Semi-Digital Hadronic CALorimeter

Introduction and Objectives for 2011

I.Laktineh

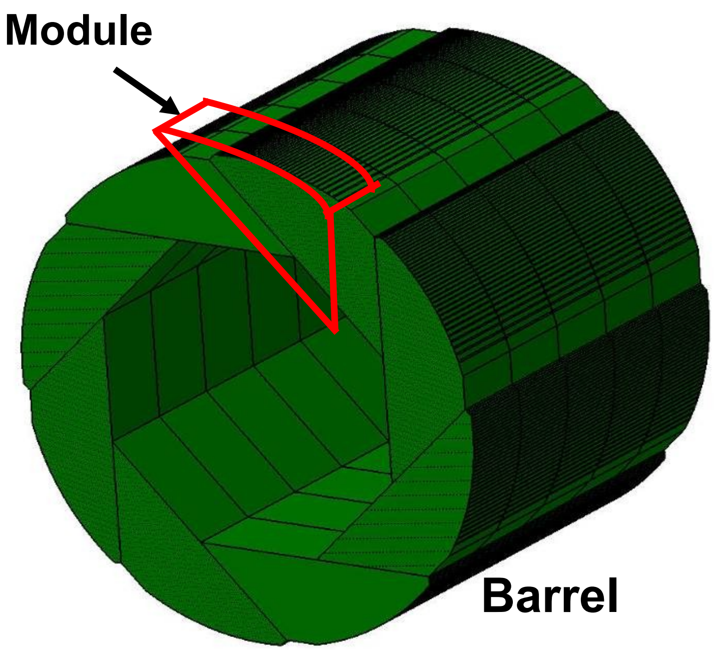
CIEMAT, Gent, IPNL, LAL, LAPP, LLN, LLR, LPC, Protvino, Tsinghua, Tunis

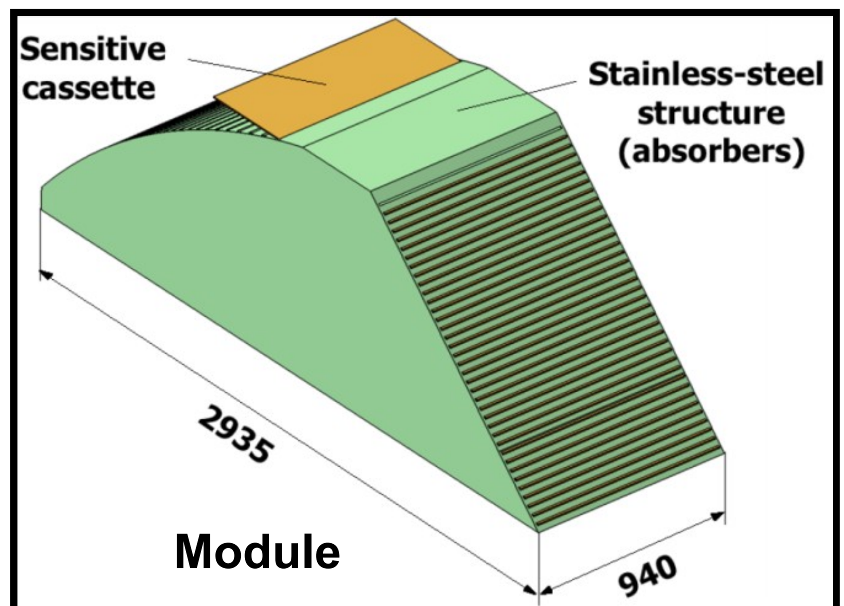
Objectives

The Semi-digital GRPC-based HCAL was proposed and accepted as one of the two HCAL possible options in the **ILD L**etter **O**f **I**ntent

A genuine mechanical structure was also proposed

- It is self-supporting
- Has negligible dead zones
- Eliminates projective cracks
- Minimizes barrel / endcap separation (services leaving from the outer radius)

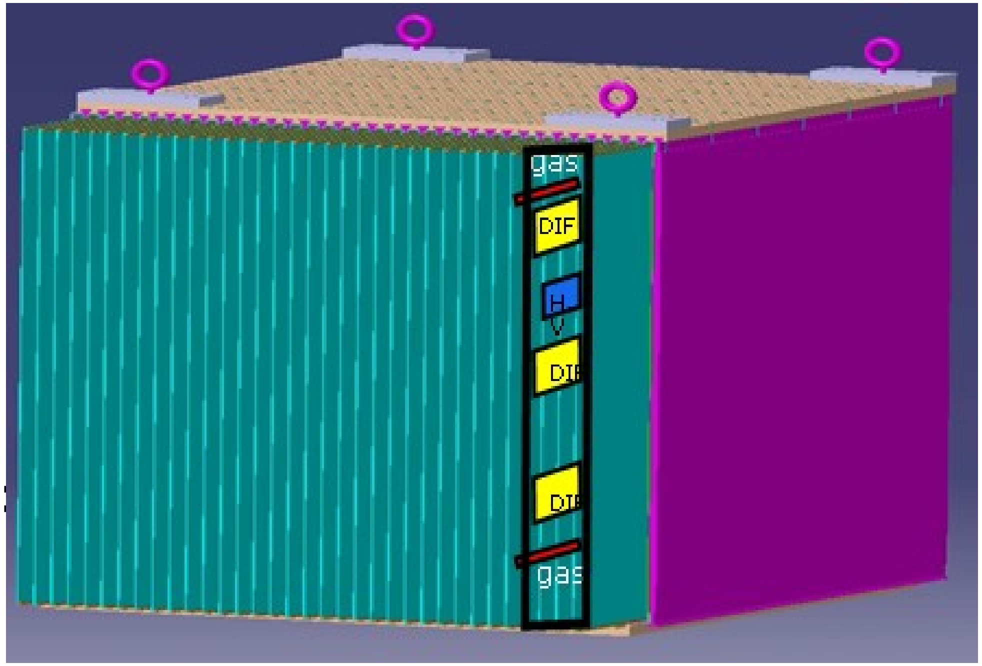




Objectives

We intend to validate the **SDHCAL concept** by building a prototype which is as close as possible **to the proposed SDHCAL for ILD to understand key issues of integration and operation** :Technological prototype

- → **Self-supporting mechanics**
- → **Minimized dead zone**
- → **Minimized thickness**
- → **One-side services**
- → **Power pulsed electronics**



The prototype will be made of 40(48) units. Each unit is made of :
2 cm absorber
+ **0.6 cm sensitive medium**
1 cm^2 transversal granularity

This is about **5(6)**$\boldsymbol{\lambda_I}$
and **368640(442368)** channels

The modular structure we propose makes it possible to increase the number of units up to 48

Realizations

With respect to the **physics prototype** our efforts to build a **technological prototype** led us to develop:

1- Large detector (1m^2) with almost no dead zones :

2- Large and thin embedded electronics board

4- One-side services : readout, gas outlets..

5- Self-supporting mechanical structure

6- Power-pulsed electronics

7- New generation of DAQ system

8- 2-bit readout.

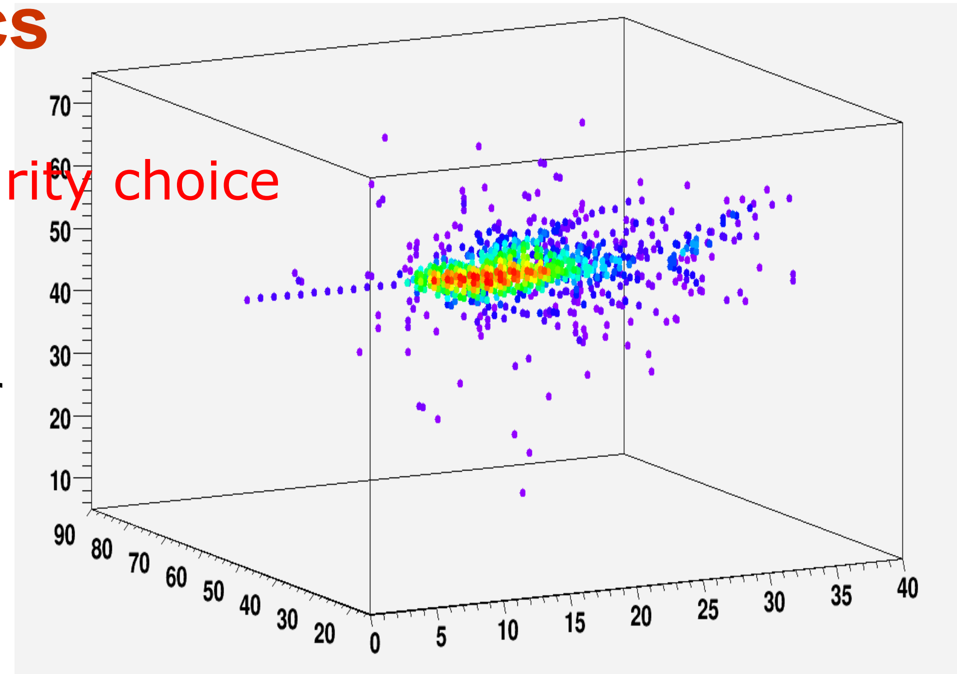
2-bit Readout Electronics

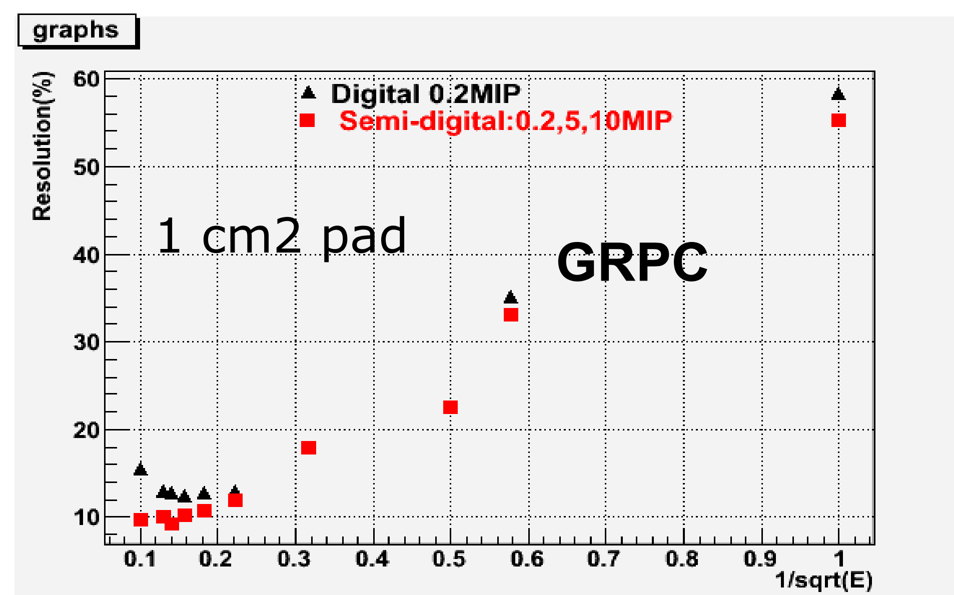
Electronics readout and granularity choice

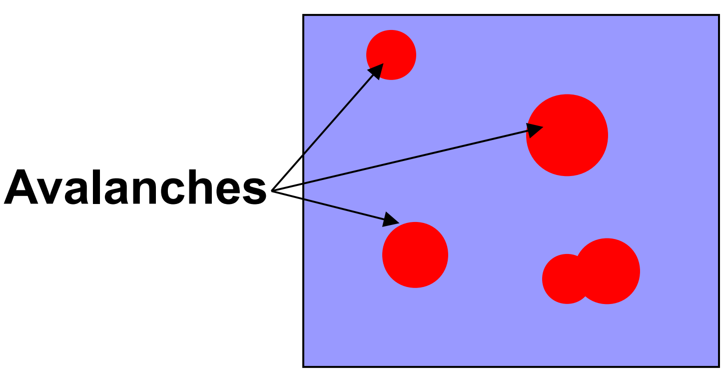
At high energy the shower core is very dense (up to 50 pc/cm^2)

