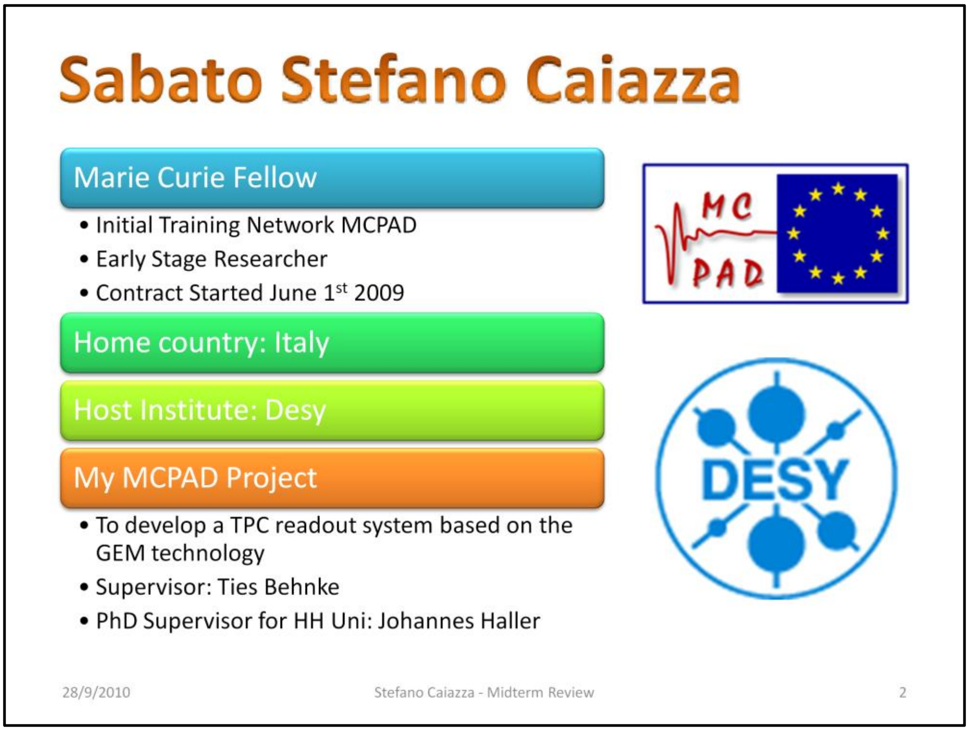
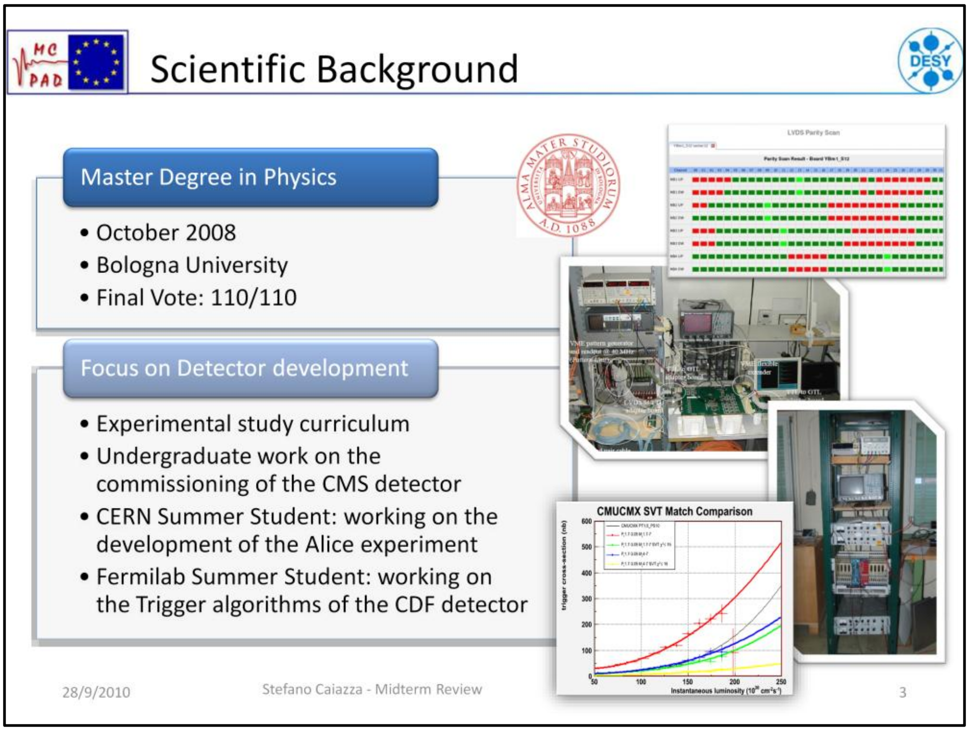
Sabato Stefano Caiazza

