Prototype Development of a GEM-TPC for the SuperFRS

OUTLINE

- Introduction and Motivation
- GEM Technology and Characterization
- First GEM-TPC Prototype HB1 – Tests
- Second Prototype HB2 – AFTER Readout electronics
- Third Prototype HB3 – Xyter Readout electronics
- Active Divider for GEM-TPC
- Open Questions and TODO List

INTRODUCTION

FAIR is Facility for Antiproton and Ion Research. The concept of the FAIR Facility aims for a multifaceted forefront science program, beams of stable and unstable nuclei as well as antiprotons in a wide range of intensities and energies, with optimum beam qualities

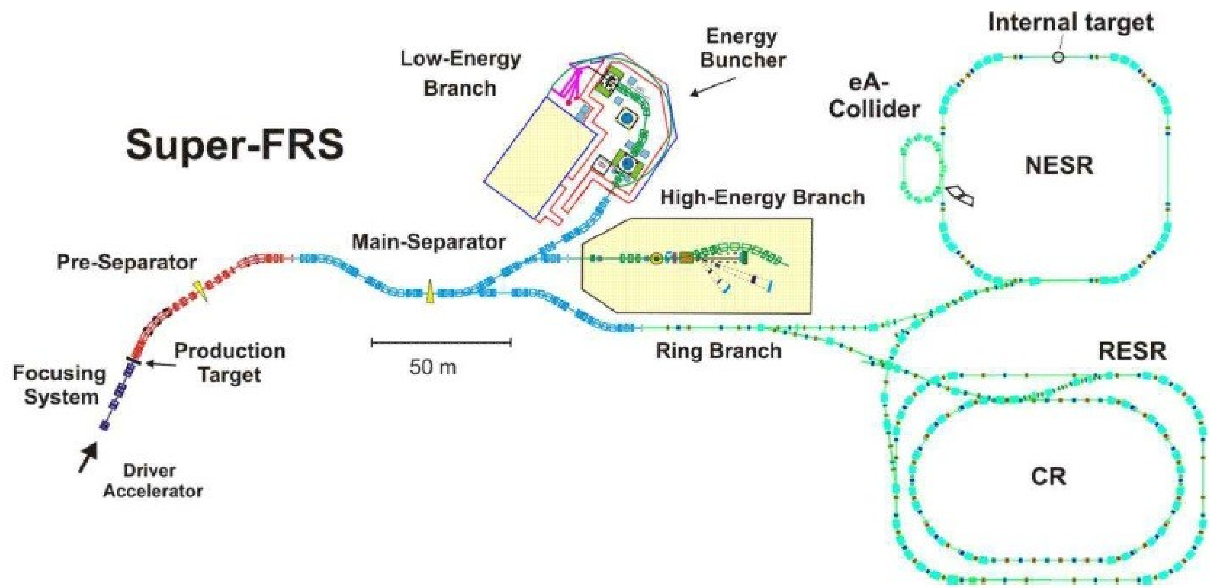
Time Table spans till end 2018

MOTIVATION

NUSTAR collaboration (Nuclear Structure, Astrophysics, and Reactions) has more than 700 members in total.

Part of the Finnish Contribution will be in the superconducting in-flight separator (Super-FRS) Diagnostic systems

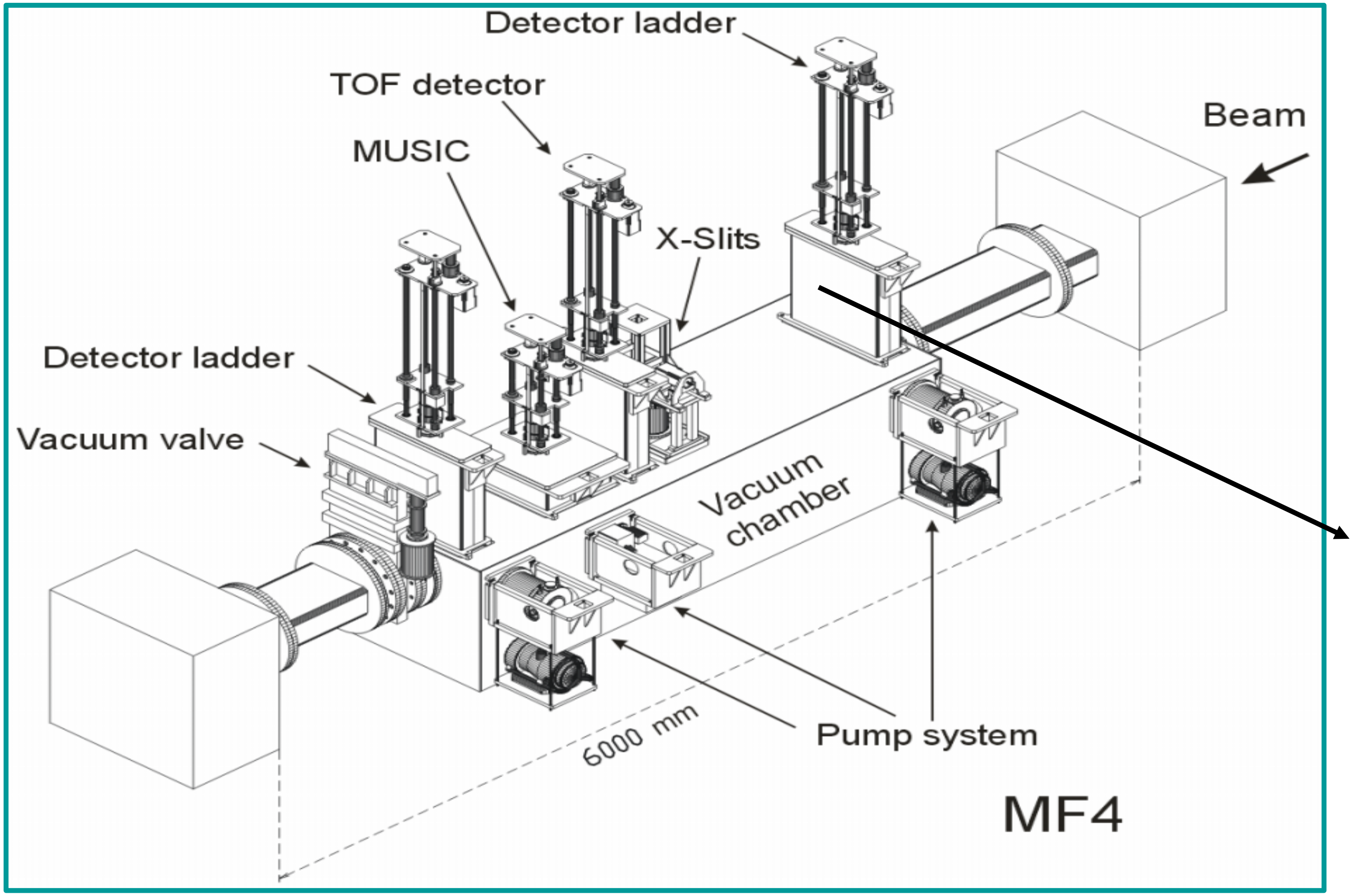
The NUSTAR Facility at FAIR
(The 3 Branches of the Super-FRS)

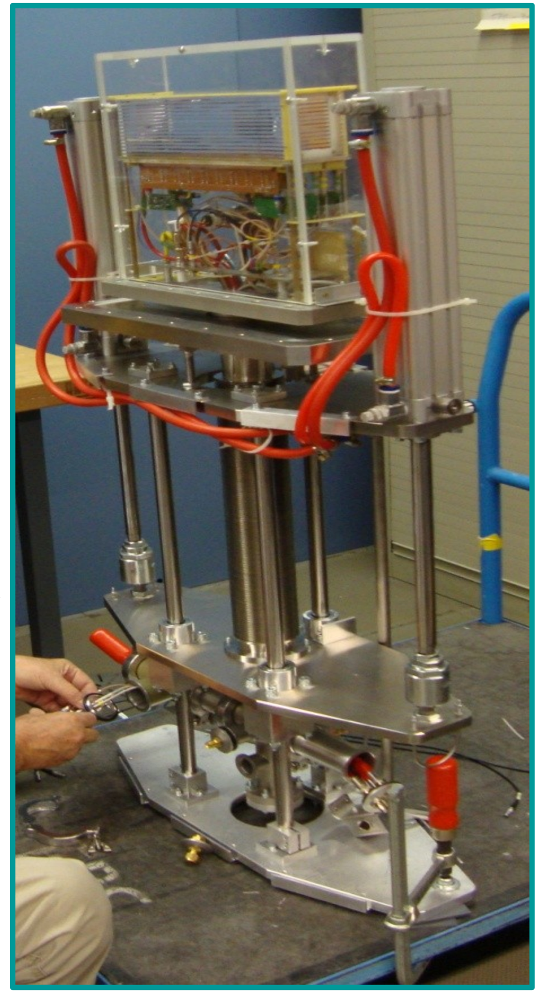


NUSTAR = **Nu**clear **St**ructure, **A**strophysics and **R**eactions

MOTIVATION (cont.)