→ simple binary readout will suffer saturation effect

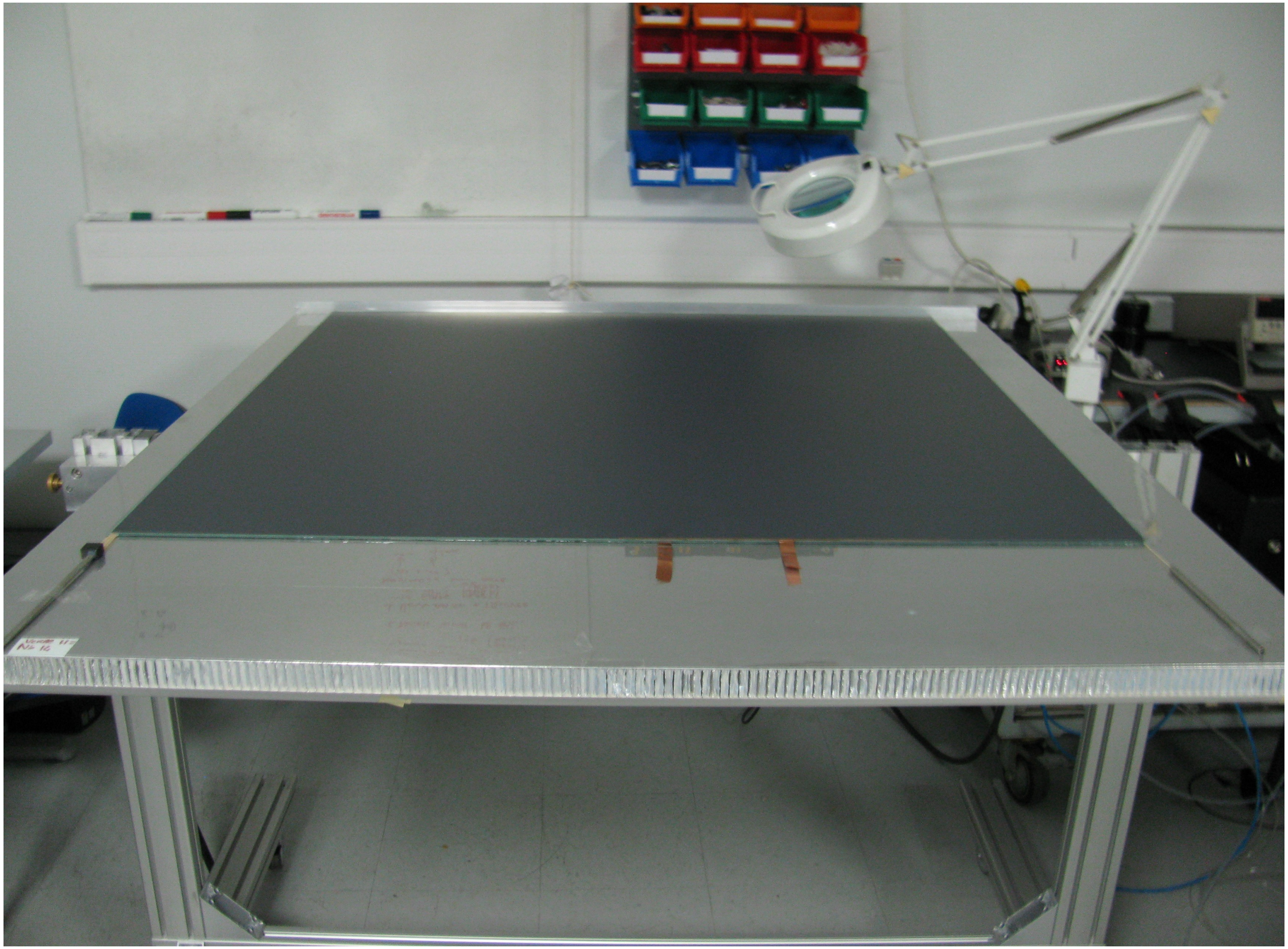
→ semi-digital readout (2-bit) can improve the energy resolution at high energy By improving counting capability





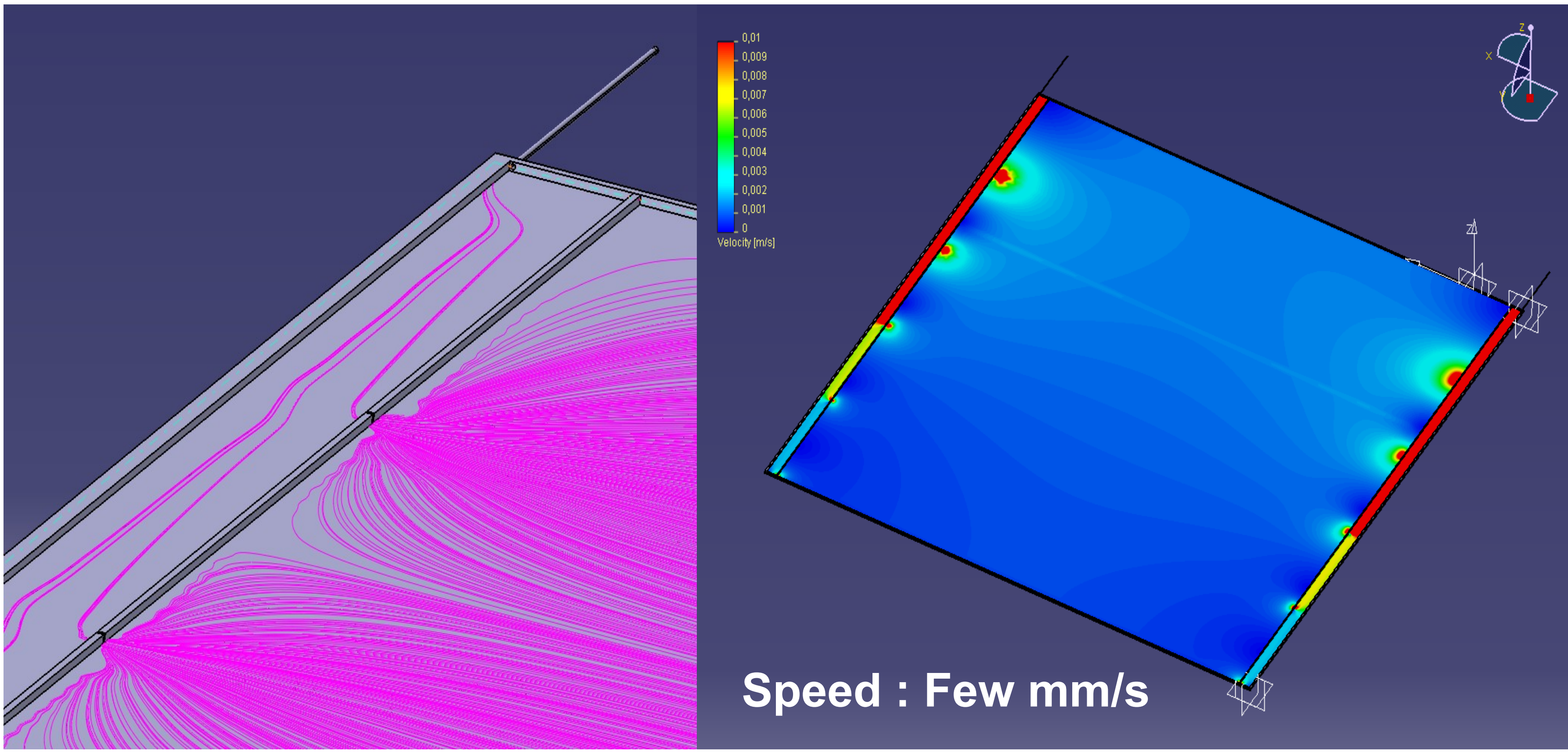


1 cm^2 pad



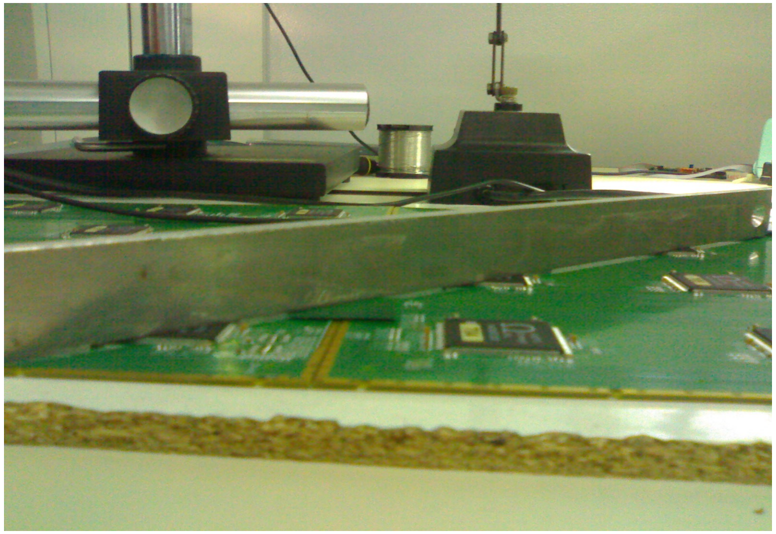
1m2 GRPC

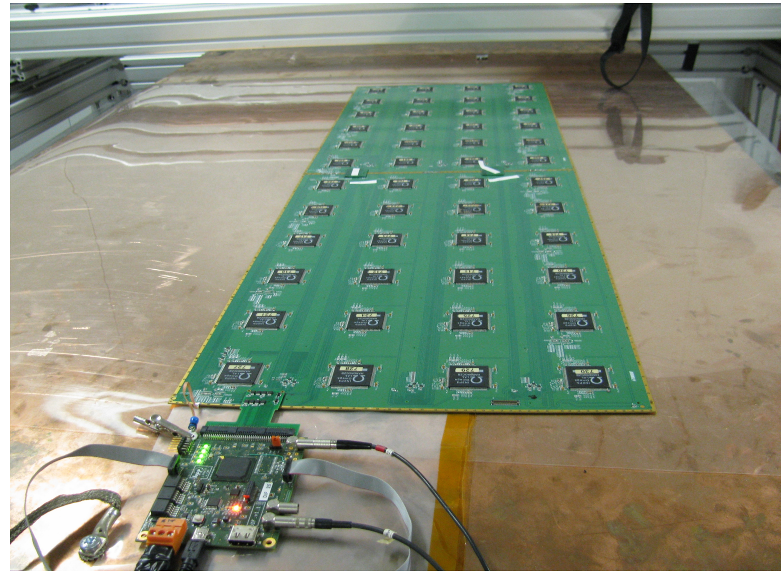
Gas circulation system was conceived and checked with sophisticated simulation tools with the aim to reduce gas consumption and to guarantee a well distributed gas



