Summer Student Programme 2010

Report on Project

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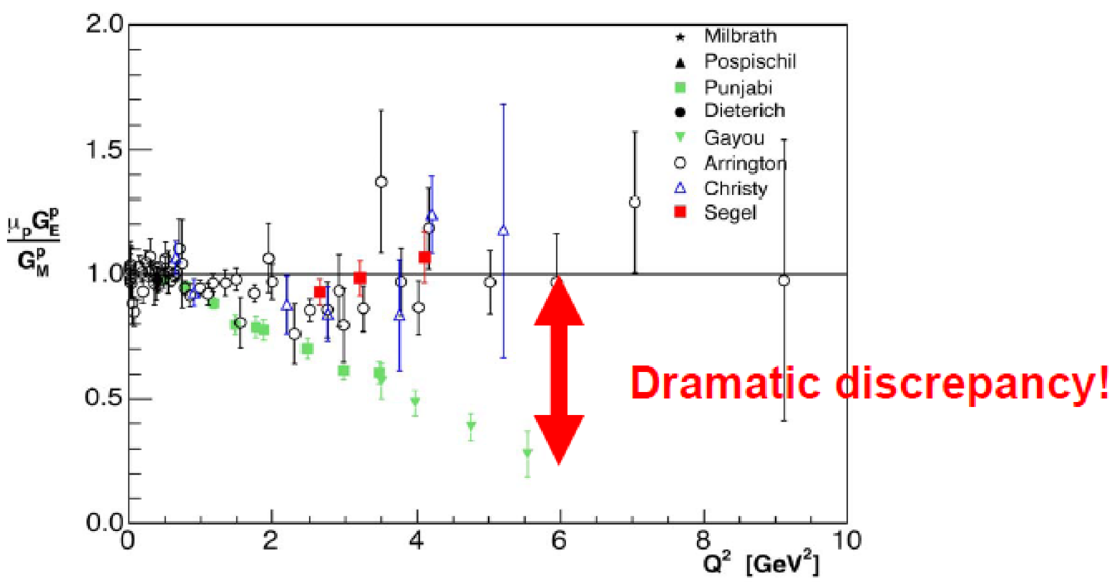
Olympus Collaboration

The Olympus Experiment

The Olympus collaboration is a new experiment for the Doris storage ring at Desy, Hamburg. His main objective is the measurement of the ratio of unpolarised positron-proton and electron-proton elastic scattering cross sections with the aim of quantify the effect of two-photon exchange. The two-photon exchange is consider to be the responsible of the discrepancies between the determinations of the proton electric to magnetic elastic form factor ratio in different experiments performed (with the Rosenbluth and polarization transfer methods)

The proton's electromagnetic form factor are basic observables to characterize the spatial extent of the proton. Some years ago a measurement of the magnetic form factor of the proton via a new type of experiment revealed a behavior completely unexpected. The classical procedure to measure the electric and magnetic form factors for the proton has been the so-called "Rosenbluth" *[unpolarised]* method (by analyzing the angular (θ) dependence of the cross section at fixed momentum transfer squared, Q^2). When the angle is about 180º, the cross section depends only on the magnetic form factor G_M, and from the slope in q, one calculates the ratio of the electrics to magnetic form factors G_E/G_M. The result of these experiments show that the dependence of G_E on Q^2 are approximately the same than that of G_M thought the uncertainty increase for large values of Q^2. However, recent determinations on the electric to magnetic form factor ratio performed at JLAB using polarization transfer (PT) technique, have shown a dramatic different behavior of the ratio G_E/G_M. The JLAB results show a linear drop of G_E/G_M till the largest value of Q^2 available



The explanation found for this discrepancy is the multi-photon scattering whose effect is important in the process at higher momentum transfers. The unpolarised data sums over all processes and do not distinguish between single and multi-photon processes

"But techniques using polarisation are sensitive primarily to single photon exchange as the polarisation information is washed out in multi-photon processes"