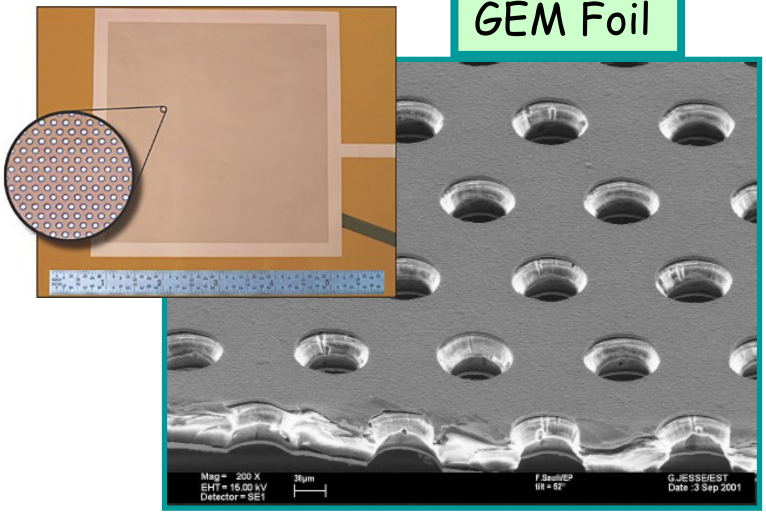
DIAGNOSTIC SYSTEM STATION



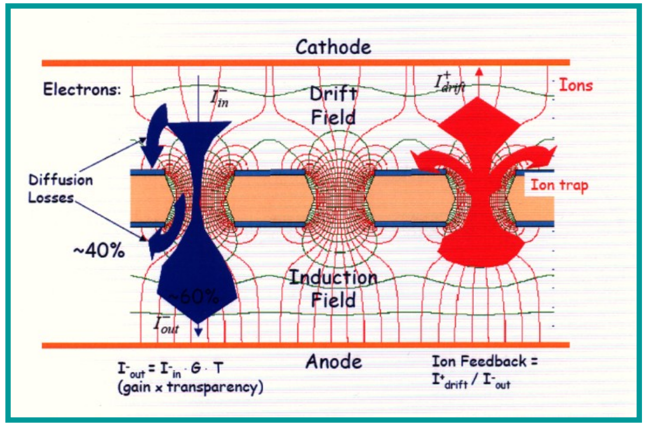


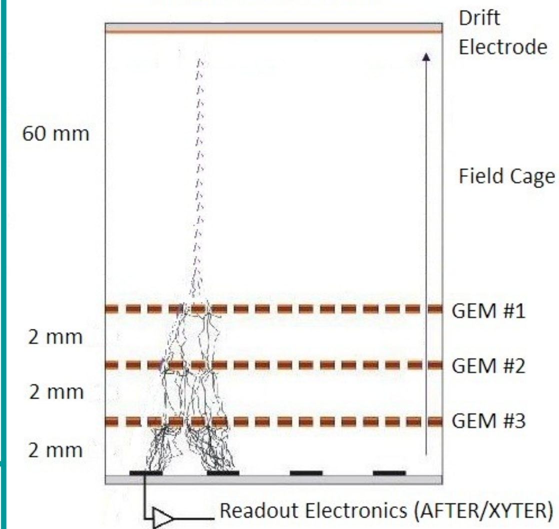
GEM TECNOLOGY and CHARACTERIZATION

GEM Foil

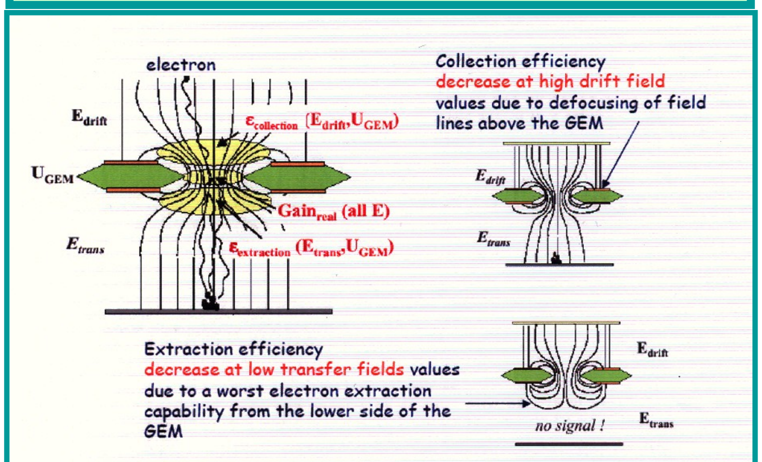


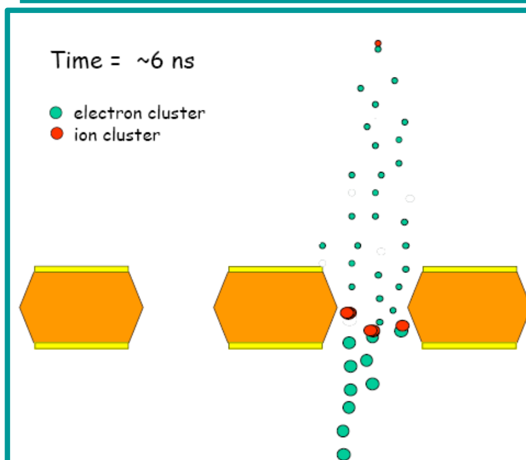
GEM Operation Principle

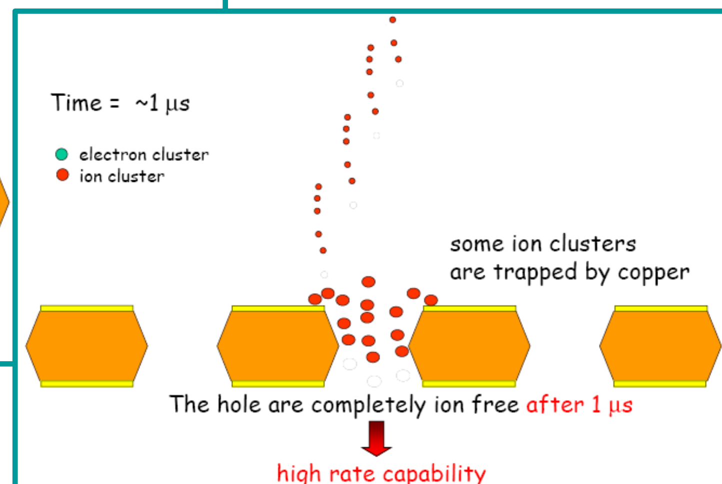




Extraction of the Electron Cloud and Signal Induction





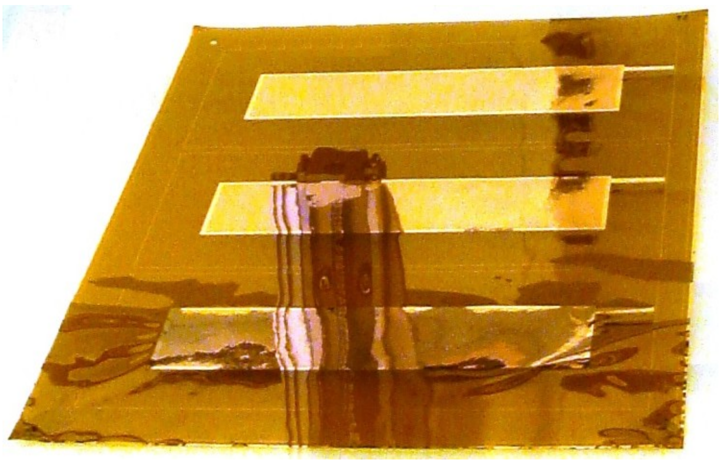


Avalanche development in time domain

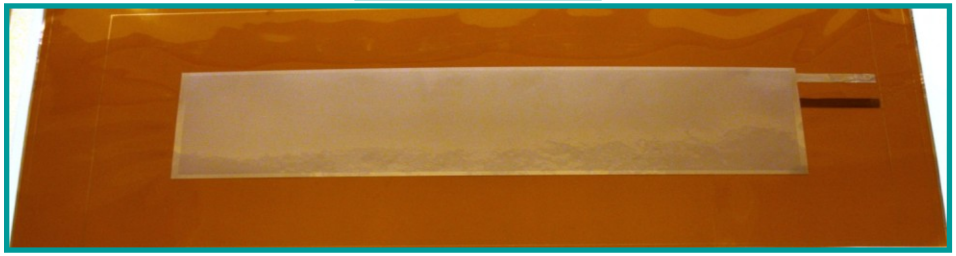
GEM TECNOLOGY and CHARACTERIZATION (cont.)

GEM mask designed at HIP and manufacture at CERN – workshop (Rui de Oliveira)

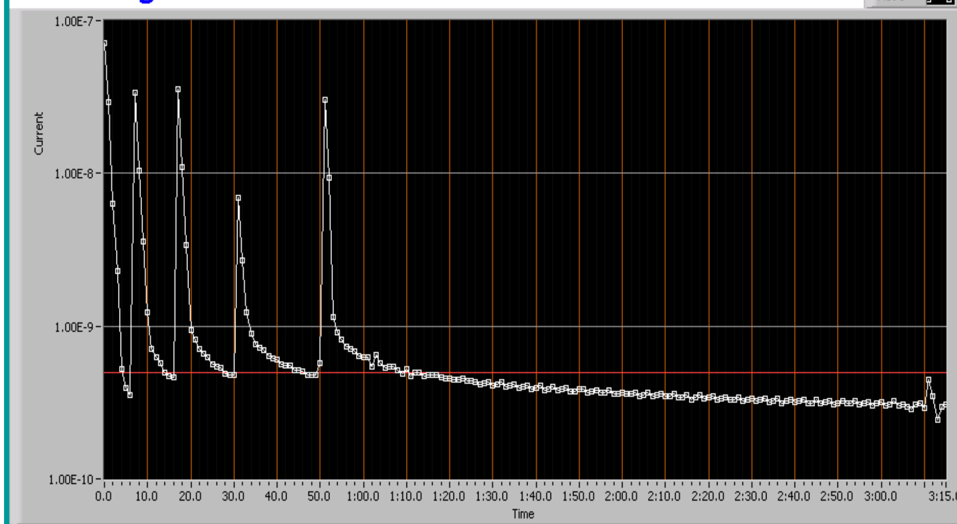
First GEM mask



GEM Foil

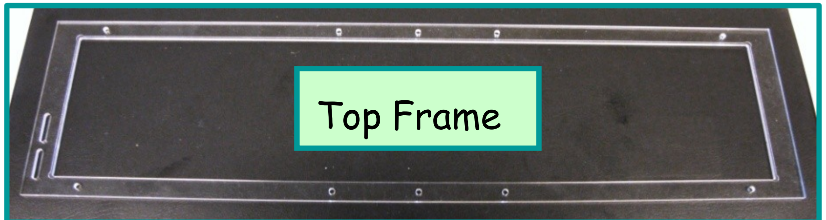


Leakage current

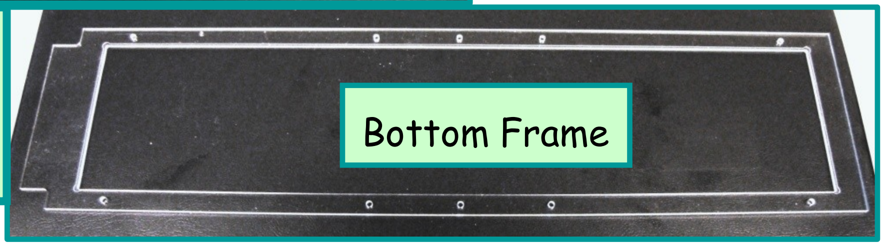


The leakage current well bellow the accepted limit of 0.5 nA during 30 min in N_2

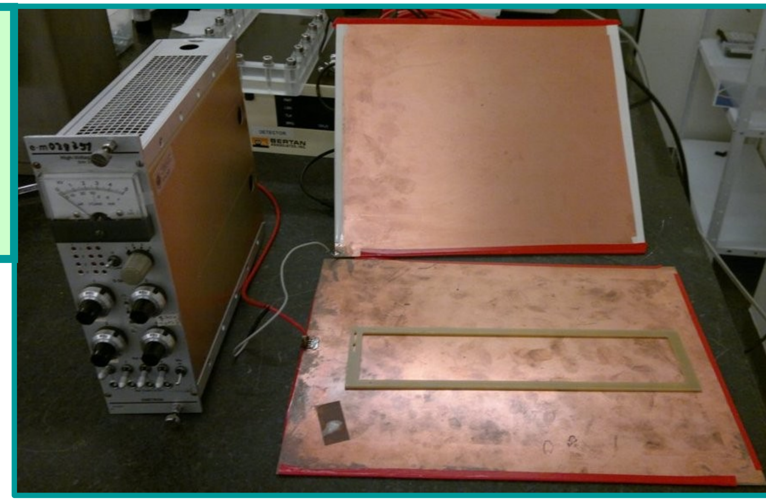
GEM TECNOLOGY and CHARACTERIZATION (cont.)