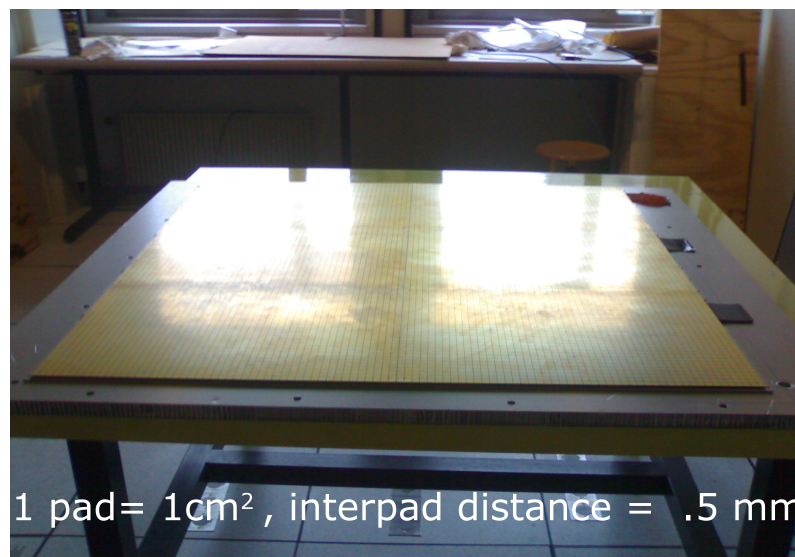
When diffusion is included→ Homogeneity is even better

Final version of electronics:



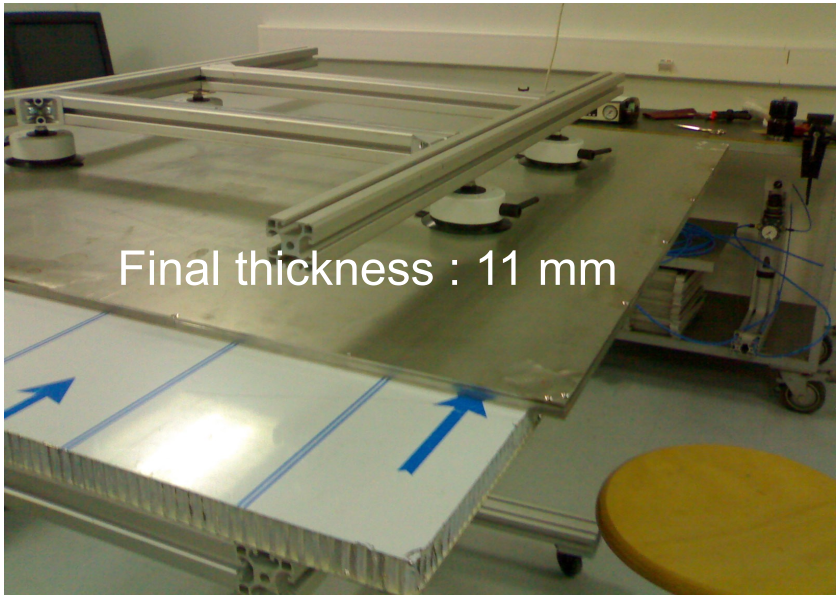


144 ASICs= 9216 channels/1m^2

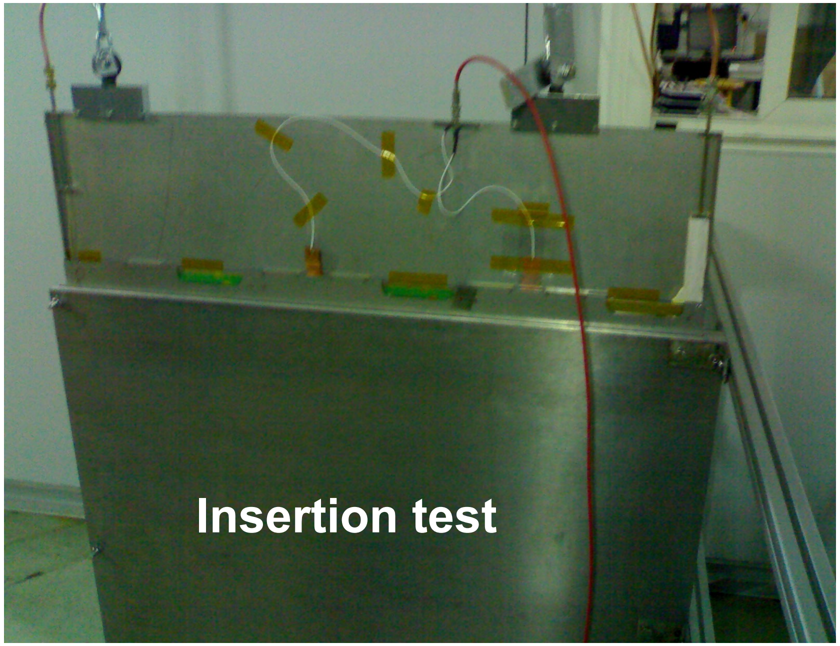


1 pad= 1cm^2 , interpad distance = .5 mm


Assembling procedure

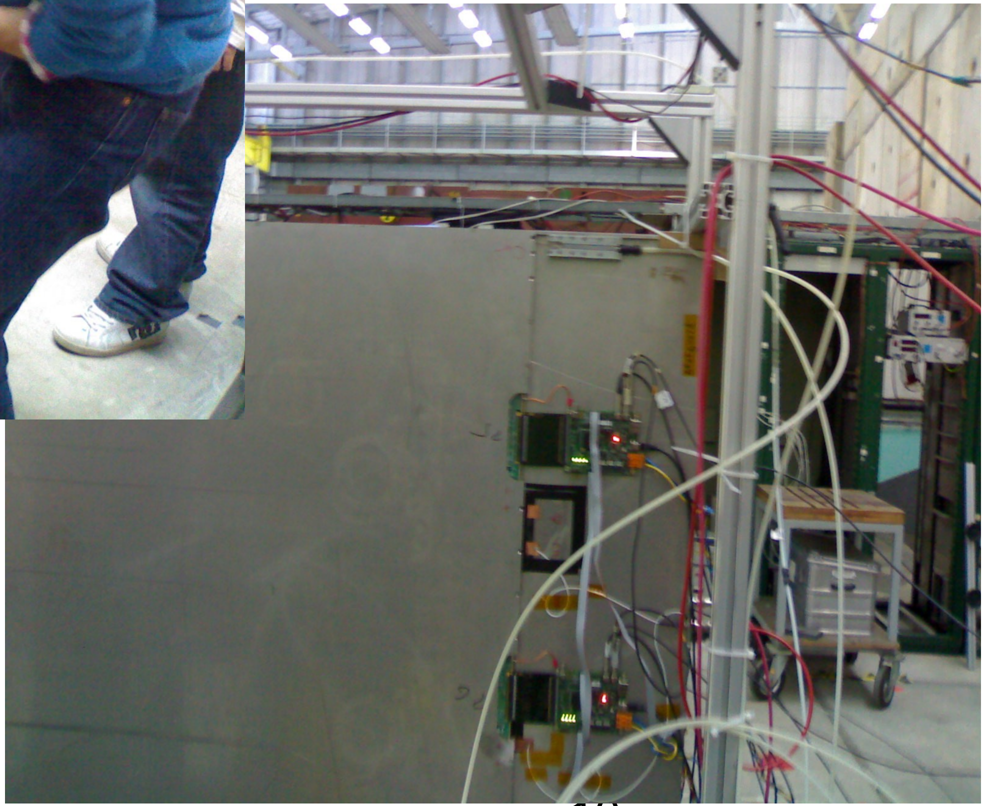

Final thickness : 11 mm


Clearance : 2 mm in Z
4 mm in X

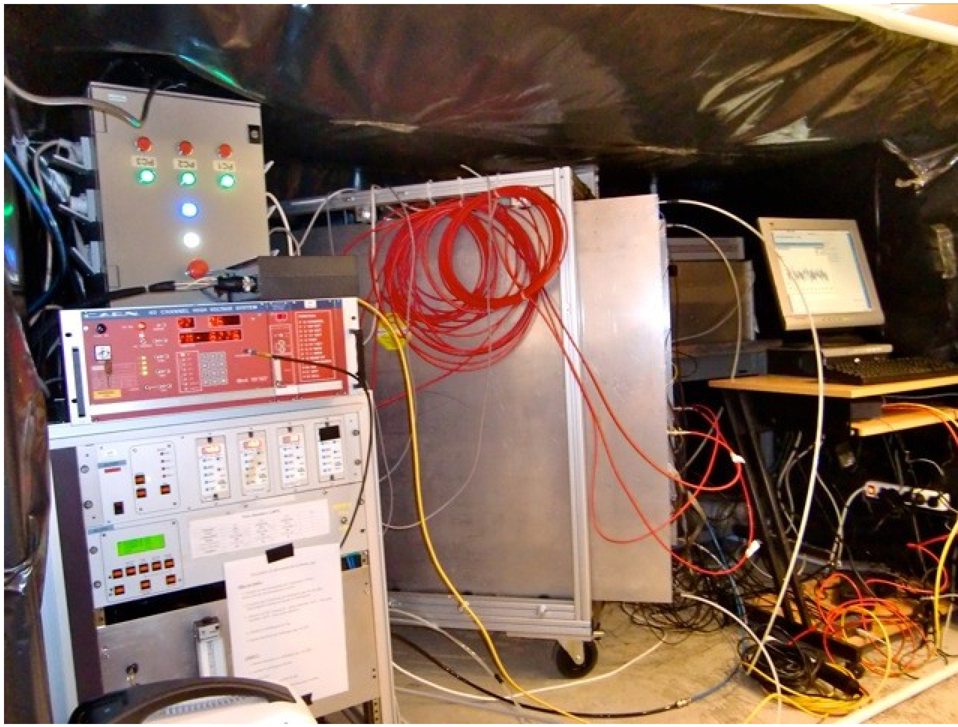
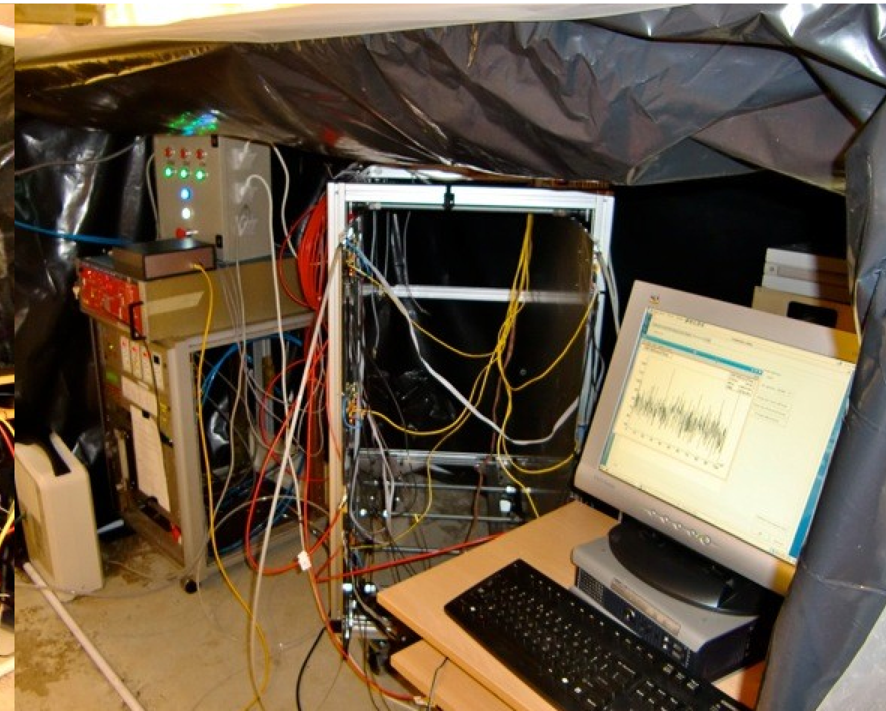

