Summary of the presentations and minute of the brain storming session

Sessions concerning WP1:

- Details about the head of the coordinate measuring machines were given as well as some information about the complexity of the probing process, including the trade of between the probing force and the application
- The measurement of the wire is a complex task which can be limited by the sensitivity of the CMM to the magnetic field, the shape and roughness of the wire, and the requirement for a non-contact probing
- The principle of frequency scanning interferometry and multilateration have been explained and an interesting method to reduce the standard deviation of the measurements has been presented (sweeping method in opposite directions)
- Development and tests were performed on Scanning Interferometry technics aiming at making possible the measurement of the copper beryllium wire: Alternatives to have a better reflection were presented
- After introducing the process of evaluation of the high index spheres as targets for FSI and their possible use, Dr Sulc concluded that these targets were looking promising, even if still under study
- The efficiency and the effectiveness of multilateration using laser trackers for CMM mapping was presented, particularly the performances are independent of the dynamics.
- The Q-Daedalus system and its capabilities have been presented, particularly for microtriangulation. More in particular, Sebastien Guillaume presented the main components of QDaedalus(Total station, CCD camera, focusing system, synchronisation system); the feature of Optical Target Recognition with 4 algorithms (Least-squares template matching, centroid operator, robust circle matching operator, robust ellipse matching operator) and some important applications (Automatic micro-triangulation, stress in reinforced concrete beam, kinematic/dynamic measurements)
- Vasileios presented the method of micro-triangulation (measure of horizontal and vertical angles to calculate 5 dofs geodetic networks); simulations of the precision (to estimate the uncertainties of the coordinates); the contribution of micro-triangulation in PACMAN(measure at the same time and in the same coordinate system the position of the wire and fiducials); and the improvements needed in order to use the system in PACMAN (software,hardware, stretched wire detection algorithm)

Reported by I. Doytchninov, P. Novotny, D. Tshilumba

Sessions concerning WP2:

Dr. Martin Albrecht (PTB)

"The activities and the equipment available in the magnetic measurement working group at PTB"

- Presentation about the magnetic measurements carried out from the magnetic measurements group at PTB, with some details about measurements with coils and calibration for coils
- Questions and discussion after the presentation:
  - Uncertainty of the dissemination of the unit Tesla, anticipated as 10^(-4)
  - Calibration done with magnets are fast and useful for the production, but the best and most precise calibration is with coils, which are more stable
  - There are standards for the gradients measurements , for some applications two coils may be used
  - Discussion about the magnetic shielding

Mr. Alexander Temnykh (Cornell University)

"Theory and applications of the vibrating stretched wire technique for high-precision quadrupole alignment"

- Theory of the vibrating wire for magnetic field measurements
- Introduction to Domenico Caiazza's talk, about the measurements on a small aperture quadrupole
- Discussion and questions after the presentation:
  - Is there a valuable difference in moving the wire or the magnet? It depends from the application and the setup available. For moving the magnet precise translation stage which can support an heavy load are required, this is why often moving the wire is easier
  - How good the tension has to be controlled? The resonant frequency depends also from the temperature, if the wire is closed in a tube it may be more stable
  - What is the quality factor of the resonant frequencies? It is around 100-200, but is it not a critical point for this application, even if from this parameter some important information may be deducted, such as temperature change and tension.

Domenico Caiazza (CERN)

"Stretched wire systems for the magnetic measurement of small-aperture magnets"

- Presentation about magnetic measurements using vibrating wire techniques, in the frame of the PACMAN project.

    - Here the challenge part comes from the small aperture diameter of the magnet, which is 8 mm.
- Introduction to magnetic field quality measurements, talk from Giodana Severino.
- He presented two methods that help to determine the magnetic center of the magnet: stretch wire and vibrating wire.
    - With the first method the idea is to displace the wire inside the magnet until finding that the magnetic field is cero.
    - With the vibrating wire method he will use two modes in order to determine the center of the wire and the tilt of the magnet.
- Experimental setup, with some measurements using both methods.
- He found solutions in order to compensate the background field that is not detectable by the stretched wire technique.
- He has already measured the magnetic axes of the quadrupole and fiducialize it. His results were presented at IPAC.
- He also was able to measure the amplitude of the oscillation of the wire with respect to the frequency and the vibrations that are described in an ellipse.
- Discussion and questions after the presentation:
    - Discussion about the background field compensation
    - About the PACMAN application, is it possible to make magnetic axis measurements with a lower current? Yes, it is possible, at the moment, the measurements are already done with a lower current, with respect to the CLIC magnet.

Dr. Walter Bich (INRIM)

<u>"A review of the state of the art, present norms and future trends in the field of the measurement uncertainty estimation"</u>

- Presentation about the uncertainty of measurement uncertainty and standard measurement uncertainty.
- He mentioned all the existing and future documents that describe the uncertainty of the measurement and there is one for each application.
- These documents don't explain how to evaluate the uncertainty but how to use it, the probability density function for the measurand,, decision rules and risks.
- Dr. Walter described the GUM method.
    - This method does not consider a few cases.
    - But there are remedies such as the Monte Carlo method explained in Supplements.
    - The GUM and its supplements are inconsistent and the GUM is ambiguous due to the definition of uncertainty in the GUM.
    - Anyways, the idea of making the GUM and its supplements as much consistent as possible is a purpose.