Universität Hamburg

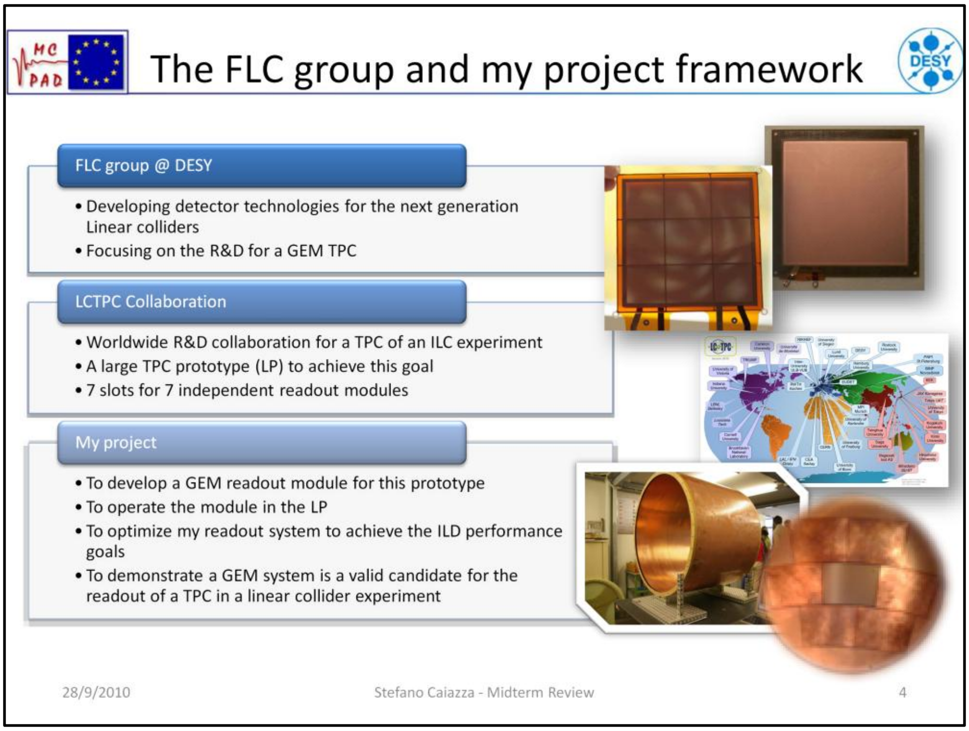
Title Slide



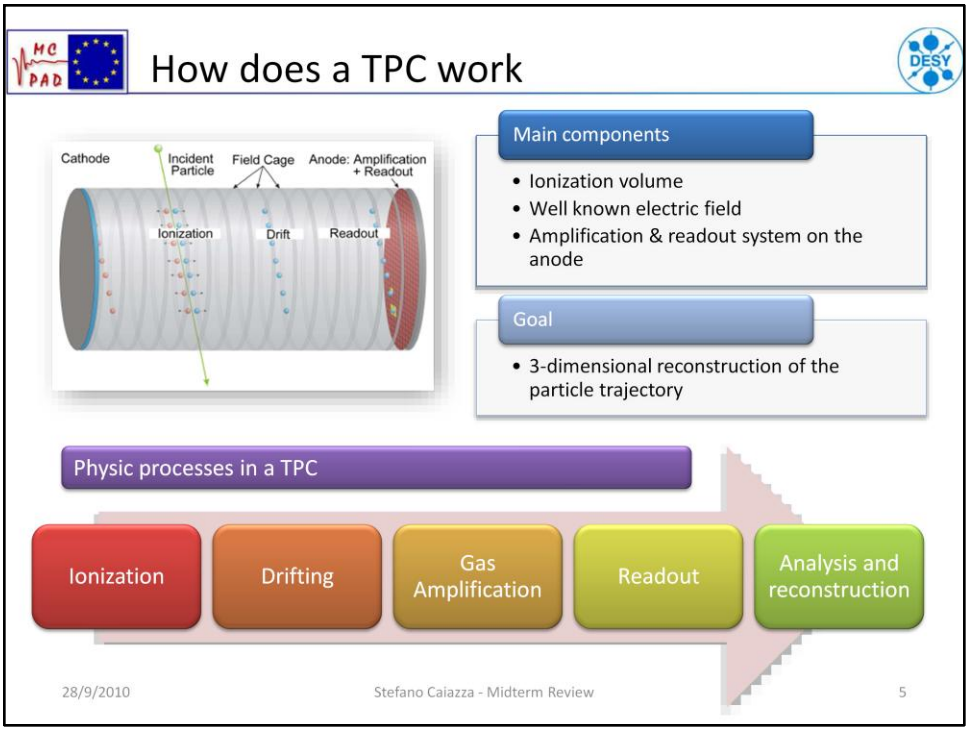
My name is Stefano Caiazza. I’m an Italian MC Fellow and I work at Desy as an ESR in the ITN MC PAD
As a MC fellow my project is to develop a readout structure for a TPC detector using GEM as a gas amplification system.
My supervisor for this project is Ties Behnke.
I also plan to use this time as a MC fellow to obtain my PhD from Hamburg Uni. My thesis advisor is Johannes Haller



I’m going to start with some details about my scientific background:
I graduated in Physics in 2008 in Bologna. And already during my studies I focused my education on the physics detector development.
During my undergraduate years I worked on the commissioning of the CMS detector and I did both my Bachelor and Master degrees on topics related to this activities.
During those years I did also have the opportunity to work both at CERN and Fermilab as a Summer Student performing research on the ALICE forward calorimeter and the CDF trigger systems.



As I said my project is developing at DESY, in the FLC group, whose research is focused on developing detector technologies for a future experiment at the ILC. They already had an extensive experience on GEM technology, for example developing a new system to frame and support the GEMs based on ceramic self supporting grids. This experience is used in the challenge to develop a GEM based TPC
My group is also part of the LCTPC collaboration, an international collaboration whose goal is to develop a TPC for a future ILC experiment. To this goal we built a large TPC prototype, which features 7 slots for mounting up to 7 independent readout modules to be able to test different TPC related technologies. This infrastructure has been used by other institutions of the LCTPC collaboration to test different gas amplification technologies, readout structures and electronic systems.
My goal is to develop a readout module for this prototype, that uses the Gas Electron Multiplier (GEM) to perform the gas amplification stage, operate it in the LP, optimize the system and demonstrate the validity of the GEM technology for an ILC experiment



Now I want to go into some more details about my project. I will start with some introductory details to framework my project and I will then spent the rest of my time on my own work

As I said my project is to develop a modern type of gas amplification system for a TPC. A TPC is a gas container with a very homogenous electric field inside. When a charged particle cross the detector it ionize the gas and electrons thus freed drift along the electric field lines to the anode. Because of the small amount of electrons produced is not possible to detect them directly, even with the low noise electronics that is available today, so you need to pre-amplify the signal in the gas volume itself. After this gas amplification stage, the electron cloud is big enough to be detected by the electronics.