Insertion test

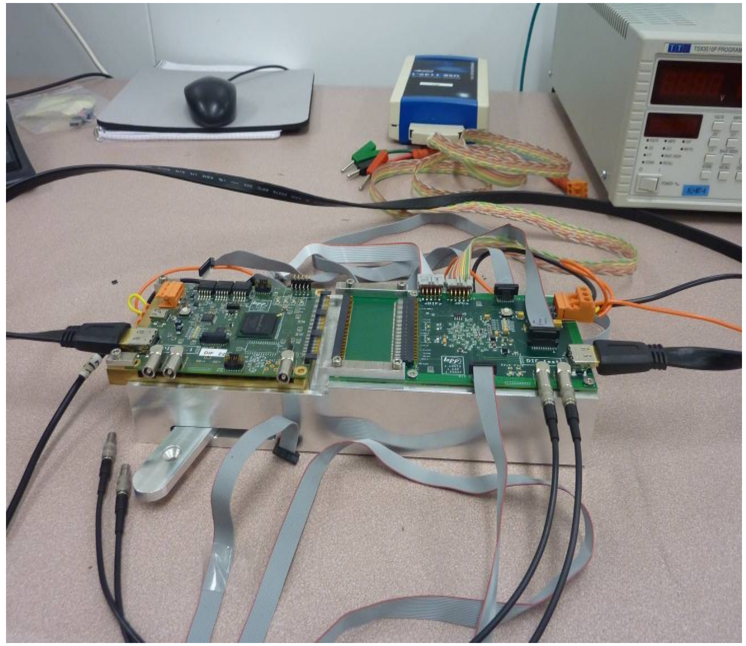
TestBeam Validation

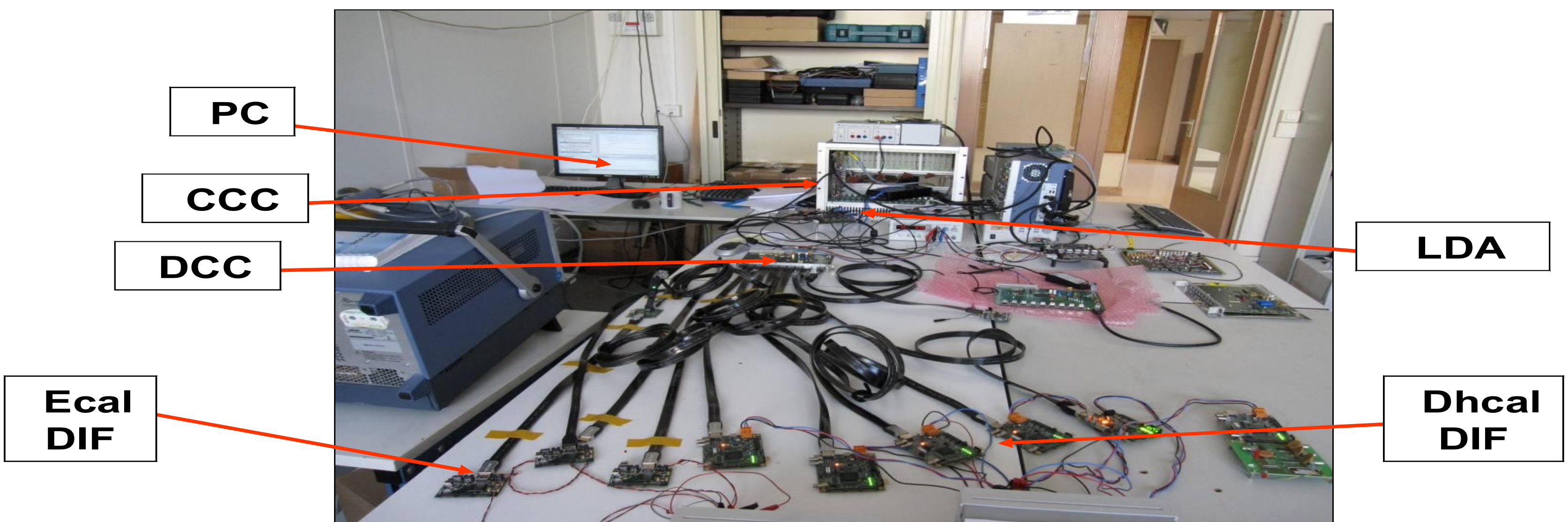
2 full cassettes were successfully tested at T9-PS May 2010 and H4-SPS in September 2010

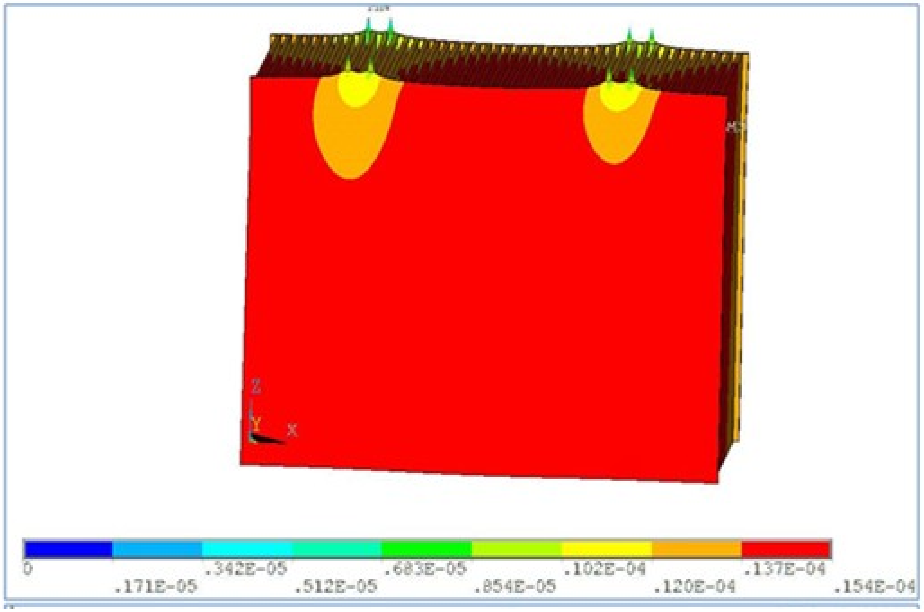


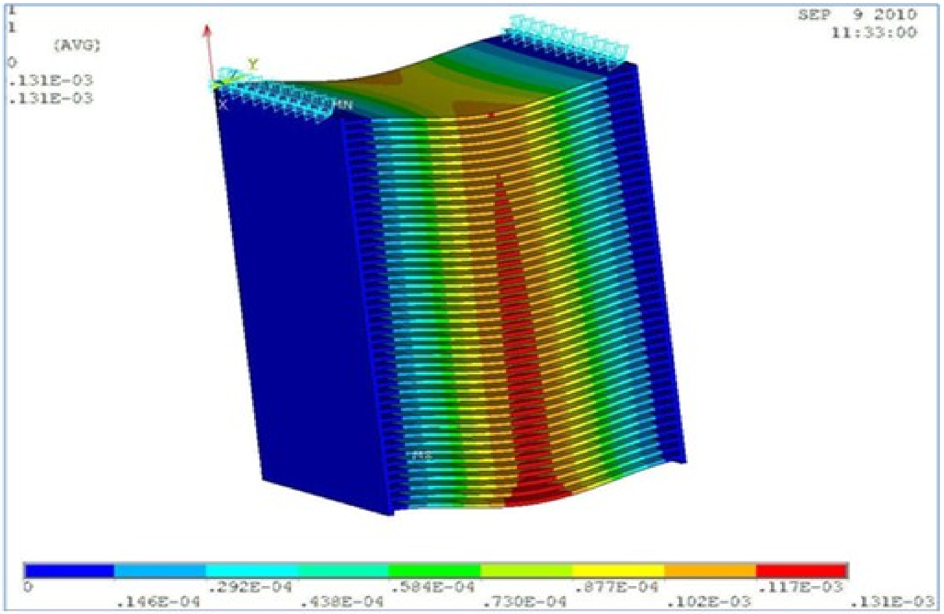
Two of our chambers are being tested since 5 January in CLERMONT

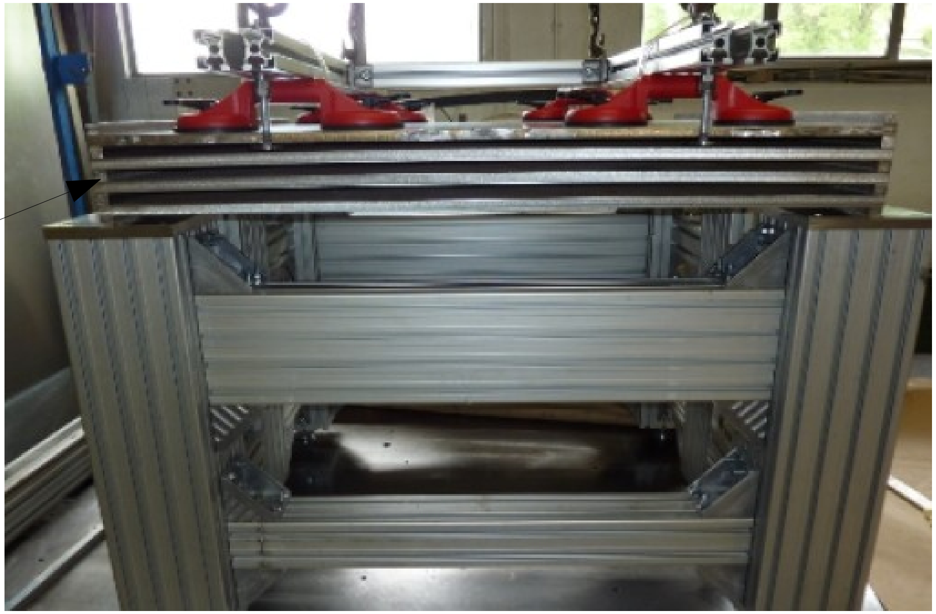



PC
CCC
DCC
LDA
Ecal DIF
Dhcal DIF

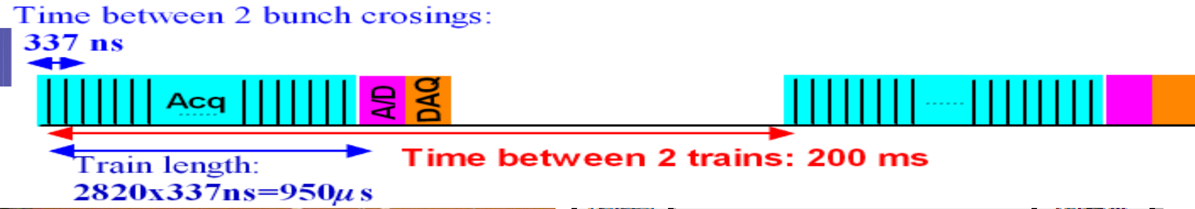

Z
Y
X
0
.171E-05
.342E-05
.512E-05
.683E-05
.854E-05
.102E-04
.120E-04
.137E-04
.154E-04

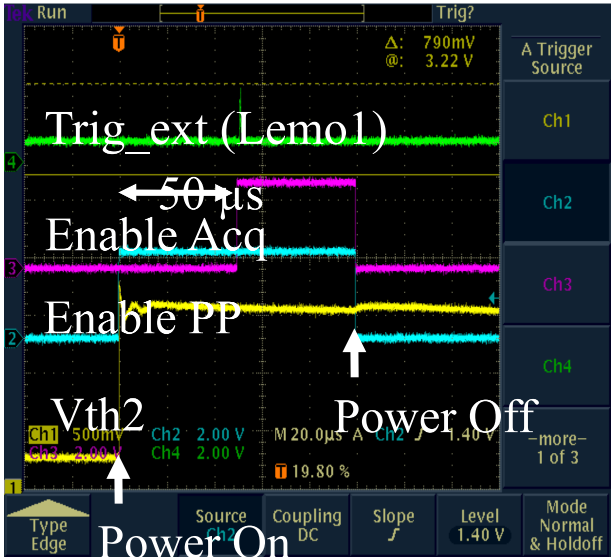

(AVG)
SEP 9 2010
11:33:00
0
.131E-03
.131E-03
Y
X
0
.146E-04
.292E-04
.438E-04
.584E-04
.730E-04
.877E-04
.102E-03
.117E-03
.131E-03