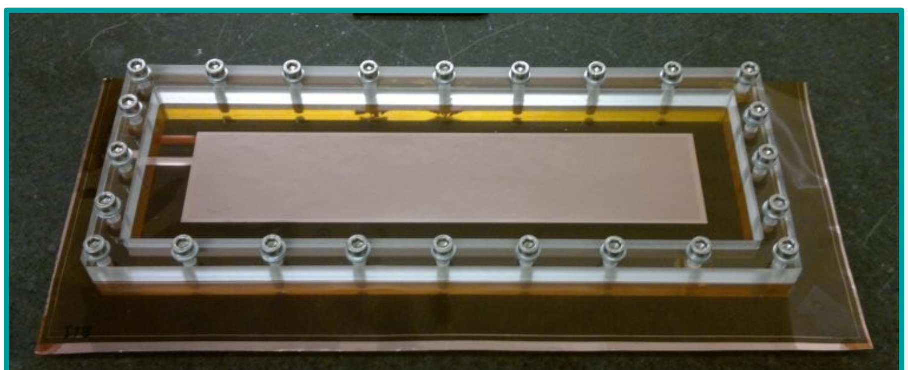
First mechanical models for the top and Bottom frames



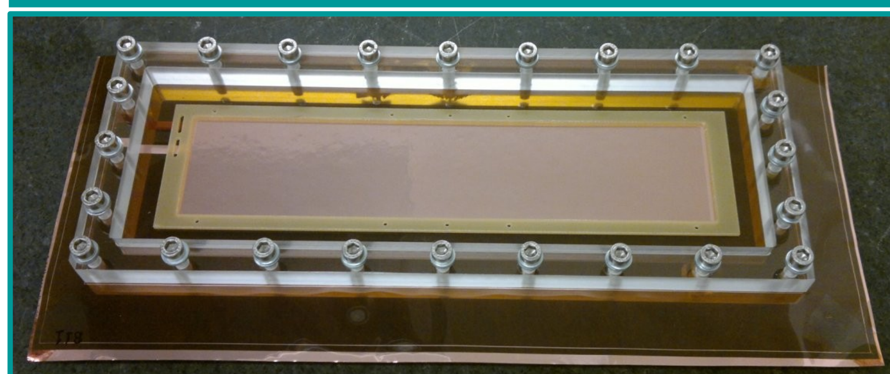
Electrostatic Test for all the frames @ 3 kV Possible breakdowns corrected with Nuvovern



GEM Foils stretcher – No repels or undulation visible

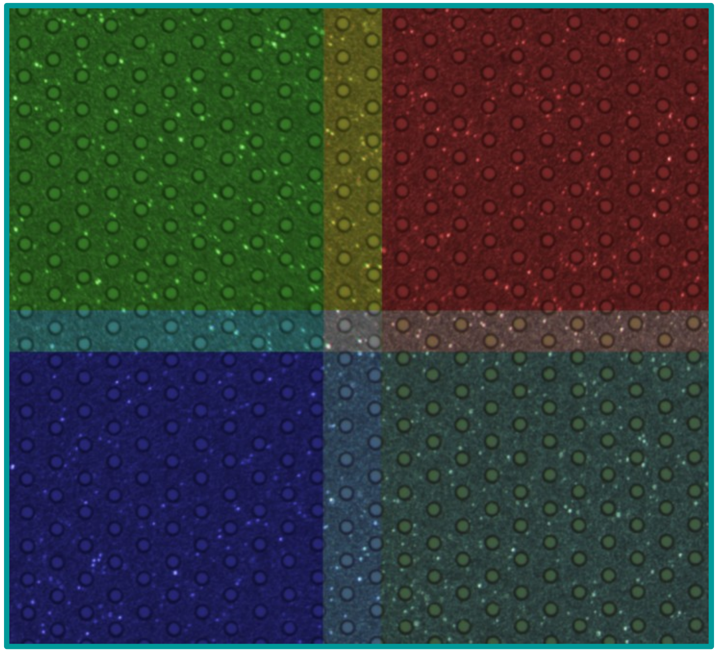


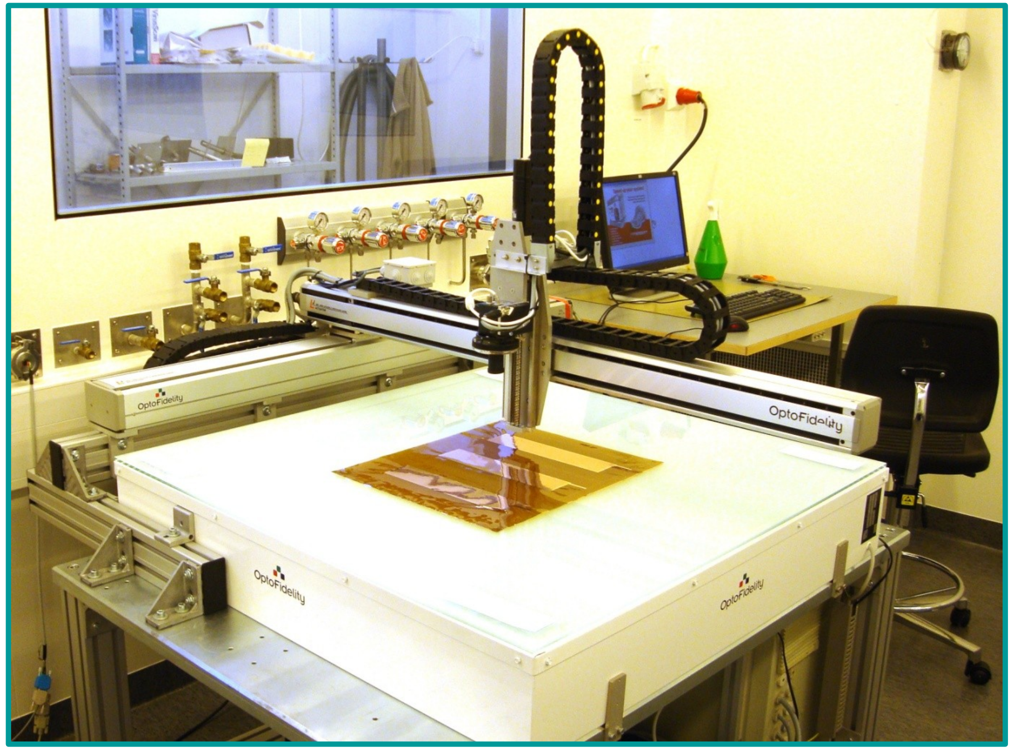
Top frame glued to the GEM foil, after cured in owen



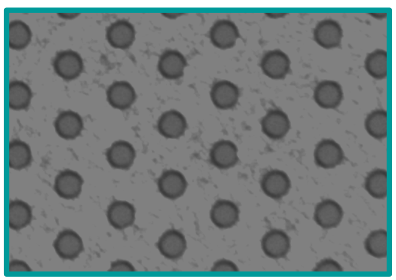
GEM TECNOLOGY and CHARACTERIZATION (cont.)

FOUR images Stitched
The overlapping on these images is of 245 μm and 140 μm

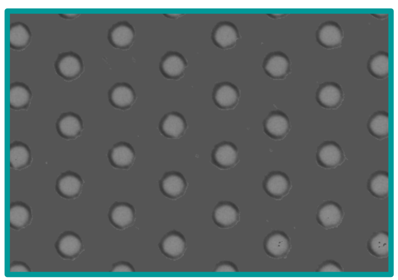




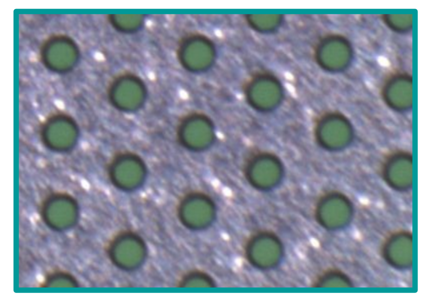
After Apply Red Filter
This procedure is used to find defects and to find the outer diameter of the holes



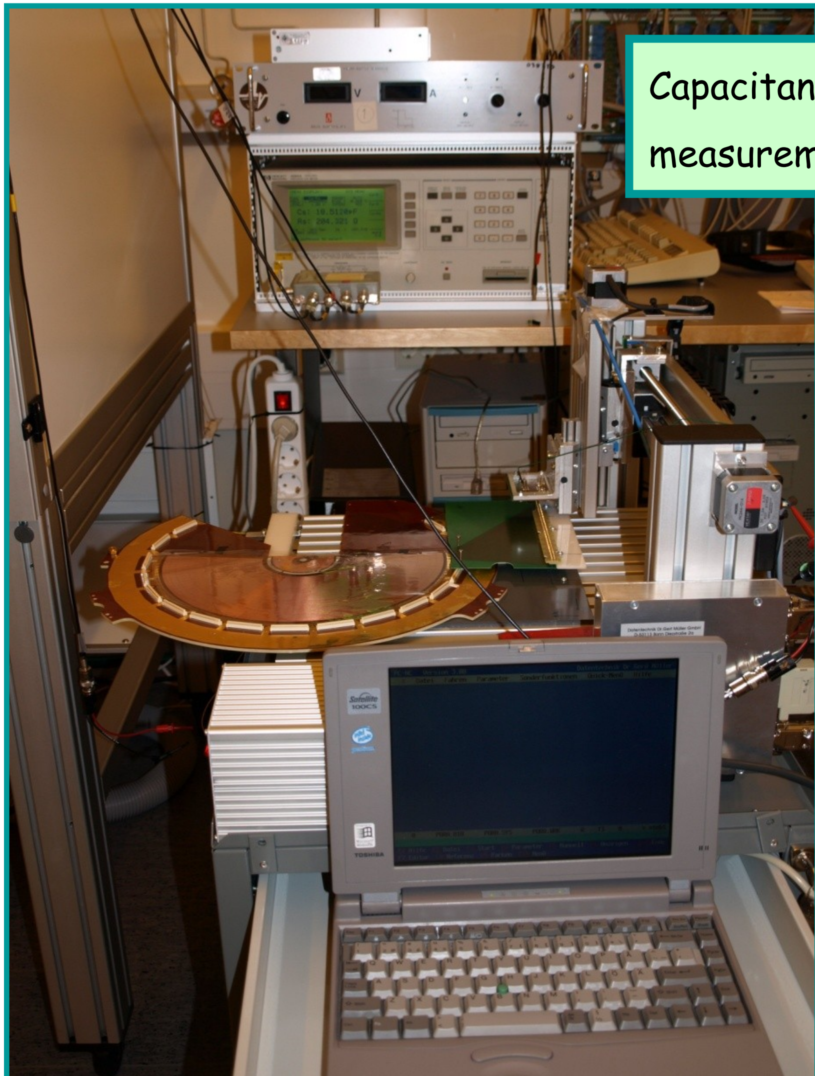
After Apply Green Filter
This procedure is used to find blind holes and to measure the inner diameter of the holes



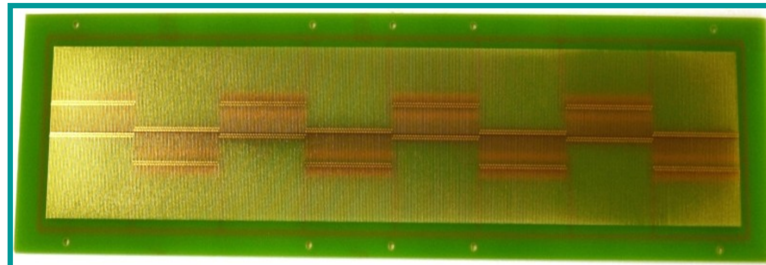
New System
Based on 9 Mpix camera with integrated telecentric optics for this setup one pixel corresponds to 1.7 x 1.7 microns

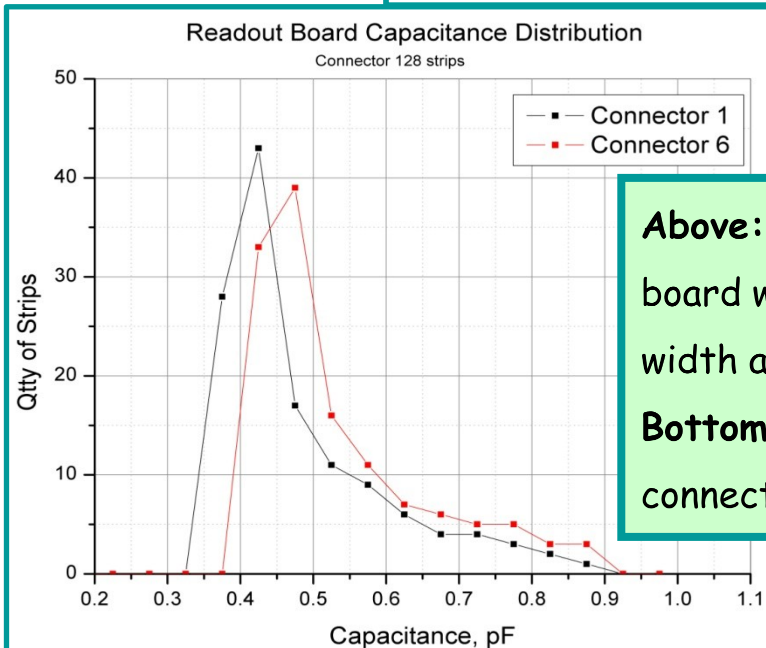


GEM TECNOLOGY and CHARACTERIZATION (cont.)