Gas amplification structures

Multi Wire Proportional Chambers

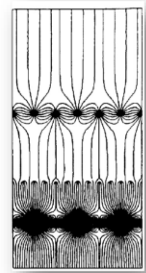
- Gas amplification system used for the last several decades

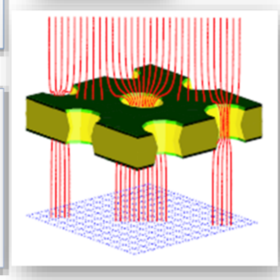
Micro Pattern Gas Detectors (MPGD)

- Modern development of the MWPC
- Resolution and rate are usually improved compared to MWPC

Gas Electron Multiplier (GEM)

- A specific type of MPGD
- Parallel plate capacitor pierced with micrometric holes
- They can be stacked over one another





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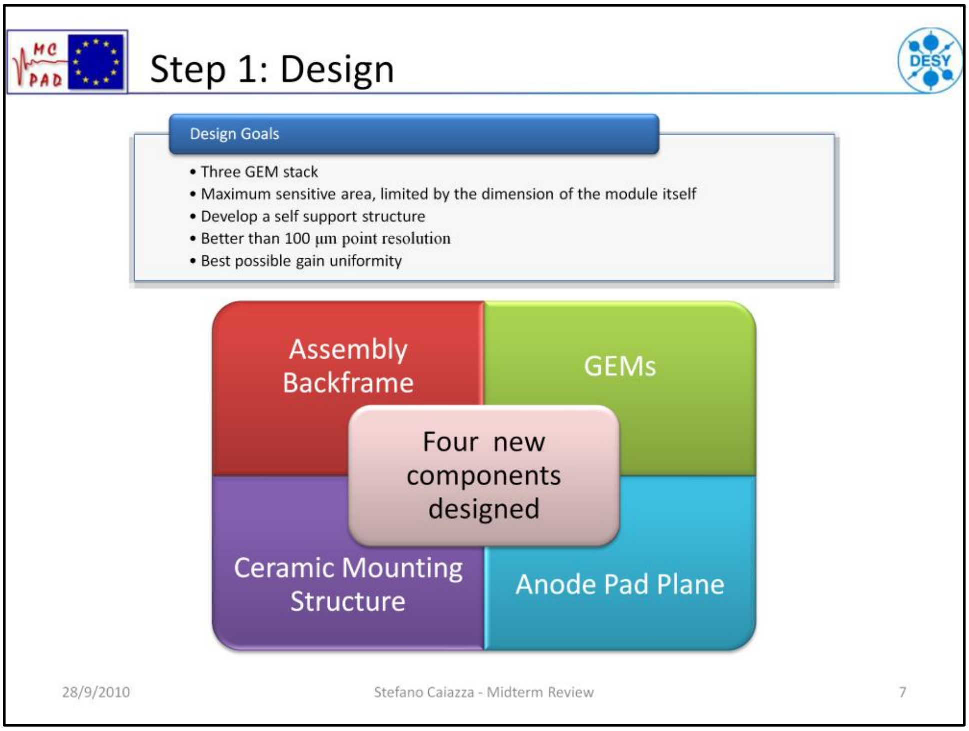
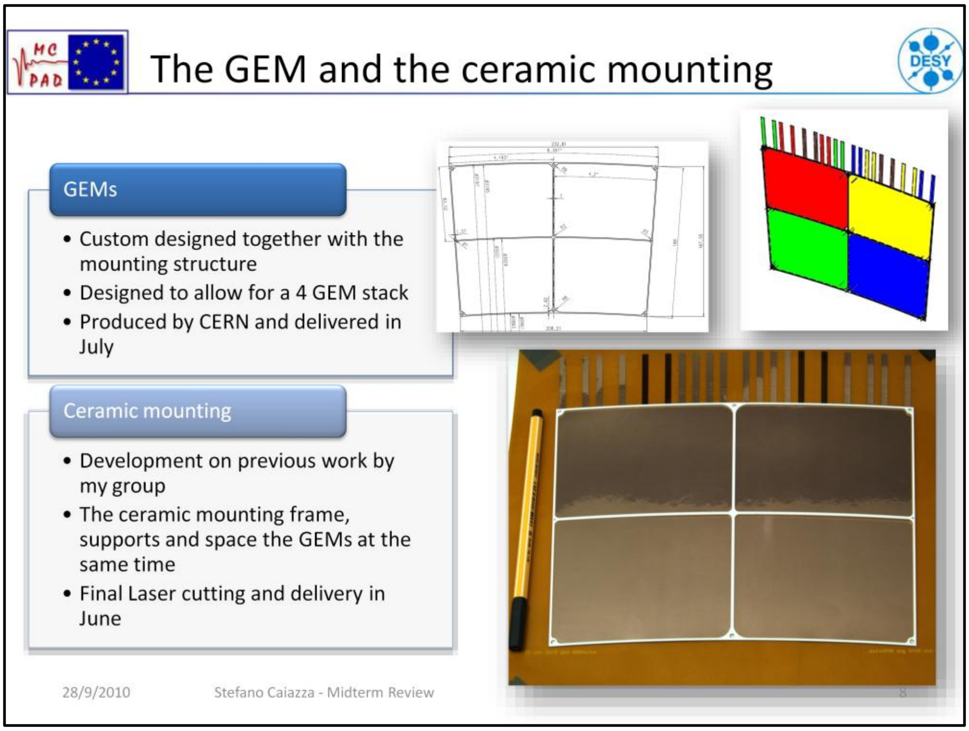
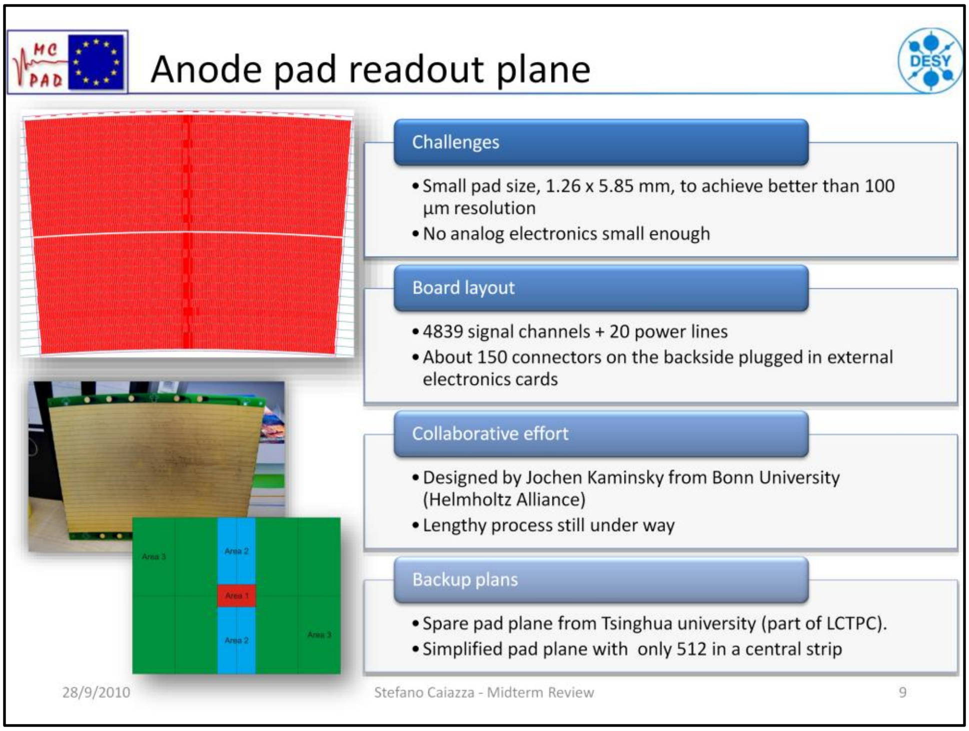
Traditionally the gas amplification was done with MWPC. In this structures the high electric field surrounding a charged wire is enough to produce a detectable electron avalanche. The minimum distance between the wires is usually of the order of the mm which makes it challenging to achieve resolution of 100 microns, which is the set goal for the ILD TPC. The maximum rate achievable is also dependent on the maximum number of wires in the system. Finally the wire itself defines a preferential direction that makes the detector not isotropic, thus more difficult to calibrate and use.
The evolution of this concept is represented now by the micro pattern gas detectors (MPGDs) where field shaping elements of the size of tens or hundreds of microns are able to produce the controlled electron avalanches necessary for the detection of the incoming electrons. Thus the size of the amplifying structure is not a limiting factor for the detector resolution. The amplifying structures are also distributed in an homogeneous way on the surface of the device so that it’s really a 2-dimensional amplifying system. All these features increase both the rate and the resolution of the MPGD compared to the MWPC. This and other advantages make the MPGD a valid replacement for the MWPC for a TPC readout system
One type of MPGD is called a GEM. A GEM looks like a parallel plate capacitor pierced my many holes. In each of the holes the electric field is strong enough to produce the electron avalanche. The cloud drifts out of the hole and can reach the readout structure or another GEM foil. As a matter of principle there is no limit to the number of GEM foils one can use in a stack, but the most common configurations use up to three GEM foil stacked



