GEM-TPC Development for the Super-FRS

Francisco García Helsinki Institute of Physics

OUTLINE

- INTRODUCTION AND MOTIVATION
- JOURNEY ACROSS THE GEM-TPC DEVELOPMENT
- SIMULATIONS ON RATE CAPABILITY
- THE TWIN GEM-TPC – HGB4
- CURRENT SuperFRS GEM-TPC CONSORTIUM
- OUTLOOK

INTRODUCTION & MOTIVATION

FAIR is a 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

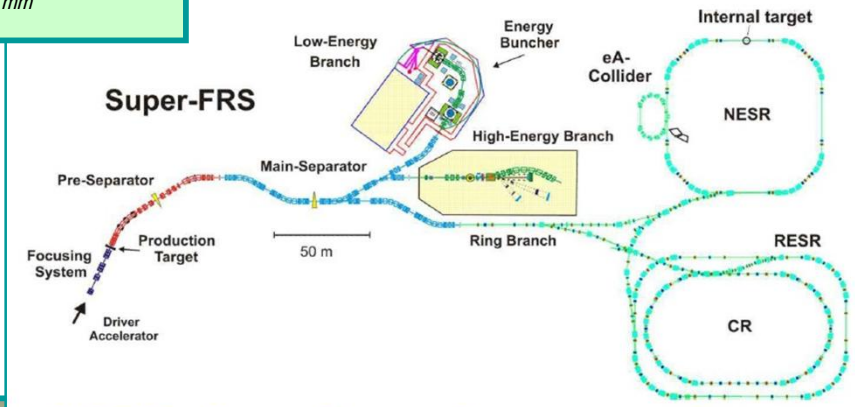
Time line:
R&D finish and Design frozen: Q2/2016

Mass production: Q2/2017 – Q4/2019

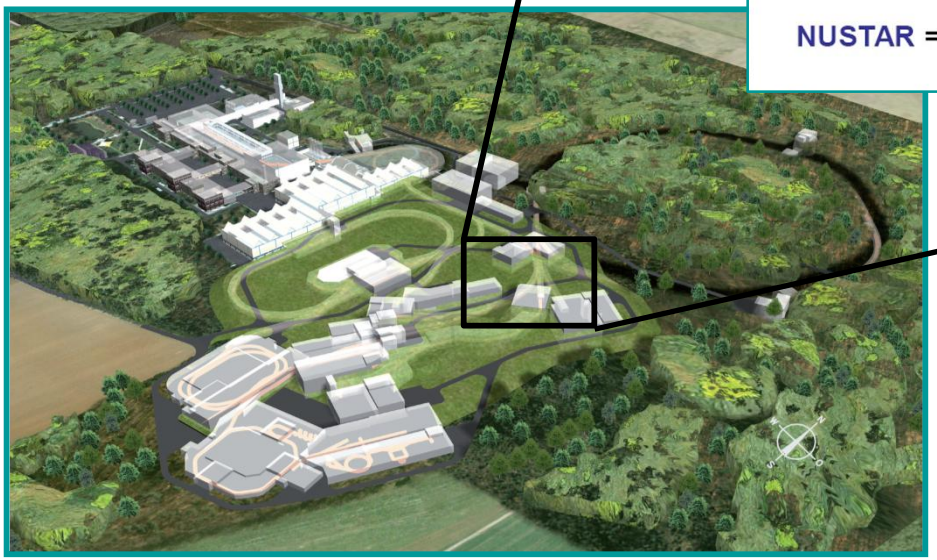
Projectile:
Elements p – U
Energy up to 1.5 GeV/u
Intensity up to 10^{12} /spill

Spot size on target:
σ_x= 1.0 mm
σ_y = 2.0 mm

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



NUSTAR = Nuclear Structure, Astrophysics and Reactions



Time Table spans till end 2025

The superconducting in-flight separator (Super-FRS) has three branches and will run in slow and fast extraction mode.

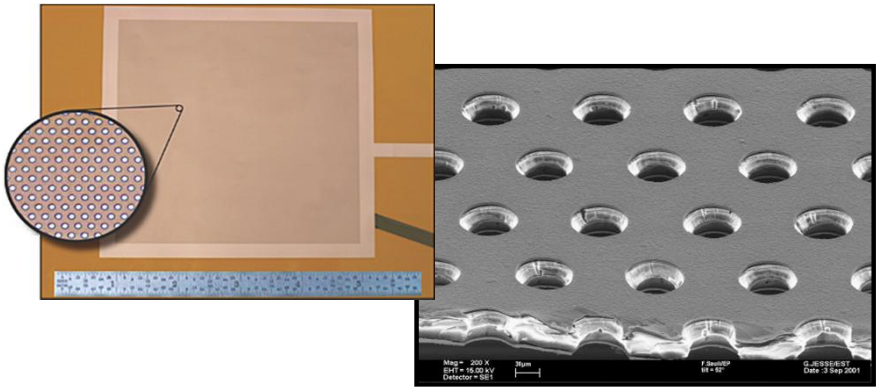
Part of the Finnish Contribution will be in Diagnostic systems, which is a work package dedicated to provide 36 GEM-TPC detectors.

Followed the LOI an EOI has been already submitted to the In-kind review board for this workpackage.

JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

The main question in Eurorib´08 was can we make such detector that will have rectangular shape, use the GEM as amplification stage, and be able of tracking ions: from protons to Uranium; with intensities up to 1 MHz and position resolution less than 1 mm

Field cage

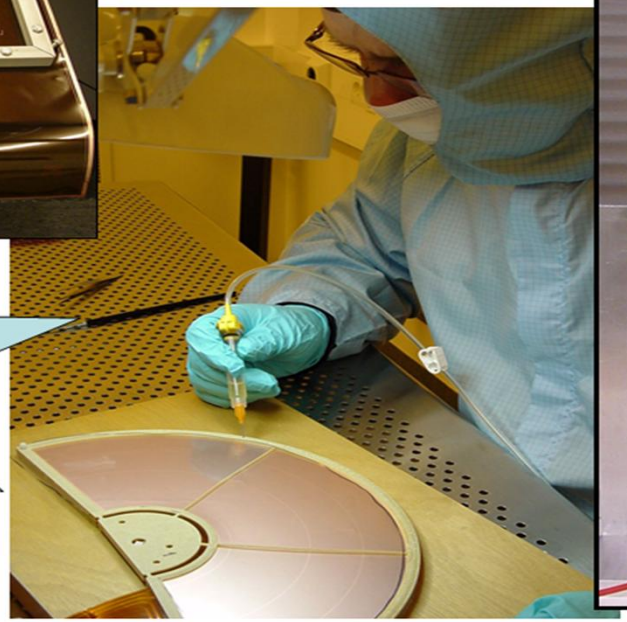


GEM foil

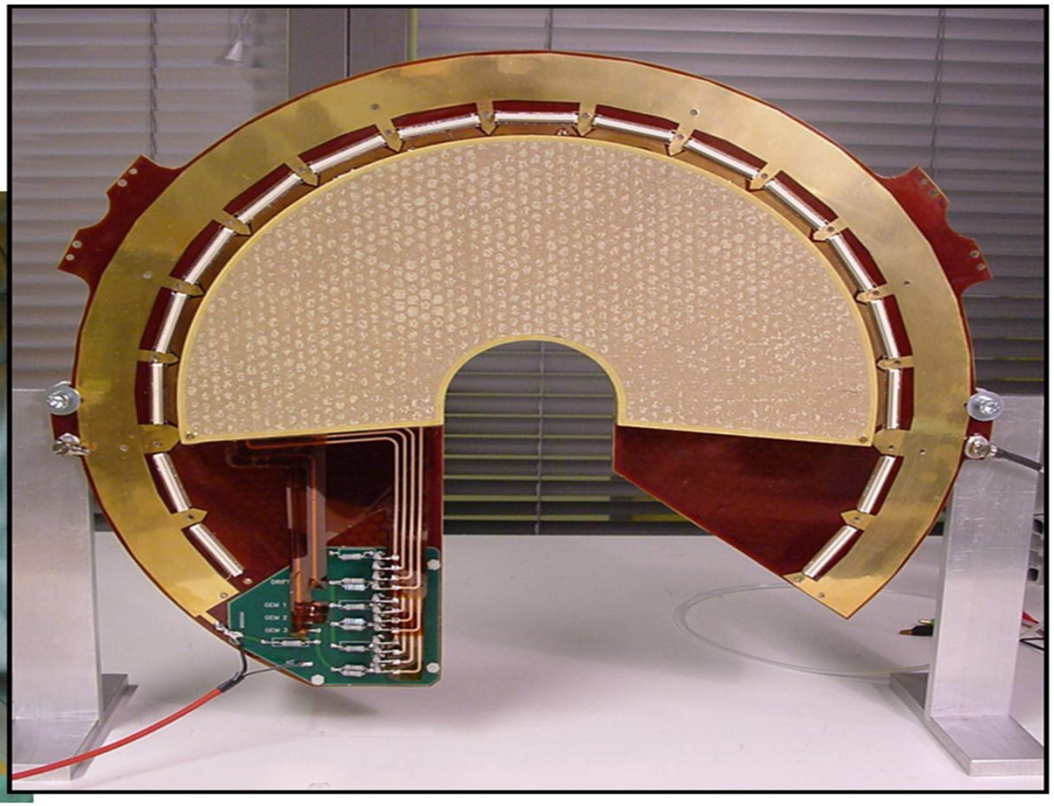
JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

TOTEM GEM Assembling

Currently in production



Up to 50 det.

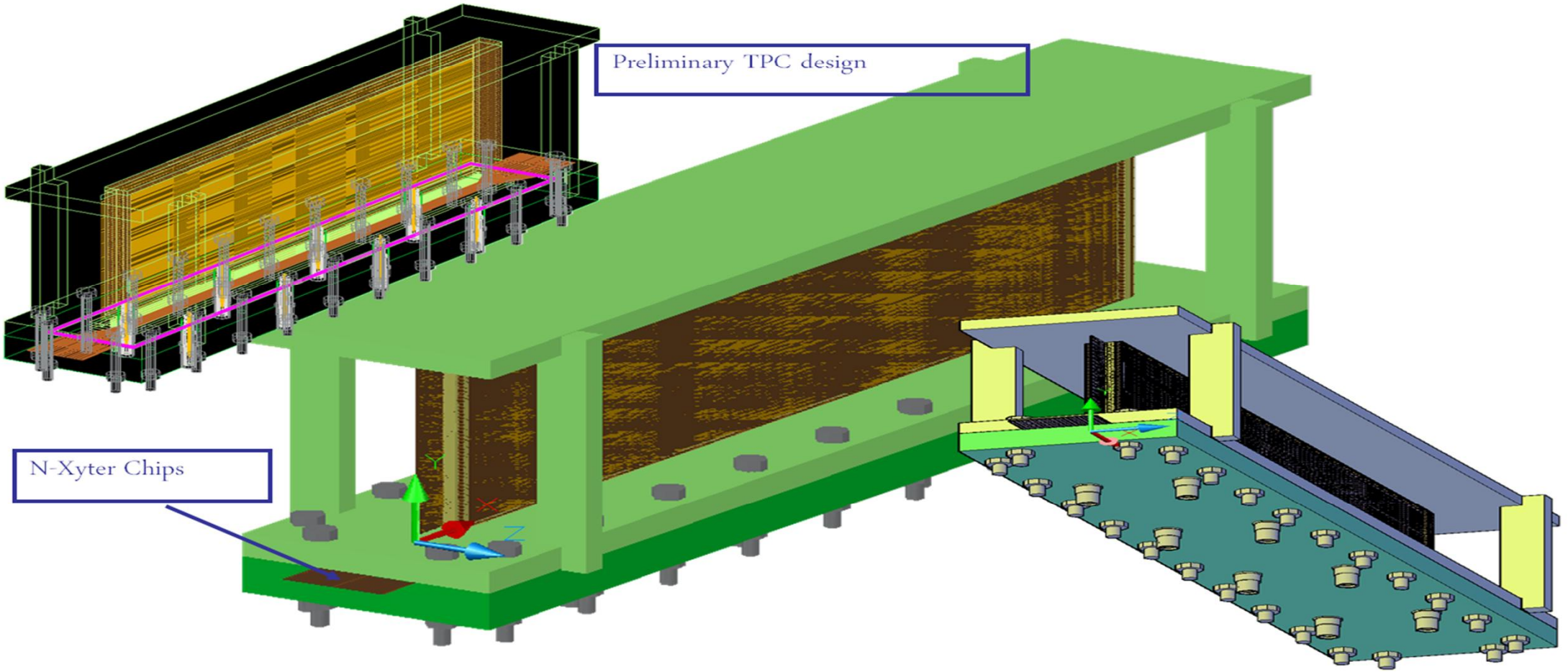


02.09.06 Francisco García – HIP for PANDA Workshop 3

JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

NUSTAR Activities at HIP / Super-FRS Diagnostics

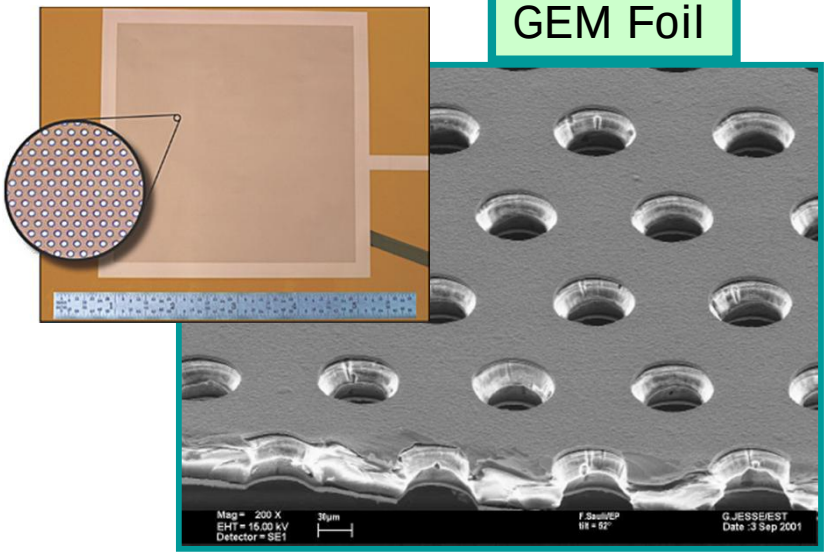
TRACKING TPC DESIGN



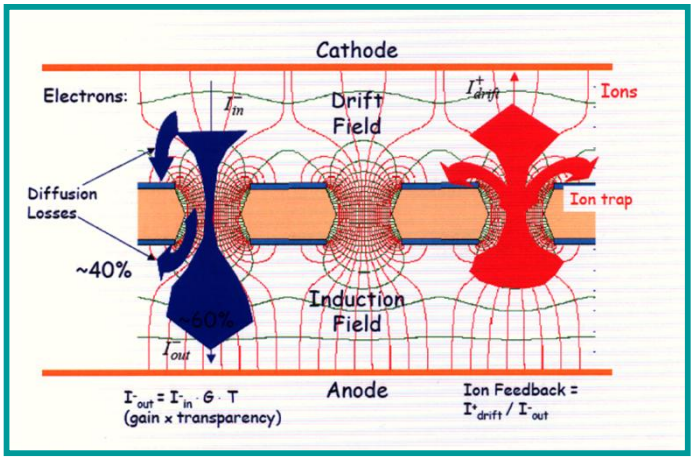
06.10.08 Francisco García – One day Workshop on Finnish Contribution for the FAIR Facility – Helsinki 6

JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

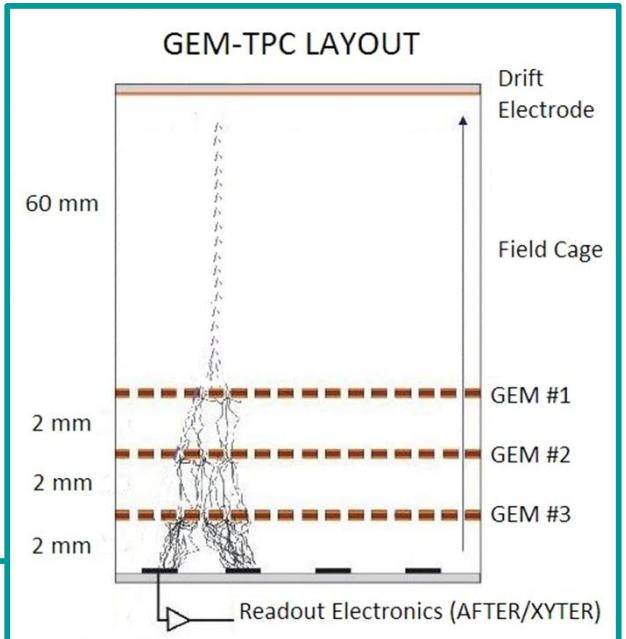
GEM Foil



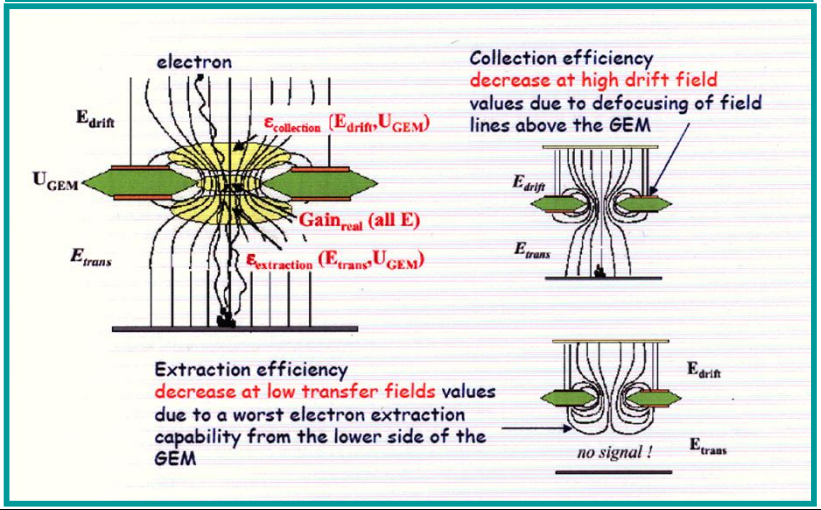
GEM Operation Principle

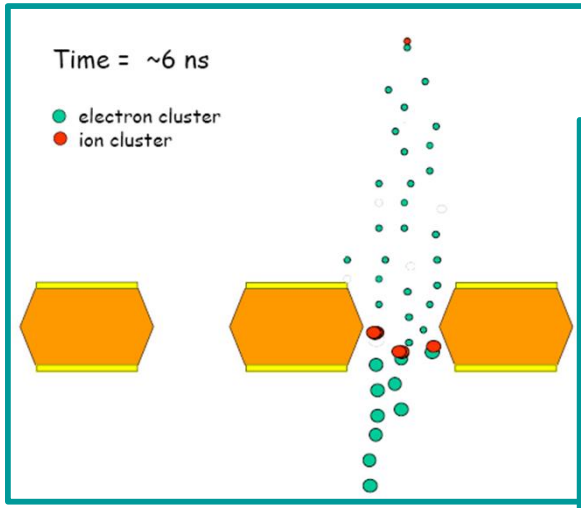


GEM-TPC LAYOUT

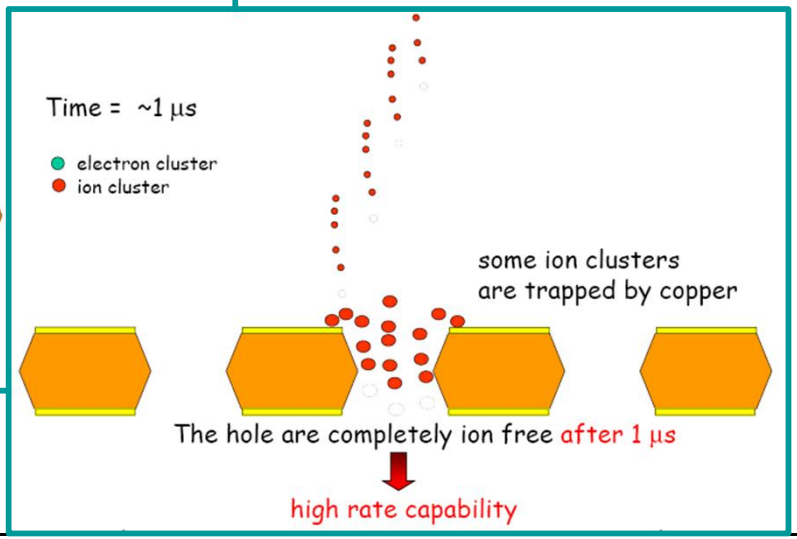


Extraction of the Electron Cloud and Signal Induction

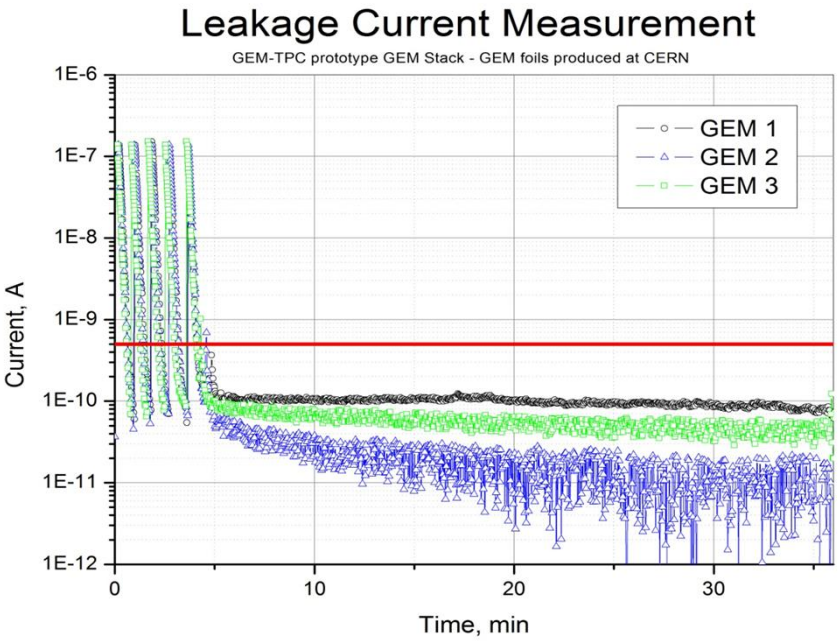




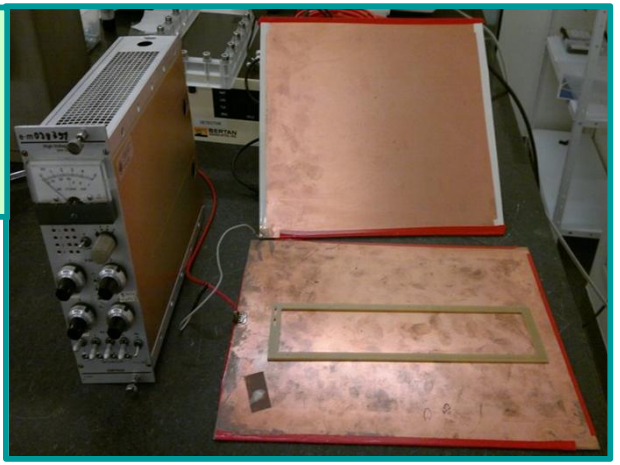
Avalanche development in time domain



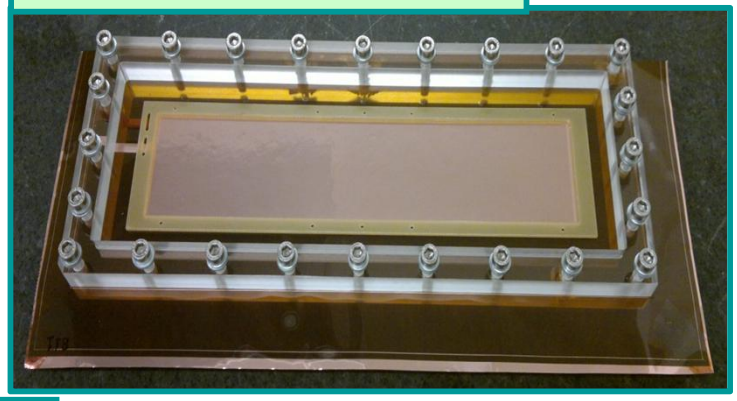
JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

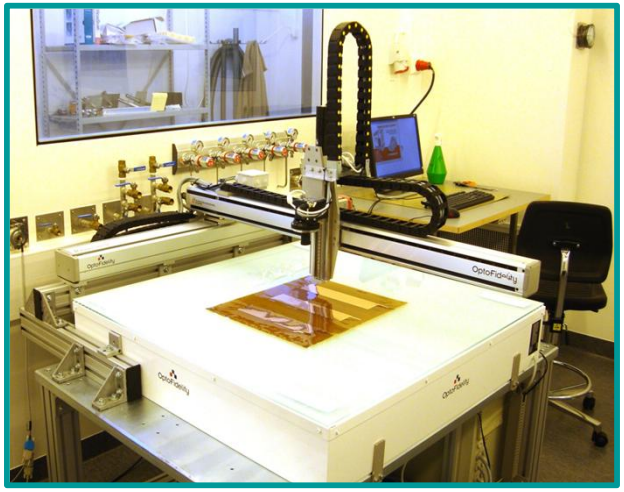


Electrostatic Test for all the frames @ 5 kV Possible breakdowns corrected with Nuvovern

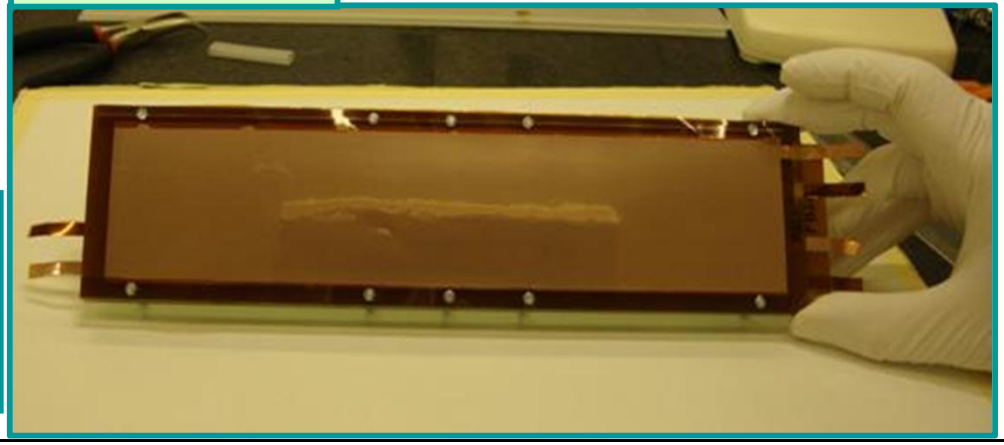


Top frame glued to the GEM foil



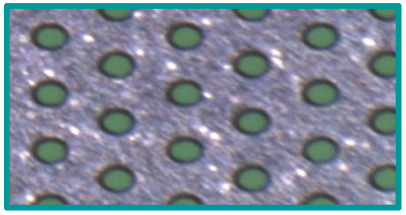


Triple GEM stack



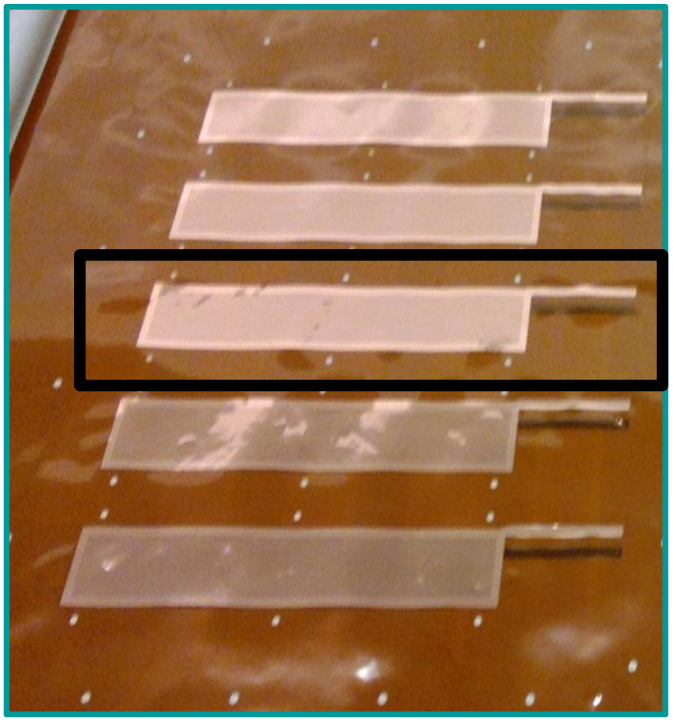
R. de Oliveira et al.

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



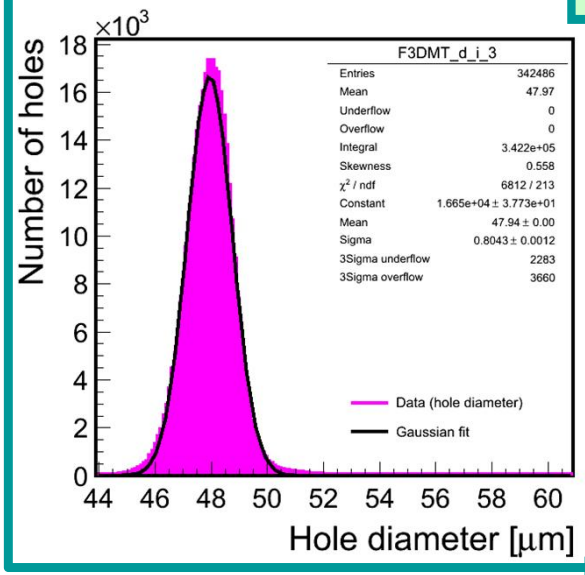
JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

Optical Characterization for the SuperFRS GEM foils



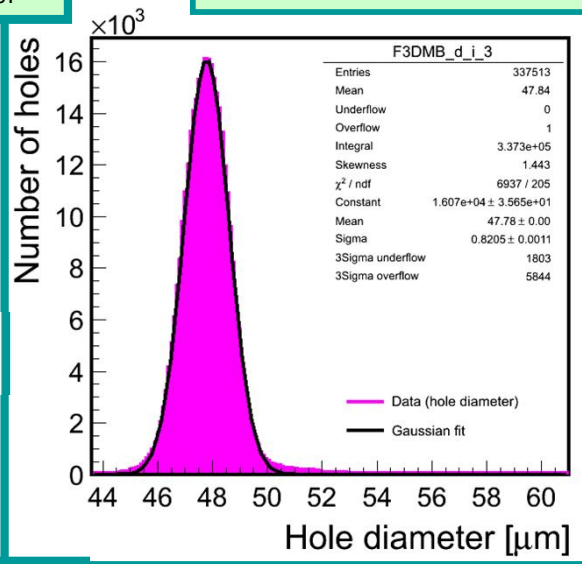
Inner Hole Diameter

A. Karadzhinova, E. Brüken, T. Hildén

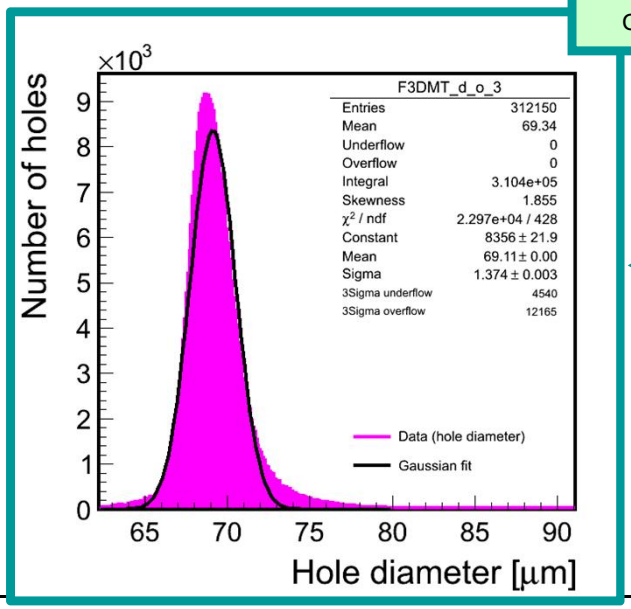


Top

Bottom



Outer Hole Diameter



Top

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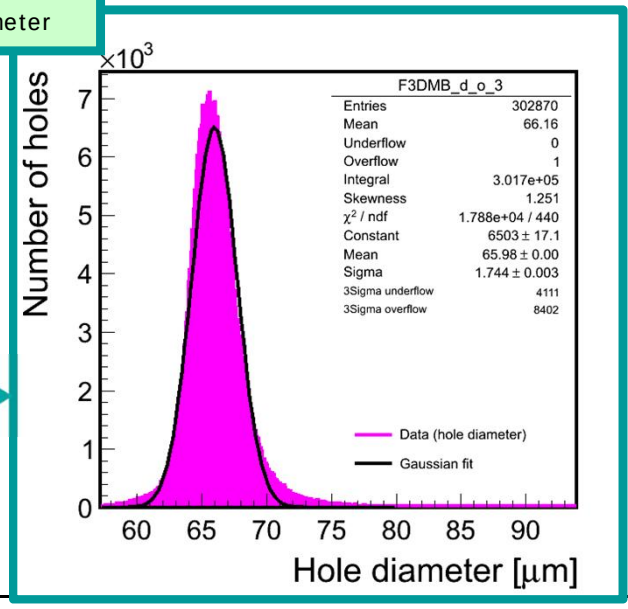
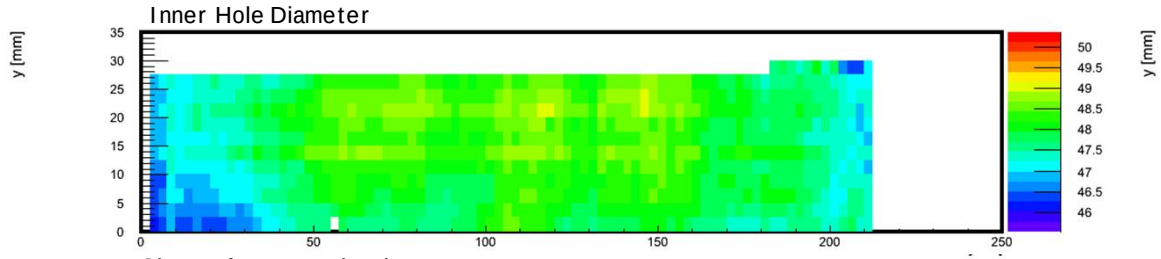
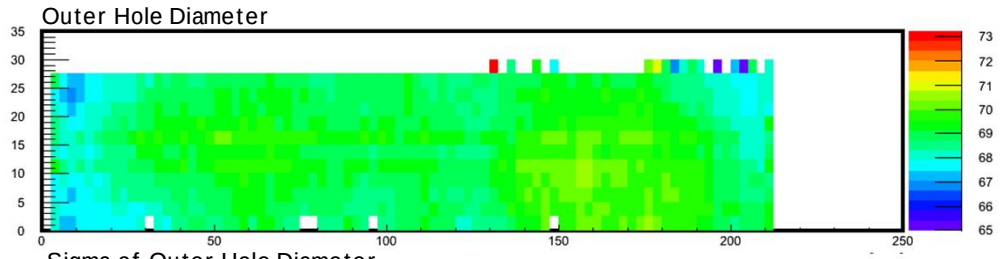
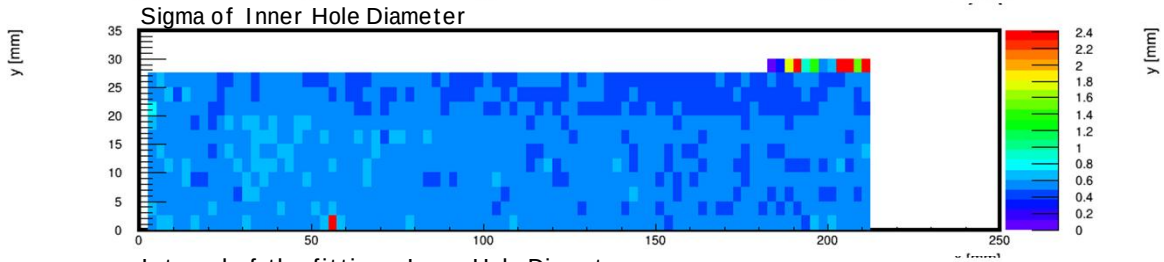


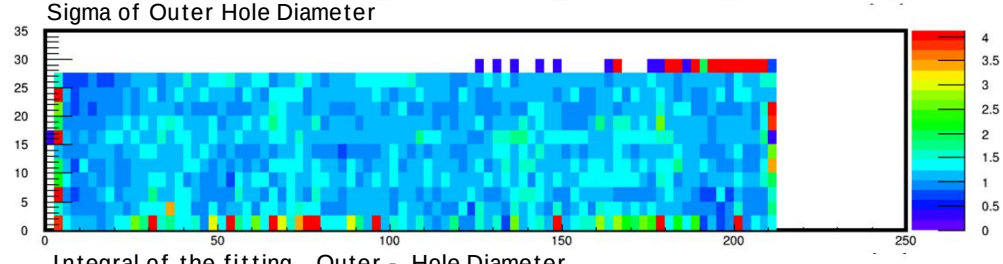
JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

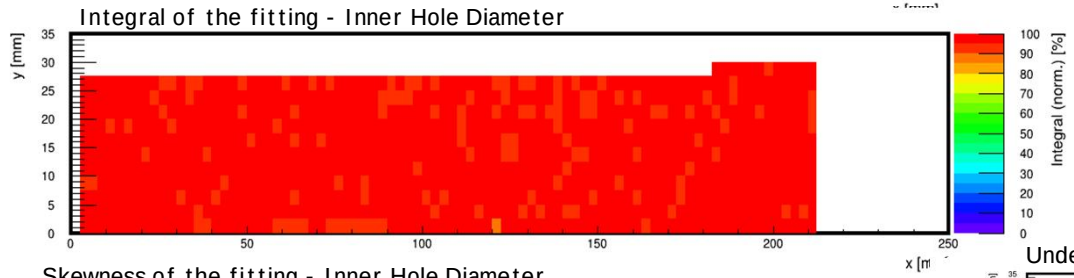
Mapping for all the parameters per GEM foil and per side

