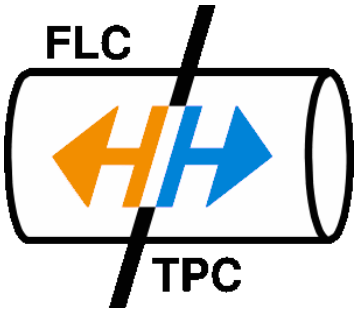
Development, construction and test of a TPC readout system



Sabato Stefano Caiazza

MC-PAD End of network event

Frascati – 20 Sep 2012

Universität Hamburg

Sabato Stefano Caiazza

Marie Curie Fellow

- Initial Training Network MCPAD
- Early Stage Researcher
- Contract Start: June 1st 2009
- Contract End: May 31st 2012

Home country: Italy

Host Institute: DESY

My MCPAD Project

- P5: TPC with MPGD Readout
- Contribute to the design and construction of a TPC advanced low mass readout system.
- Participate in the running and analysis of a test beam experiment of a large TPC prototype in DESY
- Supervisor: Ties Behnke

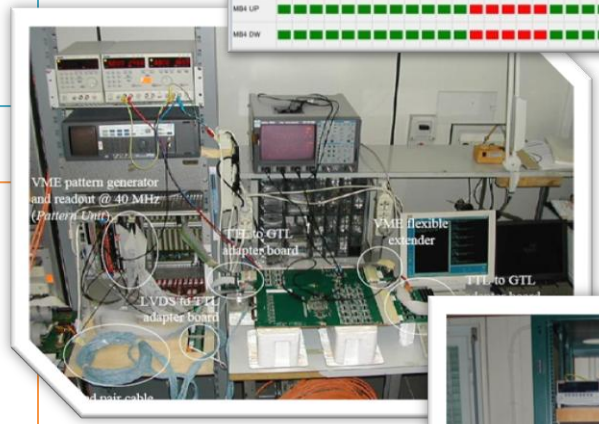
SCIENTIFIC BACKGROUND

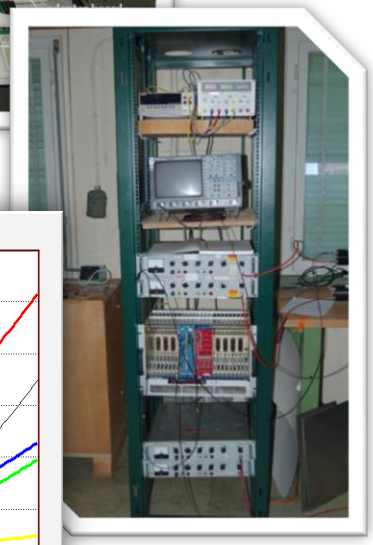
Master Degree in Physics

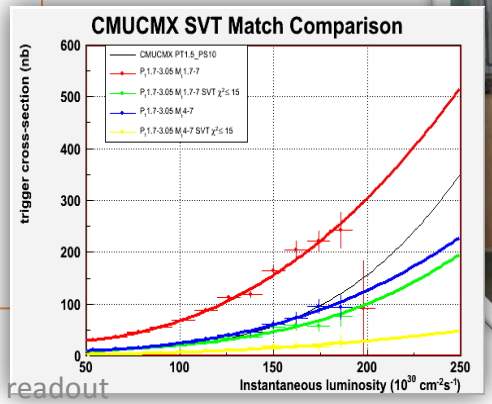
- October 2008
- Bologna University
- Final Vote: 110/110

Focus on Detector development

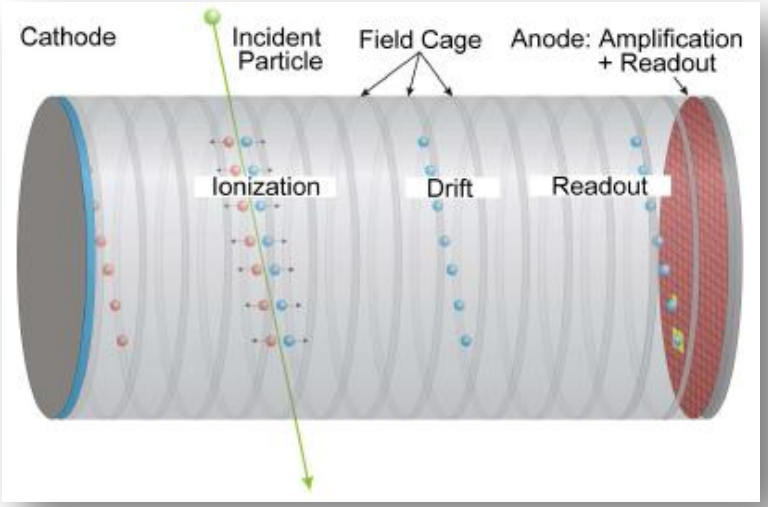
- Experimental physics curriculum
- Undergraduate work on the commissioning of the CMS detector
- CERN Summer Student: working on the development of the Alice experiment
- Fermilab Summer Student: working on the Trigger algorithms of the CDF detector
- Experienced both in hardware and software development.







TIME PROJECTION CHAMBERS



Main components

- Ionization volume
- Controlled electric field
- Amplification & readout system on the anode

Goal

- 3-dimensional reconstruction of the particle trajectory

Physic processes in a TPC

Ionization → Drifting → Gas Amplification → Readout → Analysis and reconstruction

GAS AMPLIFICATION

Multiply the primary electrons

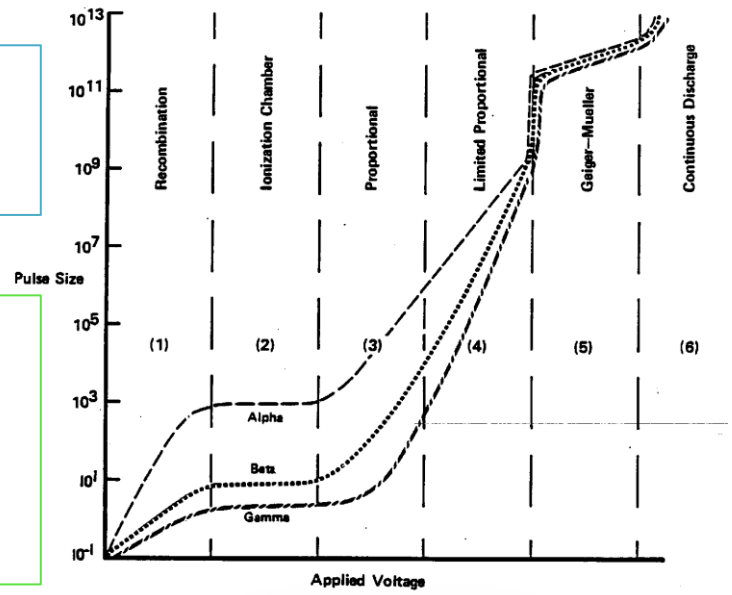
- Gain between 1000 and 10000 are needed

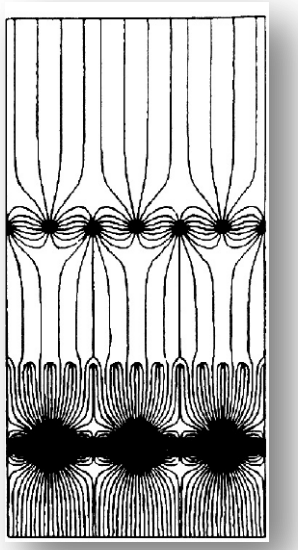
Proportional multiplication

- To recover the information about the energy deposition
- Relevant to particle identification