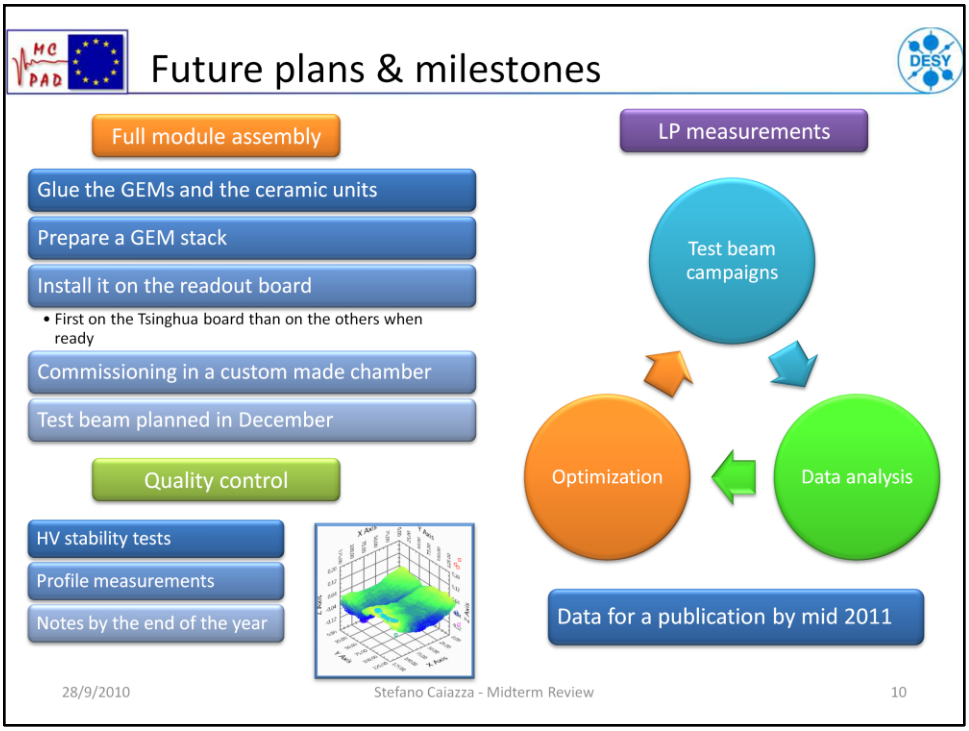
Now I want to give you some more details about my own project. The first step of the project was the design of the module itself. We had mechanical constraint due to the features of the large prototype itself and we decided to set for this goals:
To use a three GEM stack
To develop a system with the largest possible sensitive area
To use a ceramic self supporting structure
To achieve a point resolution of less than 100 micrometer (performance goal of the ILD TPC detector)
To obtain the best gain uniformity possible on the whole sensitive area
To achieve this goal I had to design four new components:
The GEMs
The Ceramic mounting structure
The anode Pad plane
The backframe to assemble everything together and mount it in the LP. I'm not going to talk in more detail about this element, which is an aluminum structure with mechanical features that allow for the mounting of the other element and the fixing of the assembly in the LP and ensuring the gas tightness of the system.