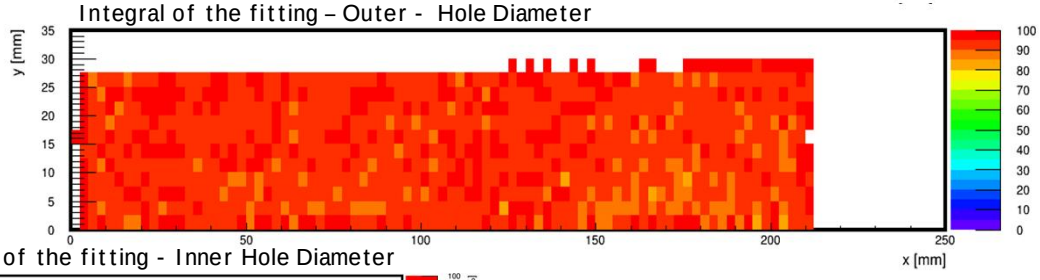


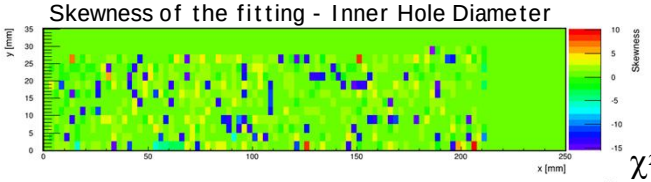


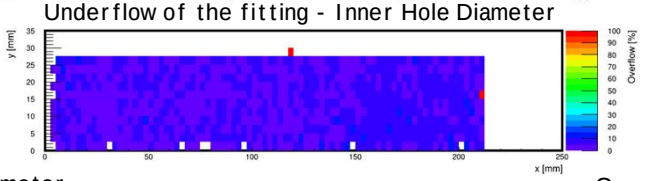


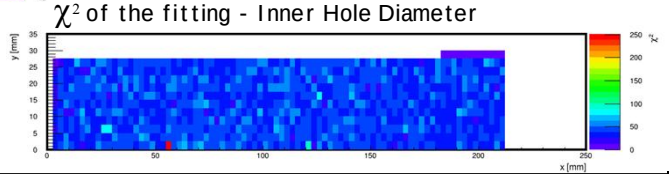


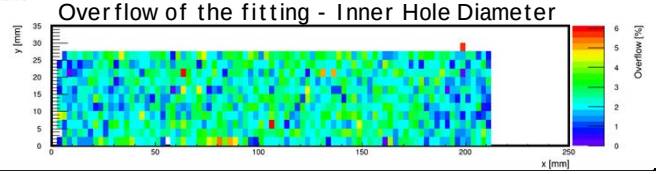








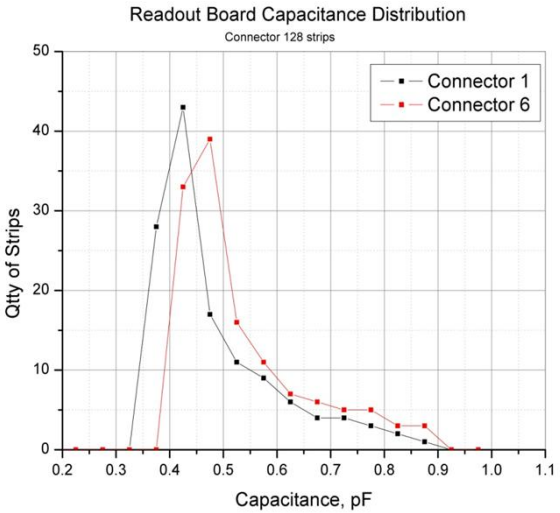




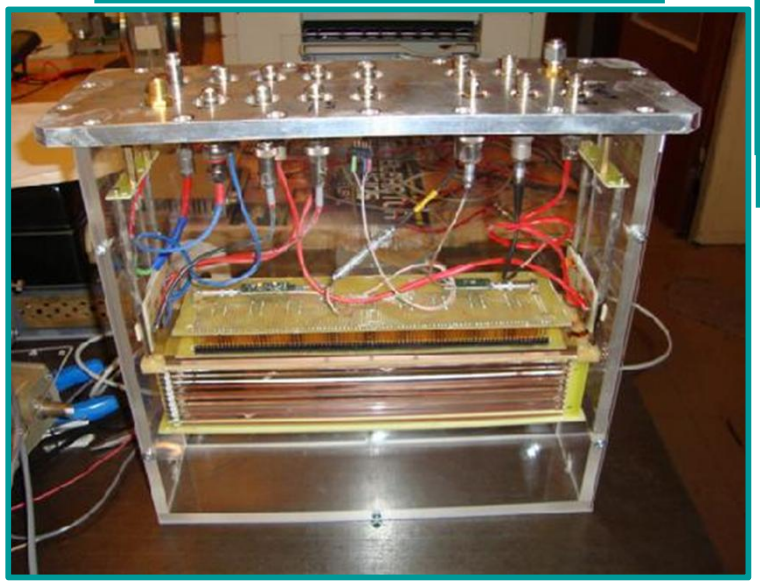
JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

Integration of the HB1, GEM-TPC, Feb. 10

Capacitance measurement setup

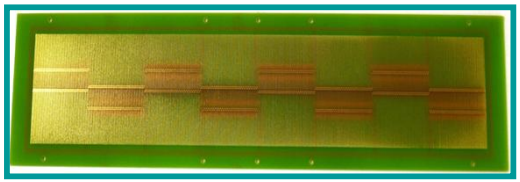


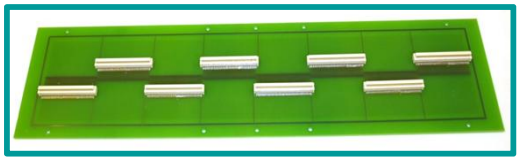
Flange of the GEM-TPC HB1, read out by delayed lines



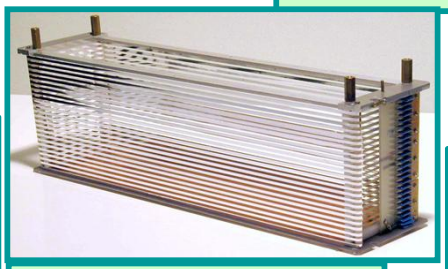
Right: The electrodes of the board with strips of 200 μm width and 500 μm pitch

And 8 Header Panasonic connectors with 130 Pin each



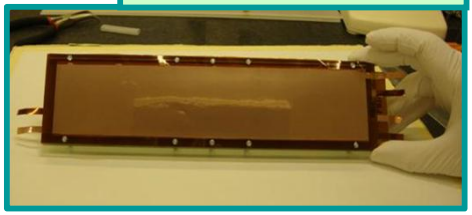


Comenius University - Bratislava

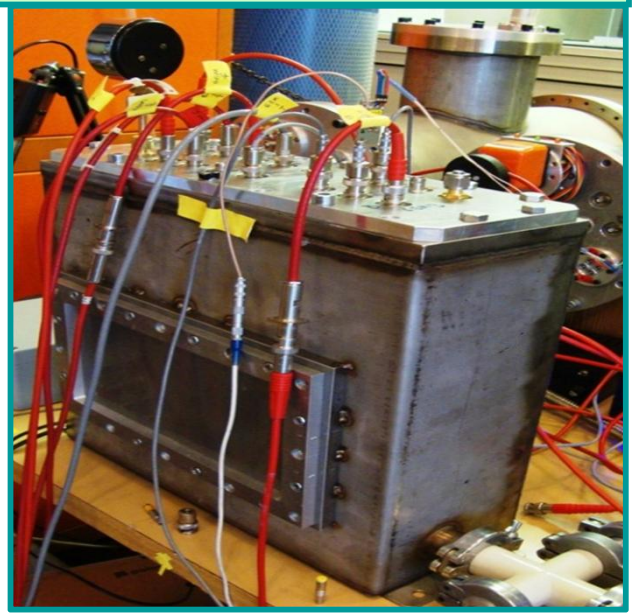


Field cage of 60 mm drift

Triple GEM stack

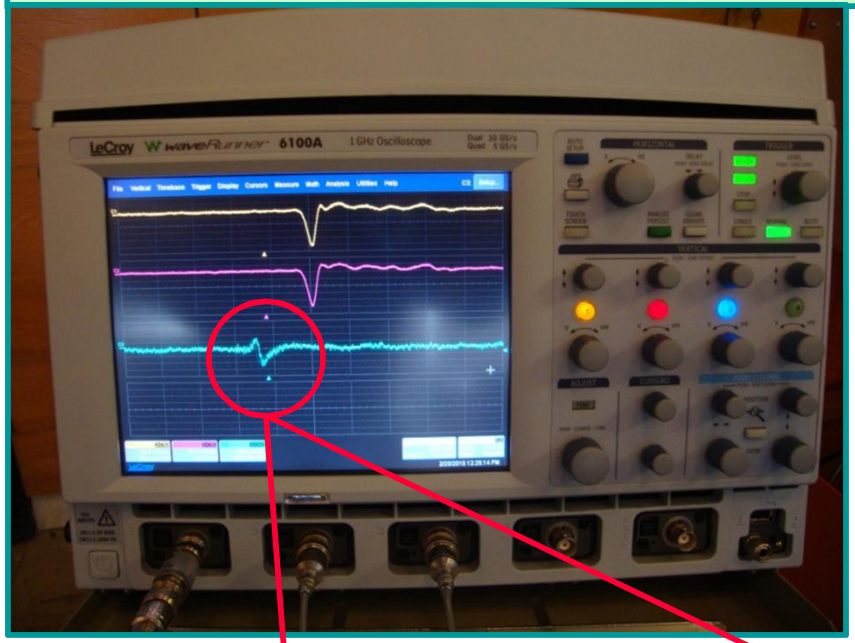


First GEM-TPC called HB1 detector (Helsinki Bratislava prototype 1)



JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

GEM-TPC test in lab at Comenius University



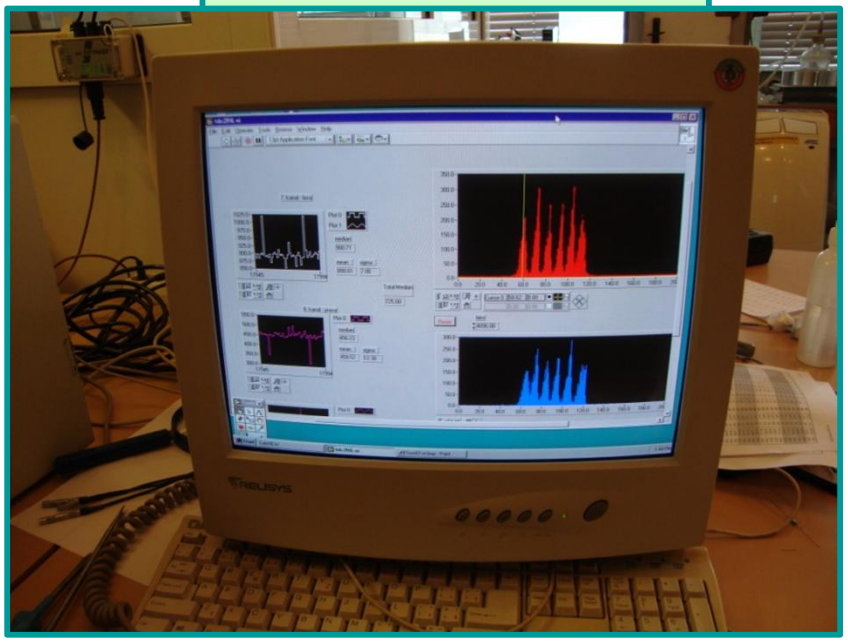
It can be observed:

- 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

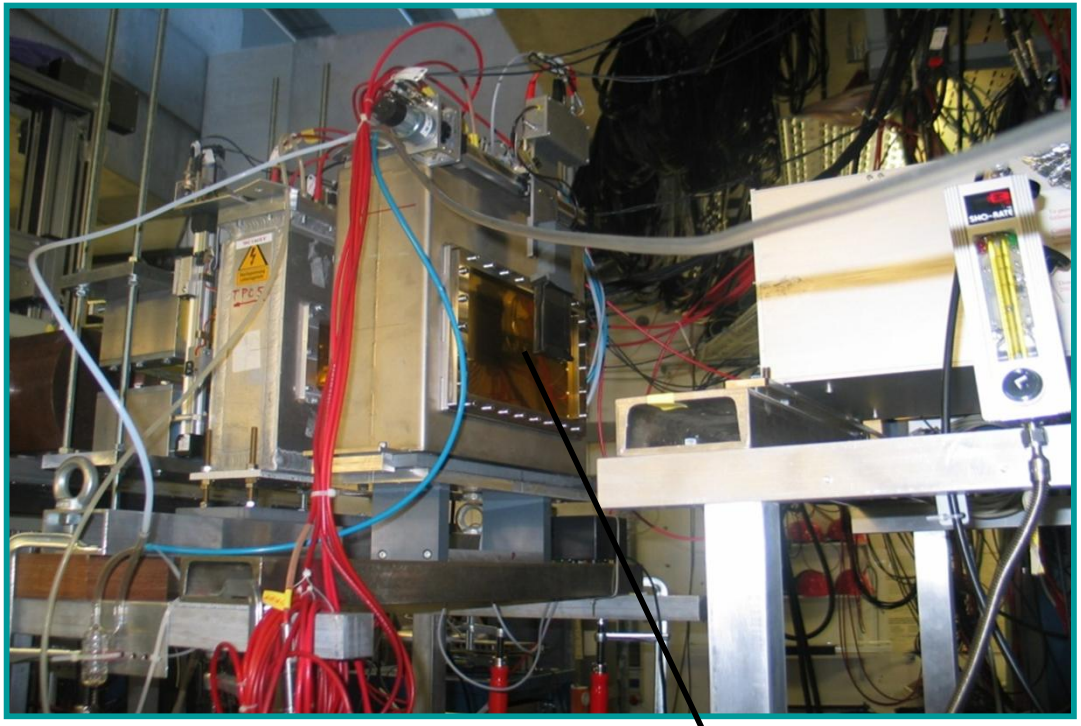
GEM-TPC tracking capabilities for ^{55}Fe

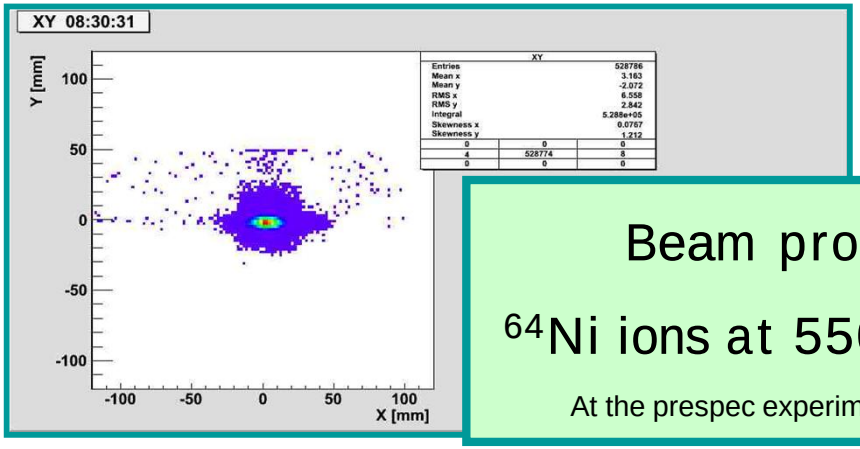


In the picture above there are multiple picks from the different source positions.
The source was not very well collimated therefore a mm scale resolution on X was achieved and the trigger was taken from the bottom of the GEM3