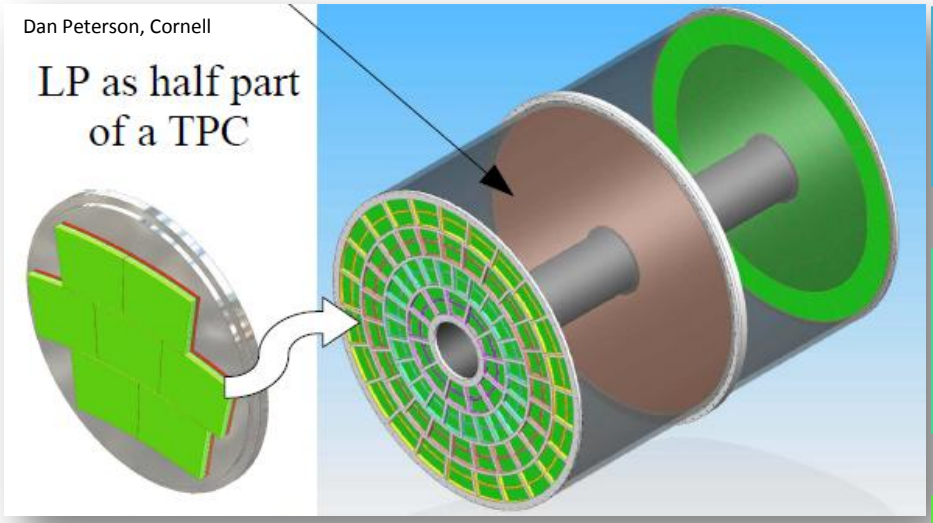
Traditionally done with MWPC

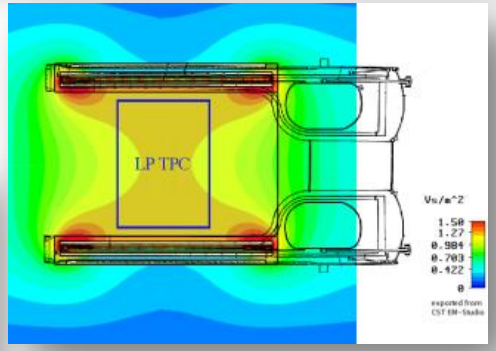
- Wires cannot be placed closer than about 1 mm which limit the resolution
- All the ion produced in the amplification drift back in the sensitive volume
- Need important support structures adding material and dead space

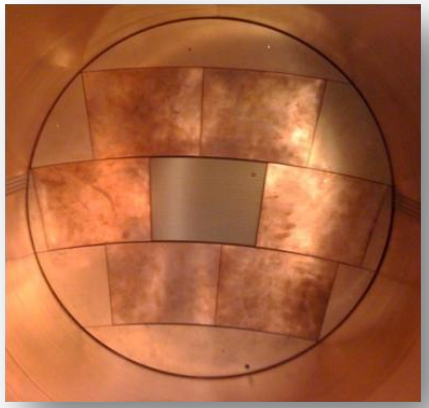




LARGE PROTOTYPE TPC







Goal

- To develop and test the technologies for next generation large TPC

Built and operated at DESY

- 60 cm drift length, 72 cm inner diameter
- Operational since the end of 2008

The Magnet - PCMAG

- 1 T superconductive magnet provided by KEK

Endplate

- 7 slots where to mount different modules
- Many modules developed by different institutions: Saclay, KEK, Bonn, NIKHEF

My project

- To design and test a module for this TPC

MICRO PATTERN GAS DETECTORS

Evolution of the gas amplifiers

- Different solutions available in this family

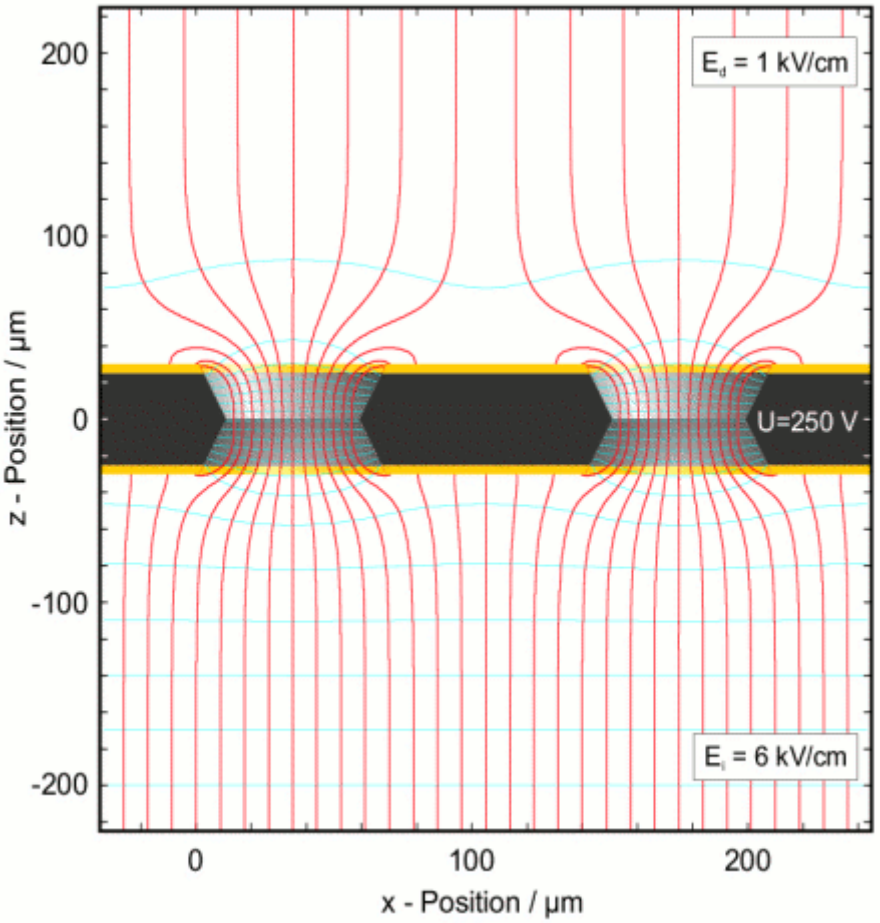
Micrometric amplifying structures

- Micrometric field distortion
- Micrometric resolution

Fast signal development

Intrinsic ion suppression

- Feature of many MPGD
- Most of the ions neutralized in the amplifying structure