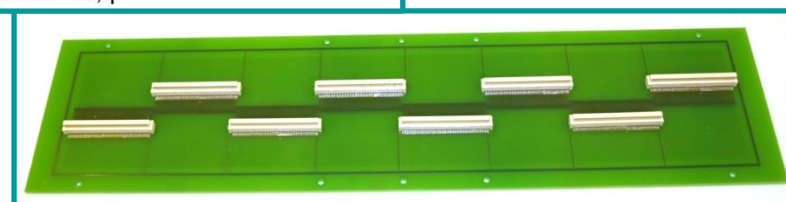
Capacitance measurement setup





Above: The electrodes of the board with strips of 200 μm width and 500 μm pitch

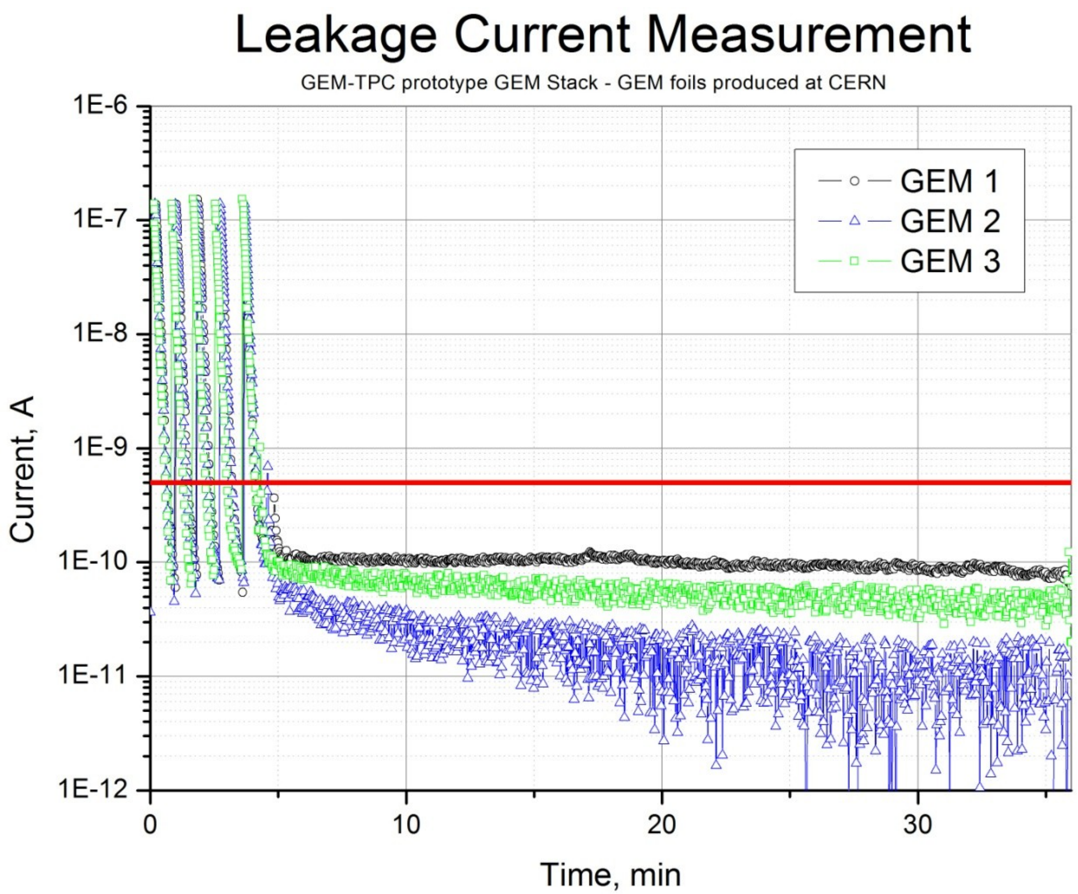
Bottom: 8 Header Panasonic connectors with 130 Pin each

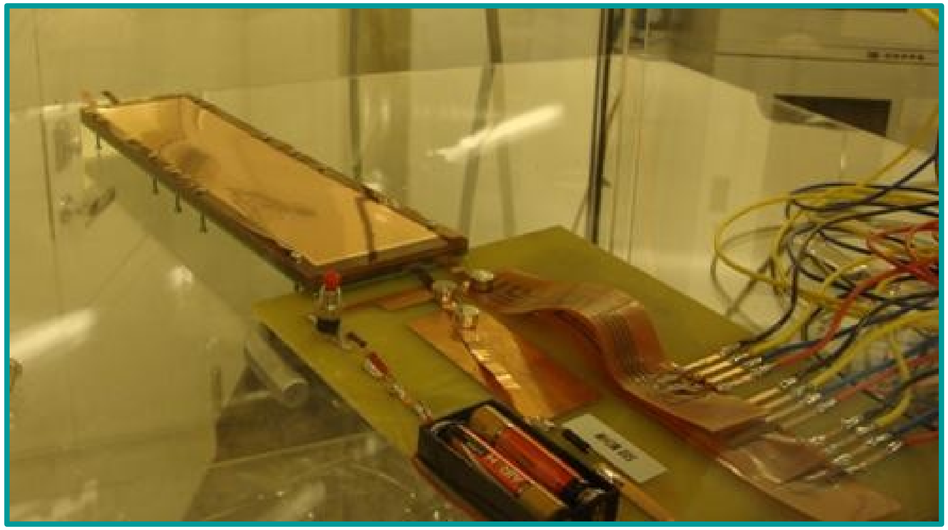


GEM TECNOLOGY and CHARACTERIZATION (cont.)

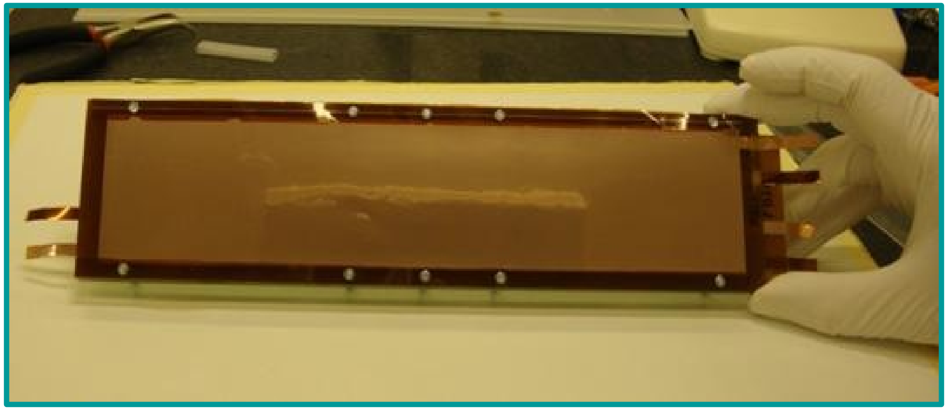
GEM Stack tests:

Triple GEM leakage current measurements





GEM Stack for the GEM-TPC prototype HB2



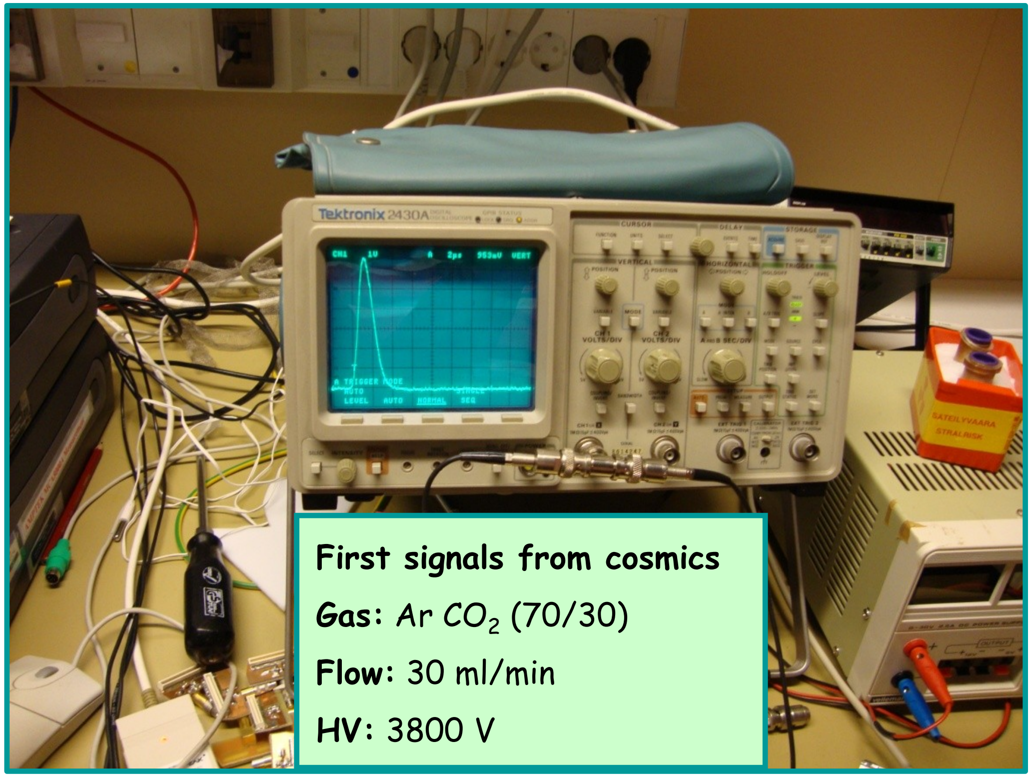
GEM TECNOLOGY and CHARACTERIZATION (cont.)