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

GEM-TPC Beam test at GSI - Darmstadt

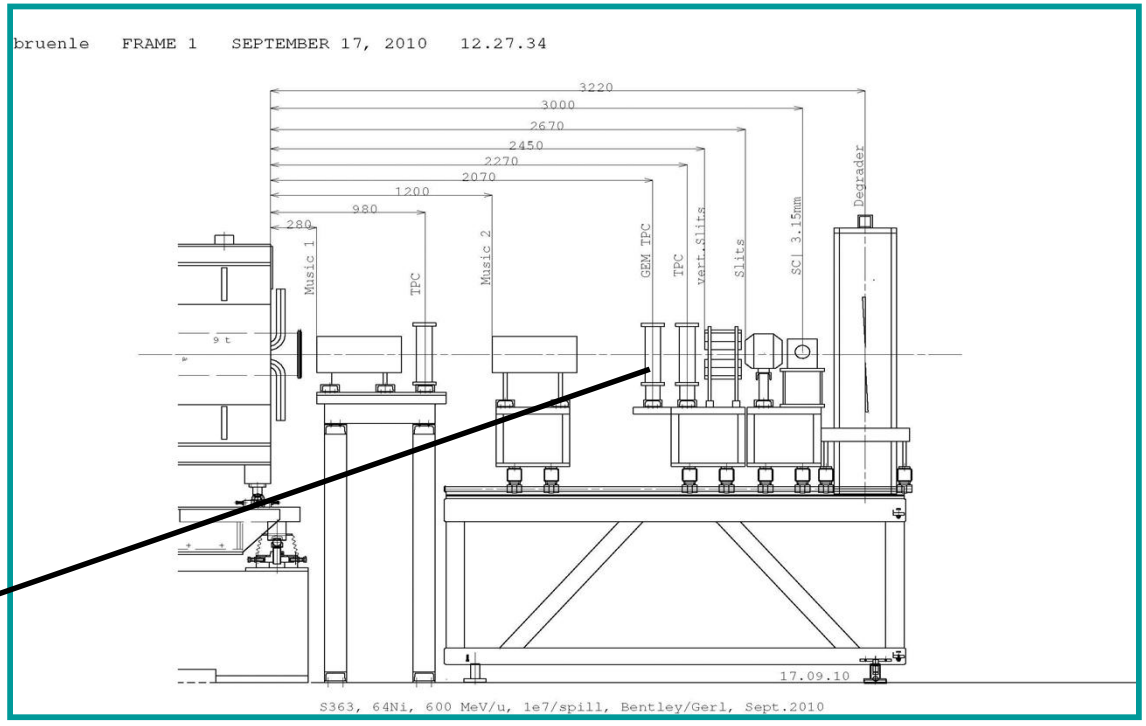


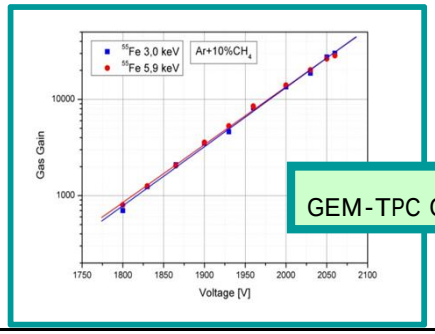


Beam profile

^{64}Ni ions at 550 MeV/u

At the prespec experiment - S363



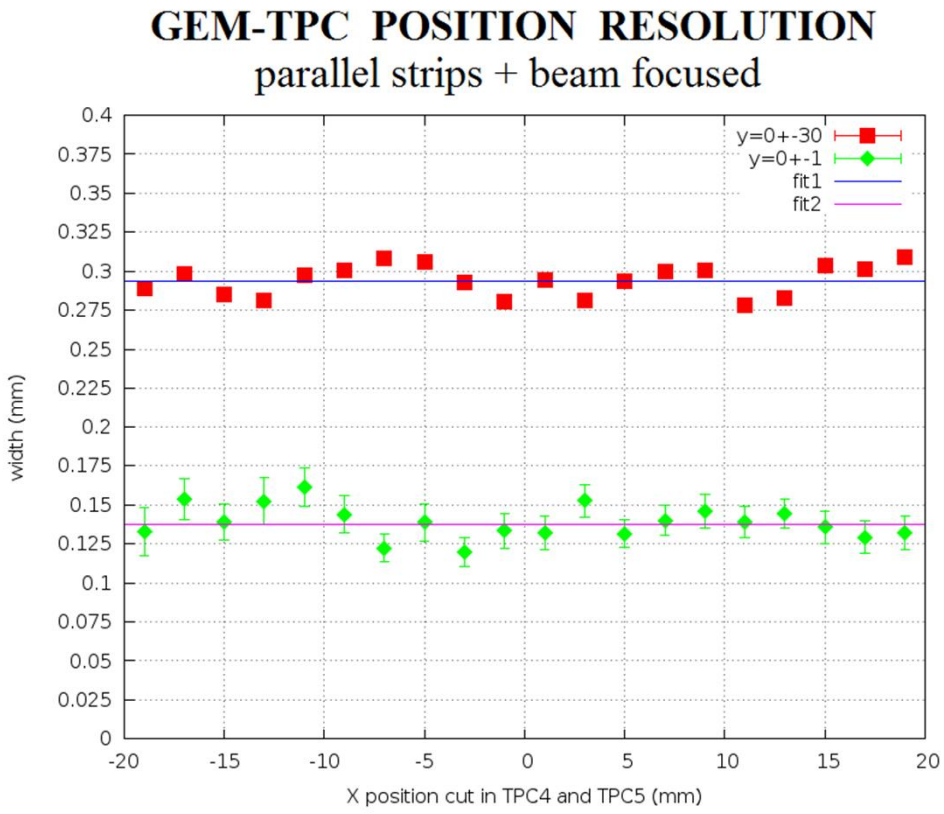


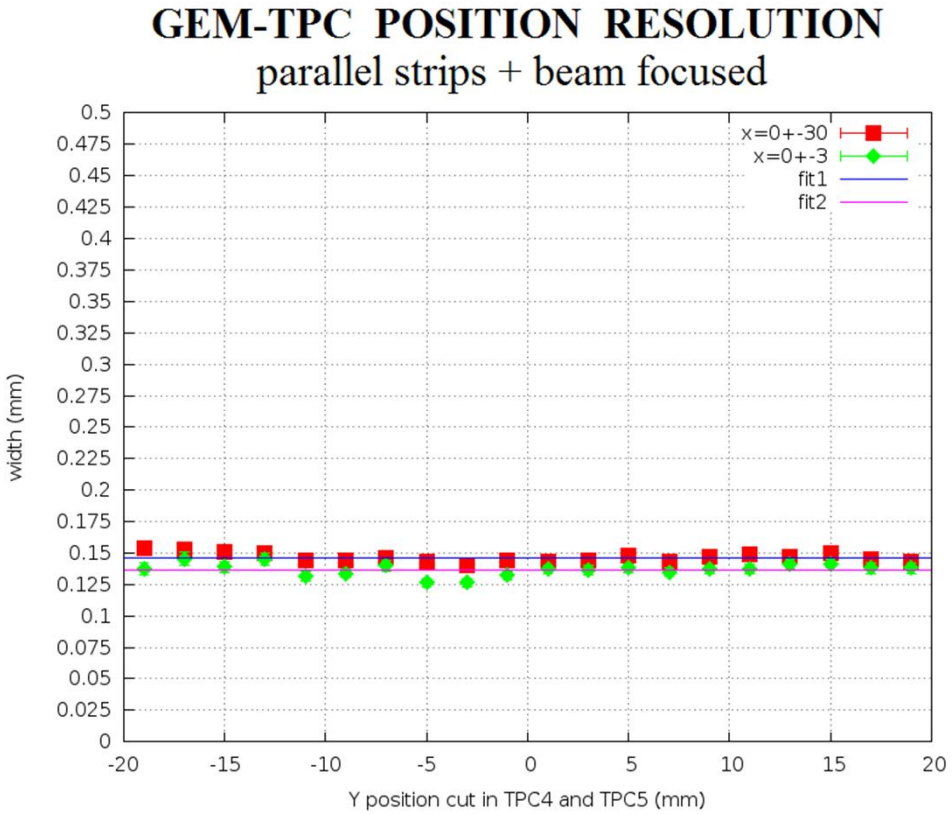
GEM-TPC Gain

GEM-TPC at S4

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

GEM-TPC Results for the Beam test @GSI

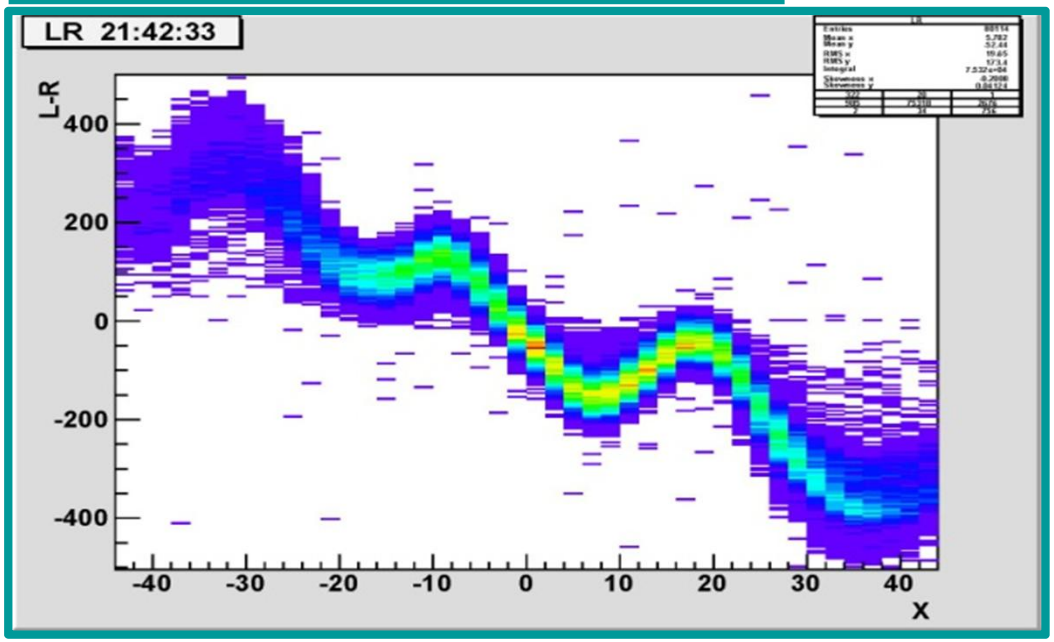


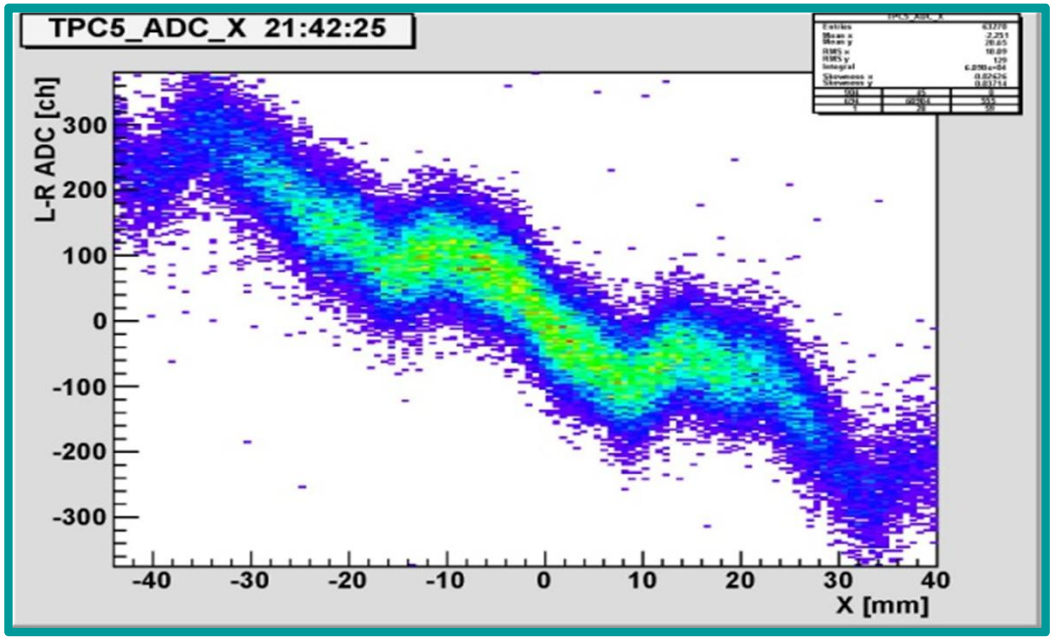


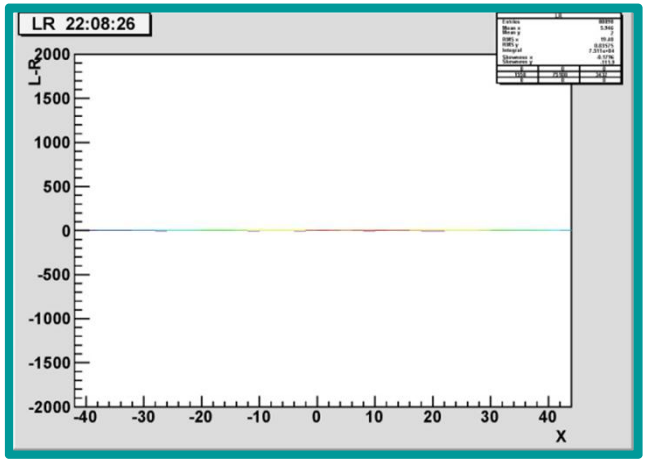
The GEM-TPC shows that the resolution in Y (Drift) reaches value around 130 μm and on X between 130 to 300μm

JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

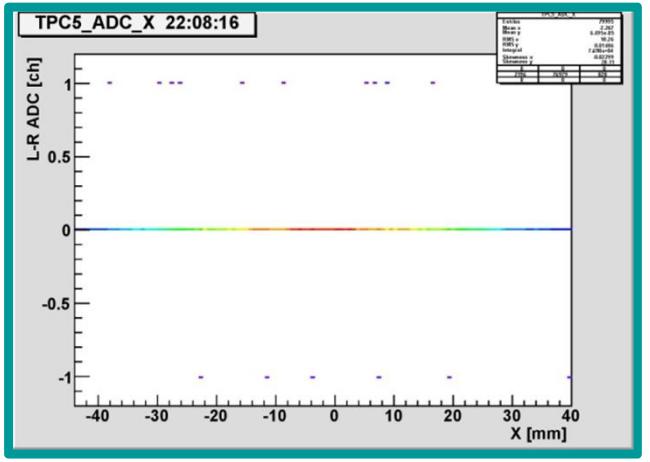
GEM-TPC Beam test Results







On the top left GEM- and on the right the C-Pad TPCs exhibit some modulation.
On the bottom after applying corrections to the preAmps signals.



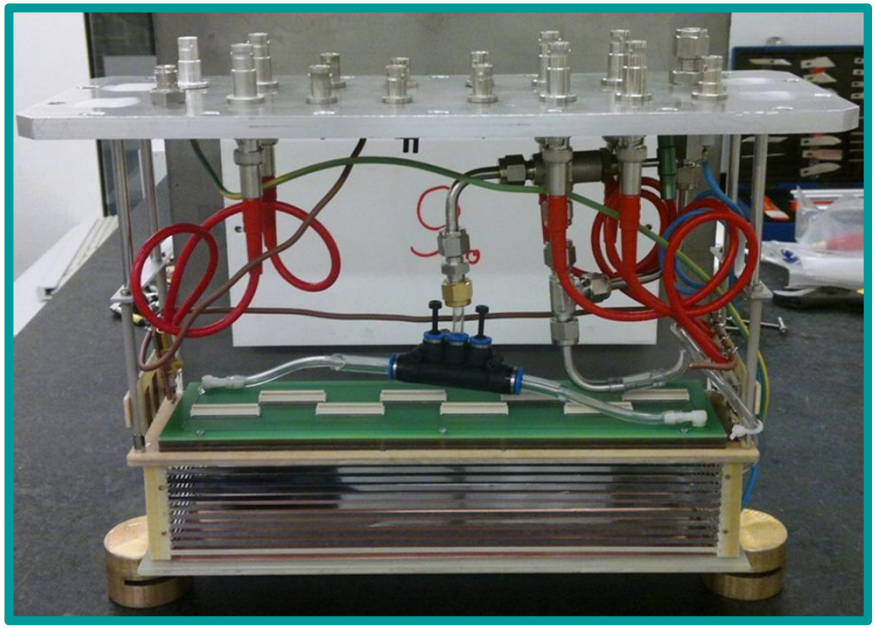
JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

We were confident that this Concept of a GEM-TPC for tracking at the Super-FRS could be a potential candidate

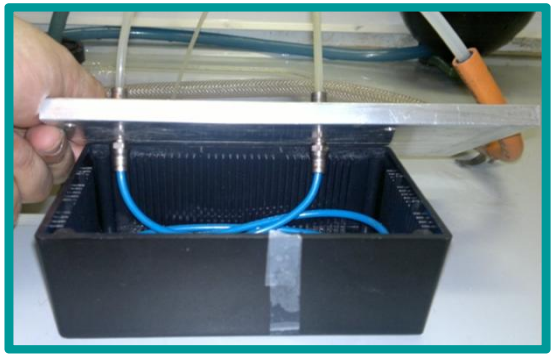
- The requirements of Spatial resolution were fulfilled and even improved.
- The detector shows good stability; run for several days very without sparks.
- The requirements, in terms of rate capability were not reach.
- In order to increase the counting rate of the detector, we would need to use high density high, speed electronics.

JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

The second GEM-TPC HB3 is now on development

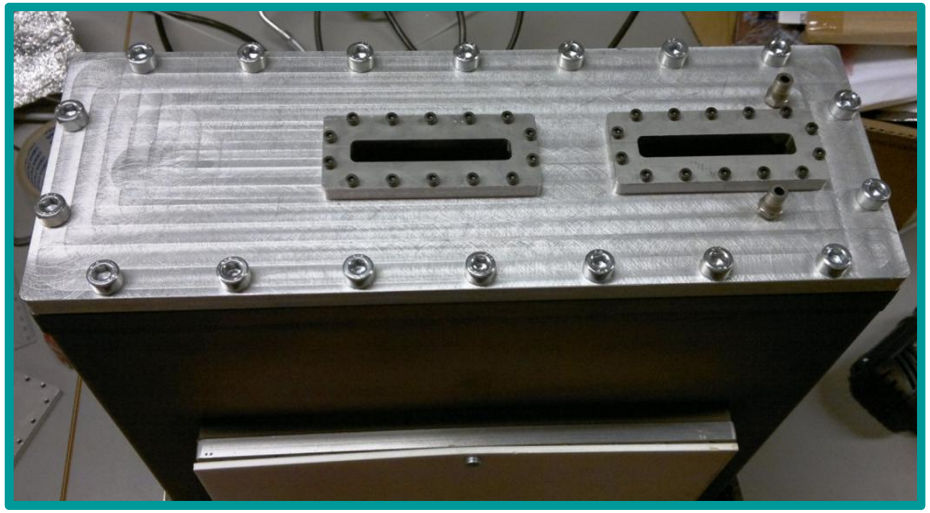


GEM stack and readout board together with the Field cage

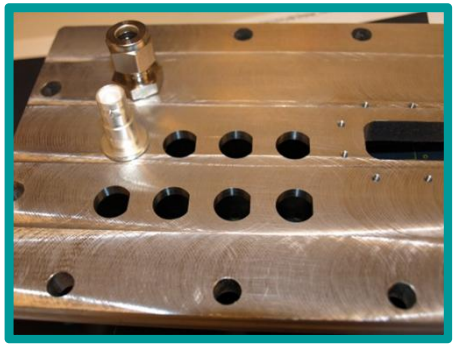


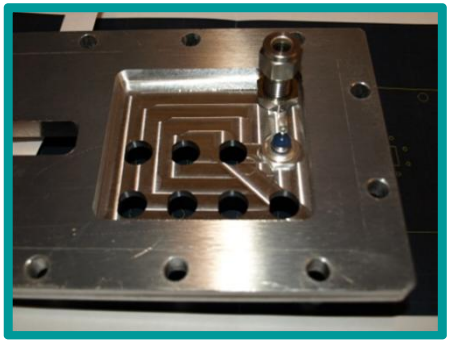
Cooling connectors and flange test bench

HB3 Top Flange



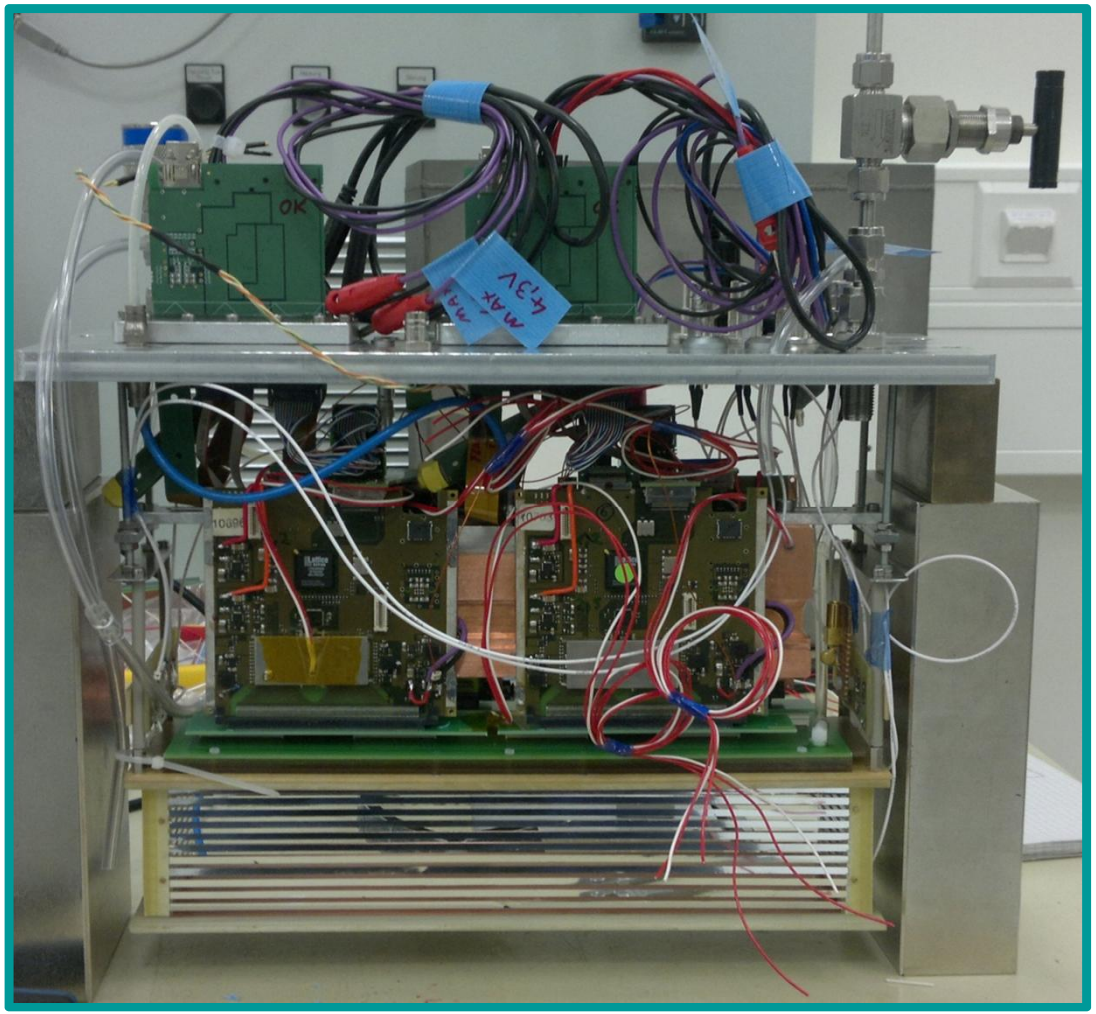
HB3 Top Flange from inside



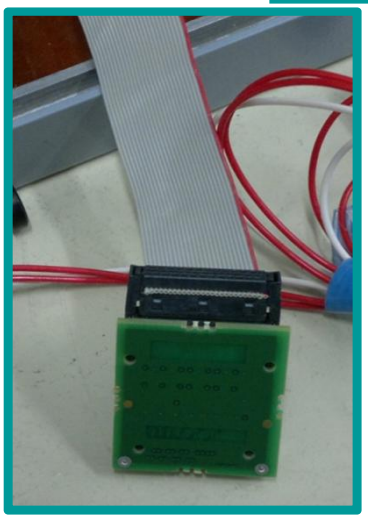


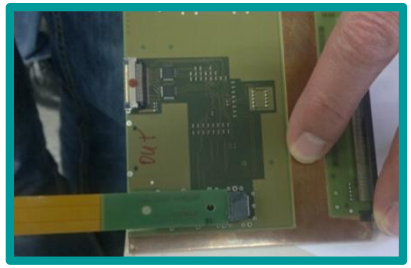
JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