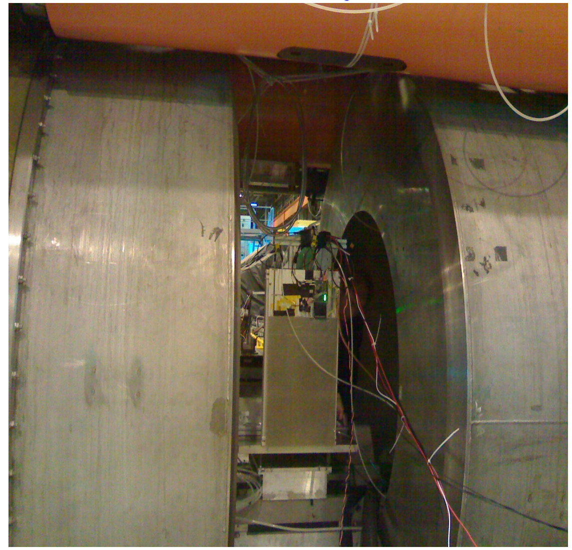
Spacers

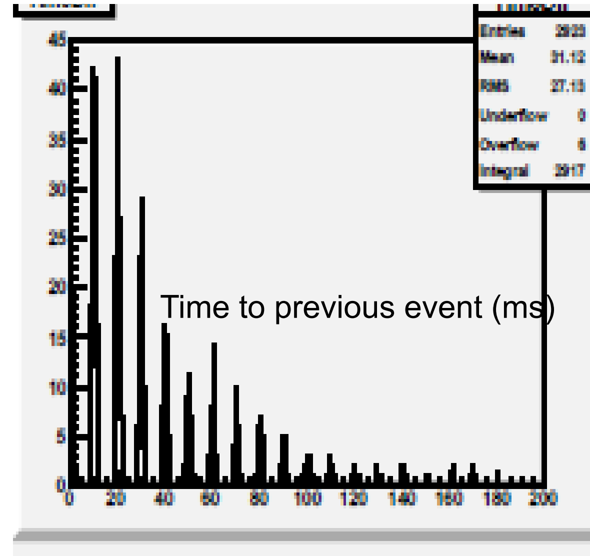


Power-pulsing test

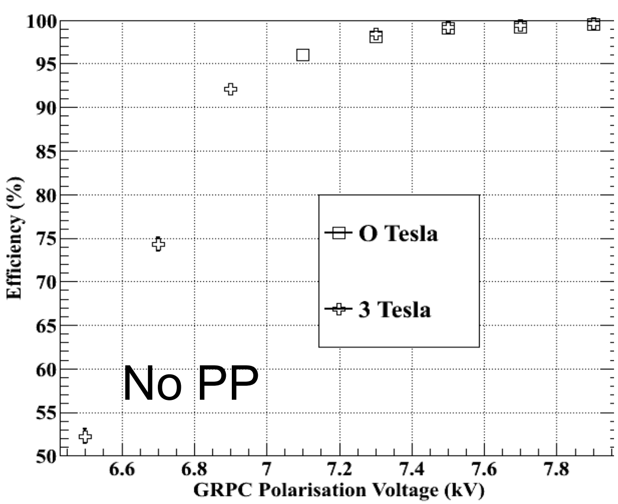


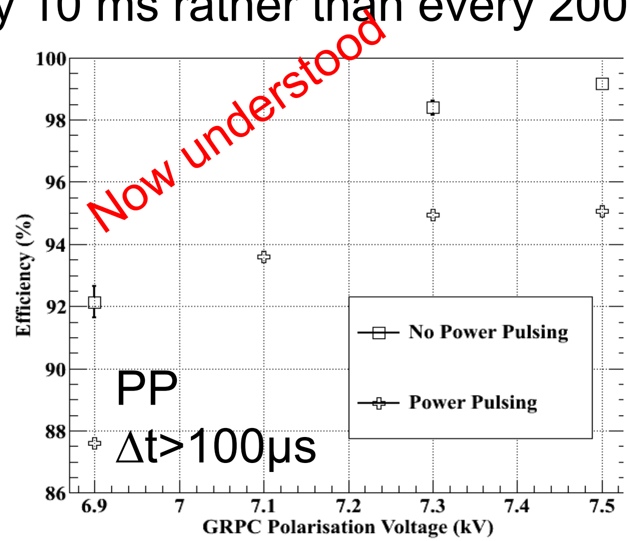


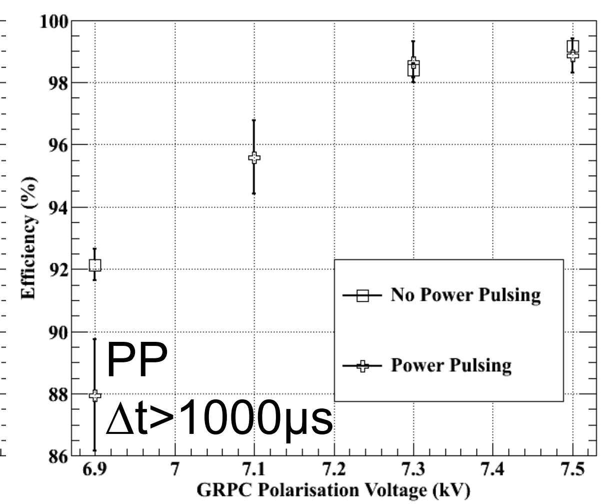




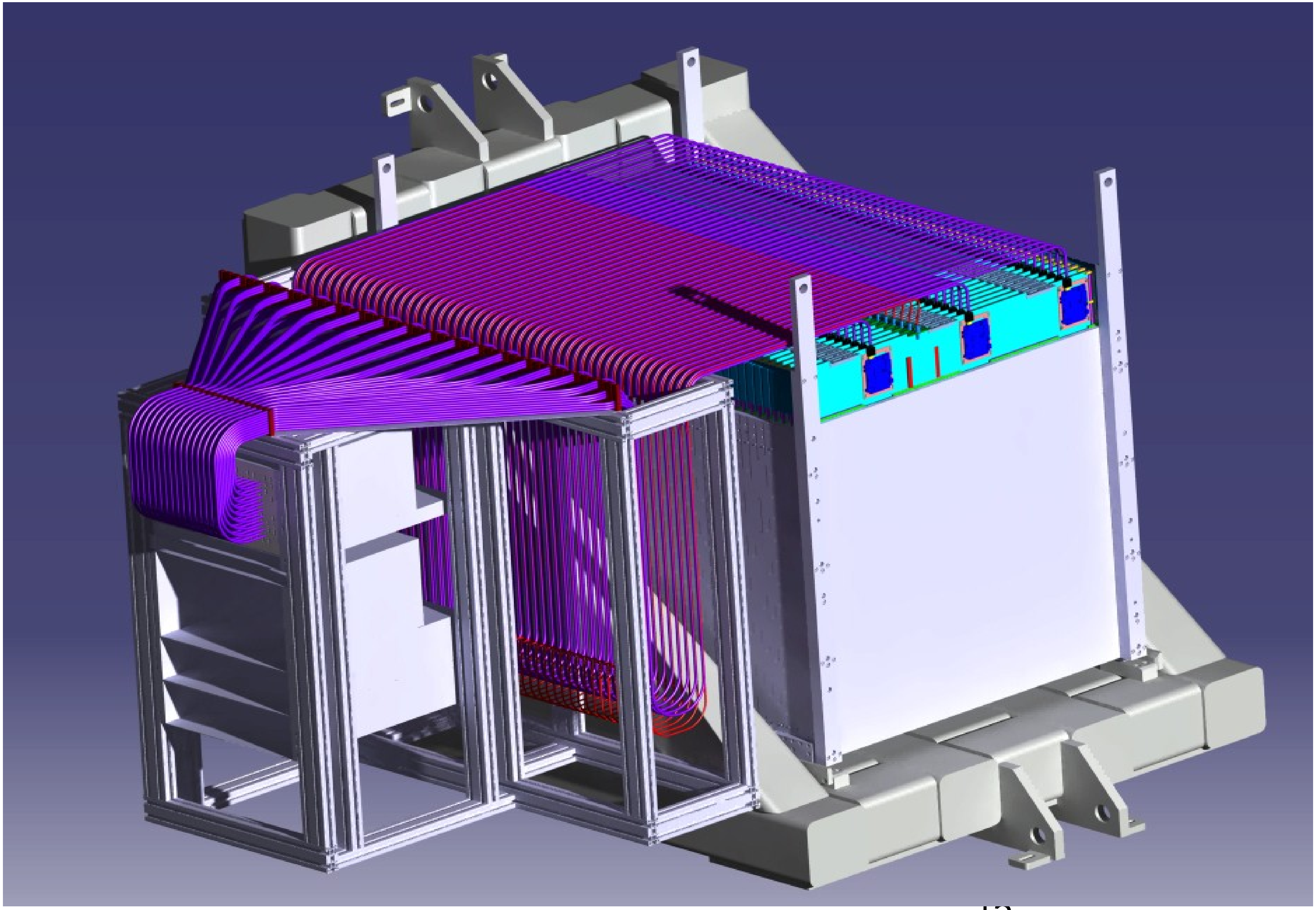
PP is on during 2 ms every 10 ms rather than every 200 ms for ILC