GEM Stack tests:

Preliminary measurements in the lab; the radiation used for these tests was the ^{55}Fe and cosmics

GEM Stack test bench

The GEM stack was assembled as a triple GEM detector with 3 mm of Drift

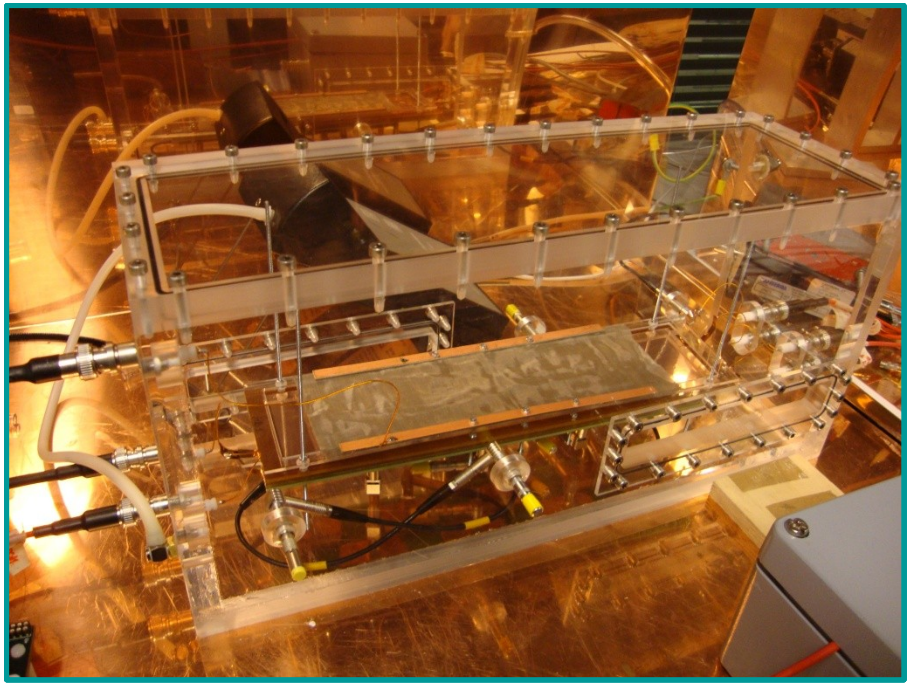


First signals from cosmics

Gas: Ar CO_2 (70/30)

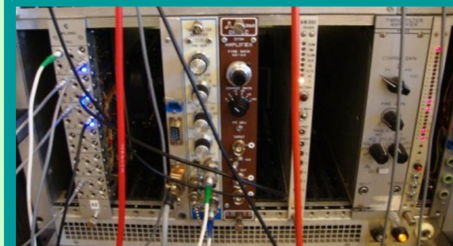
Flow: 30 ml/min

HV: 3800 V



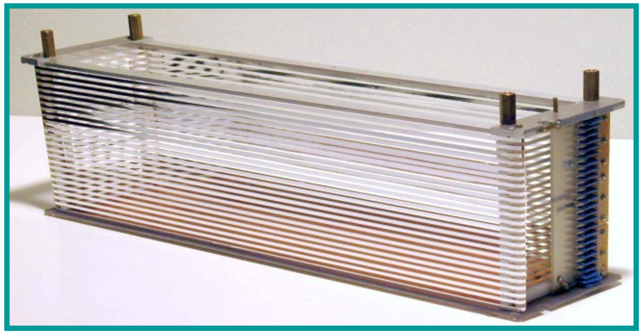
FIRST GEM-TPC PROTOTYPE HB1 - TEST

Tests and assembling at Comenius University - Bratislava

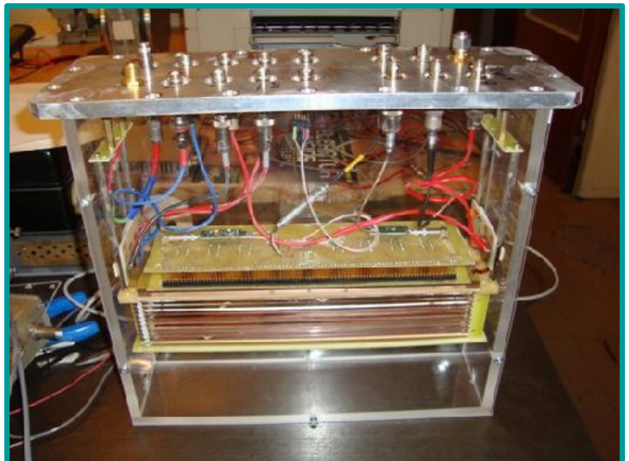


HV Power Suppliers.
TDC module.
Source 1D movement controller.
Shaper module.
Linear Amplifiers.
CAMAC create

Field cage of 60 mm drift

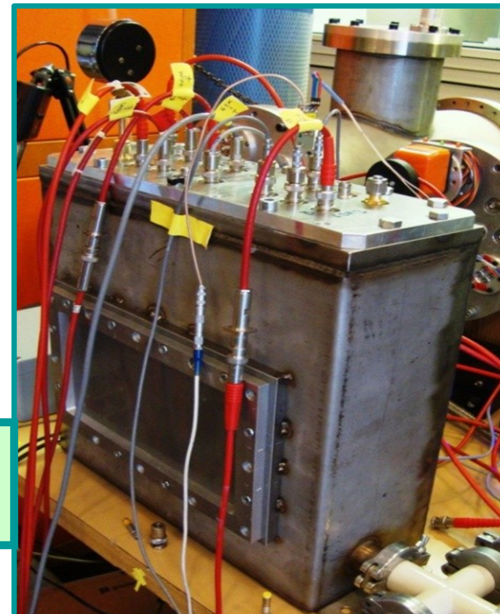


Flange the GEM-TPC HB1 equipped with delayed lines



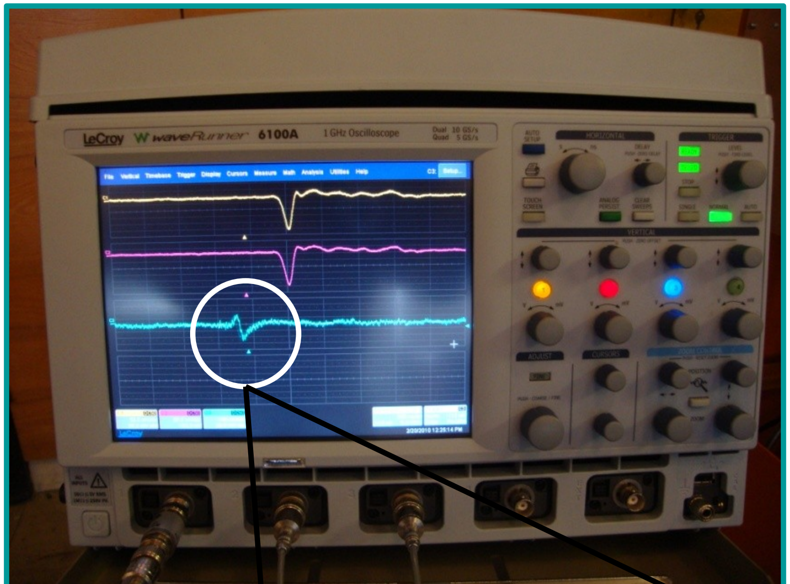
GEM Stack integration

First GEM-TPC detector



FIRST GEM-TPC PROTOTYPE HB1 - TEST

GEM-TPC test in lab at Comenius University



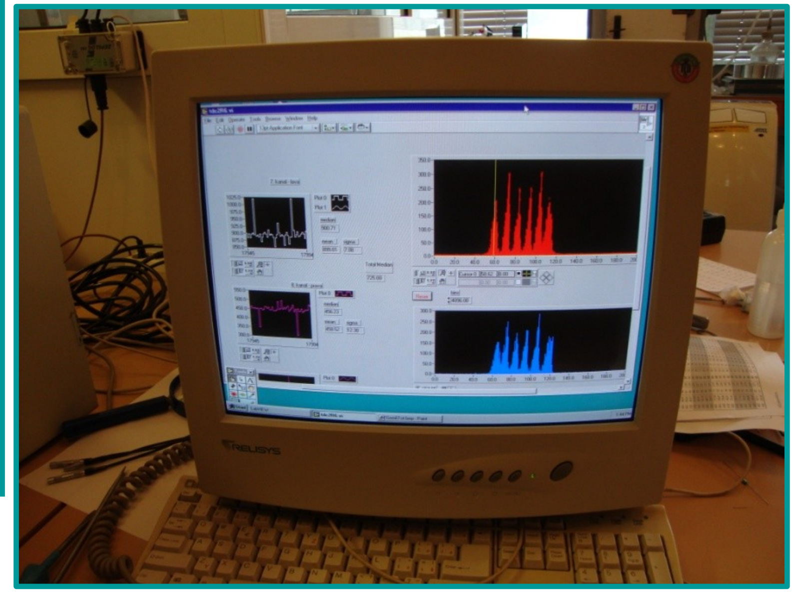
It can be observed:

- Signals from the delayed lines are very clean
  - Same relative time between them
  - Trigger signal bipolar, it can be that the 40% negative overshoot is due to e- transparency loses in the GEM 3

Trigger Signal before reshaping

Trigger Signal with rise and decay time reshaped

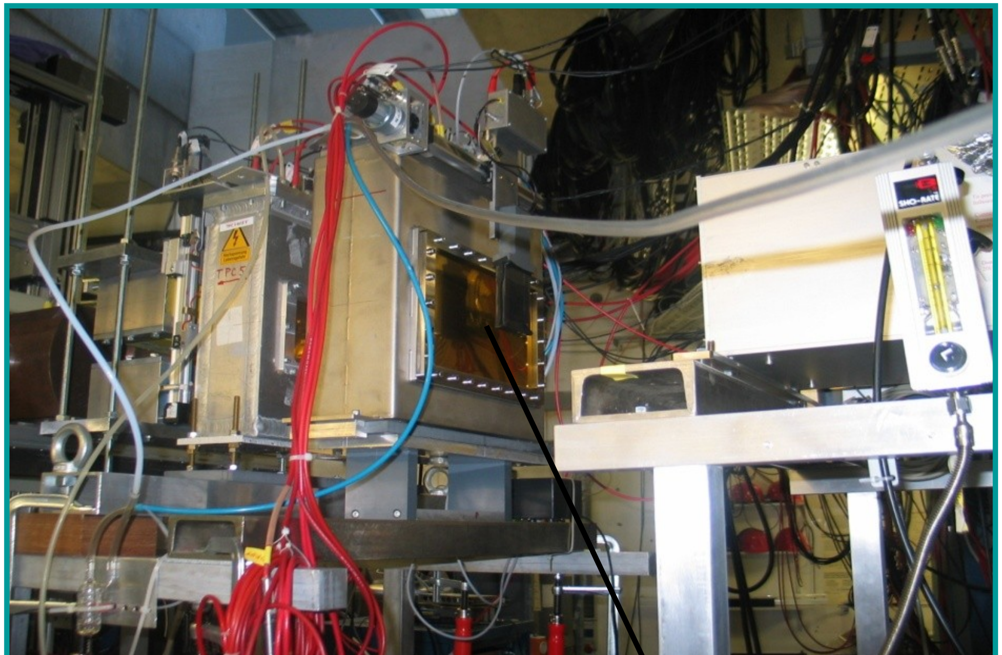
GEM-TPC tracking capabilities for ^{55}Fe

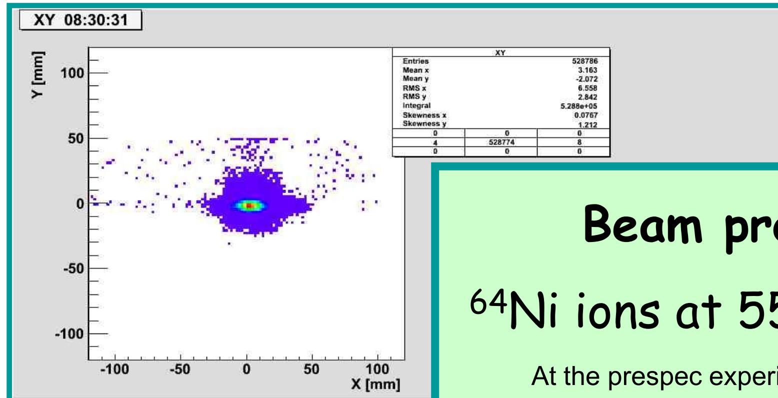


In the picture above there are multiple picks from the different source positions.
The source was not very well collimated therefore a mm scale resolution on X was achieved and the trigger was taken from the bottom of the GEM3

FIRST GEM-TPC PROTOTYPE HB1 - TEST (cont.)