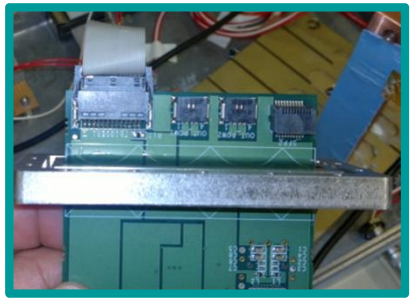
HB3 with four GEMEX cards



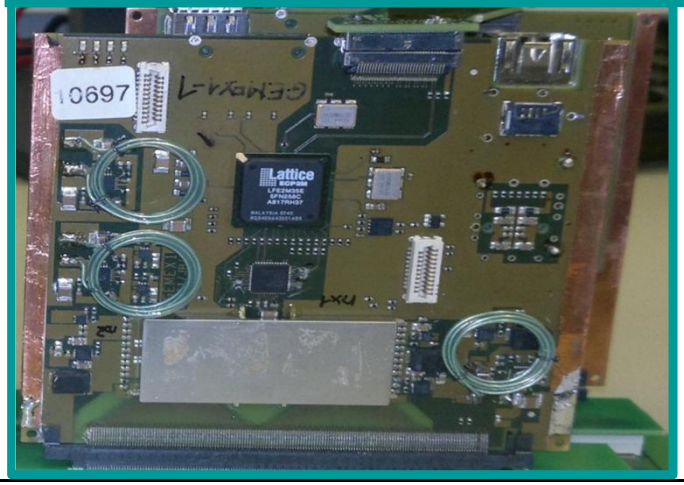
The Noisy guys





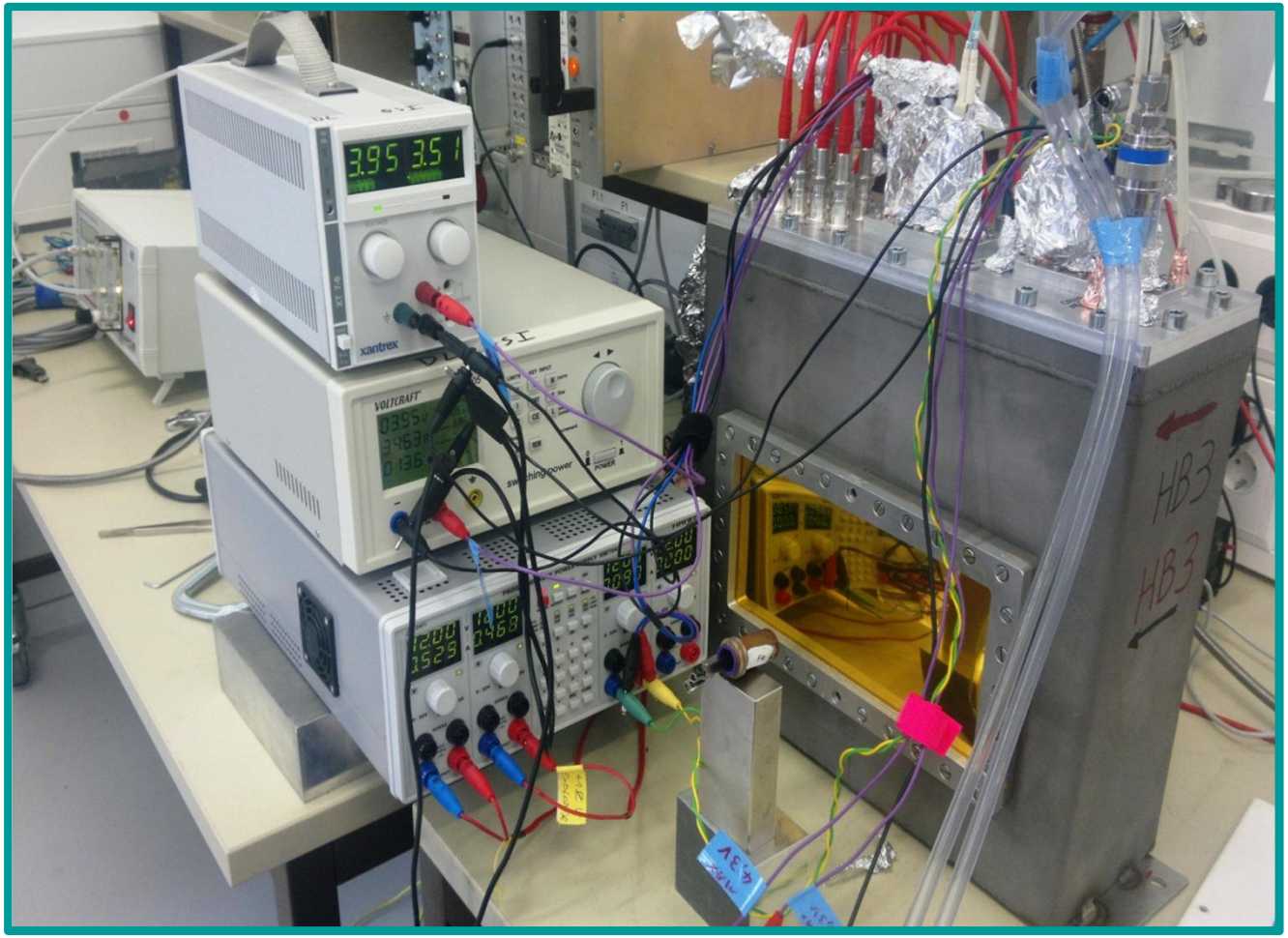


GEMEX cards provide by B. Voss et al.

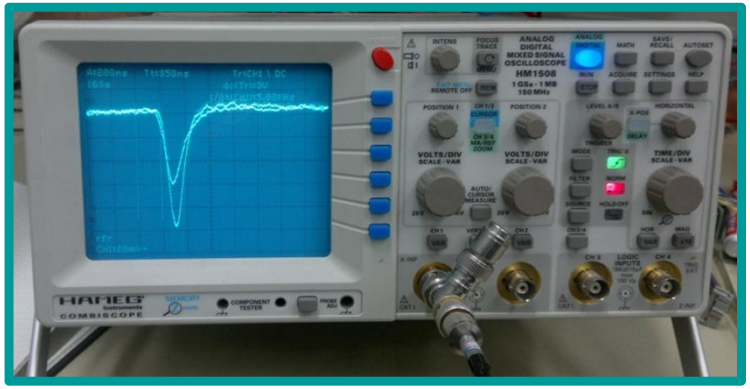


JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

HB3 under test in the Lab.

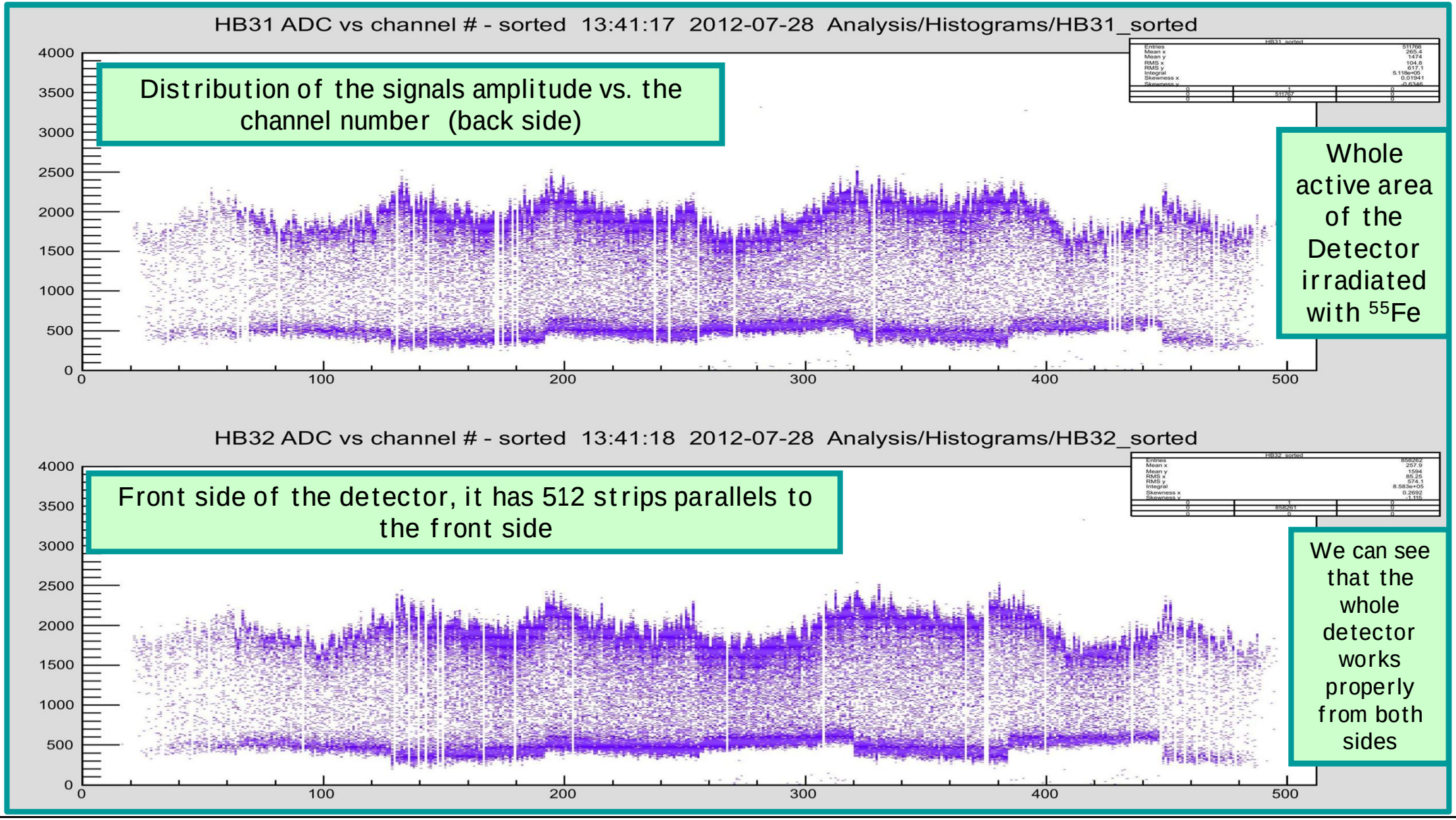


^{55}Fe Signals in the Lab



Noise of 32 MHz from Explode clock in the trigger lines

JOURNEY ACROSS THE GEM-TPC DEVELOPMENT



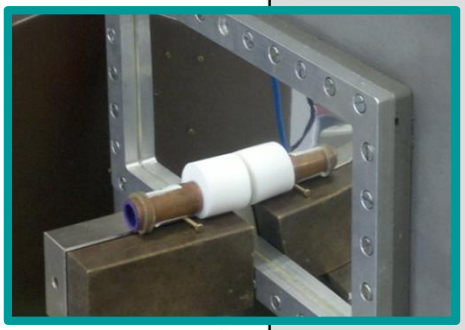
JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

HB32 ADC vs channel # - sorted 16:35:56 2012-07-28 Analysis/Histograms/HB32_sorted

Distribution of the signal amplitude for the Front side of the detector

HB32_sorted		
Entries		21164
Mean x		242.8
Mean y		1339
RMS x		71.02
RMS y		584.5
Integral		2.116e+04
Skewness x		0.03673
Skewness y		-0.3931
0	0	0
0	21164	0
0	0	0

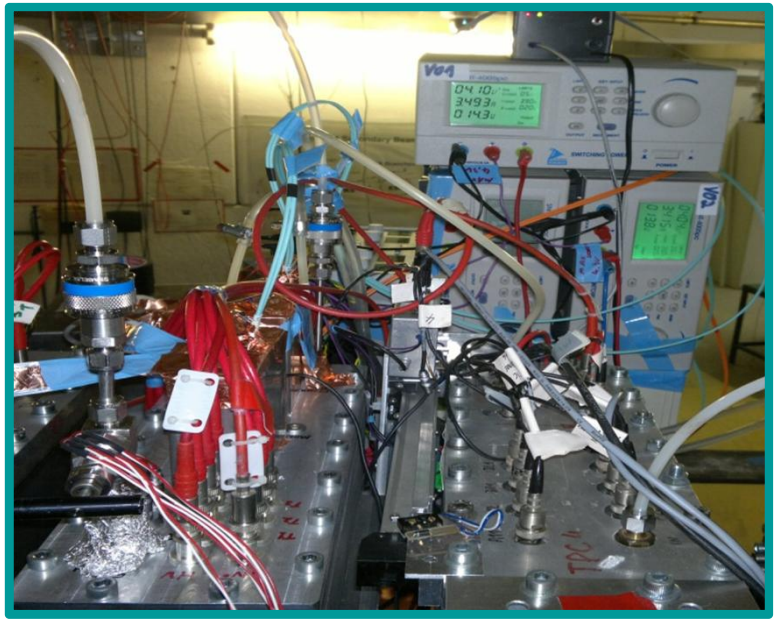
Irradiated with a narrow beam using small hole collimator



JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

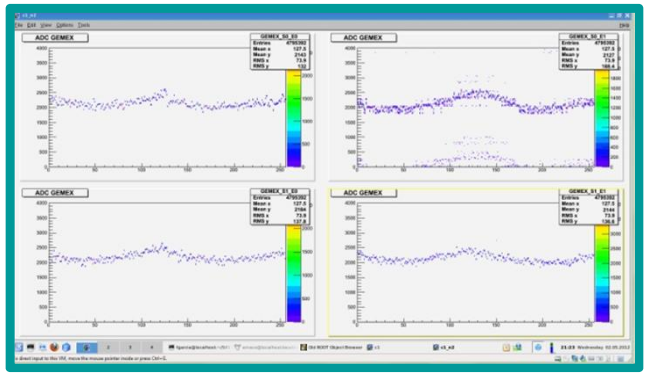
HB3 @ S2 and ready to take the Beam of ^{197}Au at 770 MeV/u

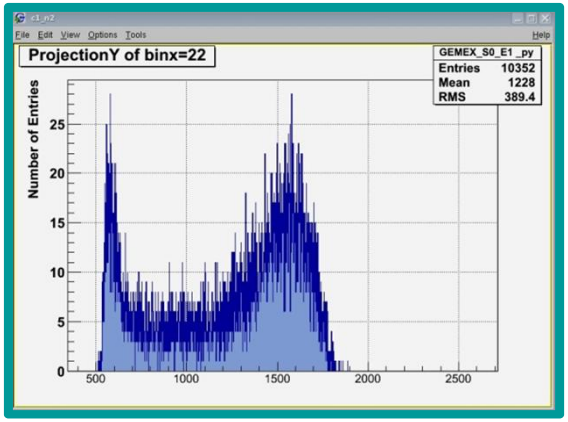
Slow Control and Power - ok



JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

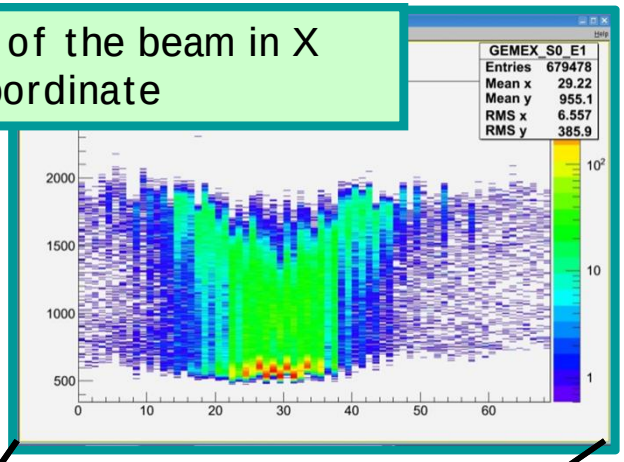
Pedestals of 4 GEMEX cards and Pulse Height distribution of one channel





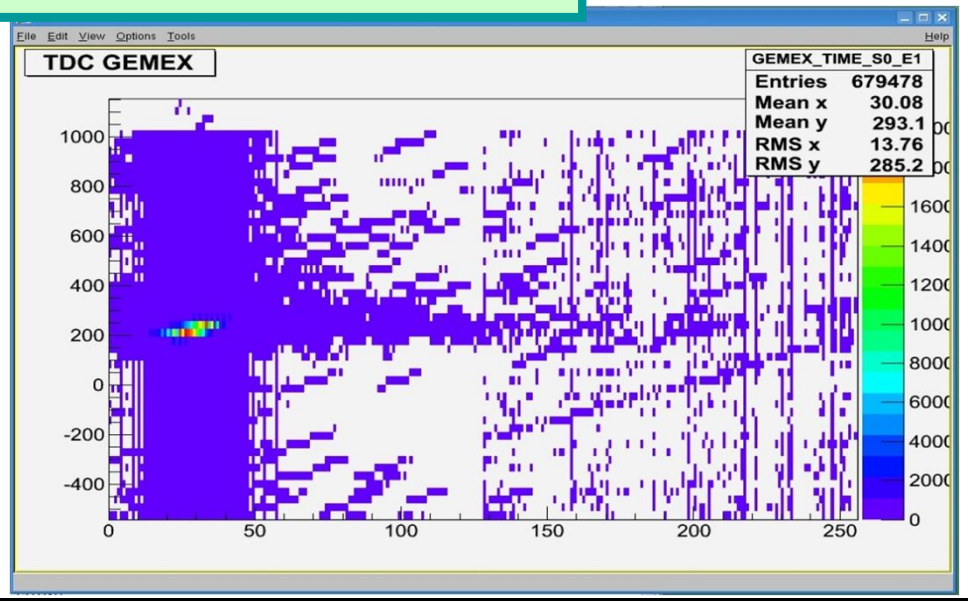
Projection of the beam in X coordinate

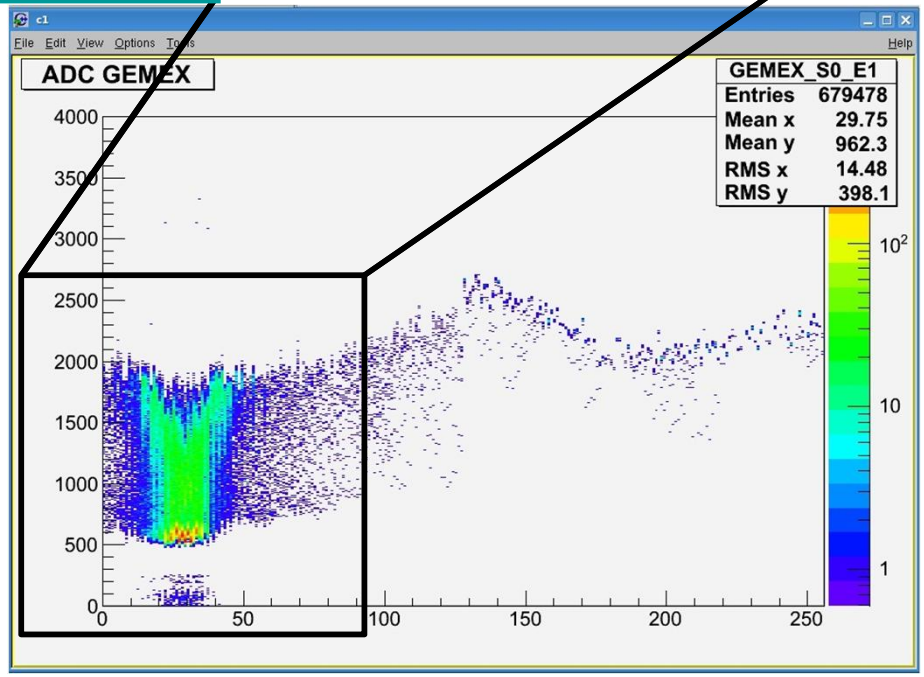
In X direction the beam size was of 7 mm. HB3 shows 15 channels at 0.5 mm per channel