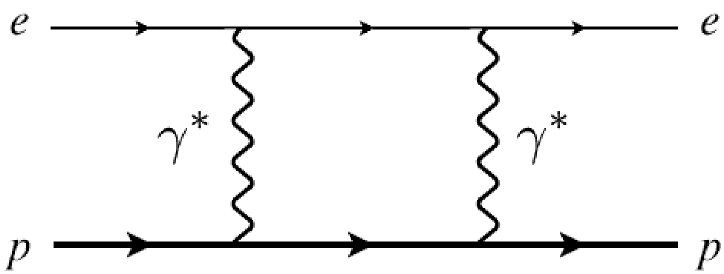


Fig. Two-photon exchange diagram for elastic electron-proton scattering.

The calculations of the two photon scattering amplitude or his interference with single photon processes were found to have a strong angular dependence in q and have the correct sign and magnitude to mostly resolve the discrepancies between the LP and PT measurements (when it's taken in account the finite size of the nucleon)

Within the Olympus experiment it is provided to show the role of the two photon processes by the measurement of quantities directly sensitive to those processes. This is the case of the positron-proton to electron-proton elastic cross sections. The Born amplitude changes sign under the interchange $e^- \leftrightarrow e^+$, while the two-photon exchange amplitude does not. Thus the amplitudes have different sign for e^- p and e^+ p scattering, in the case of one or two photon scattering. This can be seen in the experimental ratios. Currently, the positron scattering data have large errors and do not allow any conclusion.

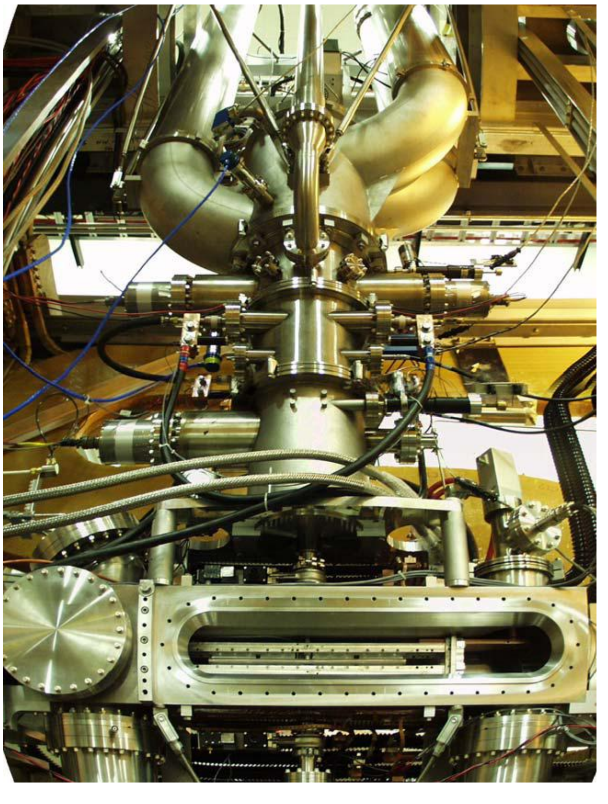
¿why is it important the measurement of the electromagnetic forms factor?

- *They give us clues about the distribution of the charge in the nucleo ("the shape")*
- *It allows theoretical essays about the microscopic origin of the dependence of the form factor with Q^2, and simulations to reproduce the data from the principles of lattice QCD.*
- *It's expected that two photons effects may play, as well, an important role in atomic physics, for example polarizability effects on hyperfine splitting in hydrogen*
- *Through the two photons processes, show the possible limitations of the Born approximation in nuclear physics.*

The BLAST detector

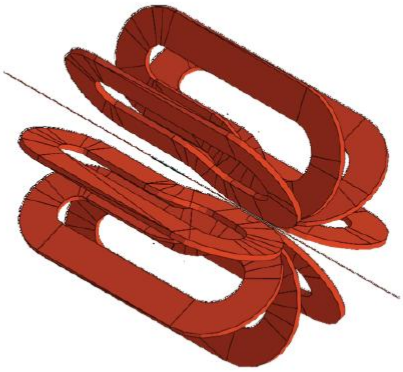
The Olympus experiment will use the existing BLAST detector from the MIT-Bates Linear Accelerator Center.