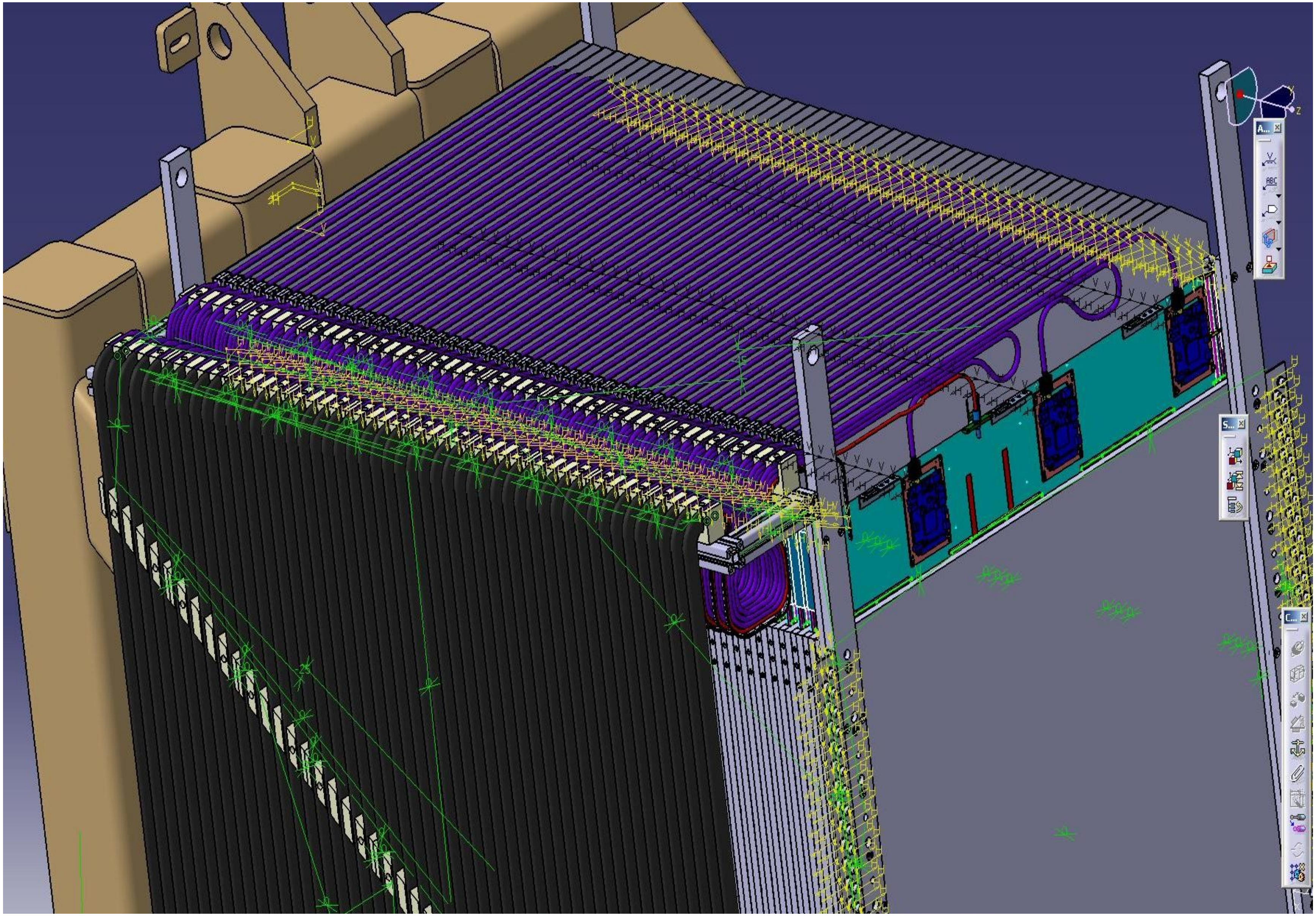






Δt : Delay of data taking with respect to PP





Objectives

First period :

First period will be used to calibrate and understand fully the Behaviour of our prototype in TB.
Few kinds of particles will be used
1- Muons for calibration and alignment
2- Pions and (protons?) for thresholds study and first approach of the the hadronic showers
3- Electrons for first approach of the electromagnetic shower.

Energy and threshold scan will be done. We would like to have enough statistics for each point rather than to have too many scanning points.
We would also study the effect of the hadronic shower on the embedded electronics.

Objectives

Second period :

The aim of this test is to have a deep understanding of the hadronic shower behavior once the detector response is well understood.
We would like to have by that time 48 units (as for the modules proposed for ILD (5→6 λ_I)) .
We intend also to have a combined test with the CALICE ECAL detector which represents an additional λ

In addition to studying the **hadronic shower behavior** we would like to study separation of two hadronic showers by increasing the beam intensity. The GRPC rate limitation is less an issue when particles start their interaction in the ECAL

Backup slides

GRPC DETECTOR

Detector

The GRPC choice was motivated also by:
1- High efficiency and stability
2- Low cost
3- Large detector can be easily built and well suited for ILD
4- Can be home-made
in addition to
1- Well known performance (BELLE, OPERA)
2- Expertise with thin GRPCs developed by IHEP group

The GRPC will be used in the **avalanche** mode
(2-4 pC/mip and 100 Hz/cm^2) rather than in the **streamer** mode
(αβουτ 300-400 pC/mip and few Hz/cm^2)

The GRPC to be used in the SDHCAL is very thin (gas gap 1.2 mm) with a gas mixture made of TFE(93 % ,Isobutane/CO_2 (5%) and SF_6(2%) at H.V = 7.4 kV.

→10 primary electrons are expected → low probability to have no signal

Summary of RPC features

№	Item	Value	Comments
1	Pad size	1x1 cm2	
2	Number of gaps	monogap	
3	Mode of operation	saturated avalanche	
4	Working mixture	TFE/Iso/SF6=93/5/2	
5	Gas gap	1.2 mm	1.6 mm can be used
6	Resistive plates	thin glass,10^13 Ω·cm	
7	HV working point, kV	7.4	
8	Induced charge, pC	~3	
9	Threshold on 50Ω, mV	1-2	
10	Efficiency, %	~98	
11	HV plateau	~600 V	
12	σ_Q / Q	~ 1	
13	Pad multiplicity	1.4-1.5 ?	
14	Noise, Hz/cm^2	~ 0.5	
15	Rate capability, Hz/cm^2	≤100	
16	Resistivity of HV coverage	> 10^6 Ω/ sq	
17	Control of RPC work	Q RO of cathode strips	
18	Maximal own RPC thickness	6 mm	try to keep 5 mm
	with 2 mm SS cups	10 + 0.5 mm	

From Ammosov LCWS04

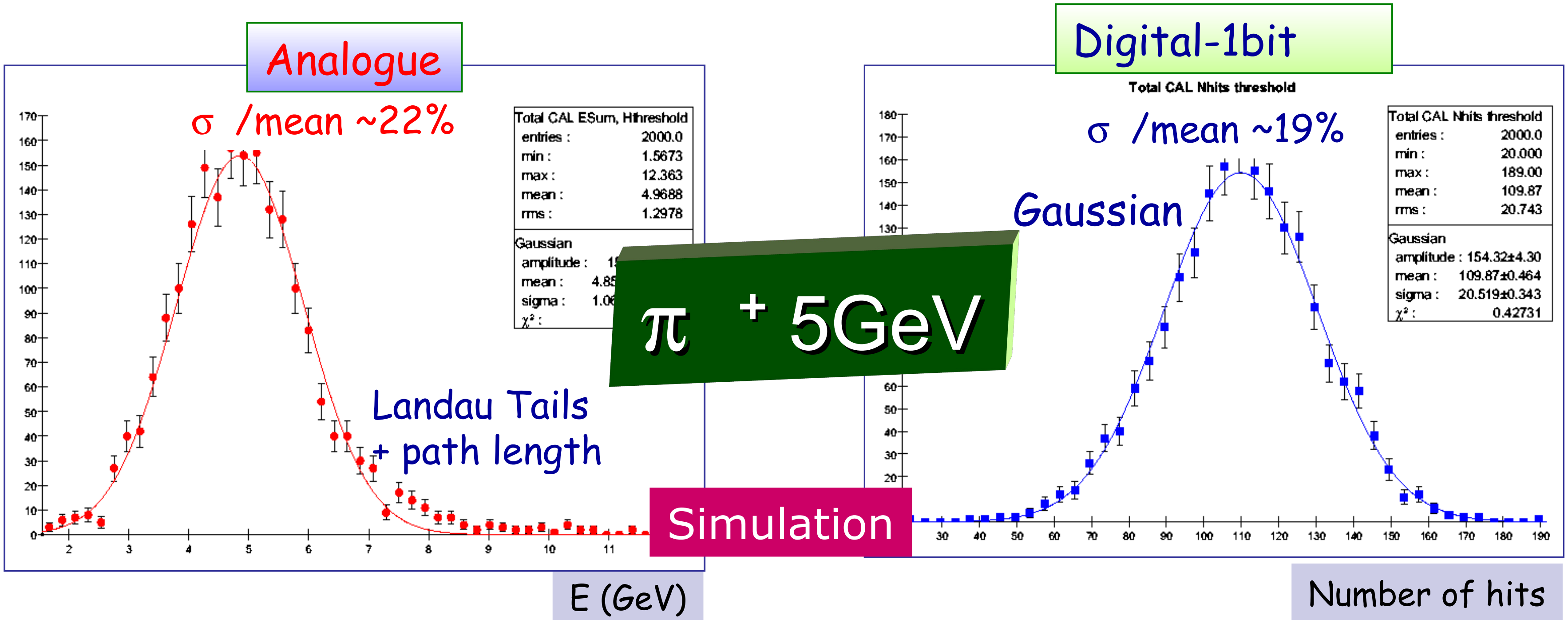
All these are confirmed by new TB with our detector

Detector

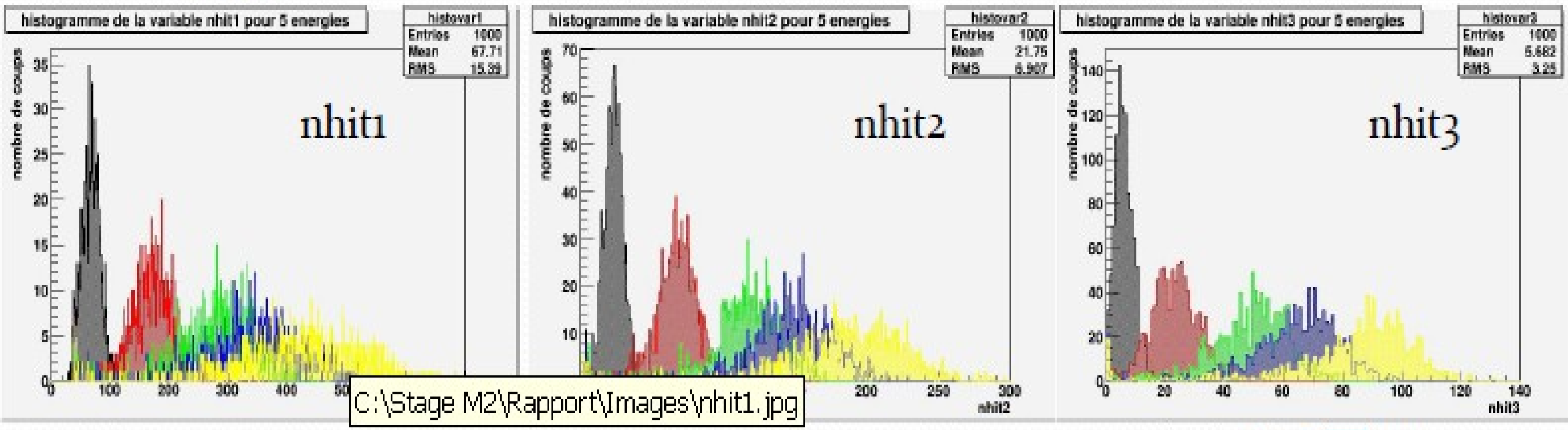
More on the GRPC choice

Although the groups involved in this project (Protvino group) had a good knowledge of GRPC, R&D was however necessary due to the need to build :
large, thin and one-side service GRPC with almost no dead zone.