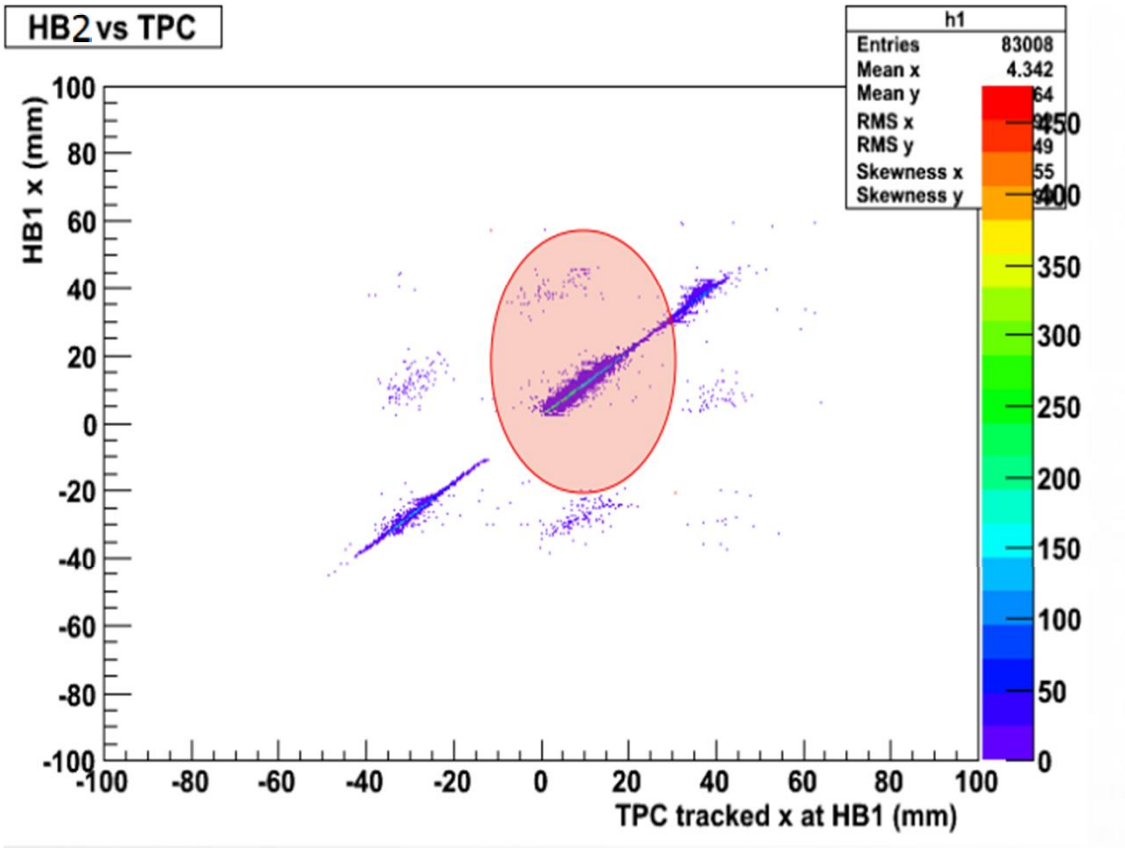
Projection of the beam in Y coordinate

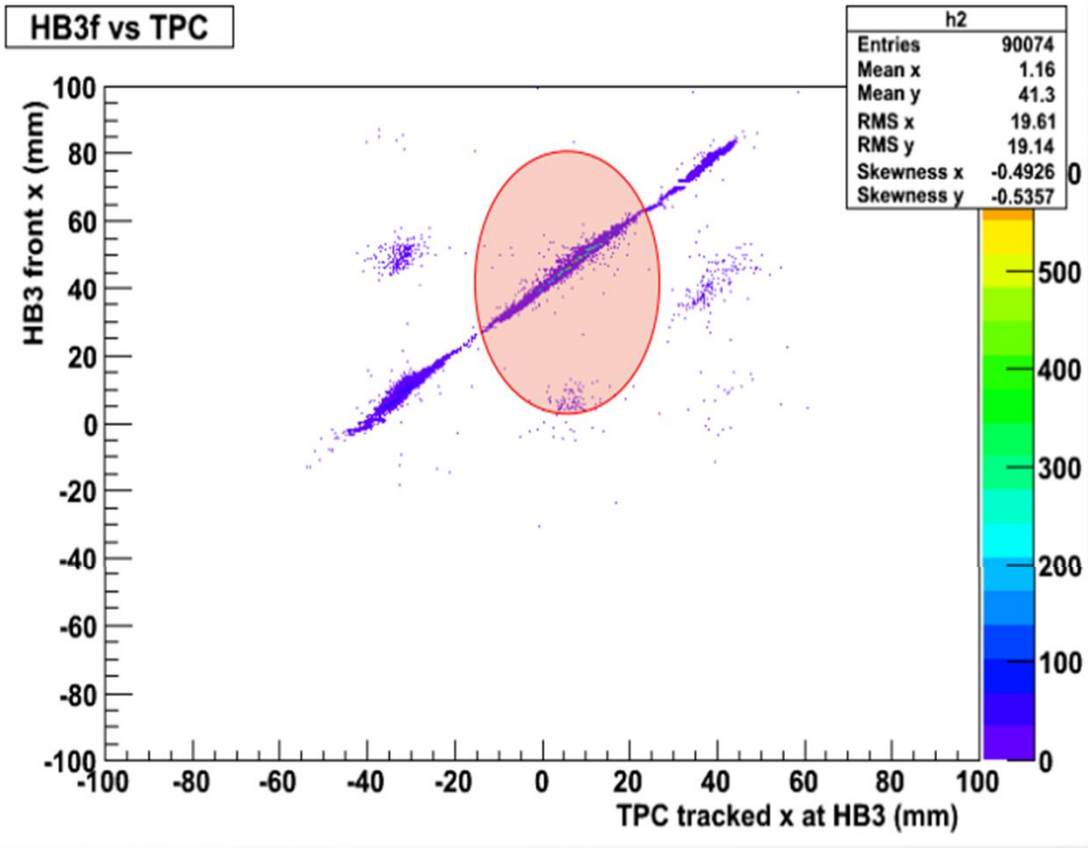
In Y direction the was at the center. HB3 shows 200 counts which is a systemic error to be corrected during data analysis





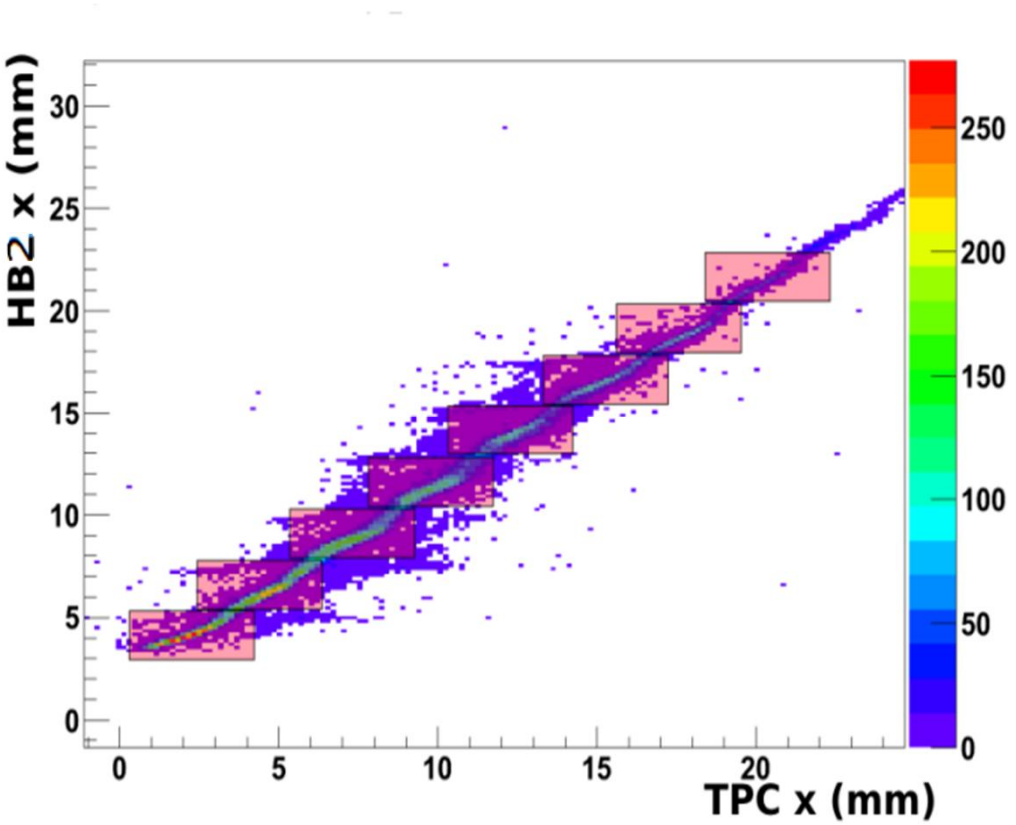
JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

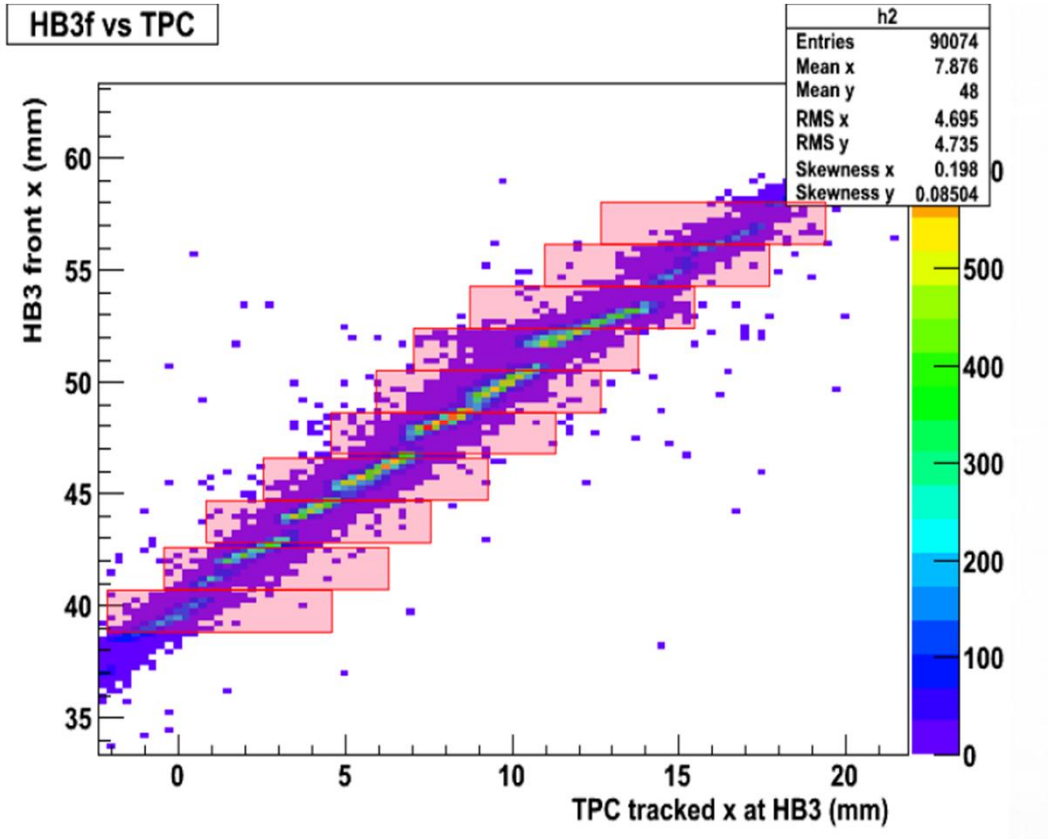




Position correlations between the TPC tracker and the HB2 and HB3 for the run 150. It can be seen that the GEM-TPC record similar distribution as in the tracker

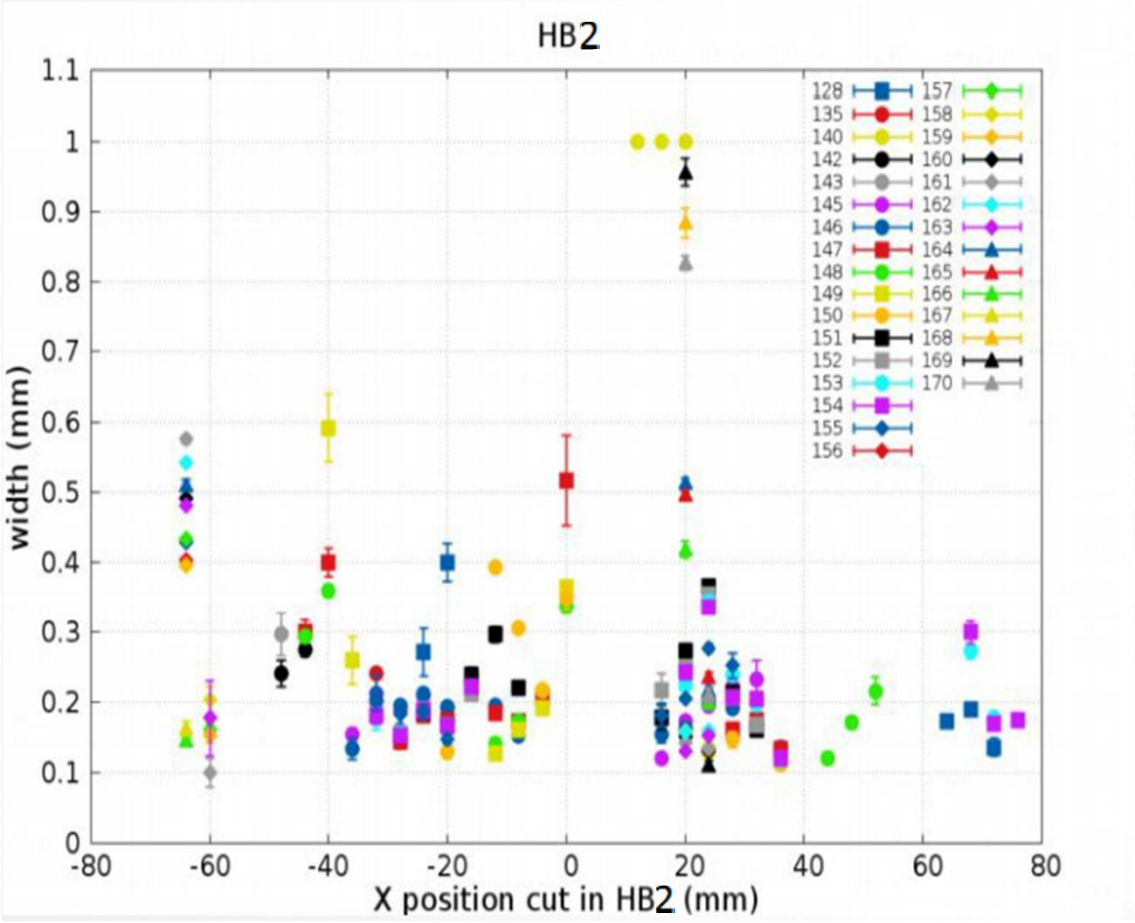
JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

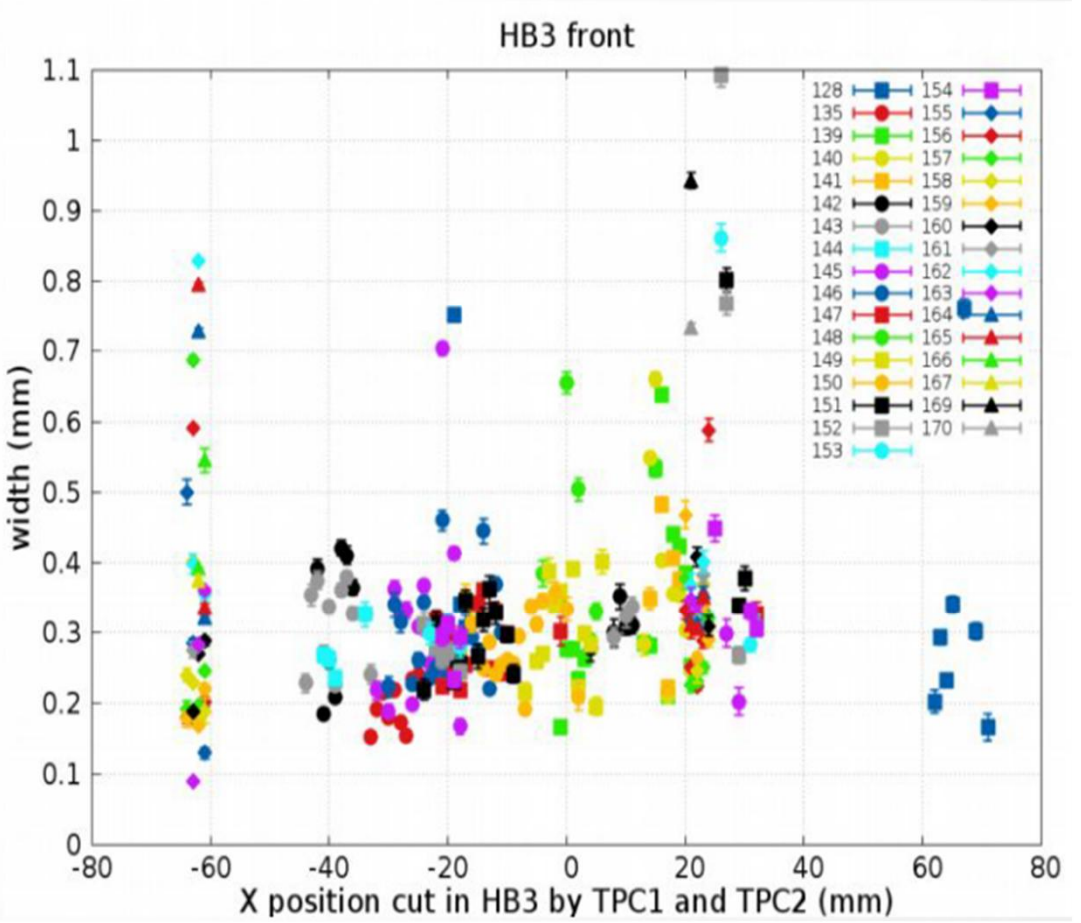




The nonlinearity for the HB2 and HB3 for the run 150. Variations are due to the fact that the baseline fluctuations were not monitored during the data taken.