GAS ELECTRON MULTIPLIERS

Structure

- Parallel placed capacitor pierced by many holes
- Each hole is an amplifier

Gain

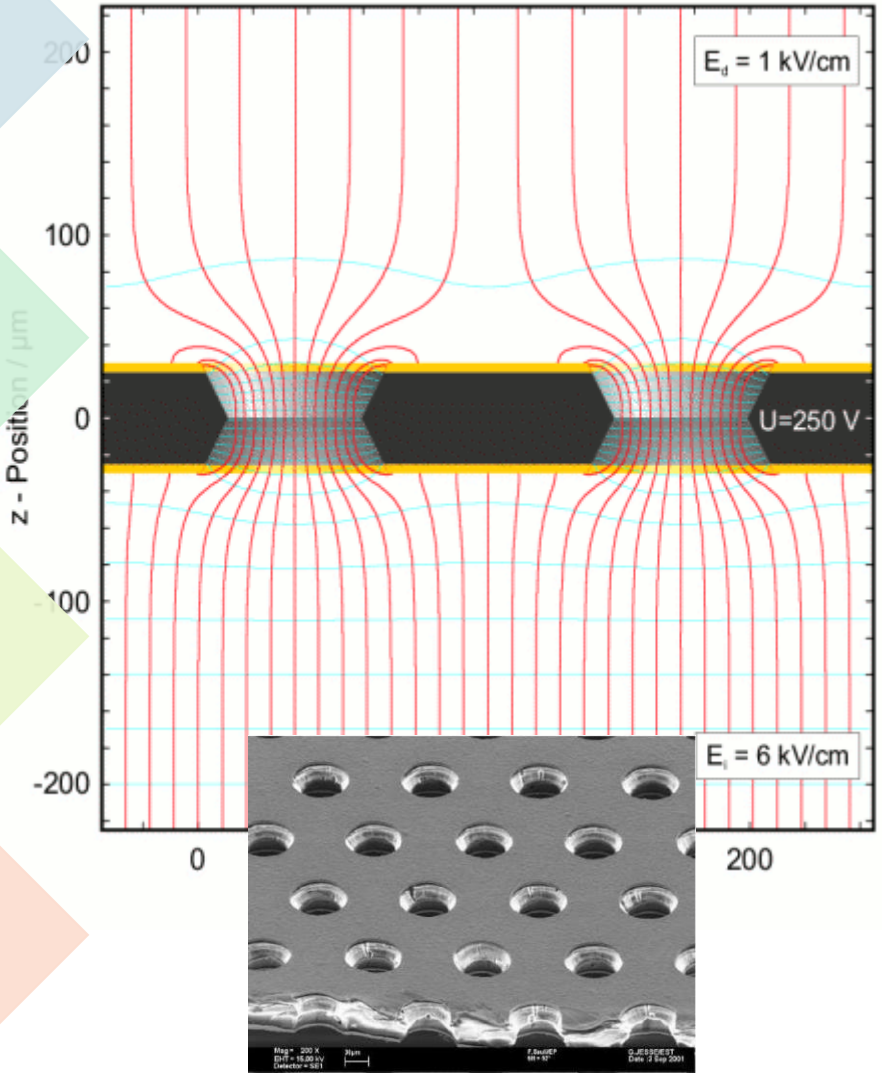
- Proportional
- 0-1000+
- 0-10000+ with stacking

GEM stacking

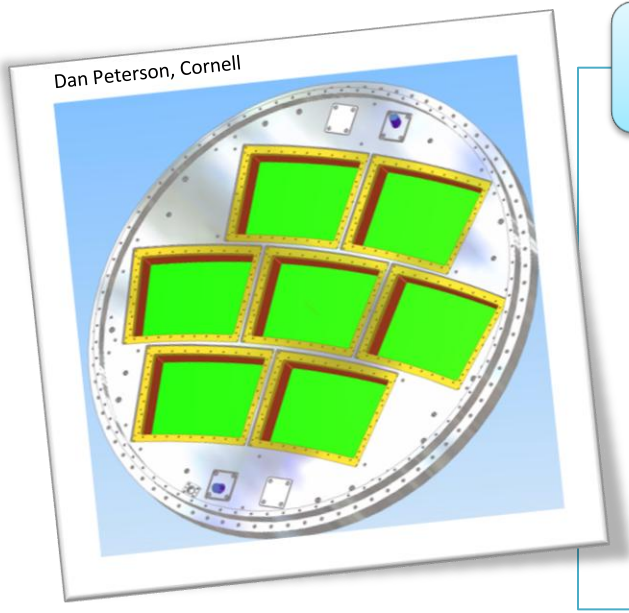
- Increased reliability
- Increased versatility

Ion Suppression

- Most of the ions absorbed by the top electrode
- 1-10% flows back to the sensitive volume



MODULES FOR THE LP-TPC



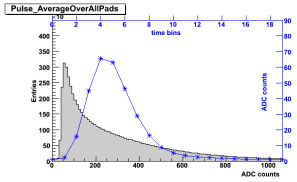
Common Features

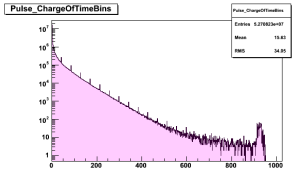
- Fixed allotted space
- Cornerstone shape
  - 20-24 cm wide
  - 17 cm high
- Common mounting system

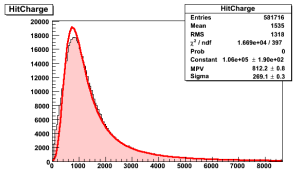
DESY Module Specific features

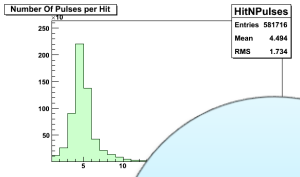
- 3 GEM stack with an optional gating module
- Ceramic mounting structure developed at DESY
- Pad readout system
- Minimal amount of dead space
- Modular system (great for prototyping) and simplified assembly

DESY READ-OUT MODULE

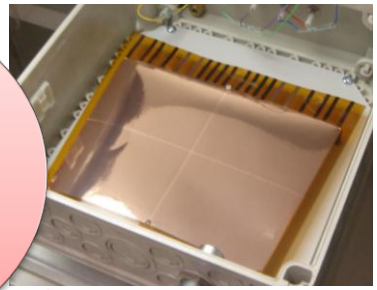






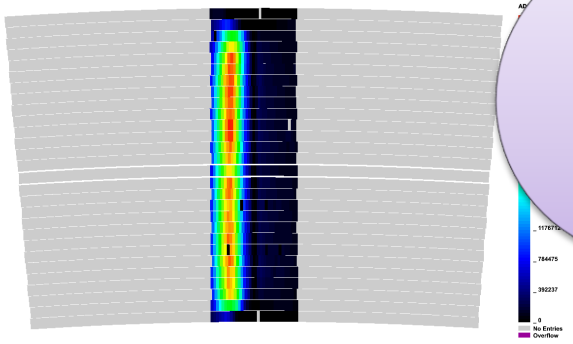


Design



Build

Test



Analysis

MODULE DESIGN

Back-frame

- Mechanical mounting
- Alignment

Readout plane

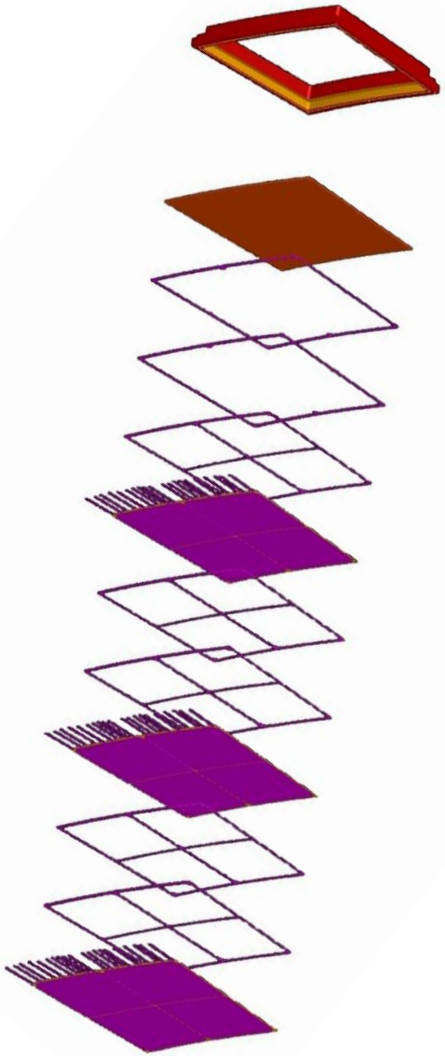
- Pad based readout
- 1.26 x 5.85 mm^2 on 28 rows
- Up to ~5000 readout channels