BLAST DETECTOR magnetic toroid

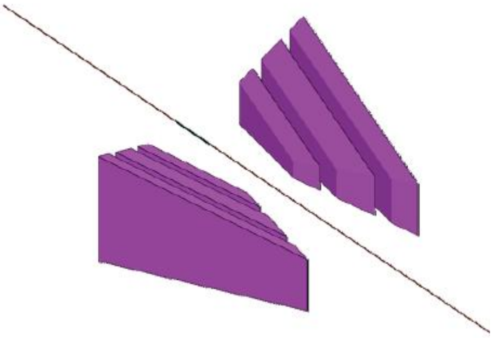


The target (at MIT-Bates)

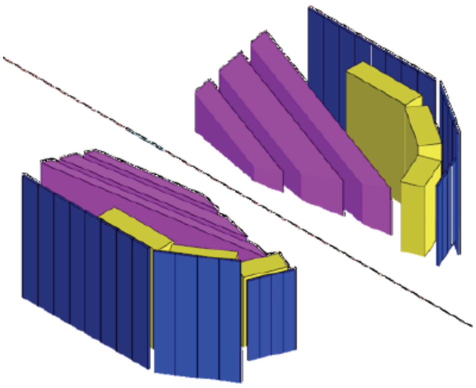
The BLAST detector consists of:



- 8 sector **toroid magnet** : a toroidal configuration was chosen in order to minimize the effect on beam transport and also to have small gradients en the region of the target cell
- 3.8 kG maximum field



- The **drift chambers** measure the momenta, charge, scattering angles, and vertices for the particles produced in the reactions. This can be done by tracking the charge particles in 3D through the toroidal magnetic field and reconstructing the trayectories. The momenta of the particles is known after measure the curvature of the tracks, while its charge is defined by the direction of the curvature.Then one traces the trayectories back to the target in order to determinate the scattering angles, and the vertex is taken as the closest approach to the beam



- **Time of flight scintilliators walls** provides a timing signal correlated with the each event in the target. This signal is used to trigger the readout and data acquisition system and provide the COMMON STOP signal for the drift chambers. The readout of the energy deposition allows identification of the particle produced in the reaction. Position information is reached due to the timing difference

The drift chambers

The drift chambers were designed to fit in the coil in such a way that the top and the botton of the chambers were in the shadows of the coils. Each sector of the detector contains three drift chambers (inner, middle and outer) joined by two interconnection section to form a single gas volume. In each of these chambers there are two rows of drift cells (superlayers). In the center line of each cell there are three sense wires (which are quite more fine) to allow solve the undetermination left/right in determining position from the drift time.

Principles of operation -

When the electric field is applied, the electrons start to drift through the gas towards the positive electrode, in their path they produce collisions with the molecules of the gas. In the other hand ions also drift in the opposite direction towards the negative electrode. As the field is strong enough in the neighborhood of the electrode an electron can reach high enough energy to free an additional electron from a gas molecule. Through the same process these new electrons can ionize more gas molecules, in such a way that they produce an avalanche in which the number of electron increase exponentially. When this avalanche reach the positive electrode, we can perform a measurement of the current, the value of this being proportional to the original number of ions created. The ration between the number of electrons deposited in the electrode and the initial number of electrons is called gas gain. The large field which is required in order to obtain these amplification is reached by forming the anode of very thin wire -100μm. An electron in the gas "far away" from the wire will "see" a much smaller field and will drift towards the anode with a velocity approximately proportional to this field. When the electron gets closer to the anode, it feels a rapidly increasing field, and the electron starts the avalanche. Due to the fact that the electron drift almost all the path to the anode with a predictable speed we can obtain a measurement of the distance of the original source particle to the anode. In this way the wire chambers are electronic devices to measure the position of a charged particle.