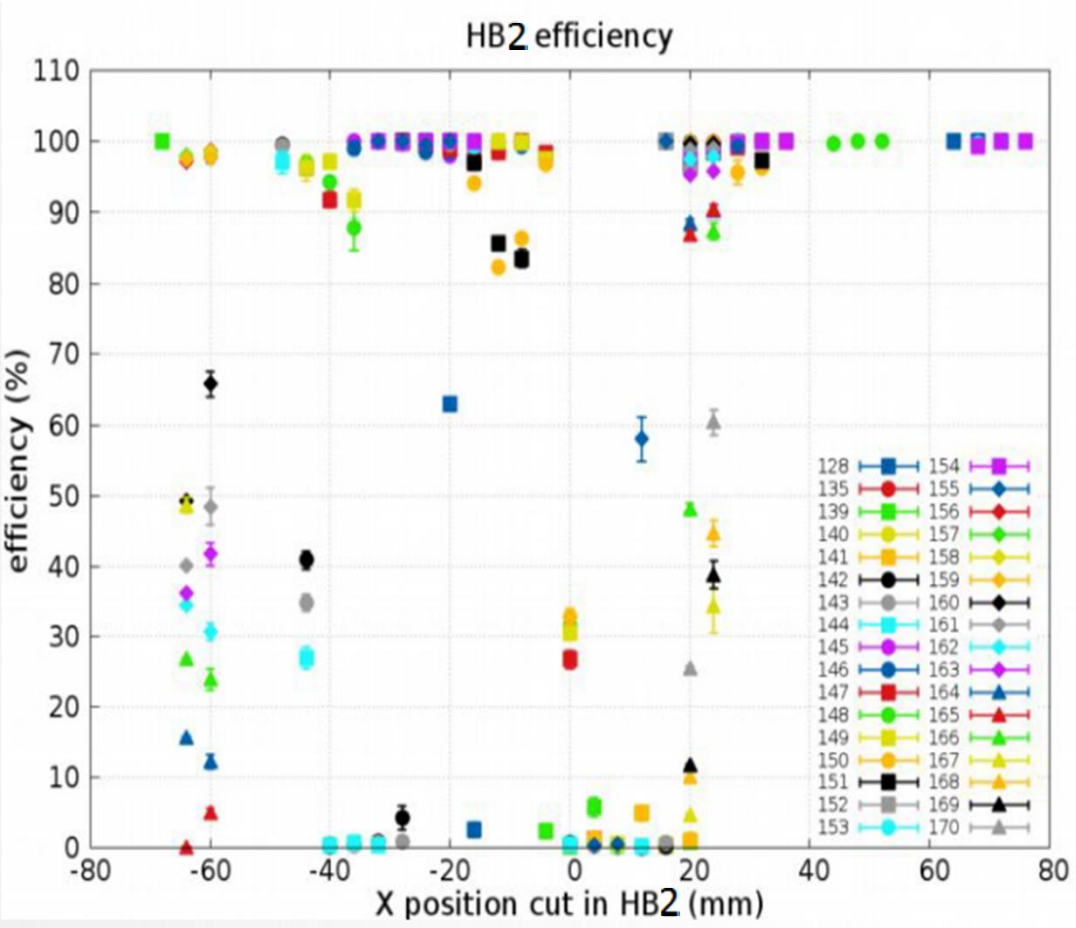
JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

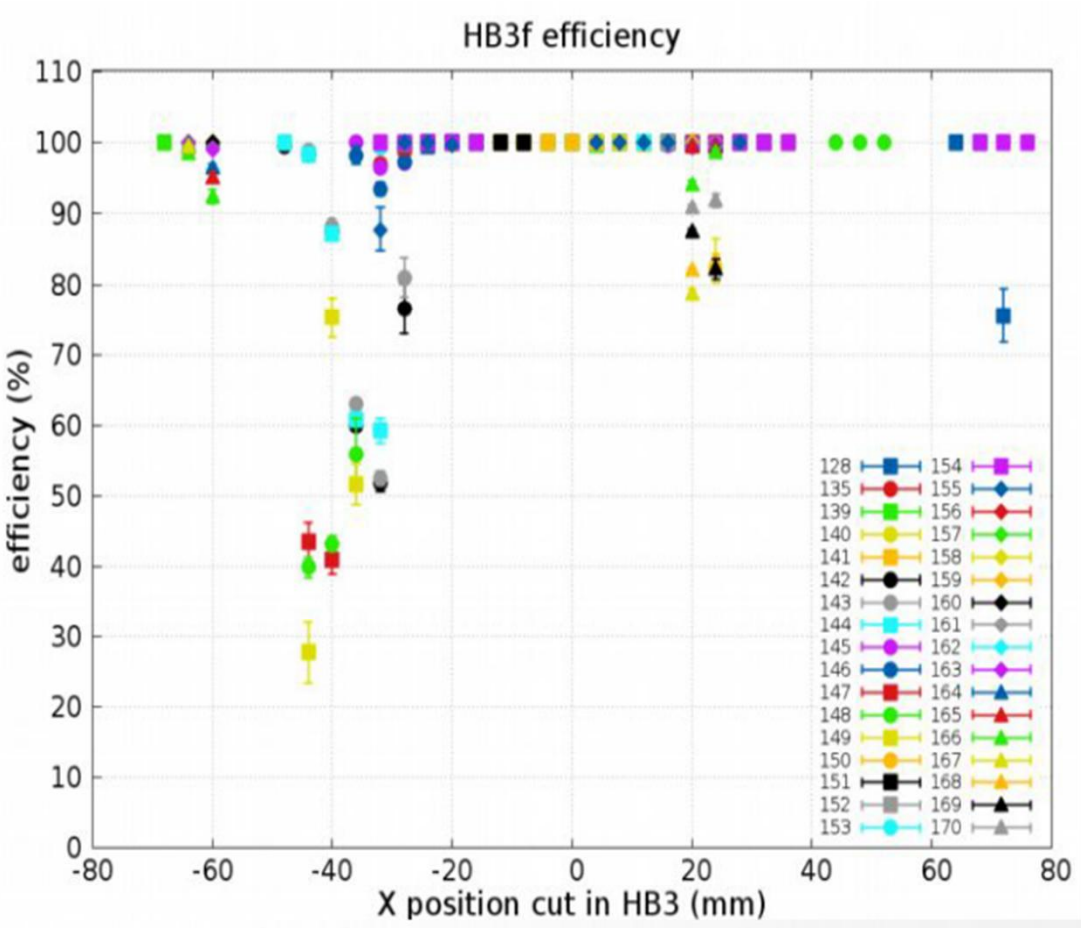




The position resolution in X coordinate for the HB2 and HB3 for all the runs. Variations are due to beam characteristics

JOURNEY ACROSS THE GEM-TPC DEVELOPMENT



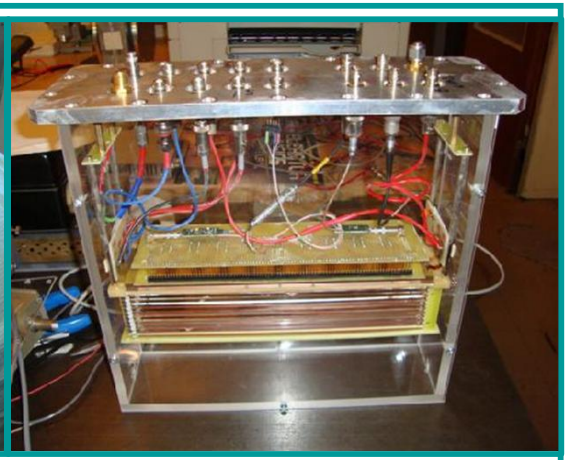


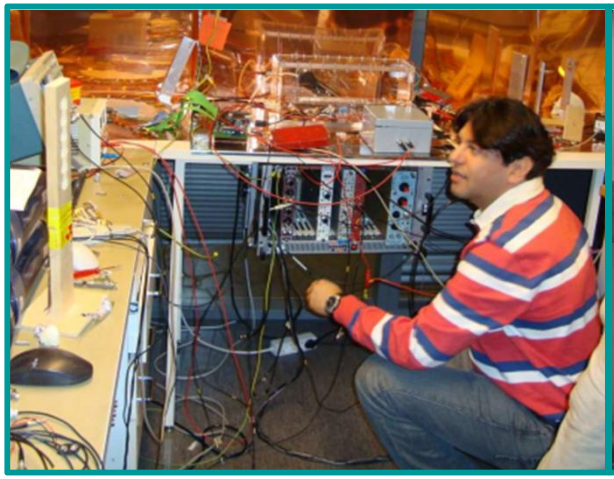
Efficiency plots for the HB2 and HB3 for all the runs. Variations in the efficiency are due to beam configuration and readout electronics settings.

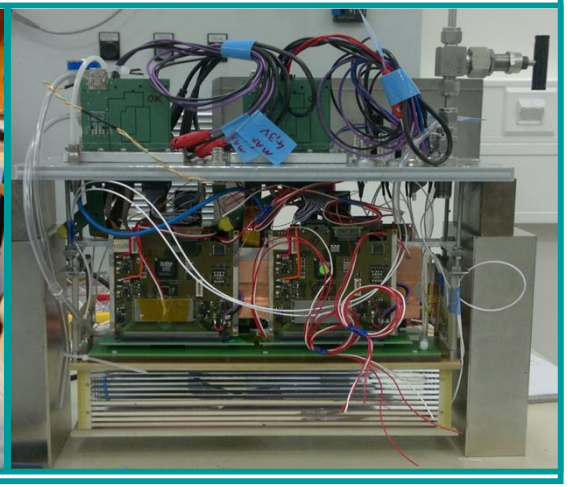
JOURNEY ACROSS THE GEM-TPC DEVELOPMENT

TO SUMMARIZE:

- First meeting at Eurorib'08 with H. Simon
- Meeting at HIP and GSI in Oct. 08 and Feb. 09
- Creation of Consortium: Comenius Univ. and Univ. of Helsinki Feb 09
- First visit to Bratislava, March. 09
- Design of GEM stack at HIP, April 09
- Production of GEM foils at CERN by R. Oliveira, Nov. 09
- Successful Tests of the First GEM stack, Dec. 09
- Integration of the HB1, GEM-TPC, Feb. 10
- First Test Beam at GSI with HB1, GEM-TPC, Aug. 10
- Meeting at HIP and NUSTAR meeting at GSI in Jan. 11 and Feb. 11
- Concept of GEM-TPC for SuperFRS presented to RD51, Apr, 11
- First discussions about twin TPC by B. Sitar, June 11
- NUSTAR meeting in Bucharest, Oct. 11
- The twin GEM-TPC design starts by R. Janik, Jan. 12
- NUSTAR meeting at GSI, Feb. 12
- Integration of GEMEX into HB2 and HB3, GEM-TPC, Apr. 12
- Beam Test at GSI with HB2 and HB3, May. 12

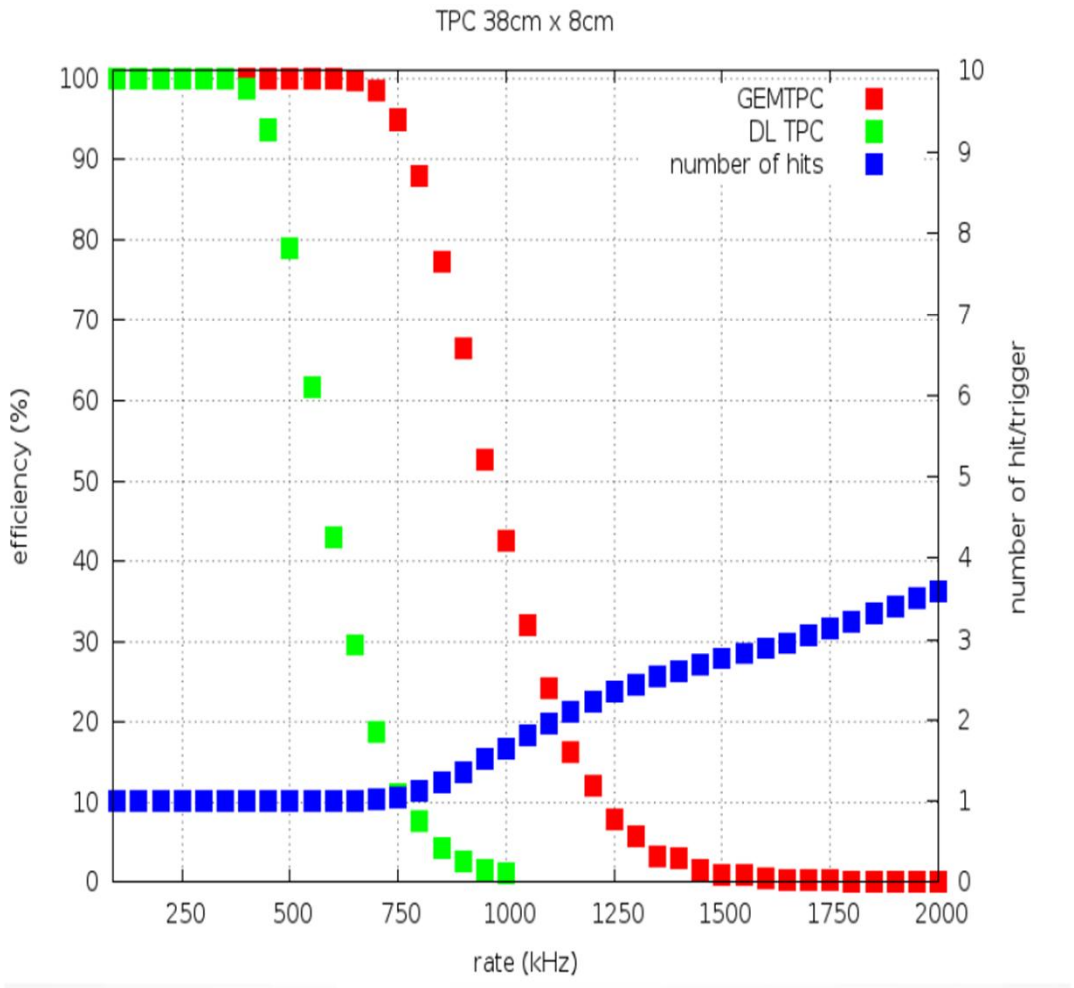


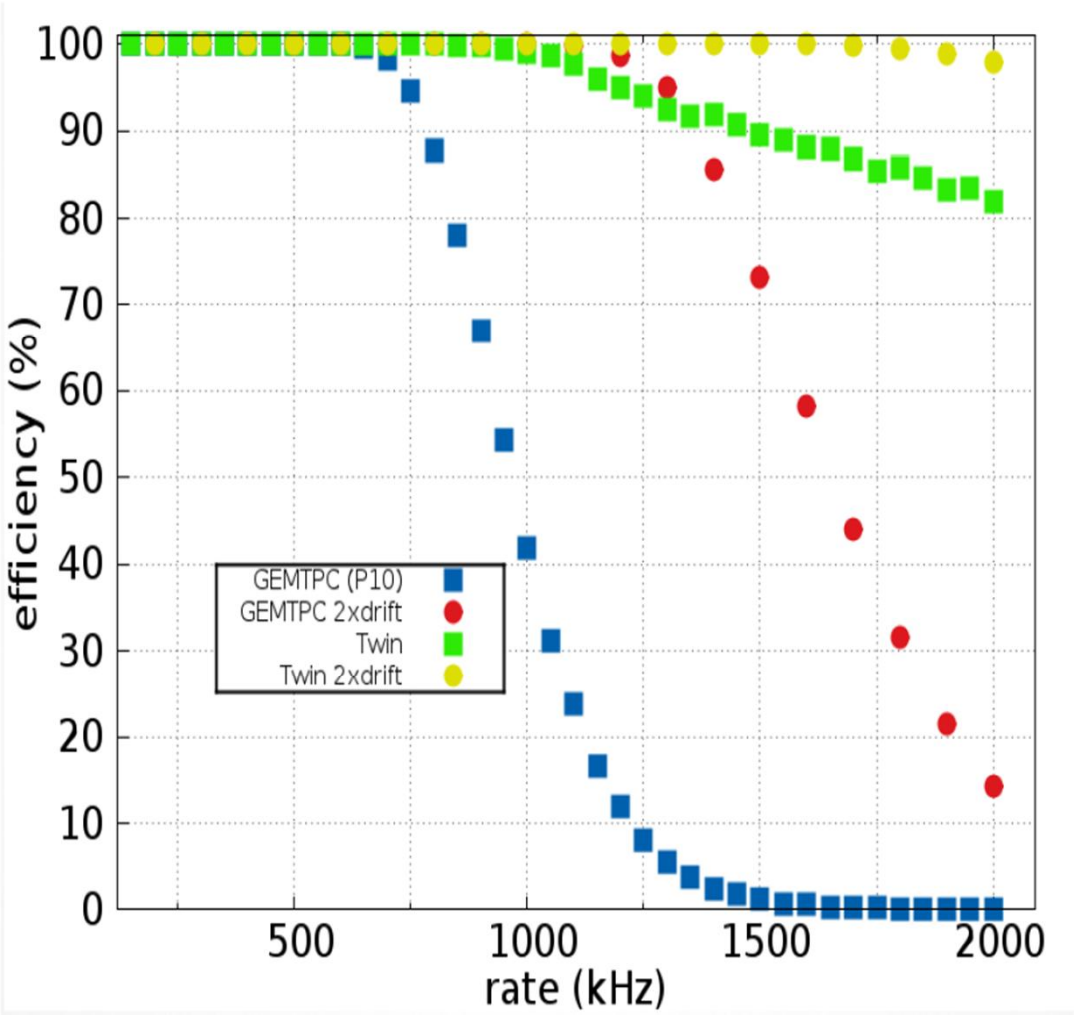




- The Spatial resolution requirements fulfilled
- The Rate capability increased, but yet no as required

SIMULATIONS OF RATE CAPABILITY



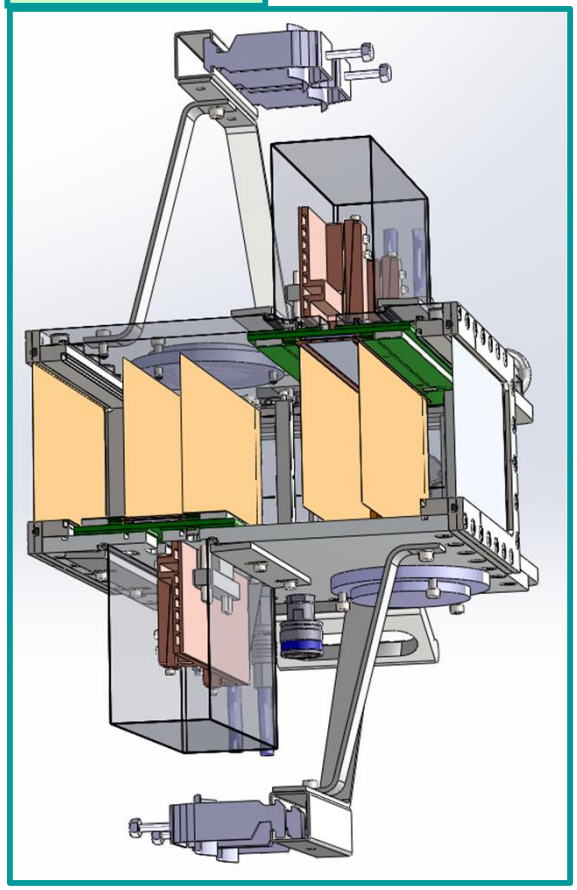


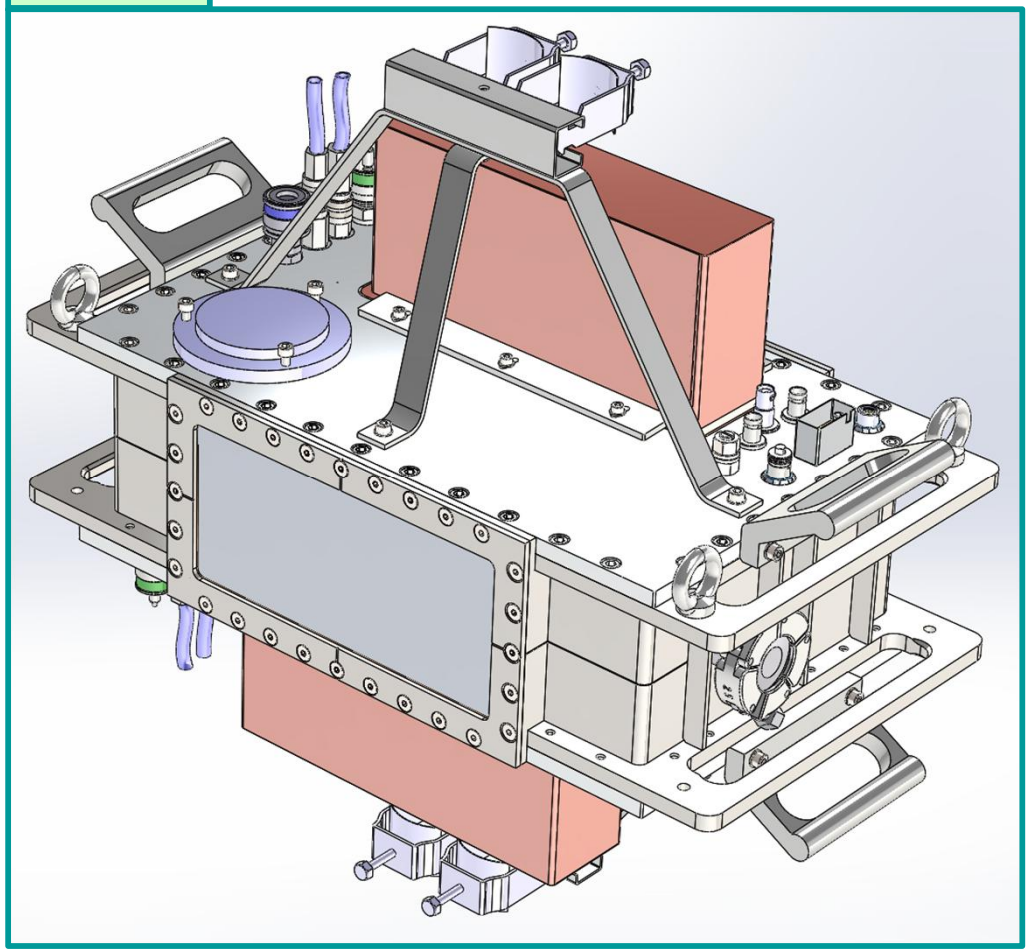
Efficiency Plots simulations for the GEM-TPC equipped with Delayed lines and with GEMEX readout for the case of P10 and a faster gas. The twin GEM-TPC using a 1.6 μs time window and a 21 ns check sum can reach 1.75 MHz