Ceramic mounting structure

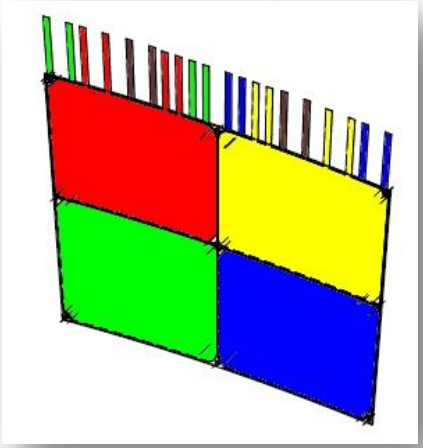
- Innovative design
- S^3 Frame: Support, Stretch, Space
- 94% Sensitive surface

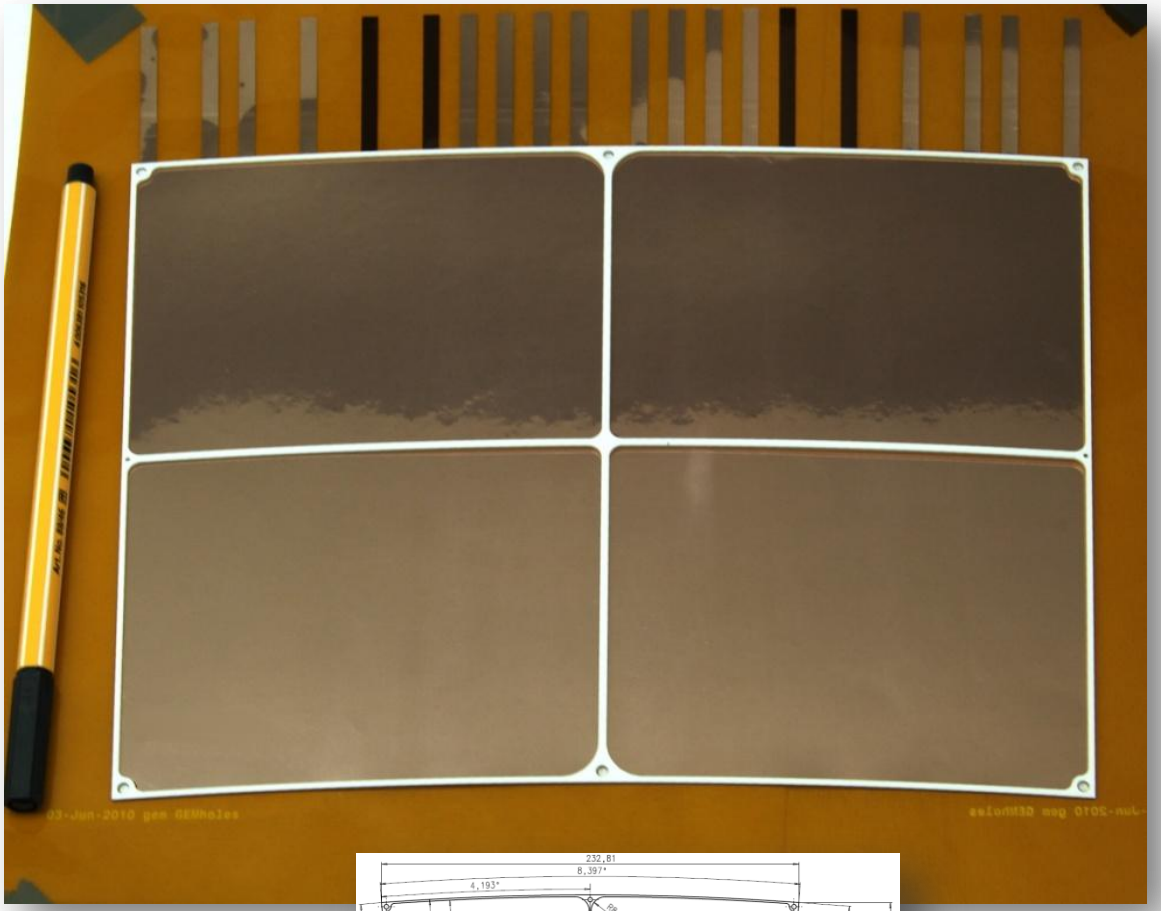
GEMs

- Glued on the ceramic support
- Up to 4 GEMs (usually 3)
- Independent from one another



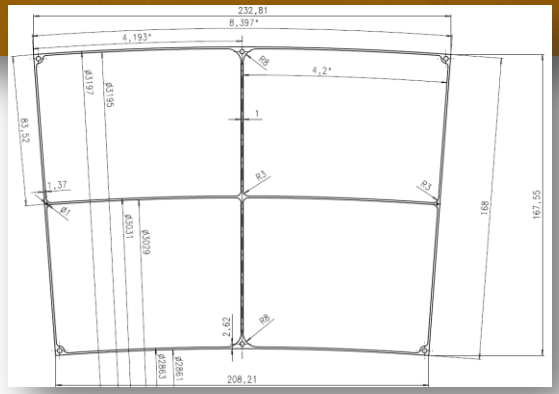
S³ FRAME





An innovative system

- Support, Stretch, Space
- Smaller than the standard GRP frames (1 mm vs 1 cm)
- Custom inner pattern laser cut on demand
- Simple stretching process