GEM-TPC Beam test at GSI - Darmstadt

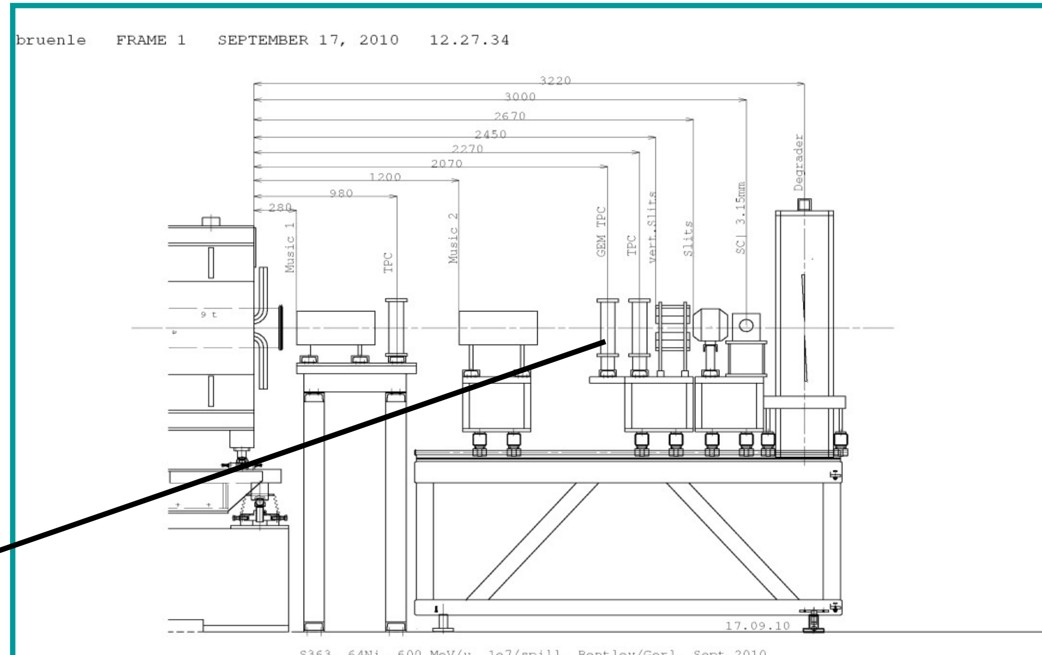


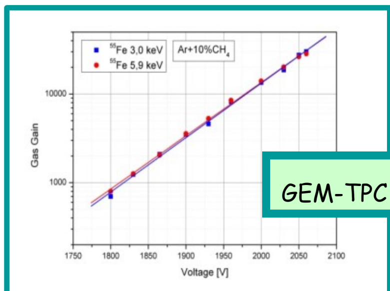


Beam profile

^{64}Ni ions at 550 MeV/u

At the prespec experiment - S363





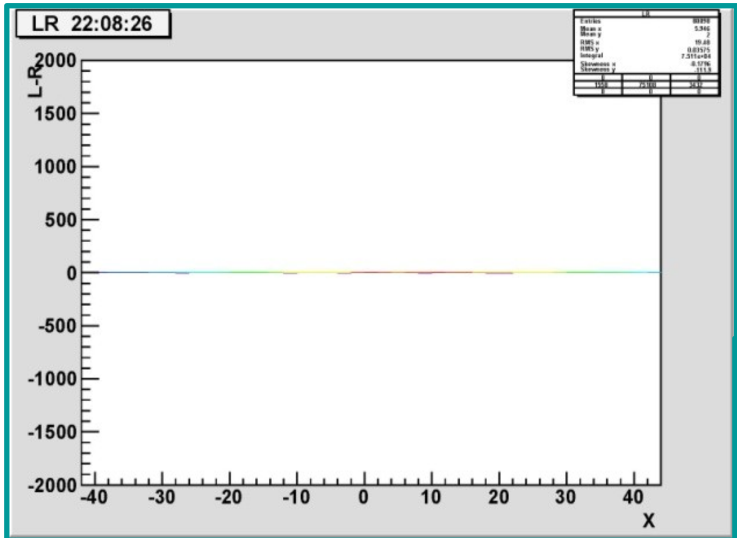
GEM-TPC Gain

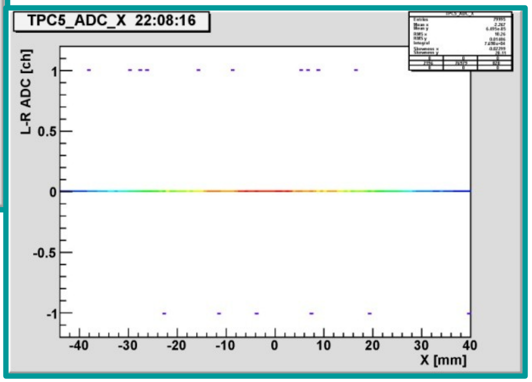
GEM-TPC at S4

FIRST GEM-TPC PROTOTYPE HB1- TEST (cont.)

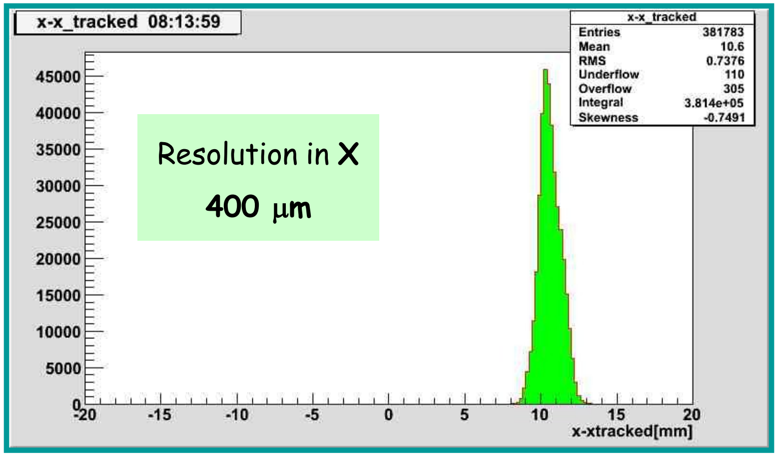
GEM-TPC Beam test Results

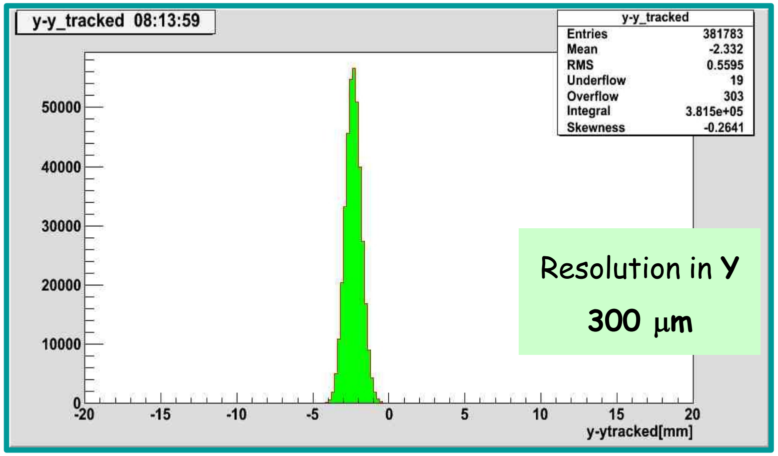
On the bottom after applying corrections for the preAmps nonlinearities, we can observe that the response is uniform along the full sensitive volume.





GEM-TPC response in X and Y coordinates



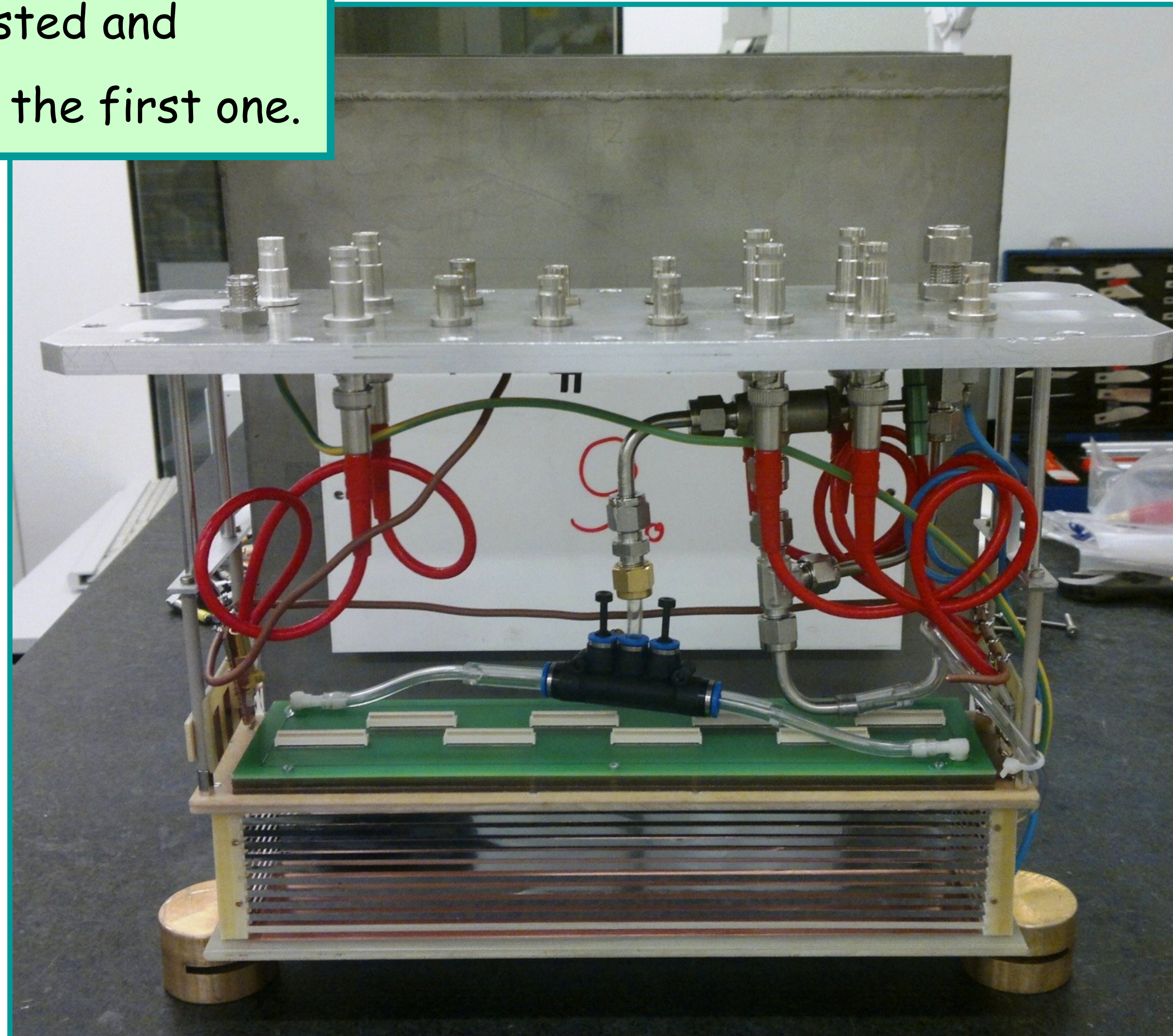


SECOND GEM-TPC PROTOTYPE HB2

The second GEM-TPC HB2 will be tested and characterized in a similar way as for the first one.