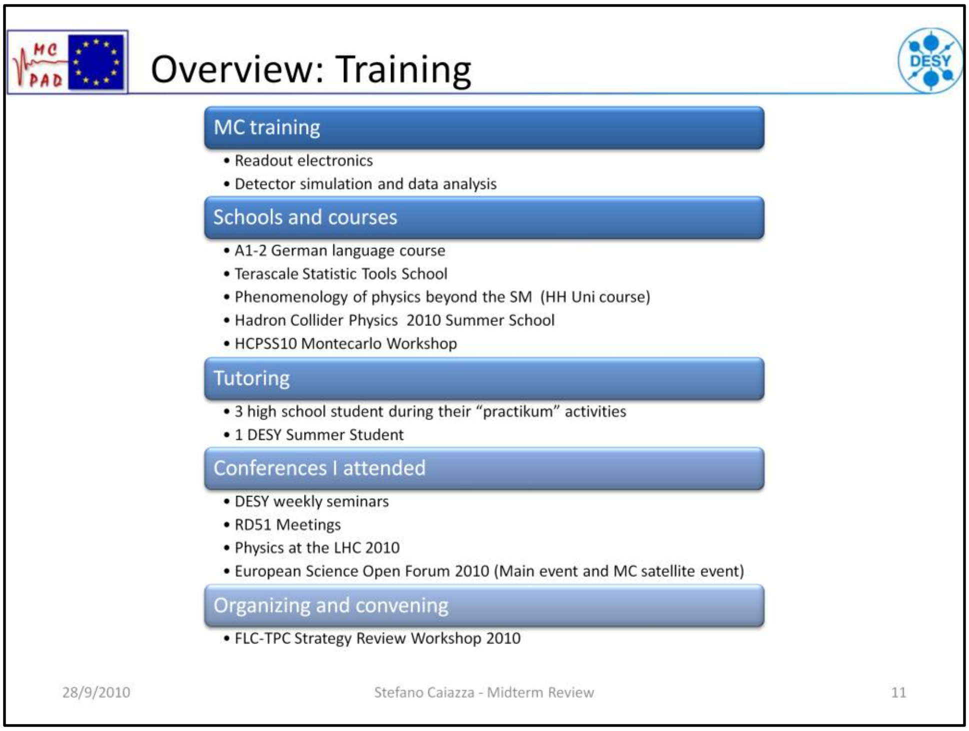
One of the first task I performed was to design the combination of the GEM and the ceramic structures for this module. The two elements were designed together as an integrated system. The design allows for the stacking of up to 4 elements, to be able perform test on the GEM gating technologies. Each GEM, mounted in his ceramic structure is an independent element that can be added or removed from a stack, thus reducing the costs, especially in the prototype phase, because we are going to be able to replace a GEM with another one if one fails without throwing away a whole stack. When the stack is complete it will be self supporting system, where the ceramic elements act as frame and spacer for the GEM while forming a solid and robust element that doesn't need any other support mechanics. This system is a development of a concept developed in my group for the mounting of smaller 10x10 cm GEMs.
This ceramic elements were produced by laser cutting and delivered in June



The fourth element of the system is the readout plane. The main challenges to develop a readout system for the module is the integration between the small pads necessary to achieve the goal resolution and the analog electronics necessary for the digitization and acquisition. To obtain the desired point resolution of 100 µm we set the pad size to be 1.26 x 5.85 mm^2. An ADC system with a footprint smaller than this pad size does not exist thus the readout electronics cannot be integrated directly on the PCB itself. Each pad is independently routed to one out of about 150 connectors on the backside of the board. Each of this connector will be plugged through a flexible cable in an external electronics card, derived from the electronics used in the ALICE experiment TPC (ALTRO electronics)
Because of the expertise needed to design such a complicated (and expensive) system this device is being designed by a colleague at Bonn University, Jochen Kaminsky, in a collaborative effort in the framework of the Helmholtz Alliance. Obviously this part of the project helped my strengthen my links with other scientific institutions outside Desy and my own group.
The design phase for this element is still going on, its duration much longer than we foresaw at the beginning so we had to devise some backup solution to perform some preliminary test while waiting for the complete anode pad plane to be ready.
We prepared 2 backup planes. The colleagues of Tsinghua University (part of the LCTPC collaboration) kindly provided us with a spare pad plane they used for their experiments in the LP to start our own measurements. This device has the same pad size as our own system but different features regarding the mounting and powering of the GEM, thus we will need to make some ad hoc adaptation to install our GEMs on this pad plane. At the same time we are also preparing a simplified version of the final pad plane, with only 512 pads in a central strip.



Now I want to spend some time on my future plans.
The most important think to do is to prepare a full module assembly, gluing the ceramic support structures and the GEMs, then preparing a GEM stack on the readout boards, the Tsinghua first, than the others as soon as they're ready.
During this process I'm going to perform quality controls on the detector elements that I'm going to produce. For example I'm already performing the HV stability on the delivered GEMs and I'm preparing the setup for the measurement of the surface profile of the GEMs
After this phases we can finally proceed with the measurements on the LP which can be summarized in an iterative cycle of test beam campaigns, data analysis and optimization of the system to reach the design goals we set at the beginning