MODULE ASSEMBLY PROCEDURE

Align and glue back-frame and readout board

Assemble the GEM with the S^3 frame

- Stretch the GEM
- Glue the GEM to the frame

Install the GEMs

- Fix the GEMs to the board
- Solder the GEM electrodes
- About 1 hour

The module is ready to be installed

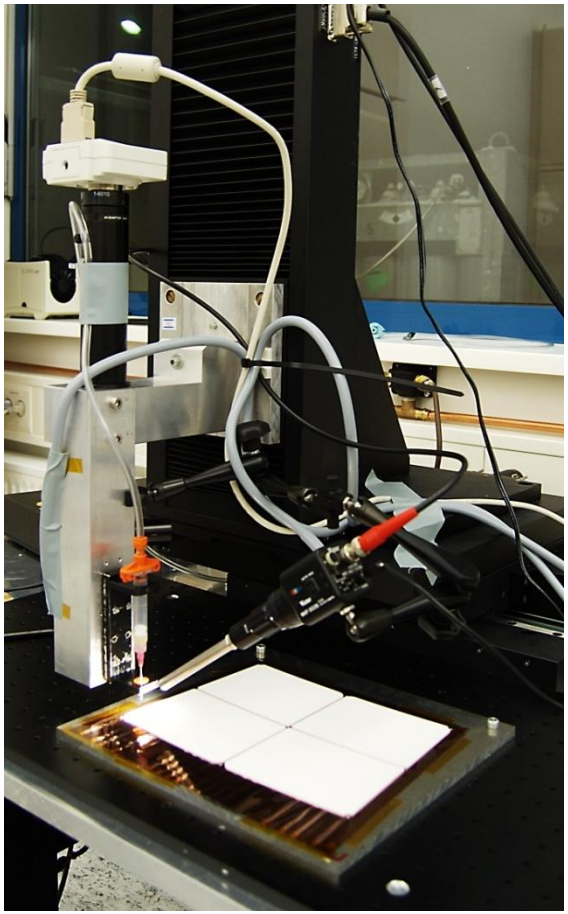
AUTOMATED GLUING

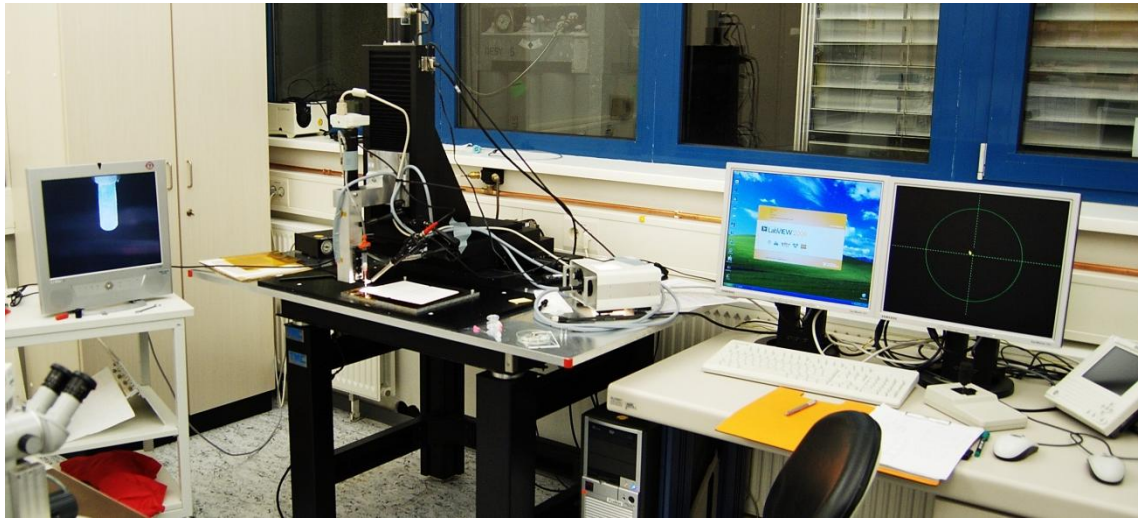
A delicate procedure

- Small width of the element to glue (1.4 mm)
- Active area close to the grid elements (<500 μm)
- Total gluing length (> 1 m)
- Complex gluing path

My solution

- Semi-automatic glue dispenser
- Steered with a custom labview program
- Monitored with a set of microscopes

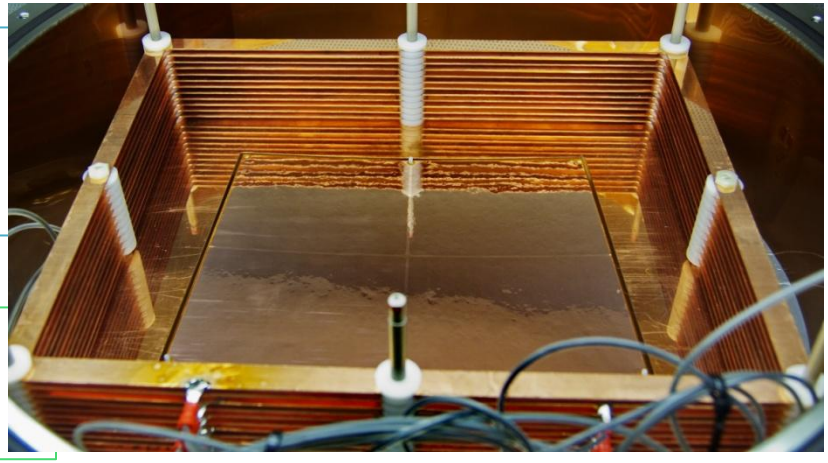




GEM AND MODULE TESTING

Single GEM testing

- Absence of shorts
- Long Term HV Stability

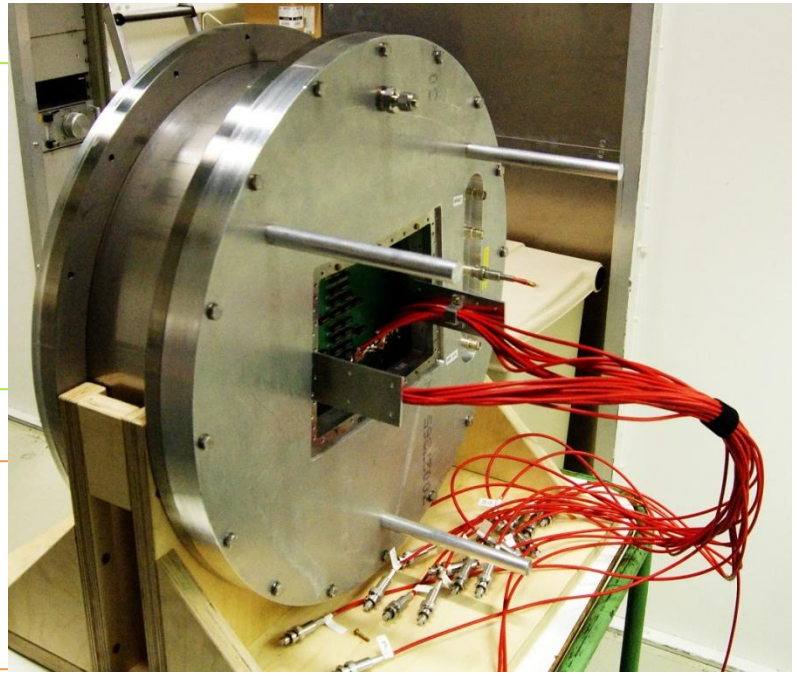


Board testing

- Long Term HV Stability

Single Module testing

- Power up test
- Long Term HV Stability
- Radioactive source calibration
- Cosmics run

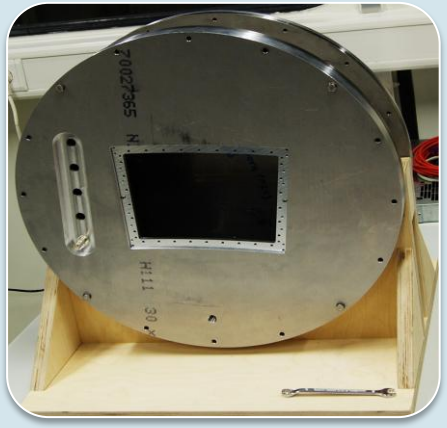


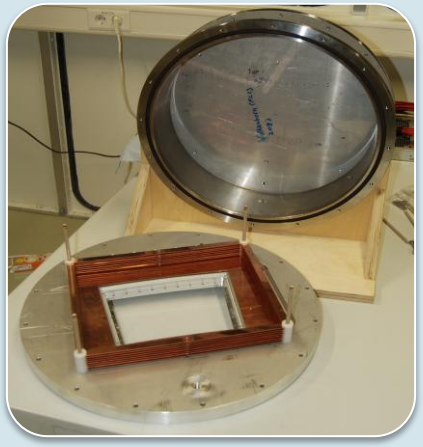
Test-beam June-July 2011

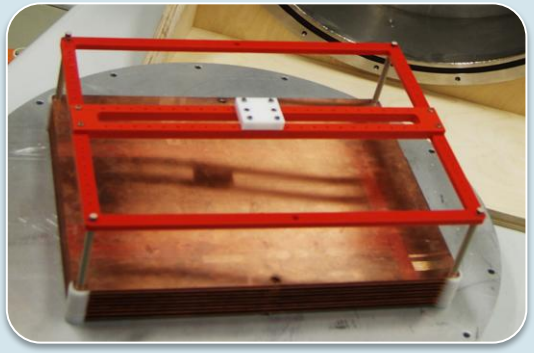
- 5 GeV electron beam from DESY II
- Single and multi module test