The drifts or wire chambers are designed to detect a large fraction of the charge produced in a volume filled with an appropriate mixture of gases. A charged particle traversing a gas layer of thickness Δ produces electron ions pairs along his path. If we have $1/\lambda$ the yield of ionization, the probability of have at least one ionization encounter is thus $1-e^{-\Delta/\lambda}$, and so to achieve detection with a efficiency of 99% the thickness of the gas layer has to be $t_{99} = 4.6\lambda$.

Thus, the charged particle passes through the gas ionizing the gas atoms. Therefore these atoms feel the force of the electric potential and drift towards the wires, which register the signal. The knowledge of the drift time and the drift velocity in the gas allows one to calculate the position of the particle. There are three drift chambers in each sector, stalking one of top of another with such configuration we are able to resolve a track left by the particle, obtaining information as the incoming angle. Because of the effect of the magnetic field the track will curve and one will therefore be able to obtain the momentum of the particle. To be able to resolve the spatial coordinates the drift chamber has a trigger to make a signal when a charger particle is present. This way, we can calculate time from the passage of the particle to the moment in which the signal arrives to the anode wire. Also one has to take into account that the timing of a signal presents some lag respect to the particle passage (i.e. the moment in which the ionization takes place along the particle track in the gas volumen). This lag is due to the time the electrons need to travel from the place where the ionization takes place to the anode wire. The time lag can be used to determine the exact position of the ionization with respect to the anode wire. The quality of the relation *drift time*←→ *drift position* determines the quality of the resolution of the coordinates of the charged particle. The drift time is related to the drift path from the location of the ionization creation along the track to the anode by:

$$t_{drift} = \int_{track}^{anode} \frac{ds}{v_{drift}(\bar{x})}$$

Wiring the BLAST/OLYMPUS detector

This has been the object of my actual work in DESY. Blast detector was in operation at the MIT-Bates Linear Accelerator Center. The OLYMPUS collaboration pretended to use this existing detector to carry out an experiment to definitely determine the contribution of two (multiple) photon exchange in elastic lepton-nucleon scattering. For that purpose the experiment will use the intense beams of electrons and positrons in the DORIS ring. With this aim the BLAST detector was disassembled and shipped to DESY during spring 2010. Because of the risk some of the wires from the drift chambers were damaged during the shipping process it was decided to remove all the wires from the drift chamber and once the detector was at DESY make a new clean set up and rewire the drift chambers. To that aim me and my partner joined to a group of student from MIT to do the new set up. This was realized in a clean room, that has a low level of environmental pollutants.

Drift chambers for the OLYMPUS detector

inside the clean room

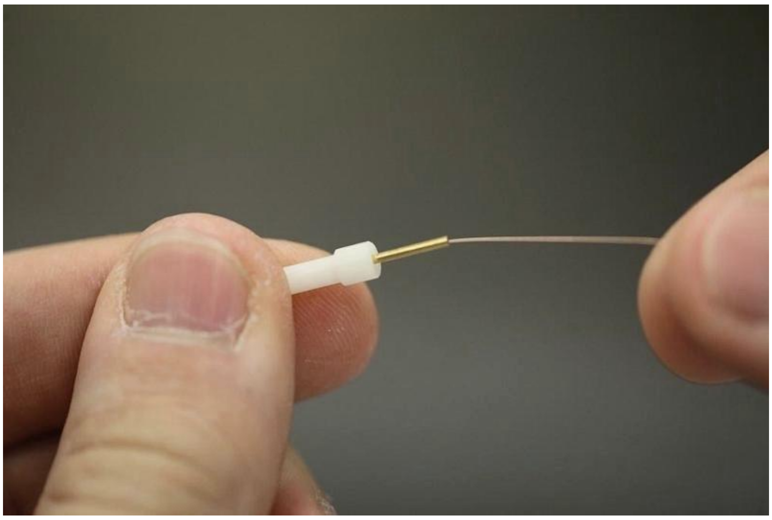
The wiring pattern was realized by stringing wires from one to the another plate of the chamber.