Test in the lab:

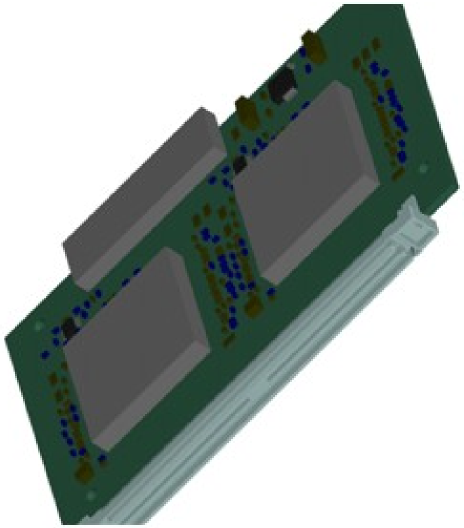
- ✓ Foils visual and scanned inspection
- ✓ Foils leakage current measurement
- ✓ Readout board capacitance measurement
- ✓ Energy resolution measurement
- ✓ Gain and its uniformity
- ✓ Oxygen concentration measurement
- ✓ Irradiation with ^{55}Fe



SECOND GEM-TPC PROTOTYPE HB2 (cont.)

GEM-TPC Readout Electronics and DAQ.

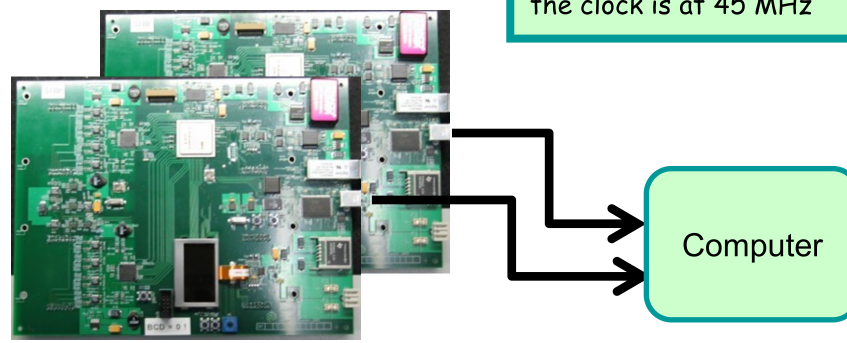
T2K FEC developed at **TUM** 4 AFTER chips for a total of 256 channels



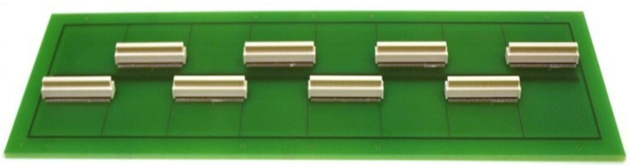
Readout Architecture

4 x AFTER FEC

2 x ADC to USB Cards

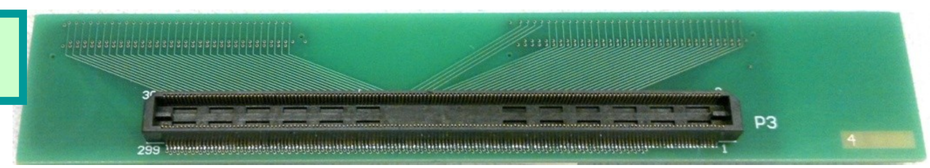


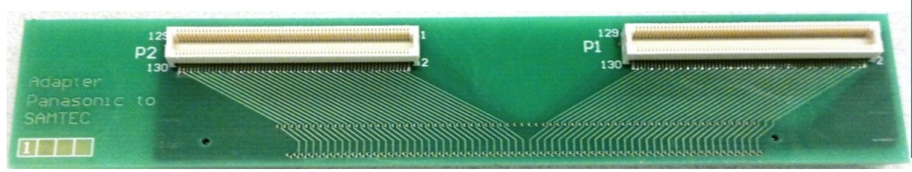
The trigger rate expected for the AFTER chip with $ArCO_2$ and 60 mm drift is of about 6.4 kHz. Taken into account that a total of 60 cells are needed and the clock is at 45 MHz



GEM-TPC Readout board with 1024 strips cut in the middle

PAN to SAMTEC Adapter

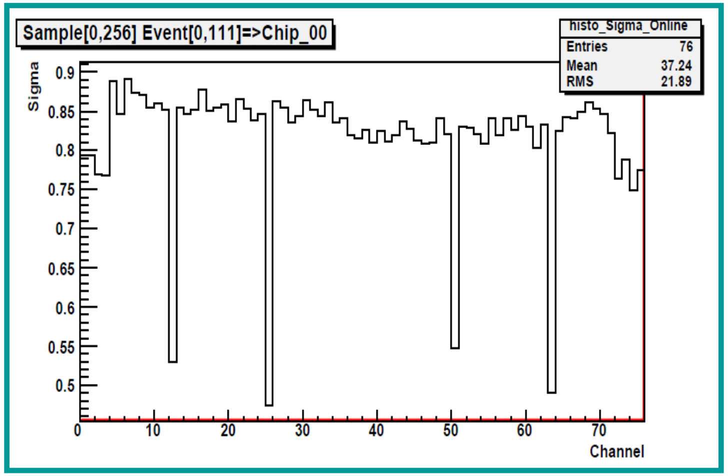




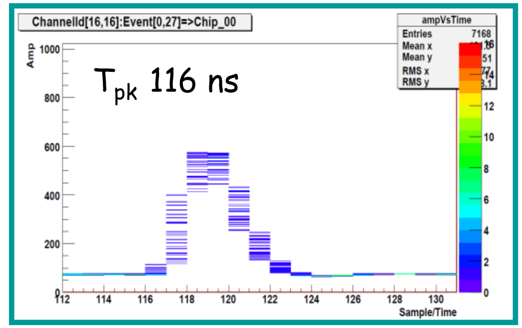
At the top a Samtec connector 300 pins and in the left side two Panasonic connectors of 130 pins each

SECOND GEM-TPC PROTOTYPE HB2 (cont.)

GEM-TPC readout electronics performance



Presented by Igor Konorov at TUM



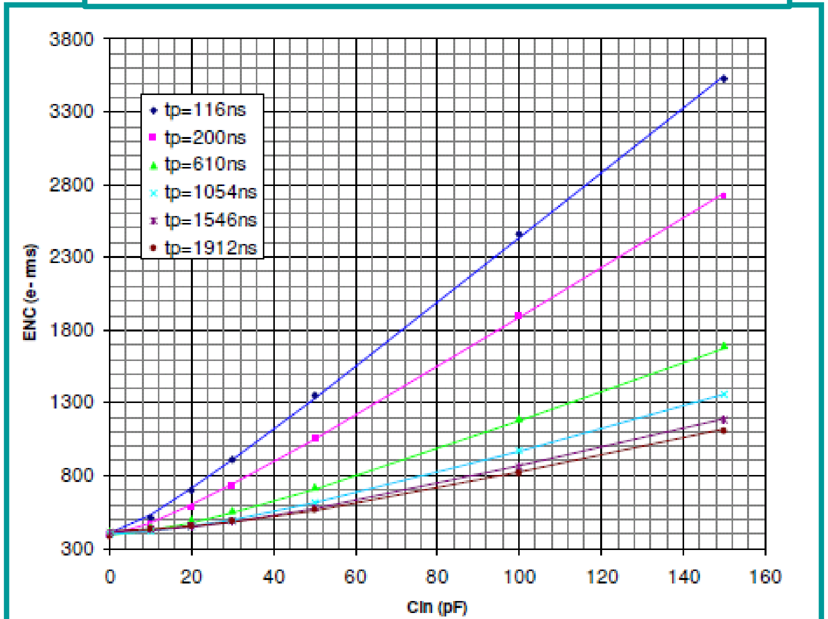
Calibration Procedure with Test pulses of 50 fC

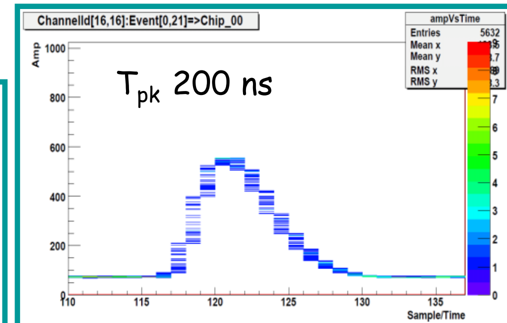
Test of One AFTER Chip which is wasn't connected to the detector and has 8 channels disconnected (the first and the last 4).

There is a fixed pattern with 4 noisy channels.

Related to the signal amplitude 1 ADC count correspond to 0.12 fC or 700 e-

T2K noise measured @ Saclay





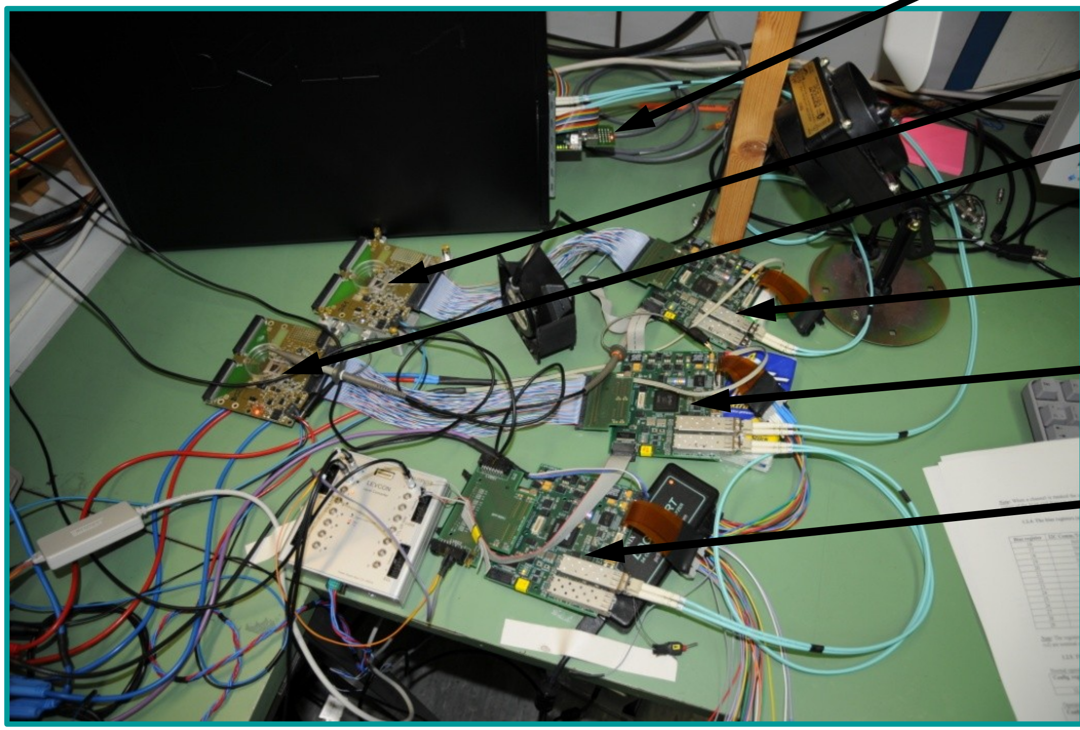
Due to strips and coupled capacitance we can expect a 400 e- noise at all the peaking times

THIRD GEM-TPC PROTOTYPE HB3(cont.)

GEM-TPC Readout Electronics and DAQ.