LP-MODULE TEST BOX

To commission the module before going to the test beam







Gas tight container

- Hosts one LP Module
- Support structure for the other elements

Versatile field cage

- Variable drift distance up to about 10 cm
- Variable ring number and ring gap

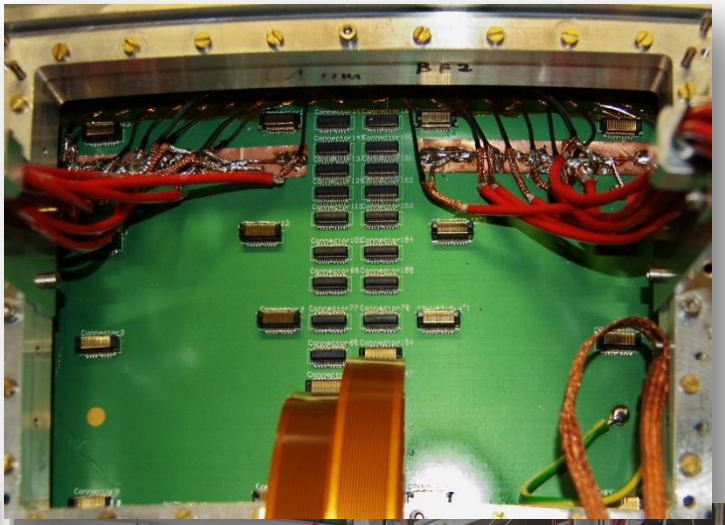
Radioactive source support

- Piled up over the cathode
- Can host more than one radioactive source at the same time

FIRST PROTOTYPE TEST-BEAM

The Setup

- One module available for the test
- Simplified readout board: 894 channel
- Ad hoc HV connections

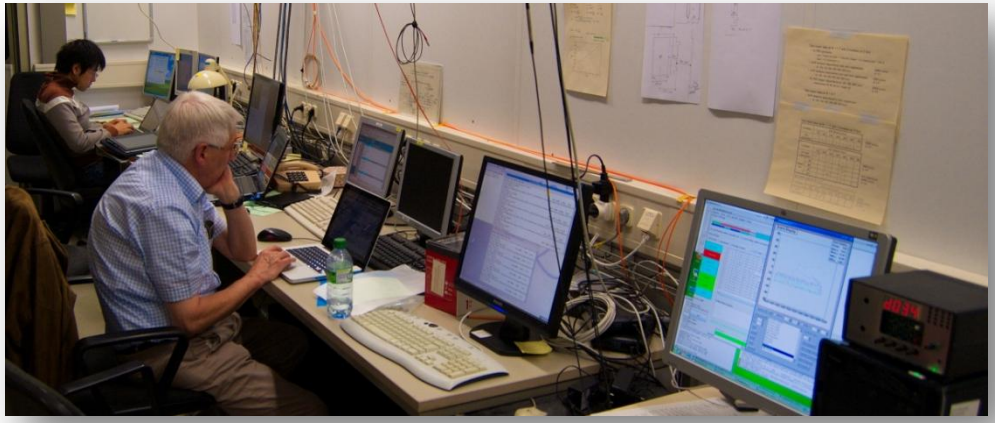


Electronics and DAQ

- Fast ADC based on the ALICE ALTRO chip
- DAQ and electronics provided by the LCTPC collaboration

An international effort

- Lund university in charge of the electronics
- Several collaborators from KEK (thanks also to the MCPAD funding)
- The whole DESY TPC group
- I was in charge of the coordination of this group



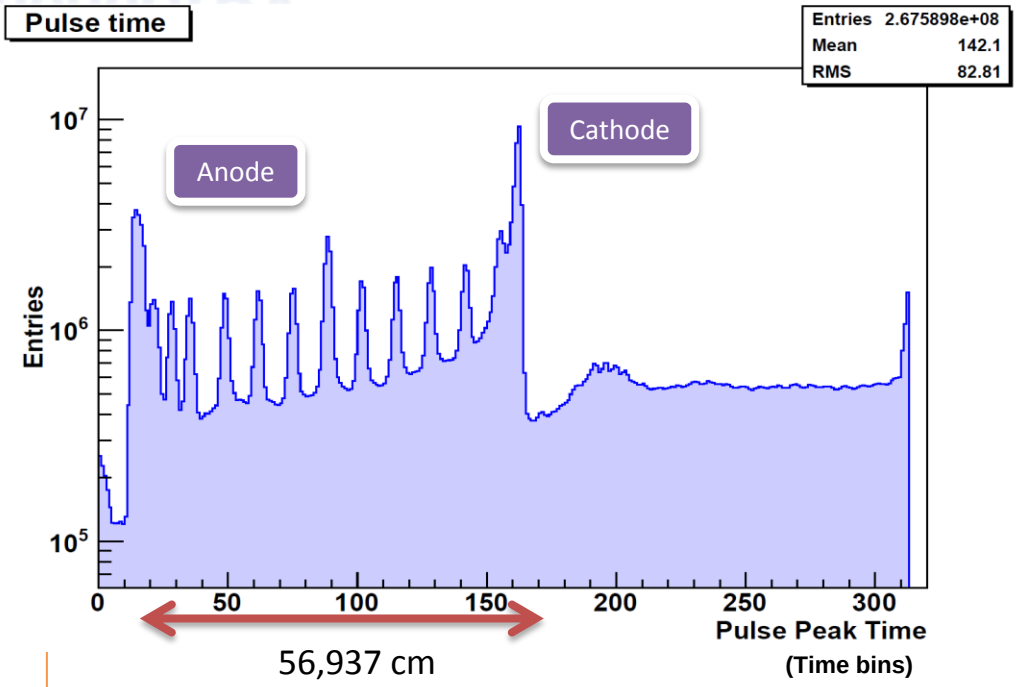
TEST-BEAM SUMMARY

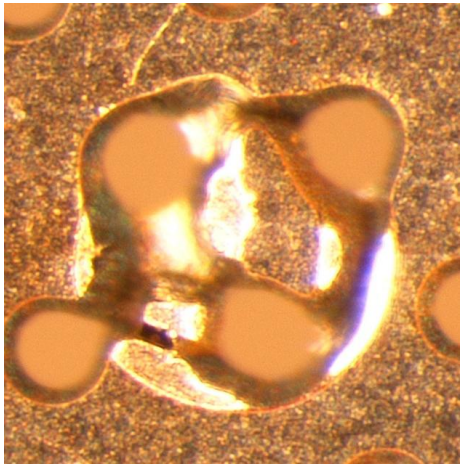
2 Millions Events collected

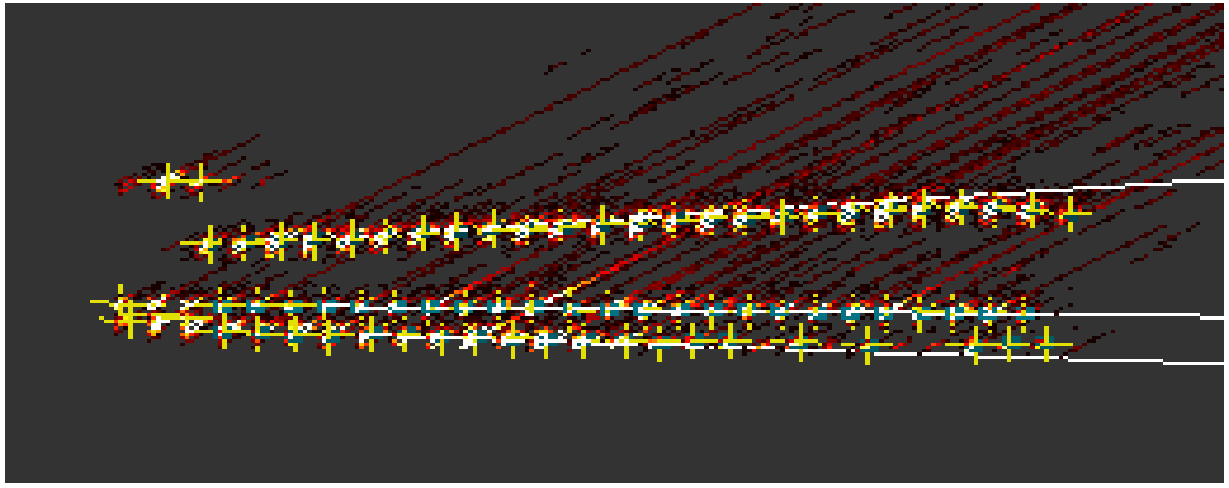
- Different GEM settings
- Different beam positions
- With and w/o B field
- Problems with magnet, TPC and module limited the amount of data