List of school and training I had

Overview: Results

Publications

- ILD Letter of Intent
- Hopefully this will soon change

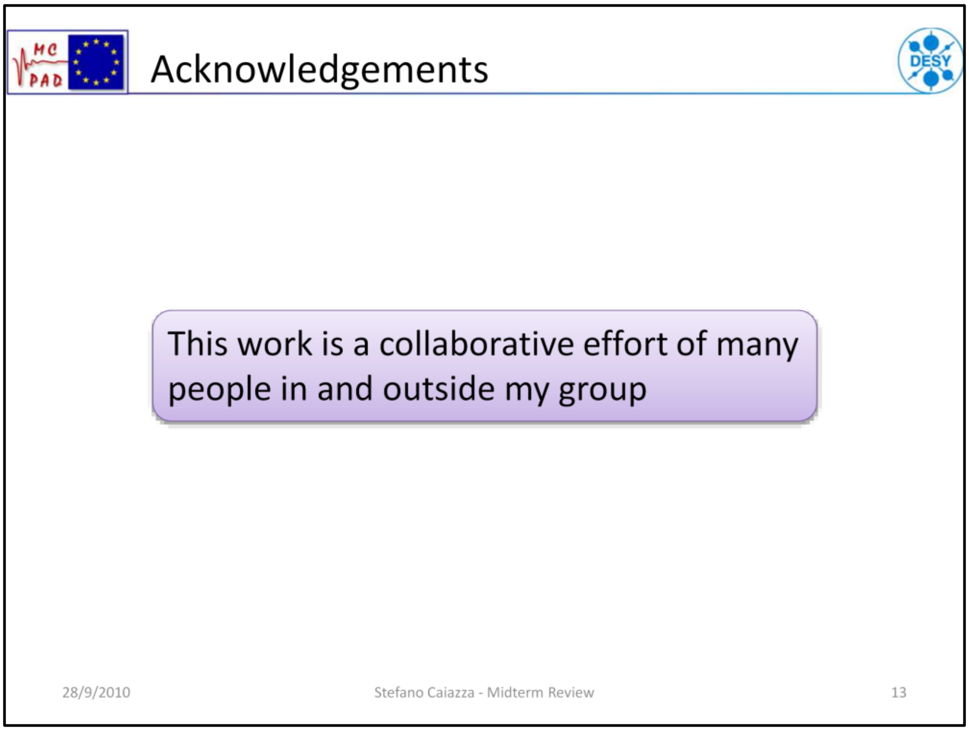
Posters

- Poster at the 1st MCPAD Training in Cracow (2009)
- Poster at the MC Satellite event of the ESOF 2010 conference in Torino

Presentations

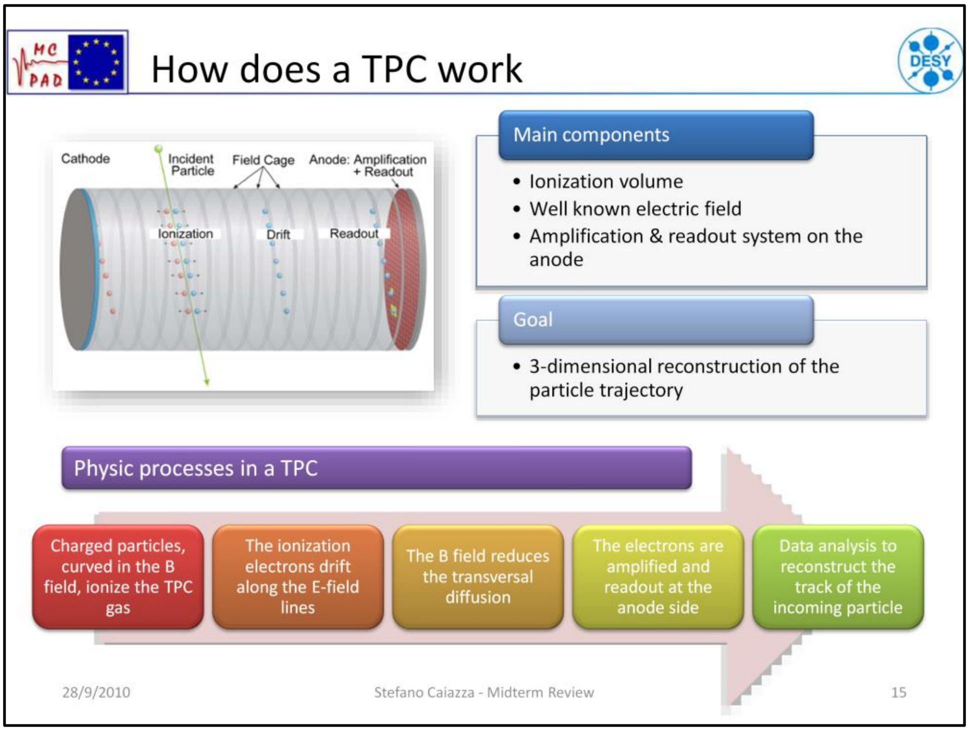
- LCTPC Collaboration meeting (DESY 21-09-2009)
- FLC Group weekly meeting (DESY 12-10-2009)
- FLC-TPC Strategy Workshop 2010 (DESY 21-01-2009)
- RD-51 Mini Week (CERN 22-02-2010)
- DPG Annual Meeting (Bonn 18-03-2010)
- FLC Group Weekly Meeting (DESY 12-04-2010)
- DESY Student Seminar (DESY 29-04-2010)

List of publications, poster and talks



Even if I’m in charge of this project most of the work is done in a collaborative effort with other colleagues in and outside DESY who complement my expertise with theirs