Wiring protocol

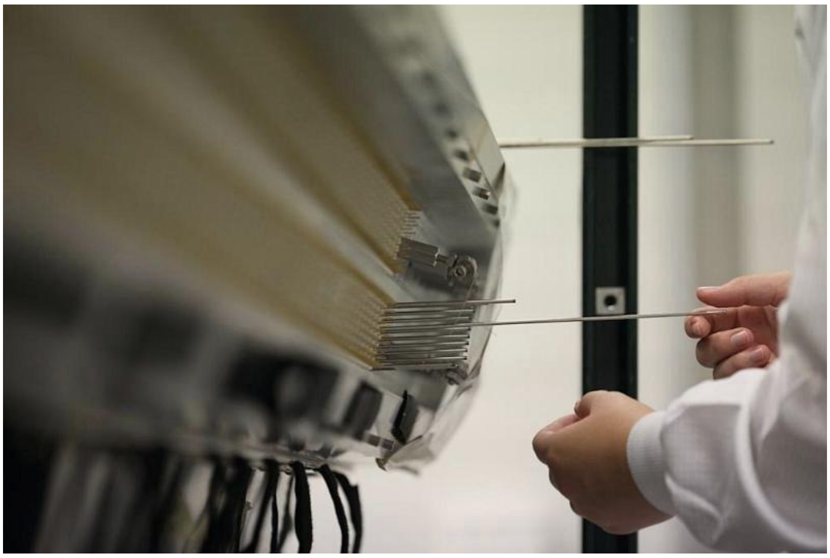
In a previous stage the chamber was pre-stressed to the tension that all the wires would exert. To make this, the piano wires were stringing through the centre of each drift cell and these piano wires were tensioning to exert the same tension as the wires would produce once the chamber is filled. Also some crystal windows were attached to the front and rear faces of the chamber, so the wires would be protected from possible accidents and the inside of the chamber would remain clean.

The chambers were wired horizontally:

- First a wire is strung through a feedthrough



- Therefore the wire is fastened to a long, hollow stainless steel needle which was threaded through the holes machined in the top and bottom plates of the drift chamber.



- By pulling the needle the wire is carried from one side to the other side of the chamber, where it was threaded through another feedthrough.

- Then the feedthroughs were pushed into the machined holes. The wire is drawn from the supply spool to make certain that only clean and straight wire is used to wire the chamber.