Presented by Dr. Christian Schmidt at GSI

XYTER readout Architecture

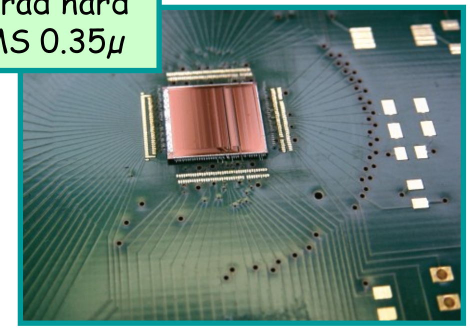


PEXOR & TRIXOR

nXyter Boards
#0
#1

Exploder Boards
#0
#1
#2 (Source of 32 MHz)

n-XYTER,
non rad hard
AMS 0.35μ



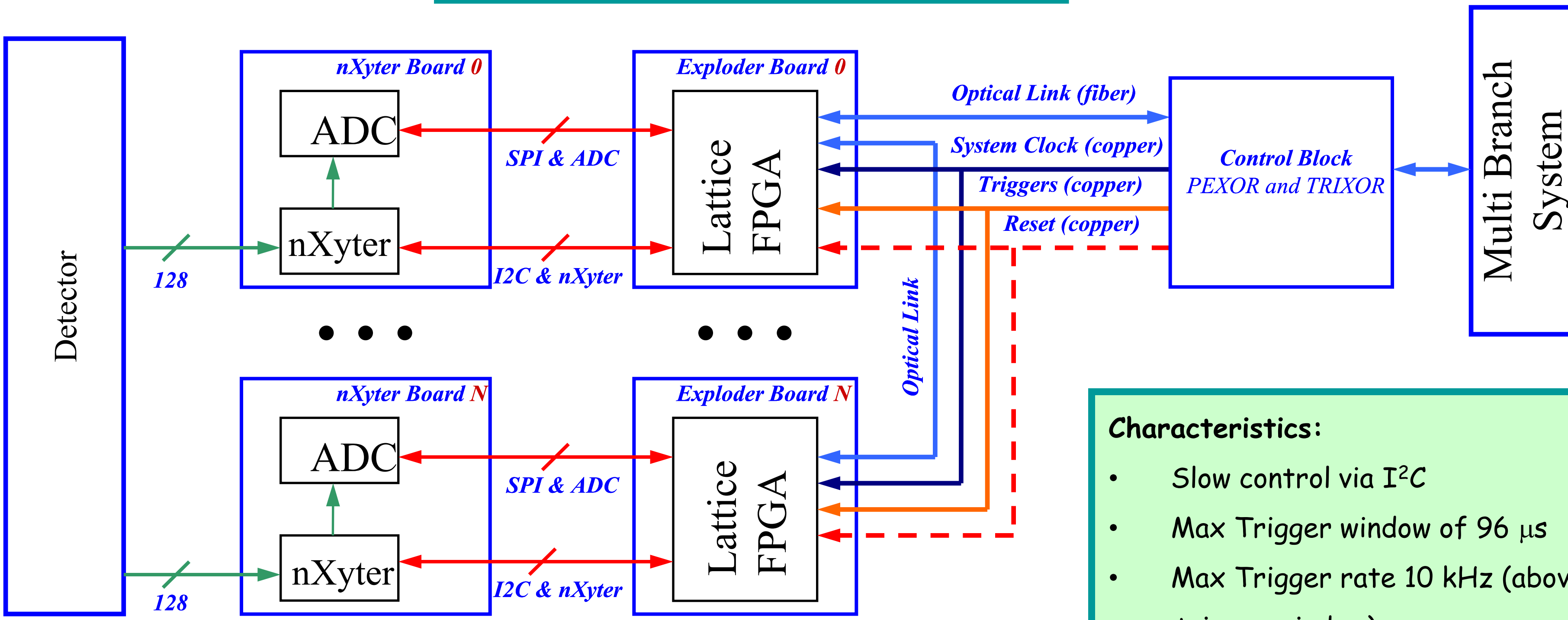
- Detector operation with purely data driven, self triggered readout
- engineering run prepared by H.K. Soltveit, PI Heidelberg

THIRD GEM-TPC PROTOTYPE HB3 (cont.)

GEM-TPC Readout Electronics and DAQ.

Presented by Dr. Ivan Rusanov at GSI

nXYTER readout Architecture



Characteristics:

- Slow control via I^{2}C
- Max Trigger window of 96 μs
- Max Trigger rate 10 kHz (above trigger window)

ACTIVE DIVIDER FOR GEM-TPC

GEM-TPC Active Divider

Presented by Dr. Fabrizio Murtas at INFN

Main characteristics:

-Standard NIM two units.

-USB & CAN-OPEN protocol communication interface.

-It has 7 independent channels with full isolation at 5kV to Ground.

With 6 channels from 0V to 700V with a max current of 150μA

And

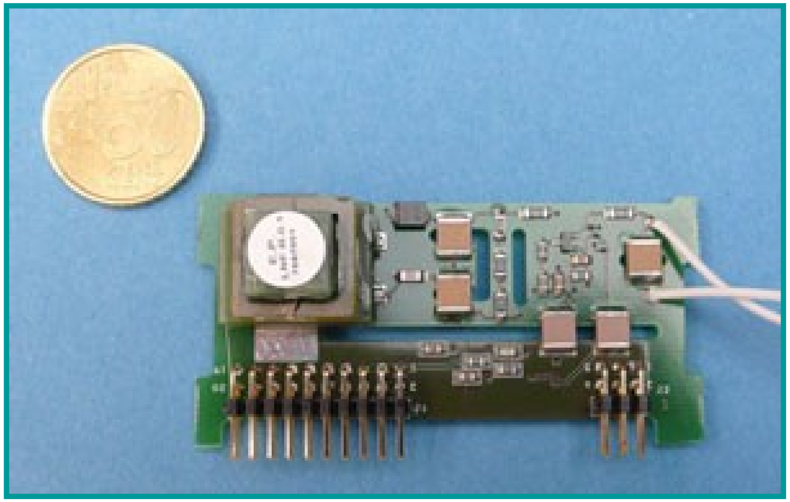
With 1 channel from 0V to 1400V with a max current of 100μA

One Channel Module With dual current limit:

In the low range from 10nA up to 6μA with a resolution of 40 nA

And

With the high range from 100nA up to 40μA, with a resolution of 40 nA

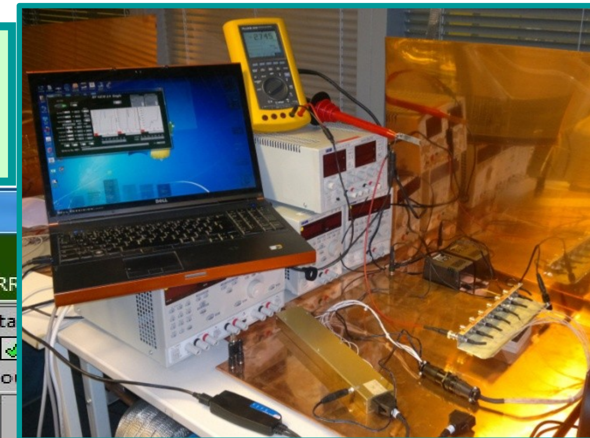


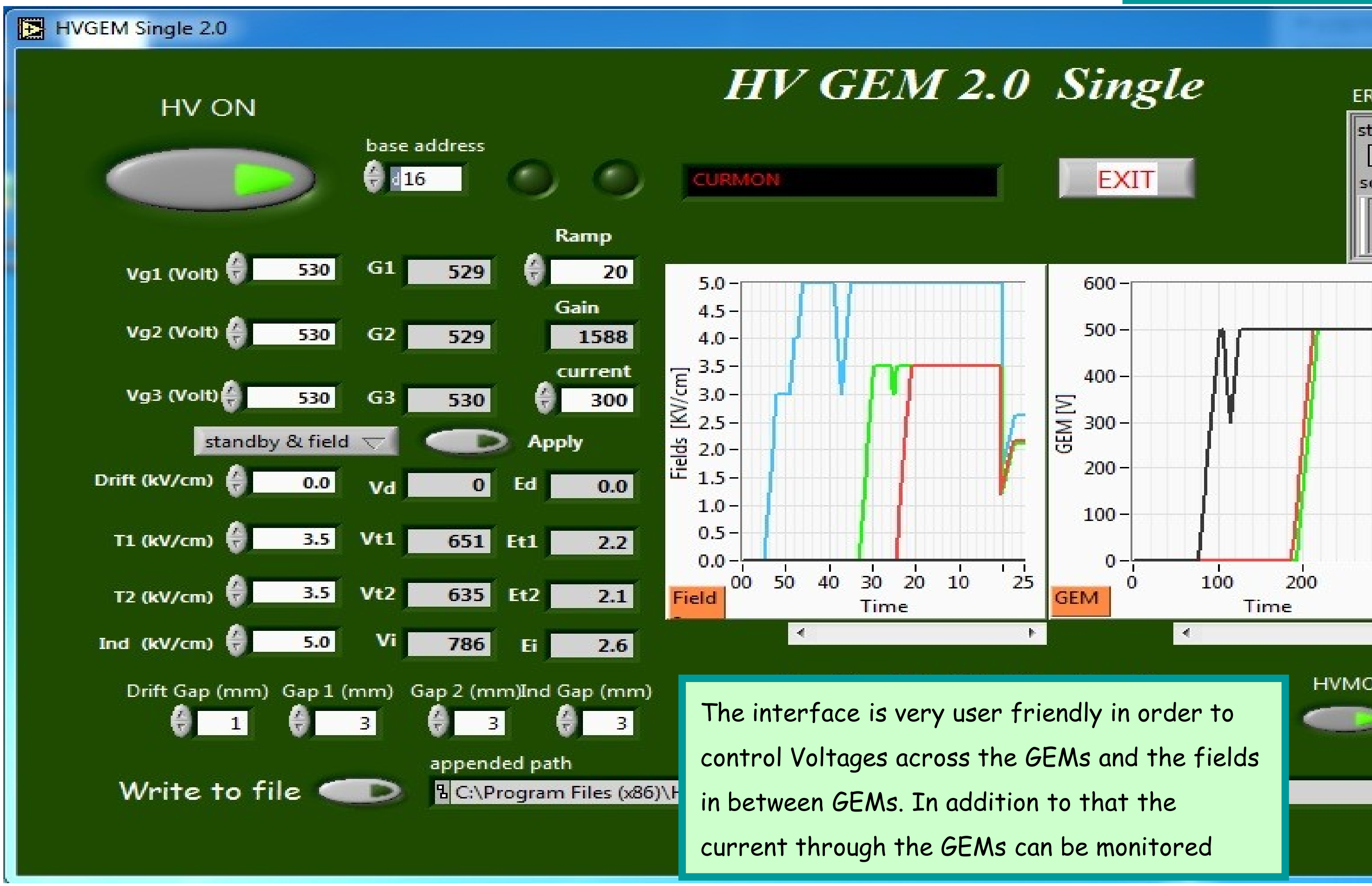
HV GEM module with High Current sensitivity

ACTIVE DIVIDER FOR GEM-TPC

GEM-TPC Active Divider

Test bench in the lab.





The interface is very user friendly in order to control Voltages across the GEMs and the fields in between GEMs. In addition to that the current through the GEMs can be monitored

OPEN QUESTIONS

- Characterization of the GEM foils defects and its uniformity
- Field Uniformity mapping for the Field cage with different strips pitch, strips widths and for single and double strips versus different field gradients
- Optimization of the Field cage for larger Drift length
- Studies on the Ion feedback – simulations and experiment
- Calculations of Charge up effects and Gain from simulations
- Readout electrode geometry optimizations for different ions types, momenta and count rate
- Signal induction for different type of gases based on $ArCO_2$ with CF_4 and other gas mixtures.

TODO

- Finalizing the Second and Third Prototypes. Lab. and beam tests
- Integration of the AFTER readout electronics into HB2 and setup of the DAQ
- Integration of the Xyter readout electronics into HB3 and setup of the DAQ
- Obtain the tracking parameters like: track resolution in X and Y and maximum count rate for HB2 and HB3
- Participate in the Beam campaigns of GPAC at GSI, RD51 at CERN and Jyväskylä
- Test the HB2 and HB3 for larger than 60 mm Drift length
- Analysis of simulations in order to set clear optimizations
- Establish road map for the development of the Full side Prototype