Backup Slides



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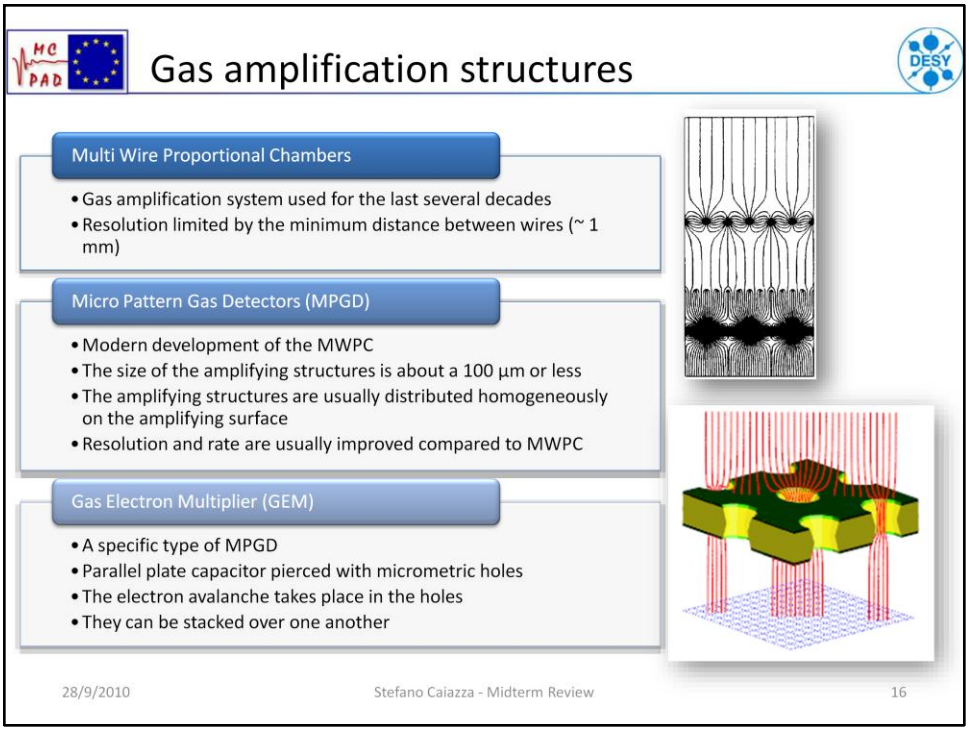

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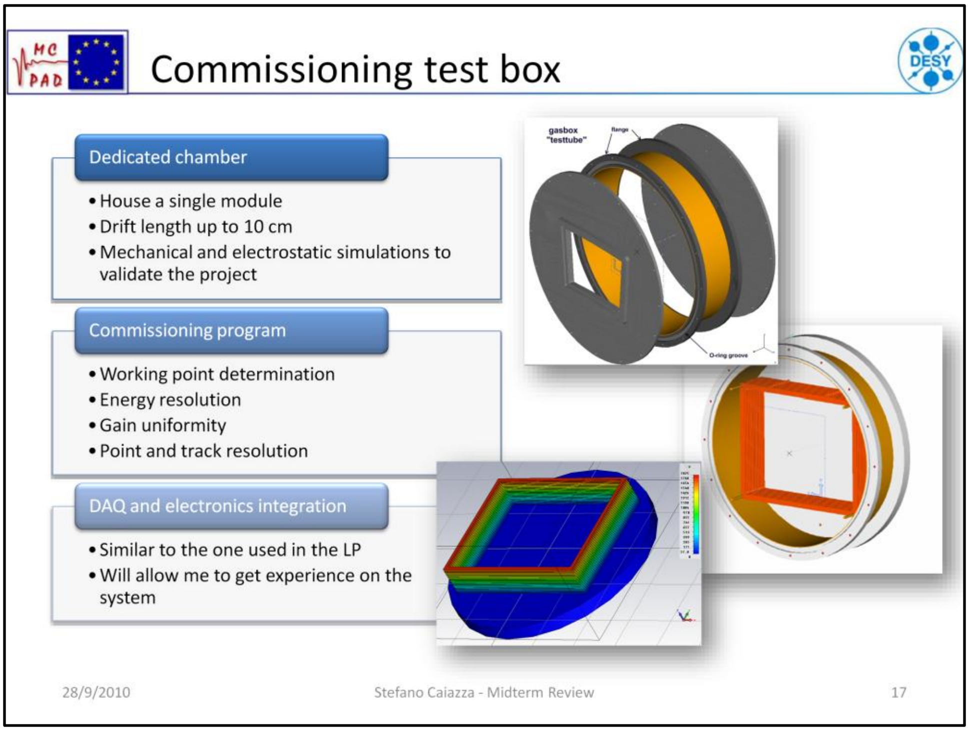


To commission the LP module before using it in a test beam campaign on the LP itself we decided to use a dedicated chamber. I'm in charge of the designing and producing of this chamber as well. The design is such to house a single LP module in a drift chamber up to 10 cm long. I performed electrostatic and mechanic simulations during the design phase to validate the project. I kept the design as modular as open as possible to be able to adapt the system to new requirements.

During the commissioning program I will measure the best working point for the GEM stack which is the best combination of fields to achieve the wanted gain, perform energy resolution measurements using radioactive source for calibration, measuring also the gain uniformity of the stack and trying to isolate the different sources of non uniformity. To this goal we set up a system to measure the surface profile of the GEMs to be able to deconvolute the non uniformities due to the sagging of the GEMs from other contributions. Finally we will complete the tests trying to reconstructs tracks from cosmic muons

To operate this chamber I'm also preparing a dedicated DAQ system. We decided to build a system similar to the one in use for the large prototype, to share expertise and equipment and to be also able to acquire experience in its operation before the test beam campaigns.