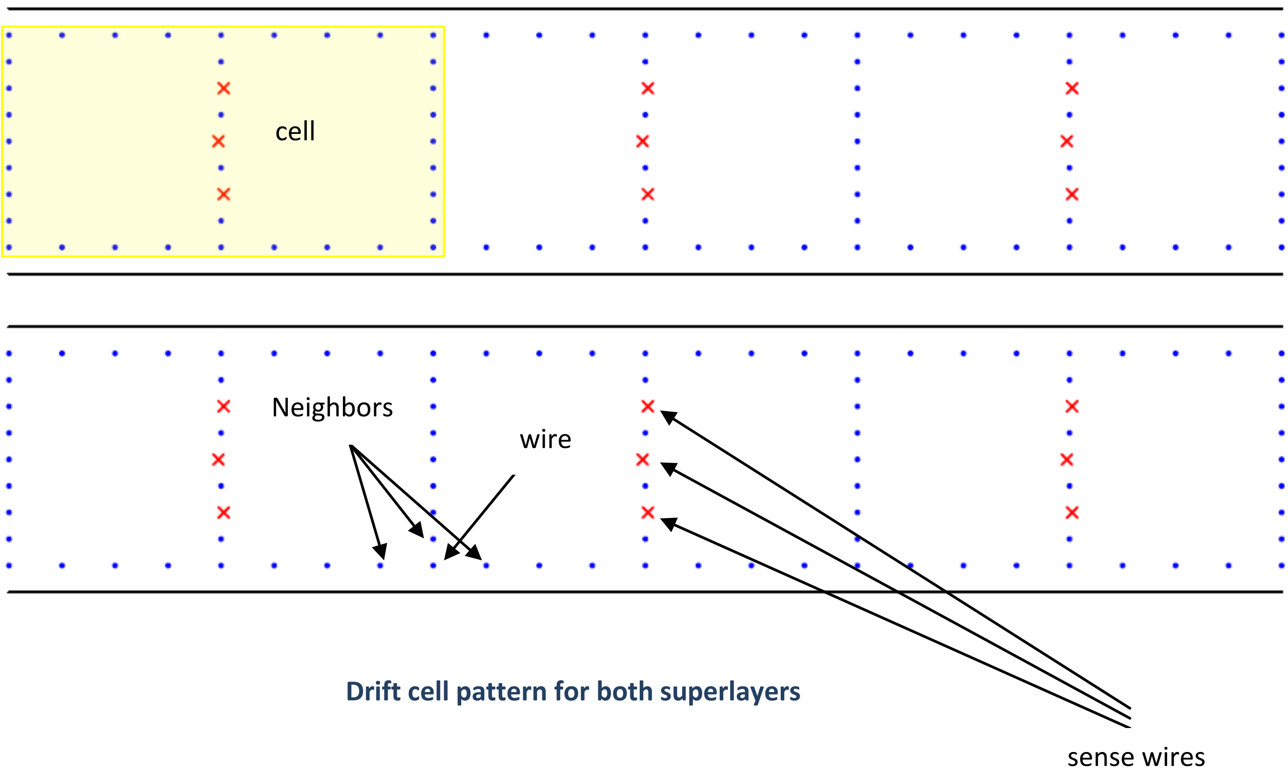
- Then the copper pin of the feedthrough was crimped on one side securing the wire

- A weight was attached to the wire on the other side and stretched over a pulley. This weight varies from one side of the drift chamber to the other in order to apply to the wires the appropriate tension needed in each of these zones. After applying the tension the other pin is crimped. And the wire left is cut and thrown.

- Eventually, this process is repeated throughout the chamber removing the piano wires as each cell was filled.

Checking wires

After complete the wiring process in one of the chambers we checked the wires in search of possible errors (wires broken, wires kinked or wires in contact). To do that, we used a multimeter and checked one by one each wire by touching with the terminal of the multimeter the wire in both ends making sure they were at the same potential (as they should be if they are connected by a conducting wire). Also we checked each wire making sure it was not in contact with other wires inside the chambers. We did this by checking with the multimeter that the resistance tends to infinite between the ends of two neighbors wires (as it should be if they are not in contact at any point)



Drift cell pattern for both superlayers

Future schedule for Olympus experiment

- Assemble the OLYMPUS detector in summer/autumn 2010
- Commission the complete OLYMPUS detector in winter/spring 2011
- Move the complete detector into the beam position in summer 2011

- Commission the complete experiment with beam in autumn 2011
- Take data in 2012 in two separate running blocks

Institutions

A list of institutions involved in the OLYMPUS project:

- Arizona State University
- DESY, Hamburg, Germany
- Hampton University, USA
- INFN, Bari, Italy
- INFN, Ferrara, Italy
- INFN, Rome, Italy
- MIT Laboratory for Nuclear Science, Cambridge, MA
- MIT-Bates Linear Accelerator Center, Middleton, MA
- St. Petersburg Nuclear Physics Institute, St. Petersburg, Russia
- University of Bonn, Bonn, Germany
- University or Colorado, USA
- University Erlangen-Nurnberg, Germany
- University of Glasgow, United Kingdom
- University of Mainz, Mainz, Germany
- University of New Hampshire, USA
- Yerevan Physics Institute, Armenia

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-And yeah, my partner, Mark Smith ☺

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Reference

web.mit.edu/olympus