Elettronica di front end per la camera a deriva del nuovo tracciatore di MEG
Summary

• MEG experiment upgrade

• The MEG tracker upgrade

• Drift chamber signal characteristics

• Front End schematic

• Front End Board

• Preliminary tests and results

• Conclusions and next steps
The MEG experiment

High energy Particle physic experiment @ Paul Scherrer Institute (PSI, Zurich)

- High resolution detector
- High performance electronics

The decay is reconstructed to look for a back-to-back positron and monochromatic photon

\[ \text{BR} = \frac{N_{\mu \rightarrow e\gamma}}{N_{\mu \rightarrow \text{anything}}} \]

\[ 10^{-54} \text{SM} \approx 10^{(-12)} - 10^{-14} \text{ SUSY} \]

Momentum conservation
Energy conservation

\[ \begin{align*}
E_\mu &= E_e + E_\gamma \\
0 &= \vec{p}_e + \vec{p}_\gamma
\end{align*} \]
MEG Drift Chamber Upgrade

Improvement on granularity, resolution and efficiency
Resolution x-y: 120 µm
(210µm present MEG)
Resolution z: 300 µm
(800µm present MEG)

Cylindrical wire DC:
12 cylinder sectors
10 layers per sector
8 cells per layer

gas mixture: 85% He-15% iC₄H₁₀

Cells are placed along beam axis with a stereo angle (8°) in order to reconstruct z coordinate by combining the information of adjacent layers

tracker: measures e⁺ energy and momentum

Liquid xenon calorimeter: detects gamma ray

Cryostats with PraepENCHMARK.

Timing counter: measures e⁺ time arrival

Field and guard wires: 50 µm diam Al(Ag) => 2688 wires
Potential wires: 40 µm diam Al(Ag) => 7680 wires
Sense wires: 20 µm diam W(Au) => 1920 wires

Stereo angle +
Stereo angle -
Guard layer

Aurora Pepino gas mixture: 85% He-15% iC₄H₁₀
In order to amplify signal coming from Drift Chamber a multistage, low noise and low distortion Front End was designed that provides a total voltage gain of the order of 10 with a suitable bandwidth. Finally signals will be digitized by the MEG Wave Dream digitizer developed at PSI.
Typical Drift Chamber Signal

- **FE** is an essential aspect for reaching acceptable time resolution and therefore an efficient spatial resolution on particle identification purpose.

- **Cluster timing technique** consists in measuring the timing of all the individual ionization clusters in the gas due to a high energy particle crossing through => promising approach to reach resolution below 100 µm.

- Opposed to the determination of the impact parameter, which uses only the arrival time of the first cluster, it produces a bias free estimator using also the timing of the clusters following the first one.

- Study of the signals spectral density done using a single 8 mm diameter drift tube with the 90% helium - 10% isobutane gas mixture.

- Signal bandwidth is of the order of 1 GHz.

- Peak separation clusters: few ns to few tens of ns => separated pulses without overlapping.

Low noise and low distortion

Wide Bandwidth (1GHz)

Gain ~ 10

Low power
Front End boards arrangement

3 different card versions need for DC layers stacking

Right
Centre
Left
The input network provides decoupling and protection, signal amplification is realized with a double gain stage.

Analog Device op-amp **ADA4927** (first gain stage). It is a low noise (input voltage noise of only 1.3 nV/√Hz), ultralow distortion, high speed, current feedback differential amplifier.

The **THS4509** by Texas Instruments (second gain stage and output driver). It is a wideband, fully differential operational amplifier with a very low noise (1.9 nV/√Hz), and extremely low harmonic distortion of −75 dBc HD2 and −80 dBc HD3 at 100 MHz. It is ideal for pulsed applications.
Front End Board

• **Input connector**
  – Custom made by Sullins (edge card type)

• **Output connector**:
  – miniSAS HD internal

• **Ground**:
  – Output connector ground and board ground separated in order to preserve ground loops
  – Possibility to connect the two grounds throughout 0 ohm resistors

• **HV**:
  – Low cost, high reliability connector: Faston
  – HV supply will take place by means of an external wire soldered

• **Layout**:
  – Channels distance to guarantee electrical insulation: **0.6 mm**
  – Central channels distance: **1 mm**
  – Power dissipation edge: **2.9 mm** (2.3 mm reserved for mechanical rail - 0.6mm for electrical insulation)
  – HV decoupling capacitors arranged in order to make board more robust
A power supply board based on the same ICs (LTM4614EV, LTM8022V) used on the WD board to power the FE has built. The board host a receiver (differential to SE) to test cables/FE cards.

After 5m cable long
Conclusions and next steps

- MEG experiment is currently under upgrade in order to increase the decay sensitivity by improving the experimental resolutions.

- The upgrade of the positron tracker consists in a new cylindrical wire drift chamber, with the axis parallel to the muon beam.

- The characteristics of the drift chamber signal establish the Front End Electronics requirements.
  
  The time separation between different ionizations clusters goes from a few nanoseconds to a few tens of nanoseconds and the main signal information content is contained within a bandwidth of 1 GHz.

- In order to separate in time the single pulses due to the different ionization clusters, a large signal sampling rate and a **low noise and distortion electronics is necessary**.

- The Front End Electronics is a multichannel board based on a double stage gain amplifier providing a **bandwidth** of 1 GHz and a **gain** of the order of 10.

- In order to balance the attenuation of the output cable, a **pre-emphasis** on both gain stages has been implemented.

- The eight channel board preliminary tests exhibits a 3 dB bandwidth of 1 GHz thanks to the implemented pre-emphasis which introduces a high frequency peak the voltage gain is of the order of 10.

- **NEXT steps:**
  
  - crosstalk measurements
  - signal integrity
  - tests on DC
References

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5. L. Cappelli, P. Creti, F. Grancagnolo, A. Pepino, G. Tassielli(a,c,d) "A fast readout algorithm for Cluster Counting/Timing drift chambers on a FPGA board" 12th Pisa Meeting on Advanced Detectors


14. ADA4927 datasheet "Ultralow Distortion Current Feedback Differential ADC Driver"

15. THS4509 datasheet "Wideband, low-noise, low-distortion, fully- differential amplifier"