Future plans

Quality Control
- HV tests
- Profile measurements

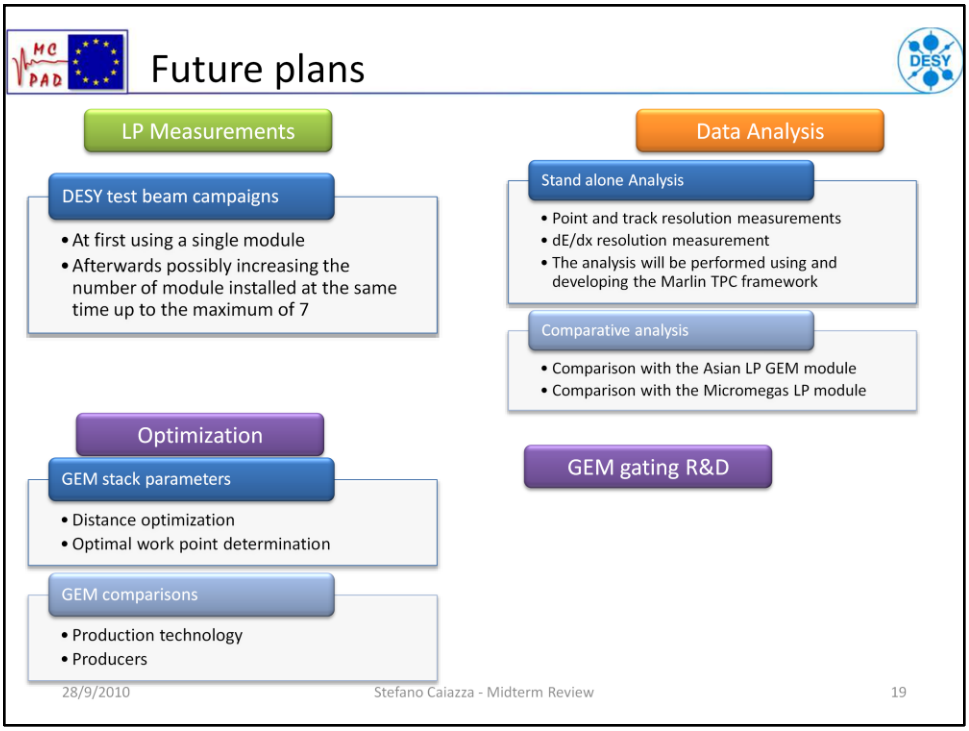
Full module assembly
- Gluing GEMs and ceramic units
- Installing the assembled GEM on the pad planes

Commissioning
- Dedicated chamber designed and under production
- Measurement with radioactive sources and cosmics
- Electronic integration

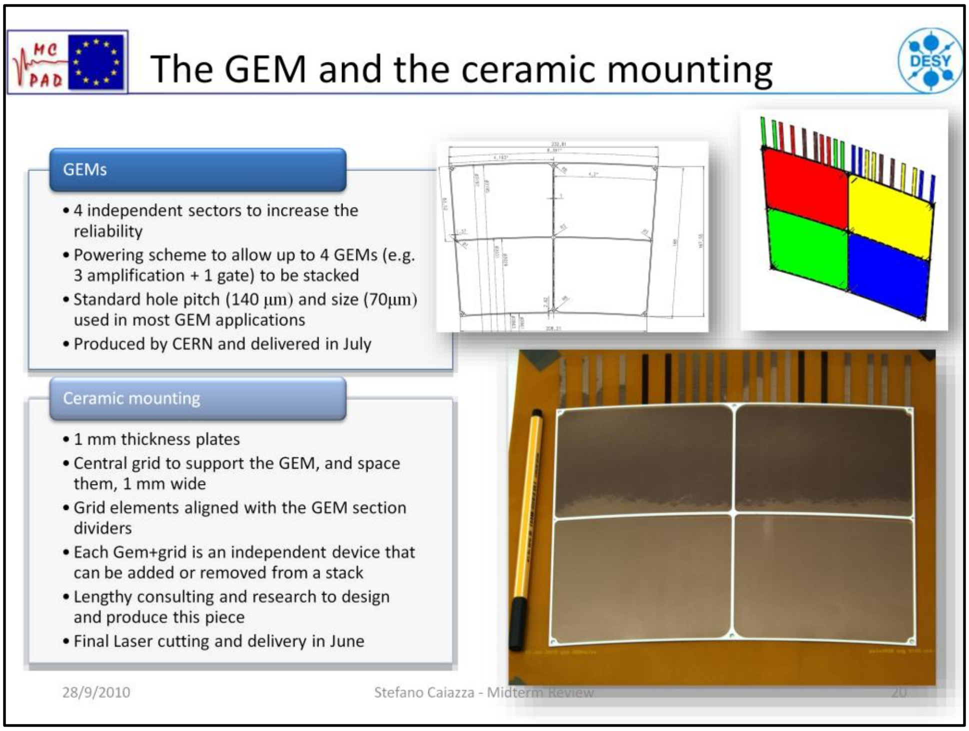
Optimization
- Stack layout optimization
- Work point determination
- GEM comparisons (e.g. production technology and producing companies)

LP Measurements
- Test Beams at DESY
- Single module first then up to 7 modules

Data analysis
- Stand alone measurements
- Comparison with the results of other groups in the collaboration
- Using and developing the MarlinTPC framework



Another of the main goals of the commissioning phase will be the optimization of the GEM stack, which means optimizing the parameters of the GEM stack, e.g. distance between the GEM and voltage loads across the GEM and the gaps
In a second moment it may be possible to compare different GEM types and producers in this same test box comparing, for example, the single mask etched GEMs with the normal double mask etched GEMs, or different producers like CERN, Techetch, SciEnergy ...
After the commissioning I'm going to perform data taking campaigns in the LP using the DESY test beam as a particle source.
The goals will be the measurements of the point and track resolution of the system and the measurement of the dE/dx resolution, at first using a single module than increasing this number up to the 7 that can be fitted in the LP endplate.
The data analysis will be performed using the MarlinTPC framework. After the stand alone analysis of the data of the module I designed I plan to compare this performances with the other GEM modules used in the LP and the Micromegas module



Because a GEM is like big capacitor, to avoid destructive discharges it's necessary to reduce the amount of energy that can be released in each of these discharges. For this reason the GEM surface has been divided in 4 electrically independent sector, each of which as an area about the same as a standard 10X10 cm^2 GEMs, usually used for testing.

The powering scheme of this GEM is one of the most important features and allows for the use of a 4 GEM stack that is up to a 3 GEM stack for amplification but with the additional possibility to introduce a 4^{th} stage to test, for example, gating schemes.

I choose the standard hole size and pitch used in the test GEMs. The GEM were produced by CERN and delivered in July

The ceramic mounting was produced by laser cutting 1mm thick raw ceramic plates. The central elements of the grid are 1 mm wide as well. The design allows for a good modularity of the system because each GEM is mounted separately on the ceramic structure and can be added or removed easily from a stack. Because of the small size of these features the production of this element was a lengthy process. Finally the width of the ceramic elements had to be slightly increased to 1.4 mm and the plates were delivered in June