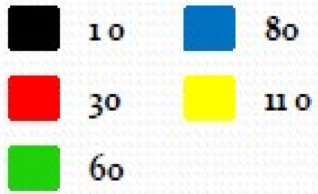
The R&D items that were developed were:
1- Spacers
2- Resistive coatings
3- Gas distribution system
4- Aging studies
5- High Voltage connections


Analogue
σ /mean ~22%
Total CAL ESum, Hthreshold
entries : 2000.0
min : 1.5673
max : 12.363
mean : 4.9688
rms : 1.2978
Gaussian
amplitude :
mean :
sigma :
χ² :
Landau Tails
+ path length
E (GeV)
π + 5GeV
Simulation
Digital-1bit
Total CAL Nhits threshold
σ /mean ~19%
Gaussian
Total CAL Nhits threshold
entries : 2000.0
min : 20.000
max : 189.00
mean : 109.87
rms : 20.743
Gaussian
amplitude : 154.32±4.30
mean : 109.87±0.464
sigma : 20.519±0.343
χ² : 0.42731
Number of hits

- Variables **nhit1**, **nhit2** et **nhit3** :
  - nombre de **hits passant les seuils** 1, 2 et 3
  - Seuils = 0.15 -4.5 -15 pC
  - Variables **importantes -> E proportionnelle** au nombre de **hits**



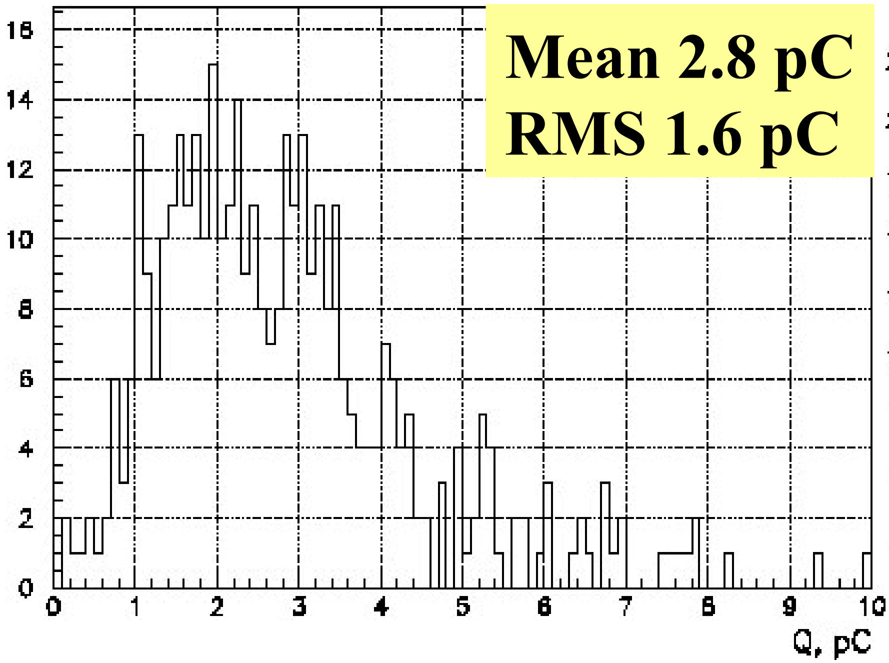
nhit1, nhit2 et nhit3 -> pions de 10, 30, 60, 80, 110 GeV



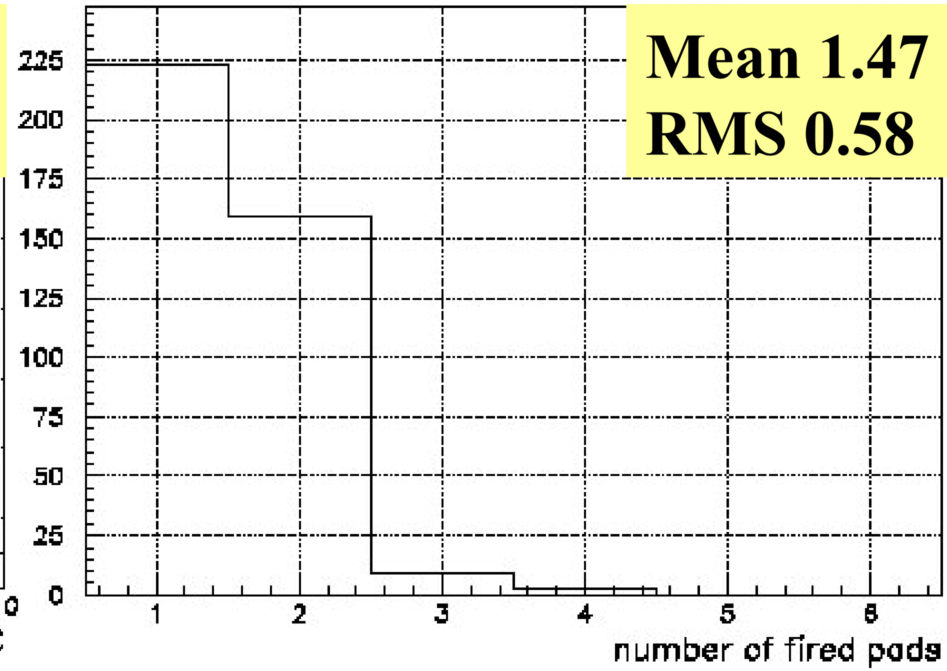
11

RPC in avalanche mode

Typical Q and m distributions
1.2 mm, 2% SF_6, 8.4 kV - working point, 2.2 mV thr



Mean 2.8 pC
RMS 1.6 pC



Mean 1.47
RMS 0.58

Q ~ 10^7 e

2 adj pads

From Ammosov LCWS04

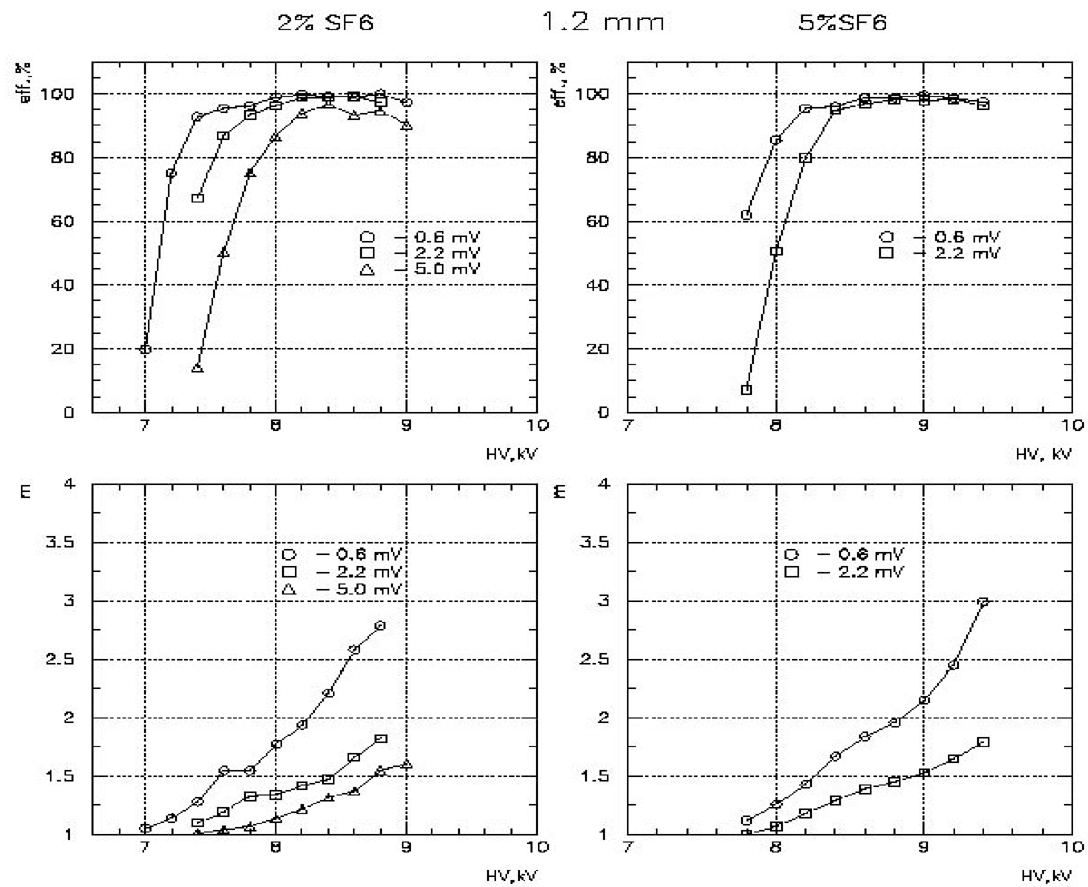
RPC in avalanche mode

<u>1.2 mm gap RPC</u>
<u>eff, <m> vs HV</u>

- 2% and 5% of SF_6

Thresholds ○ - 0.6 mV
□ - 2.2 mV
Δ - 5.0 mV

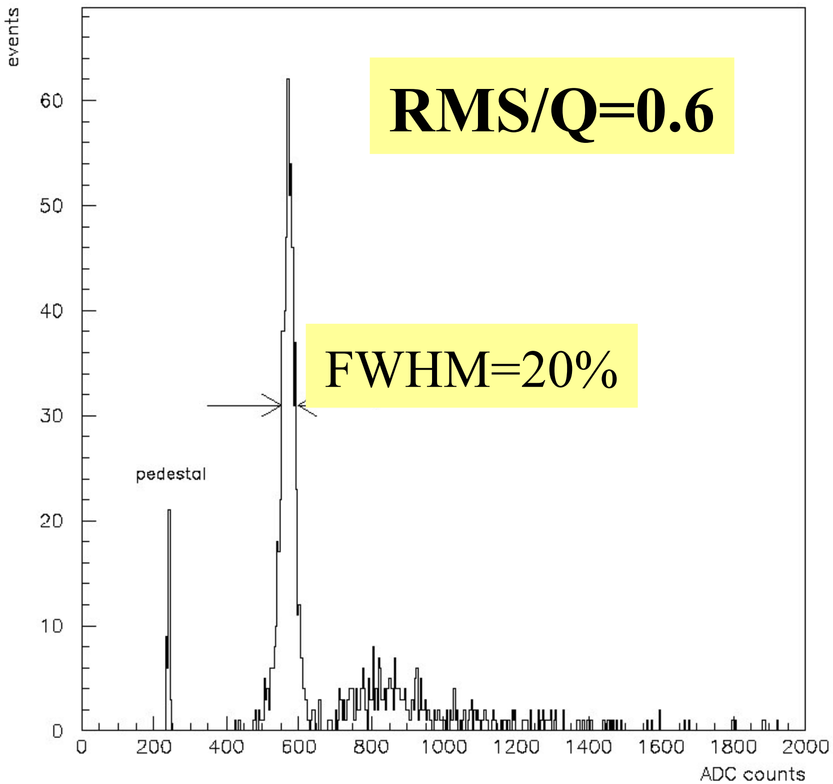
2.2 mV is best threshold
eff >99%
low <m> ~ 1.4

