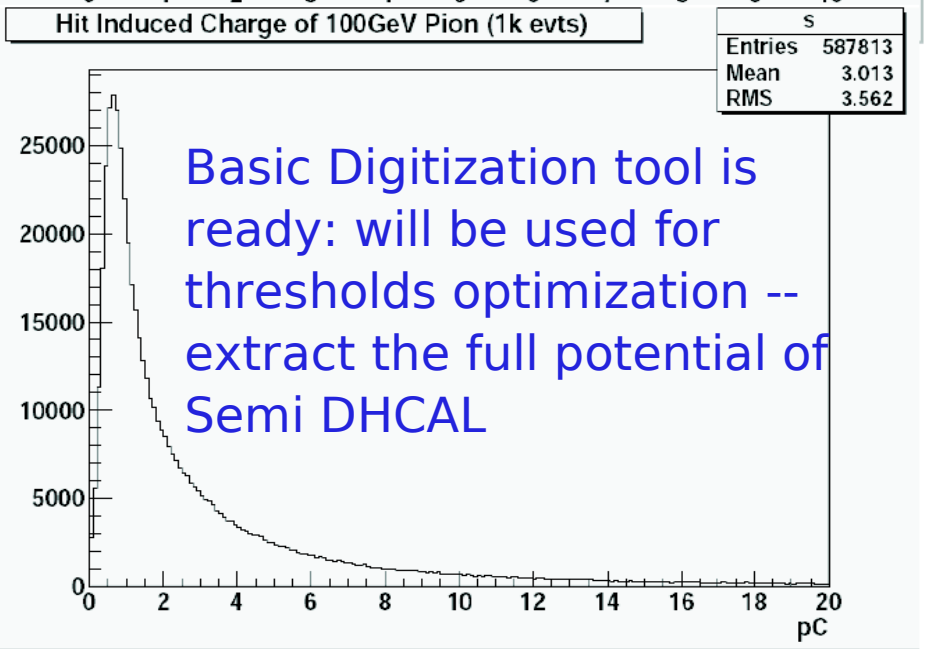
MC Simulation: our RPC has sufficient rate capability!

MC Digitization: Estimate the induced Charge

Digitization with 100 GeV Pion





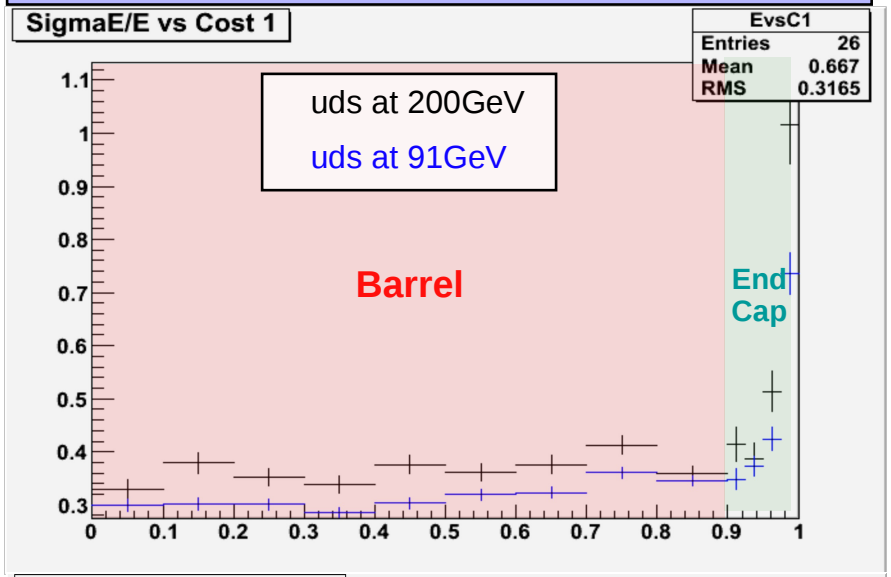


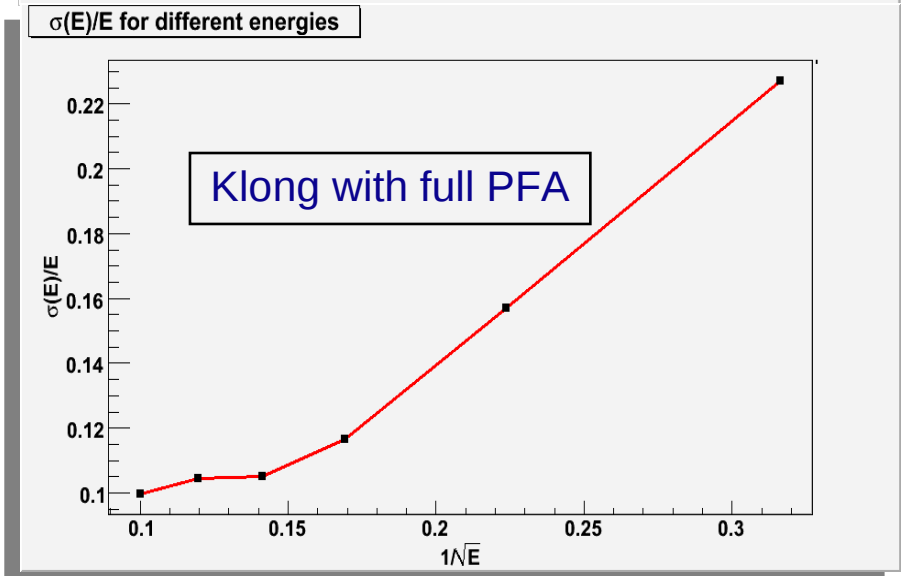
Basic Digitization tool is ready: will be used for thresholds optimization -- extract the full potential of Semi DHCAL

ILD Integration

- Simulations were done with Mokka software integrating DHCAL geometry.
- **Event produced:** single klong & uds.
- First analysis was done using Marlin with single threshold at 0.1 MIP in Mark Thomson's PFAnalysis module.
- **P**article **F**low **A**lgorithm need to be optimized to use the **full potential** of a multi threshold DHCAL.
- More work has to be done for it.

Detector's resolution Vs polar angle





SemiDigitalHCAL with PFA:

Conclusions & perspectives

- A Semi-Digital Gaz Hadronic Calorimeter with embedded readout is a very promising candidate for future linear colliders experiments
- A mini SDGHCal based on first generation readout with GRPC and 1 m^2 prototype were successfully tested in laboratory and in test beam at CERN
- A lot have been learned from the test beam experiments: searching for the best design of the RPC for ILC
- A technological prototype “1 m^3” (RPC or MGRPC) is funded and expected in 2009-2010
- MC Simulation and Analysis are well undergoing