Prototype Development of a GEM-TPC for the SuperFRS
OUTLINE

- Introduction and Motivation
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- Second Prototype HB2 - AFTER Readout electronics
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- 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.

NUSTAR = Nuclear Structure, Astrophysics and Reactions

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

DIAGNOSTIC SYSTEM STATION

Detector ladder

TOF detector

MUSIC

X-Slits

Detector ladder

Vacuum valve

Vacuum chamber

Pump system

Beam

6000 mm

MF4
GEM TECNOLOGY and CHARACTERIZATION

Extracting the Electron Cloud and Signal Induction

Avalanche development in time domain

GEM Operation Principle

GEM Foil

GEM-TPC LAYOUT

Drift Electrode

Field Cage

60 mm

2 mm

2 mm

2 mm

Readout Electronics (AFTER/XYTER)

Time = ~6 ns

- electron cluster
- ion cluster

Time = ~1 μs

- electron cluster
- ion cluster

The hole are completely ion free after 1 μs

some ion clusters are trapped by copper

high rate capability
GEM TECHNOLOGY and CHARACTERIZATION (cont.)

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

The leakage current well below the accepted limit of 0.5 nA during 30 min in N₂
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GEM TECHNOLOGY and CHARACTERIZATION (cont.)

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

First mechanical models for the top and Bottom frames

- GEM Foils stretcher - No repels or undulation visible

- Top frame glued to the GEM foil, after cured in oven

14.04.11  Francisco García  -  RD51 Collaboration Meeting at GSI  -  WG1 Technology & New Structures
GEM TECHNOLOGY and CHARACTERIZATION (cont.)

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

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

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

After Apply Red Filter
This procedure is used to find defects and to find the outer diameter of the holes
GEM TECHNOLOGY 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
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GEM TECHNOLOGY and CHARACTERIZATION (cont.)

GEM Stack tests:
Triple GEM leakage current measurements

Leakage Current Measurement

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 $\text{CO}_2$ (70/30)
Flow: 30 ml/min
HV: 3800 V
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FIRST GEM-TPC PROTOTYPE HB1 - TEST

Tests and assembling at Comenius University - Bratislava

Field cage of 60 mm drift

Flange the GEM-TPC HB1 equipped with delayed lines

GEM Stack integration

First GEM-TPC detector

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

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 at S4

GEM-TPC Gain
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**

- Resolution in X: 400 μm
- Resolution in Y: 300 μm
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.

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

PAN to SAMTEC Adapter

Readout Architecture

4 x AFTER FEC  2 x ADC to USB Cards

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

The trigger rate expected for the AFTER chip with ArCO₂ 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

At the top a Samtec connector 300 pins and in the left side two Panasonic connectors of 130 pins each
GEM-TPC readout electronics performance

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-

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

T2K noise measured @ Saclay

14.04.11 Francisco García - RD51 Collaboration Meeting at GSI - WG1 Technology & New Structures
THIRD GEM-TPC PROTOTYPE HB3 (cont.)

GEM-TPC Readout Electronics and DAQ.

Presented by Dr. Christian Schmidt at GSI

XYTER readout Architecture

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

PEXOR & TRIXOR
nXYTER, non rad hard AMS 0.35µ

nXYTER Boards
#0
#1

Exploder Boards
#0
#1

#2 (Source of 32 MHz)
THIRD GEM-TPC PROTOTYPE HB3 (cont.)

GEM-TPC Readout Electronics and DAQ.

nXYTER readout Architecture

Presented by Dr. Ivan Rusanov at GSI

Characteristics:
- Slow control via I²C
- Max Trigger window of 96 µs
- Max Trigger rate 10 kHz (above trigger window)
ACTIVE DIVIDER FOR GEM-TPC

GEM-TPC Active Divider

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

Presented by Dr. Fabrizio Murtas at INFN

HV GEM module with High Current sensitivity
ACTIVE DIVIDER FOR GEM-TPC

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 ArCO₂ with CF₄ 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