Module reliability problems

- Sections of the GEMs destroyed by single powerful discharges
- Design flaw due to the temporary board used







SOFTWARE DEVELOPMENT

Existing framework

- LCIO: Data persistency
- Marlin: Plug-in based framework to process LCIO based data
- MarlinTPC: Set of plugins for Marlin to perform TPC data analysis and reconstruction

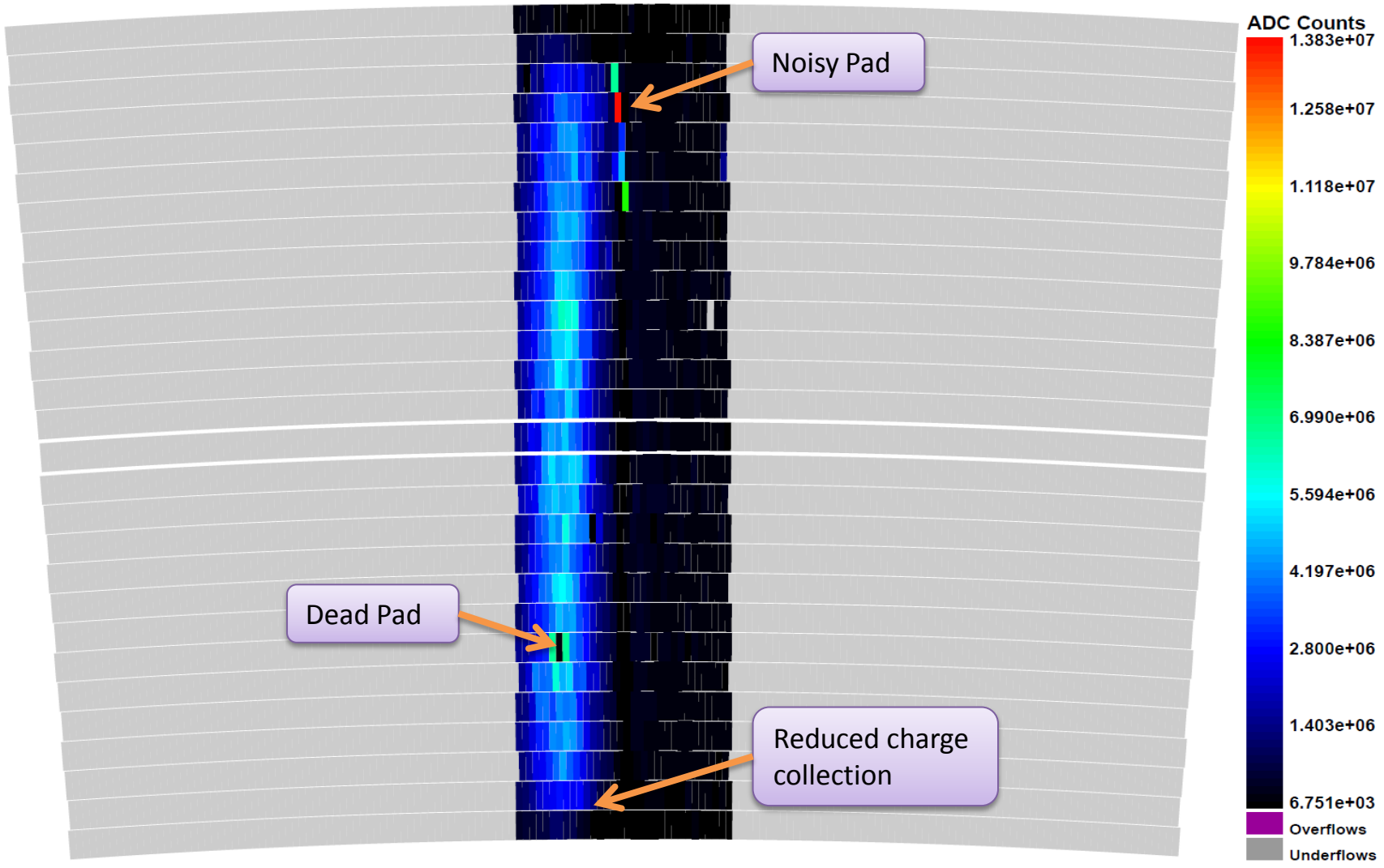
Status of the framework in 2011

- Many reconstruction modules
- No analysis modules
- Difficult to perform a “quick and dirty” analysis

Test-beam analysis library

- Standard summary plots for DQM purposes
- Interfacing the LCIO data with ROOT trees for “quick and dirty” analysis
- More analysis modules
- All software objects usable in ROOT, Marlin or stand-alone