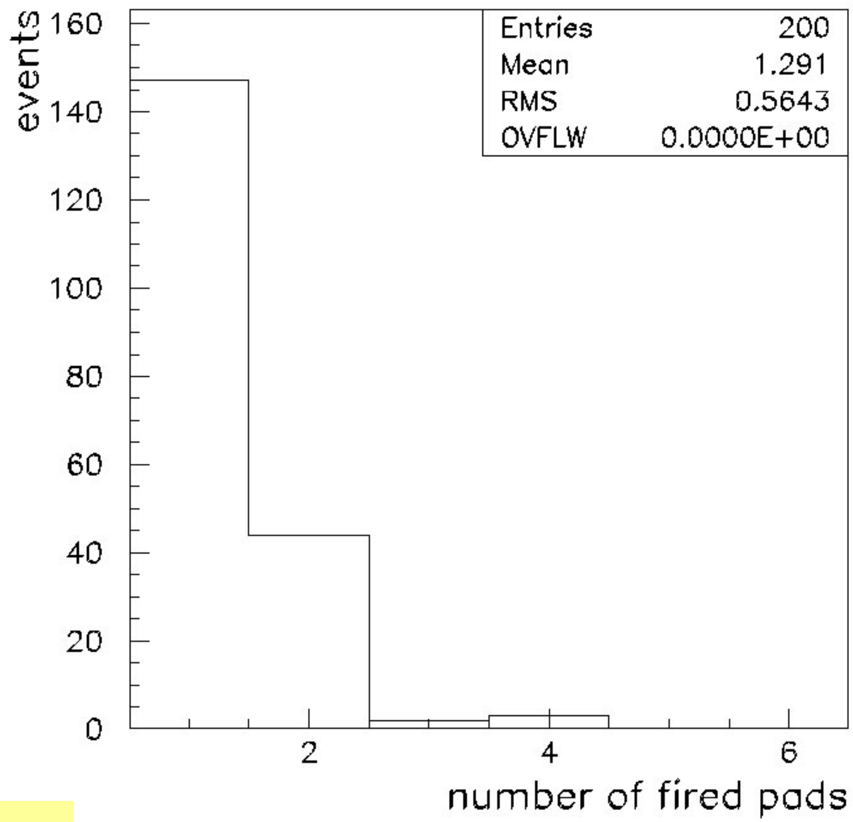


For 2.2 mV		2% SF6	5% SF6
	Knee	8.2 kV	8.6 kV
	ΔV	0.6 kV	0.6 kV

RPC in streamer mode

Typical Q and M distributions, 200 V above knee
1.2 mm gap, TFE/Ar/IB=80/10/10





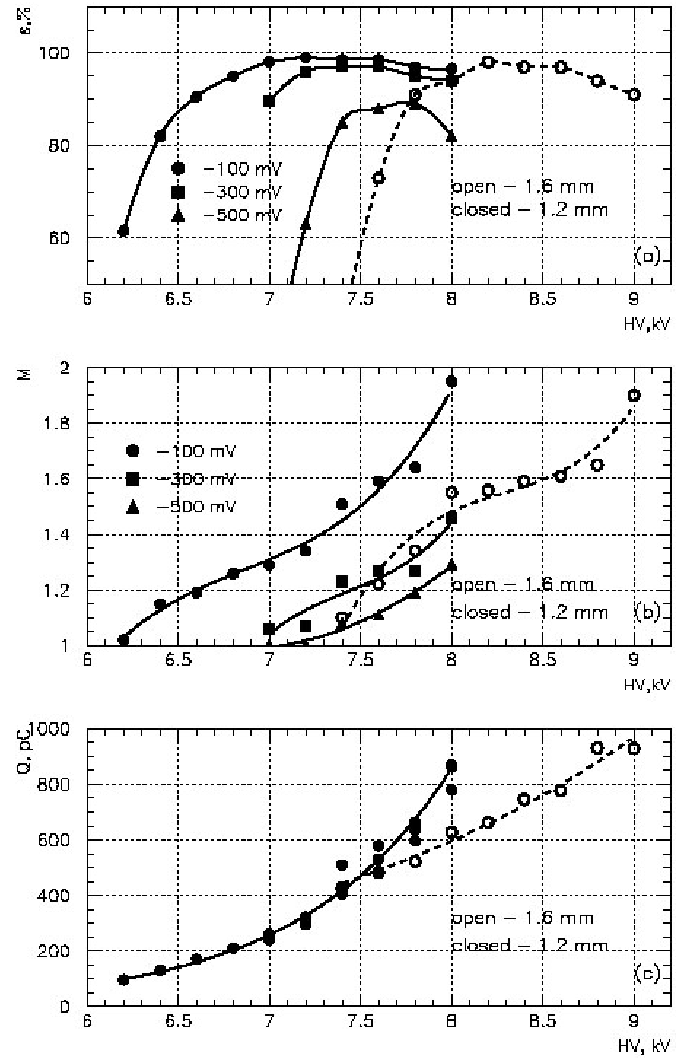
No ways to suppress multi streamer tail

From Ammosov LCWS04

RPC in streamer mode

Eff, M and Q vs HV
for 1.2 and 1.6 mm gaps
Ar10 mix
for different thresholds

best choice - thr = 300 mV



From Ammosov LCWS04

Comparison of avalanche and streamer modes

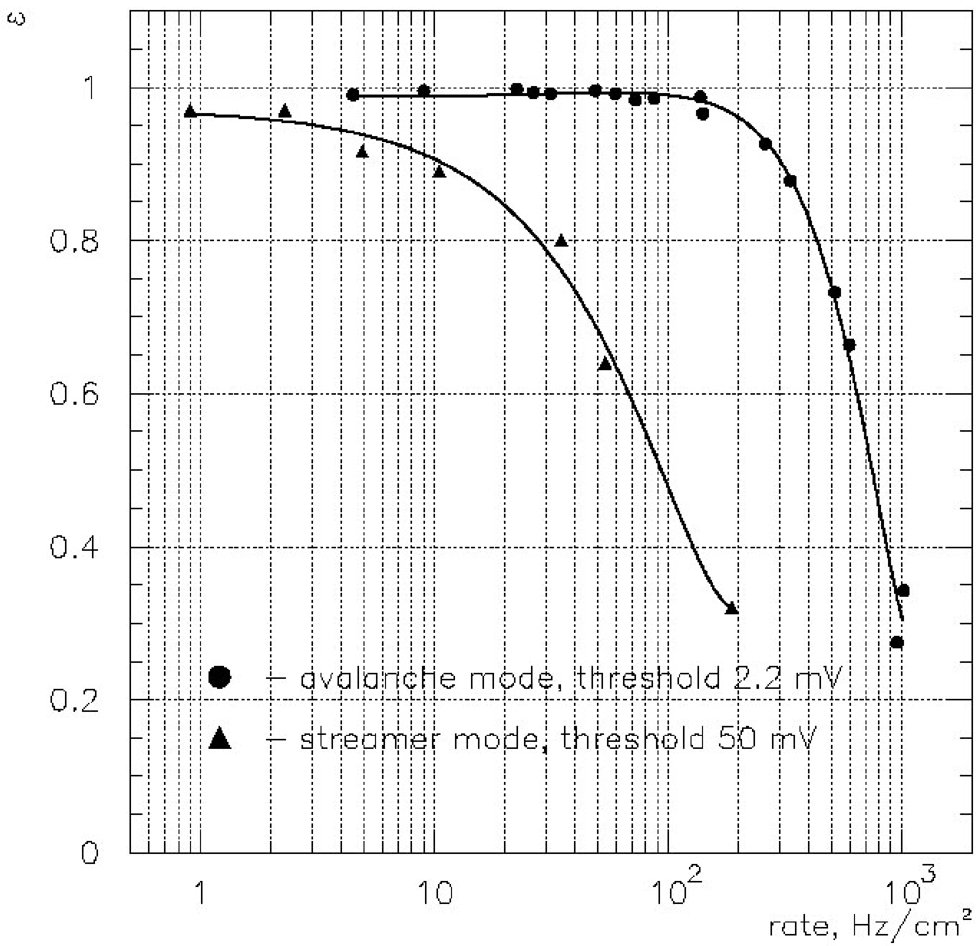
Rate capability

streamer ~2-3 Hz/cm²

avalanche ~100 Hz/cm²

It is hard to work in streamer mode even for usual beam conditions

Streamer is suitable only for very low rates like e+e⁻ FLC



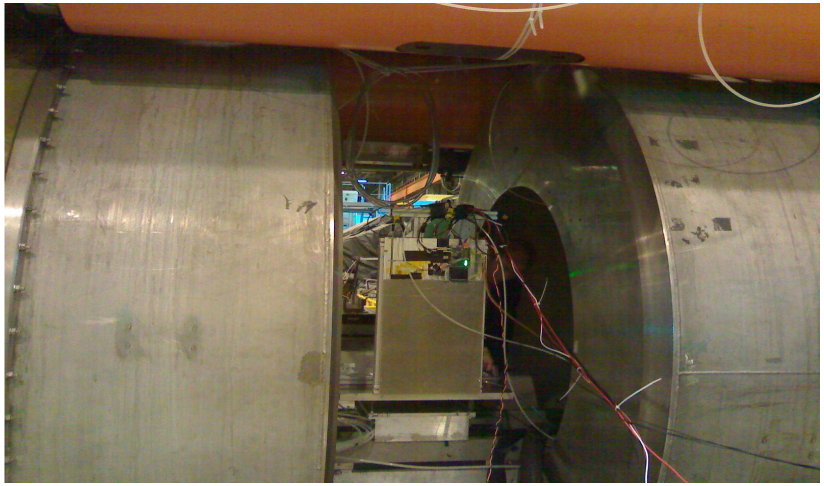
From Ammosov LCWS04

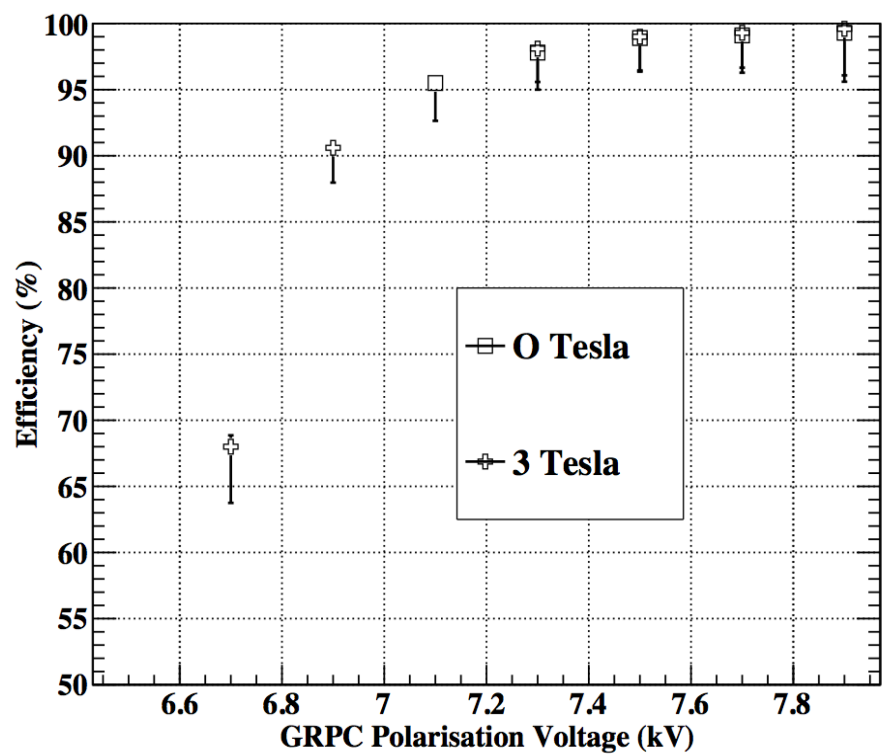
Comparison of avalanche and streamer modes

As example, for 1.2 mm gap

№	Item	avalanche	streamer
1	Working mixture	TFE/Iso/SF_6=93/5/2	TFE/Iso/Ar=80/10/10
2	HV working point, kV	7.4	7.4
3	Induced charge, pC	3.4	400
4	Threshold on 50Ω, mV	1-2	300
5	Efficiency, %	~98	~95
6	σ_Q / Q	~ 0.9	~ 0.6
7	Pad multiplicity	1.4-1.5	1.2 - 1.3
8	Noise, Hz/cm^2	~ 0.7	~ 0.1
9	Rate capability, Hz/cm^2	100	2 - 3

From Ammosov LCWS04





100
95
90
85
80
75
70
65
60
55
50
Efficiency (%)
O Tesla
3 Tesla
6.6
6.8
7
7.2
7.4
7.6
7.8
GRPC Polarisation Voltage (kV)