THE TWIN GEM-TPC – HGB4

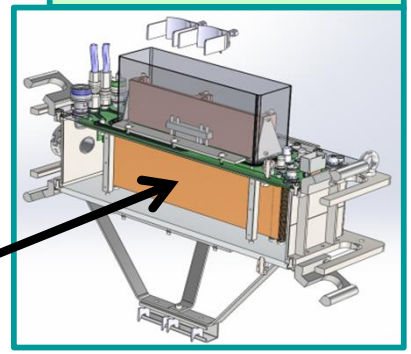
B. Voss

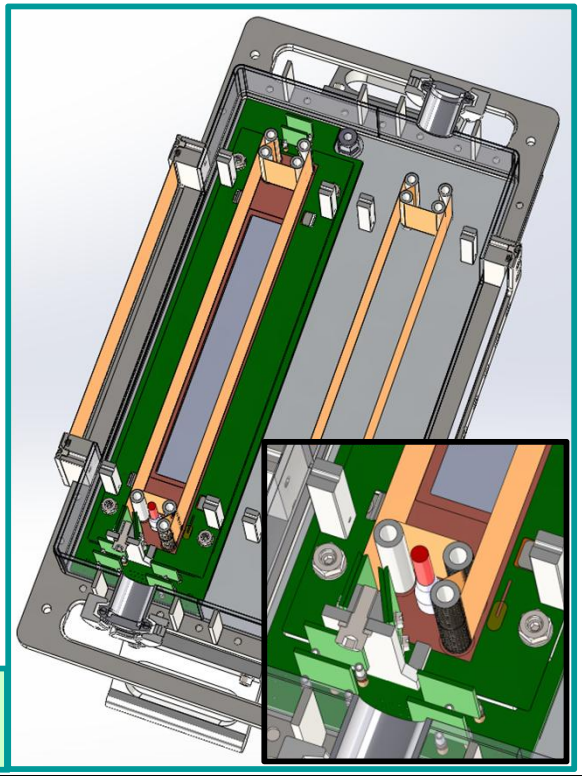
Lateral view





View beam downstream

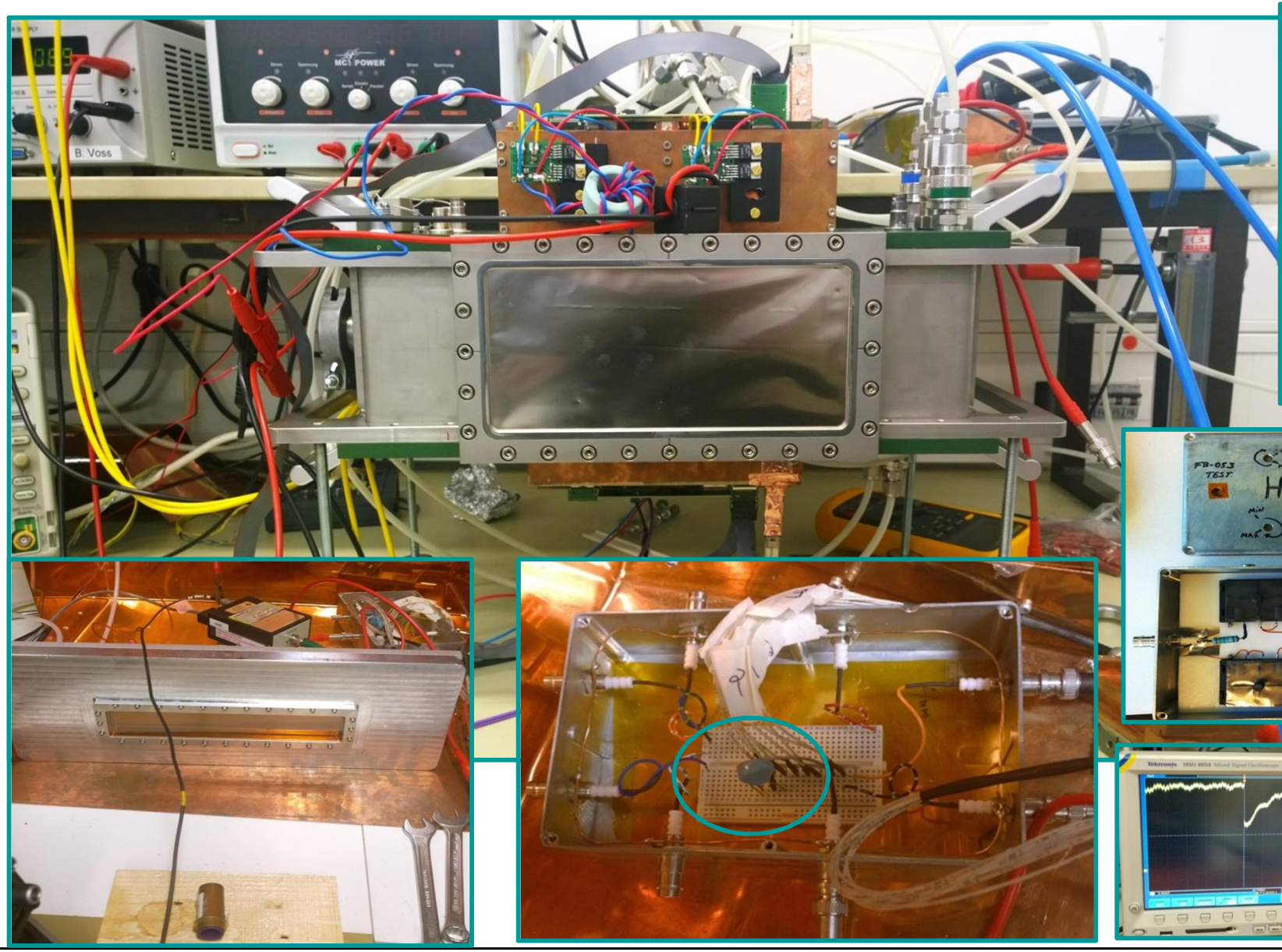


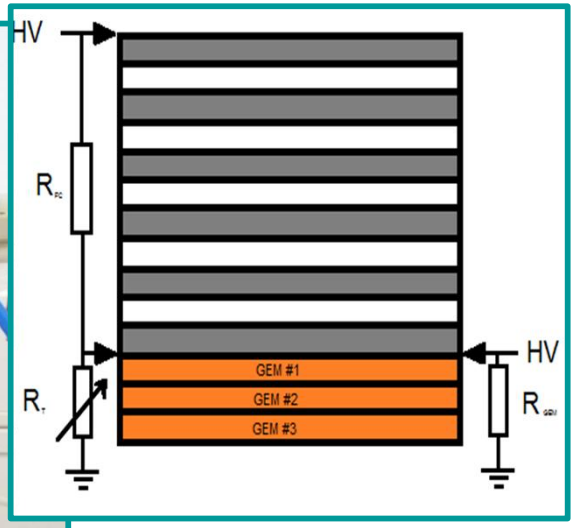


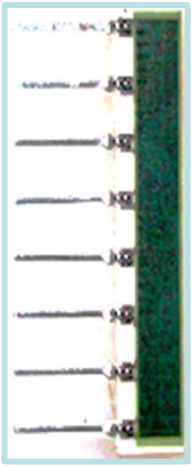
View from the top

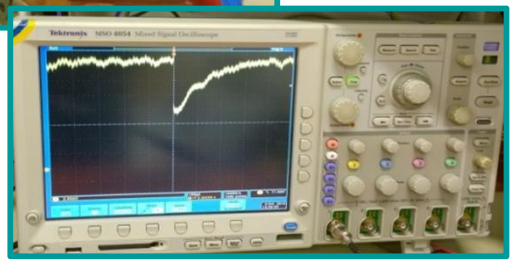
This GEM-TPC has a twin configuration, which means that two GEM-TPC are positioned back to back. This will allow us to increase the tracking efficiency in high rate environment.

THE TWIN GEM-TPC – HGB4



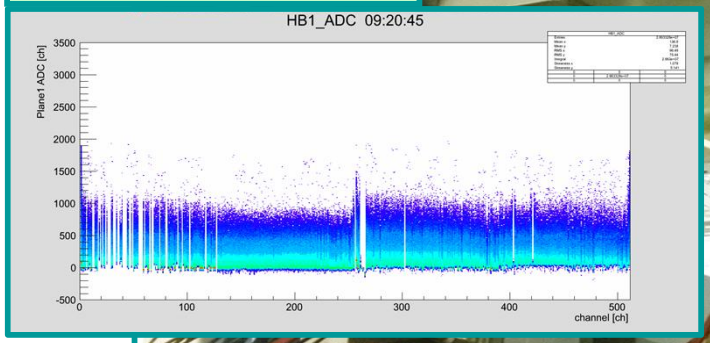






THE TWIN GEM-TPC – HGB4

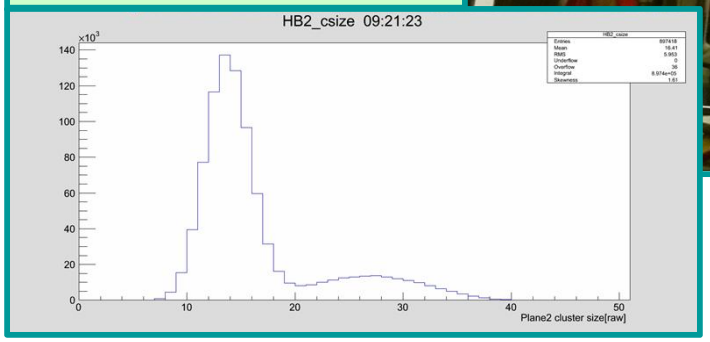
Hits on the X coordinate



Projectiles: ^{238}U @ 330 MeV/u
Master Trigger from Sofia experiment was taken

Correlation hits on X of front and back field cages

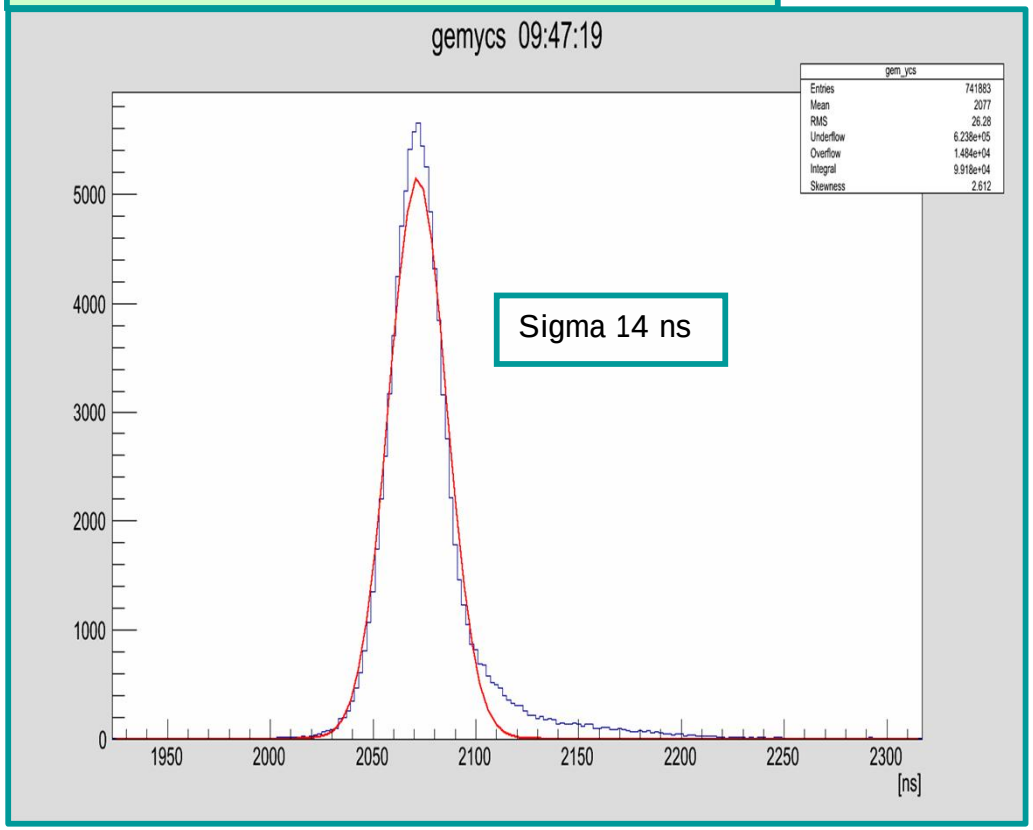
Cluster size from triggers

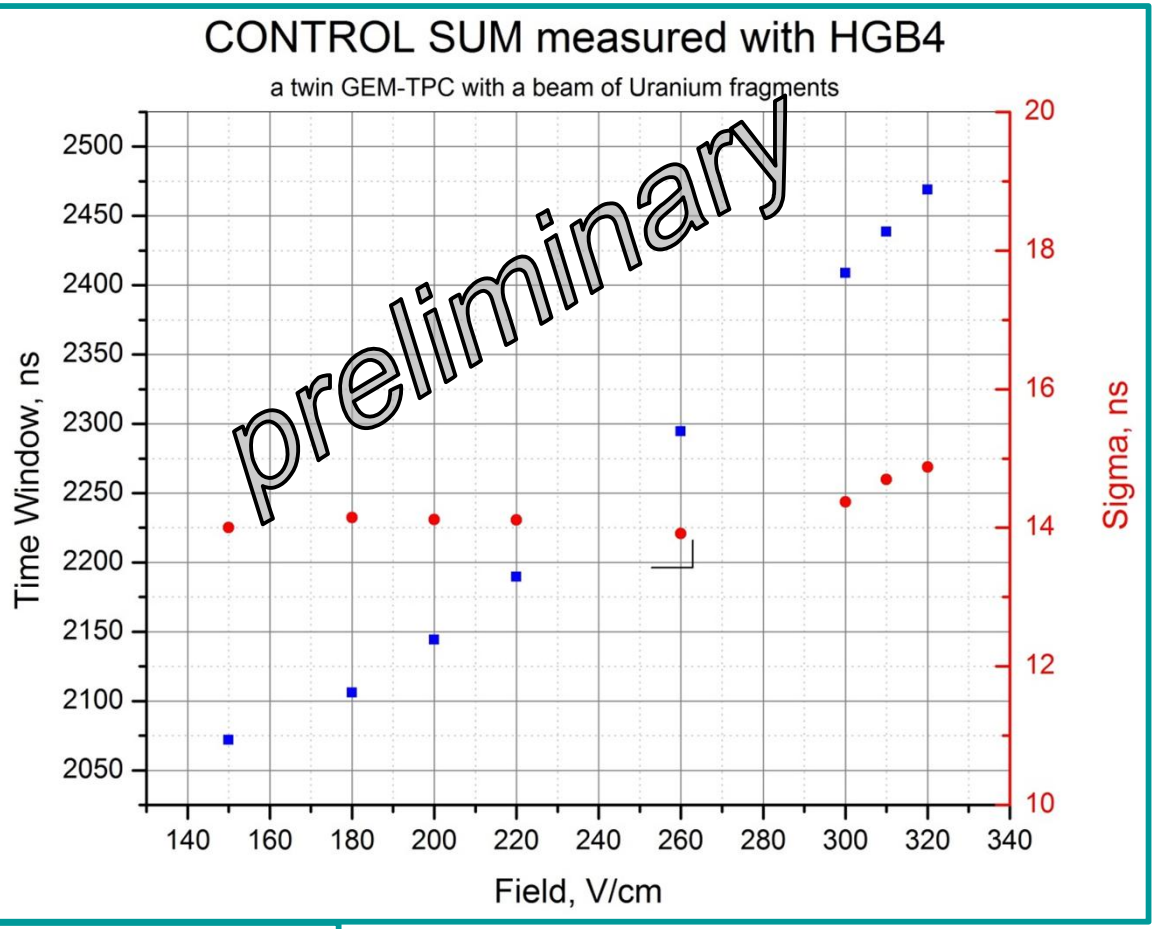


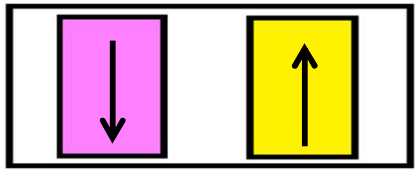
Hits on Time Y coordinate

THE TWIN GEM-TPC – HGB4

Hits distribution for a field of 150 V/cm



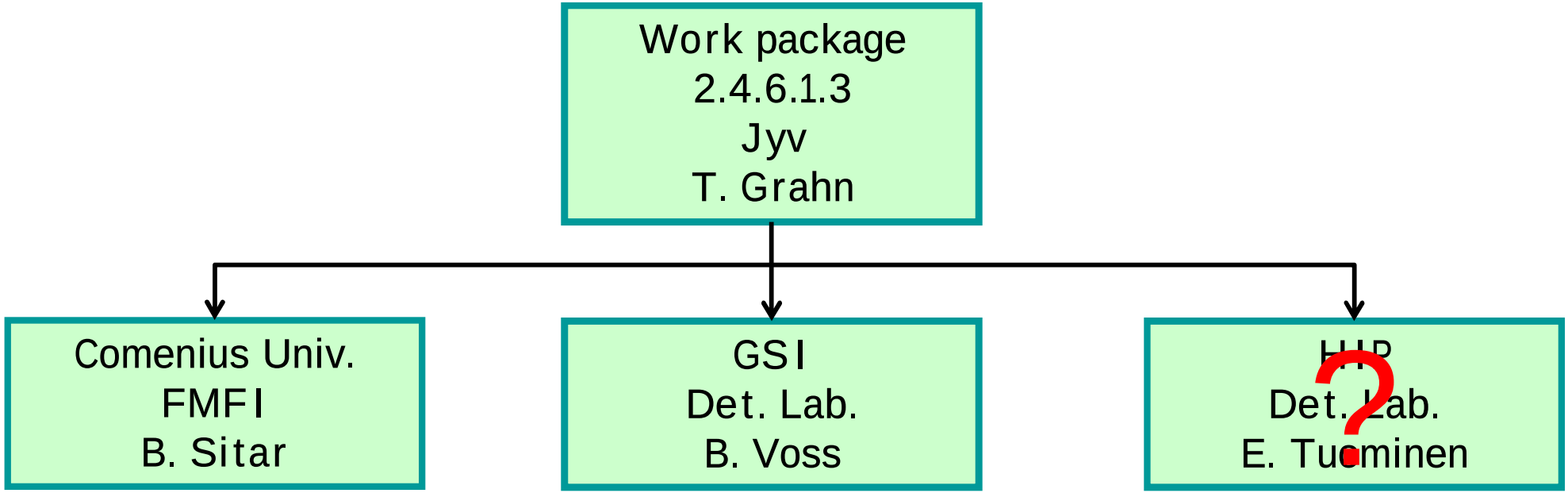




HGB4

t_2 t_1

ORGANIZATION



Issues:

- Consolidation of the Consortium
- Proposal to the In-Kind review board has been submitted
- This year is dedicated to test Final Prototype
- Requirements has been established

Relevant Milestones:

- Preparation work → ending Jul. 2016
- M4 Contract sign → ending Oct. 2016

OUTLOOK

- Tests with protons in Jyväskylä, sometime in March'2016. main goals are: proton detection, efficiency scan, measure the Control Sum and performance stability
- Test of the new GEMEX cards and their integration to the HGB4-1 and HGB4-2, sometime in May'2016
- Beam test at GSI in several campaigns with Uranium and fragments and lighter primary ions. The main goals are: Tracking and efficiency scans, position resolution in both coordinates, control sum and stability test. These program will be between will start in April until July'2016
- Beam test at SPS (H4/H8) at CERN with mouns and pions, throughout the whole year 2016. The main task are gain scans and stability, tracking and efficiency, cluster multiplicity for different gases and stability tests.
- Preparing the Test Bench for Ion back flow measurements in order to find the optimal operation conditions for the lowest ions back flow to Field cage.
- Gas aging studies at GSI for the materials currently in use in the final prototype.

COLLABORATORS

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Thank you for your Attention