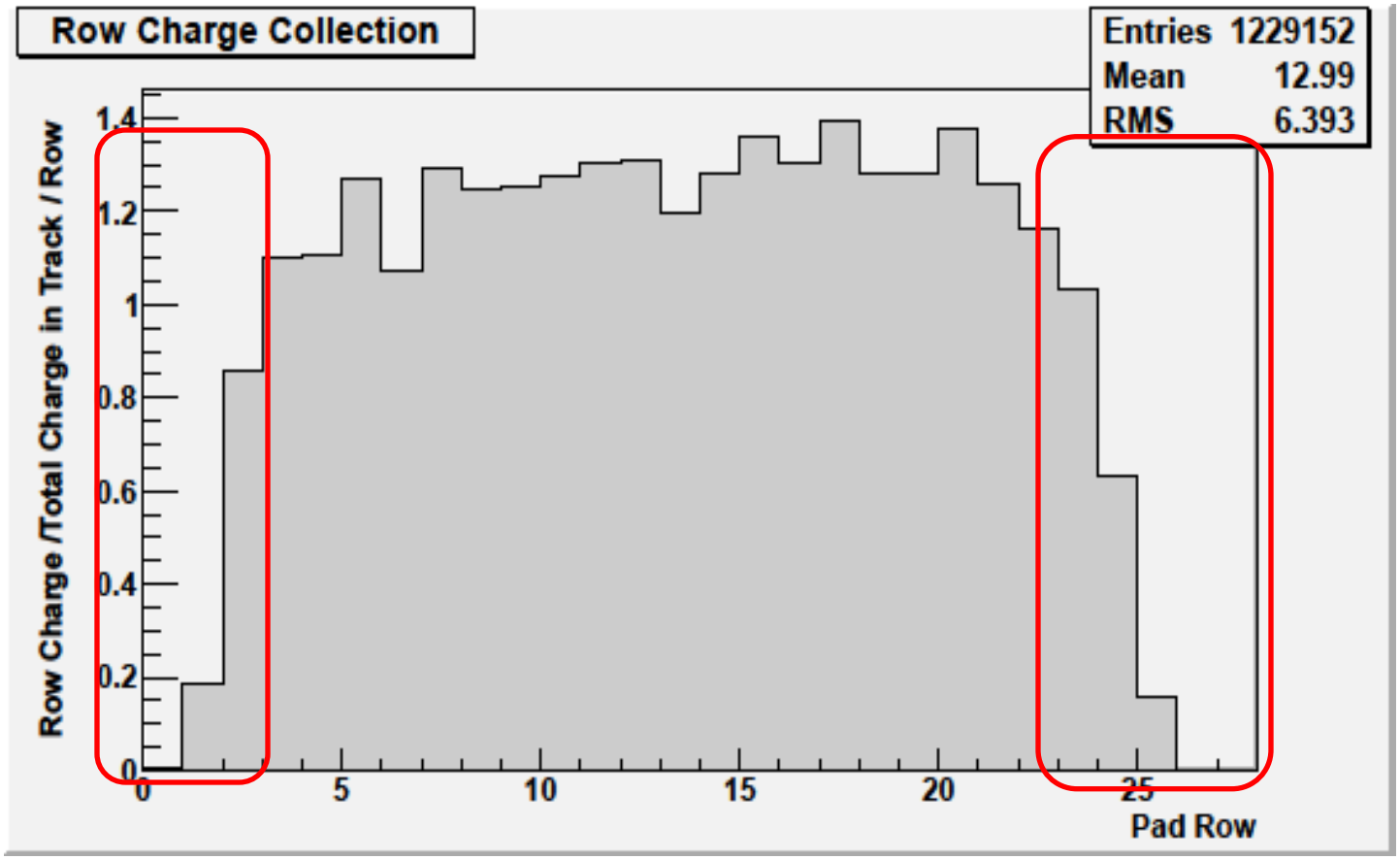
STATUS

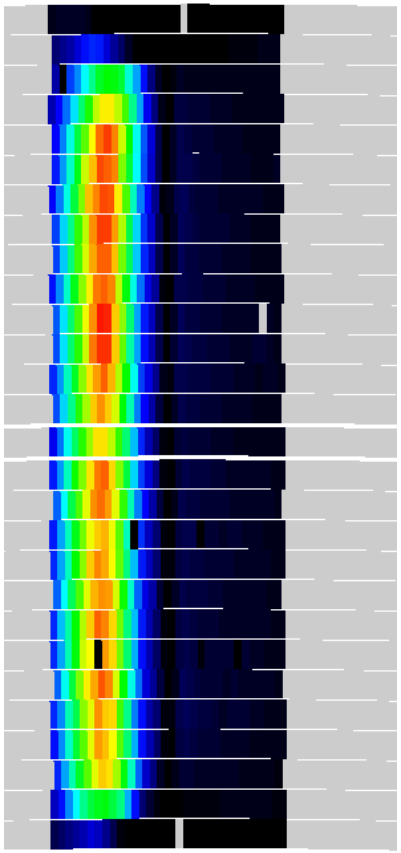


Integrated charge per pad for one run (20000 events)

ELECTROSTATIC DISTORTION

20 runs at different drift distances. No B field

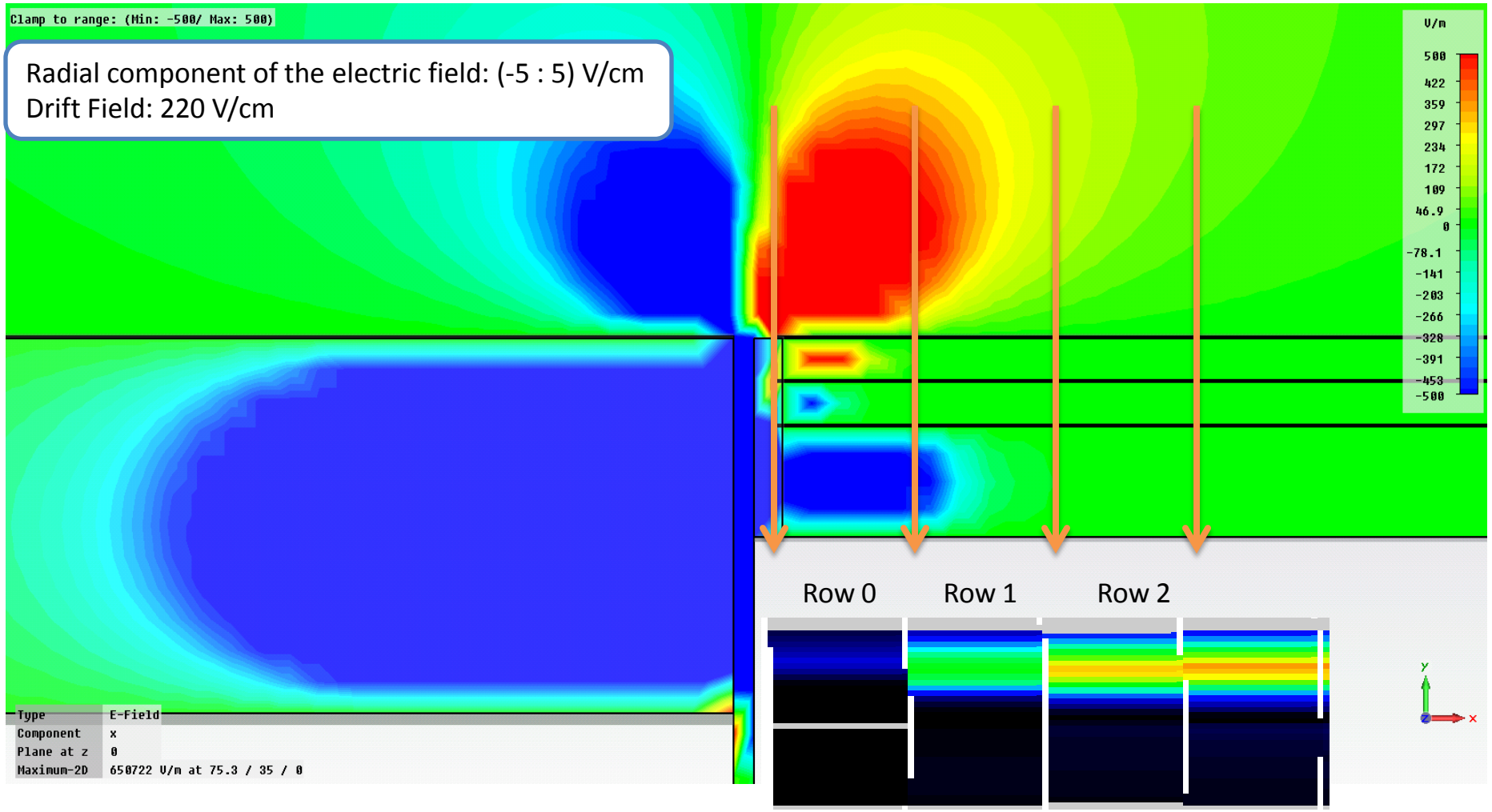




Charge collection reduced on the edges of the module

THE SOURCE OF DISTORTIONS

Electrostatic distortions focus electrons in the gap



OUTLOOK FOR THE FUTURE

A new module version developed

- Complete readout board: 5000 channels
- Guard ring in the gap to reduce distortions
- Improvement in the assembly procedures
- Improvements in the test procedures
- A new PhD student already working on this

New test-beam ongoing

- Using 3 modules at the same time
- Using my test beam analysis library tools and programs to monitor and analyze the data

Thesis and publications

- A lot of work done not yet documented.
- I have a lot of writing to do.

What next?

- Very rich curriculum thanks to MC-PAD
- I can look for the best opportunity in academia or industry somewhere around the globe

NOTES ABOUT MC-PAD

A lot of opportunities

- Lots of travelling
- I had a change to attend several schools and conferences
- Intra-network mobility could have been better
- Industry involvement absent

Training events

- A great opportunity to learn
- A great opportunity to meet
- I would have liked longer events with more practical sessions

MY PERSONAL DEVELOPMENT

Being a jack of all trades and master of none, but oftimes better than master of one

Manage a complex project

- Engineering teams
- Technical support
- External companies for purchasing and manufacturing
- Internal DESY departments
- Using only soft power

Team leading

- Multinational collaboration to complete a test beam effort
- Had to quickly solve many small and big problems
- With a lot of support from the rest of the group

Multiple hard skills acquisition

- A decent sample is in the previous slides

A network of brilliant friends and scientists

- I know a place to go for every problem and every detector