Gioordana Severino (CERN)

<u>"PCB technology for small diameter field probes."</u>

- She will use rotating coils in order to measure the field quality of accelerating magnets for CLIC in which the aperture diameter is 8mm.
- This consists on measuring multipoles coefficients.
- She explained the advantages and disadvantages of using milti-wire coil and PCB coil.
- The key point is that the measurement of the multipoles depends on the geometry of the coil.
- The calibration of the coil is very important in order to achieve a good sensitivity.
- She wants to use an in-situ calibration.
- She explained that she simulated the flux measurement in order to set the radious of the coil.
- The next step is to make measurements in the laboratory.
- She needs to measure the shape of the rotating coil with metrology.
- She presented the differences between using a polygonal or a cylindrical reference magnet.
- She also has to evaluate the sag of the coil.
    - This problem can be corrected.
- Finally, she exposed which are the future studies that need to be done.

Reported by N. Galindo and S. Zorzetti

Sessions concerning WP3:

- Introduction to Mechanical Integration and Error budgeting for the PACMAN project was made by Iordan Doytchinov. The precision engineering issues related to the mechanical integration and the assembly of MBQ magnet and MBQ and BPM integrations were outlined.
- Ms. Gomez presented the DMP company and their activities. DMP is a state of the art company which produces high precision components for different fields of industry and science like aerospace, military, particle accelerators etc.
- Mr. Garlasche introduced the challenges of the alignment of the collimators, one of the components the most exposed to the radiations of the beam.
- Peter Novotny explained why we want to use seismic sensors in the PACMAN project. And compared advantages and disadvantages of the current state of the art seismic sensors. He also introduced promising candidates which performance and resistance is currently tested.
- Dr Cougoulat introduced us to requirements of seismology to seismic instrumentation and showed us various instruments used in seismology covering the range of measurements extended in time.
- Dr. Janssens presented the different steps which have led to the design and testing of the nano-positioning prototype for the quadrupole magnet

- Using simulations, David summarised the performances requirements of the actuation stage for the nano-positioning of the magnet and described options to increase the range of this stage

More details about the WP3 PACMAN students:

Iordan's PhD topic: How to assemble the magnets to the highest accuracy: how to assemble the 4 parts to +-10µm, so that they work (the defects can add or subtract to each other and change the results), how to put the BPM on the magnet, and how to coordinate everything on the final bench so that they work together. Measurement of the position of the zero of the magnet with regards to the zero of the centre of the magnet -> error budget of the system: where do the uncertainties come from and what are their impact, how to overcome their impact or deal with them. At the moment, the subject is not well defined so it is reduced to the magnet, or to the uncertainties and how they propagate, to stop spreading and focus on only one point for Cranfield University to accept the subject. We have a final design of the magnet (we might change the inside but not the outside nor the size: ~80cm). It will have a frame, but we can maybe redesign it. The frame is attached to the magnet and aims at adding stiffness and reduce the resonances to improve the dynamical performances of the actuators.

Peter's part in the PACMAN project: Why do we want to use seismic sensor? The ground is always moving, and the bench can attenuate of amplify some frequencies of moves, we want to know which ones, and to see the correlation between electromagnetic measurements and ground motion. The frequencies of the seismic vibrations are low frequency, but the noise which Peter needs to measure is the technical noise, with higher frequencies. The sensor is doing nanometre and high resolution, but the measurements at higher frequencies are noisier. There are different types of sensors and one \might be easy to do change to fit the PACMAN project.

Reported by C. Sanz, V. Vlachakis, S. Kamugasa

Sessions concerning WP4

Mrs. Silvia Zorzetti (CERN)

"Stretched wire techniques for a 15 GHz RF-BPM"

- Presentation about the CLIC beam monitor cavity
- The cavities BPM are diagnostic instrument for accelerator to determine the beam position. To center the beam inside the quadrupole measures are done with BPM cavity. The aim of PACMAN is to align the magnetic center of quadrupole and the electric center of BPM.
- In the cavity different modes are exited: monopole mode (11GHz TM010) and the dipole mode (15GHz TM110)
- The study of interest is the TM110 .
- With four slot-coupled waveguide is possible to discriminate modes: with the monopole mode any signal is pickup by the guide while with the dipole mode a signal is pickup.
- For the Slater theorem if on a stretched wire inside a cavity it is present a perturbation to the Eigen frequency this cause the excitation of the interest mode TM110 .With the

displacement of wire it is possible to scan the area to find the minimum of the signal corresponding to the center (aligned position)

- The read signal has a quadratic dependence to the line displacement .The aim is to find the electric center and for this there are two technics:
- Signal excitation: more precise but are necessary more tools and the wire must be exited. Higher excitation around electrical center.
- Perturbation analysis: are easier fewer complexes to integrate inside the system. Lower sensitivity around the electrical center.

- Has been presented the actual test-bench and has been underline that for future implementation it is necessary to improve the actual test-bench and to develop a more complex system.
- The two stretch-wire methods introduced will be tested to find the most efficient method to implement.
- The first method will be presented in March

Dr. Dirk Lipka (DESY)

"Experience on design, prototyping and testing of the cavity BPM for the European-XFEL"

- Linear accelerator compress the beam very much so the energy is more concentrate .The European XFEL in building-up the most powerful laser with short wavelength. Desy has more repetition compared to other accelerator (Japanese) .The time between two bunch is 222ns. This means that the decay must be faster than 222ns.
- DESY is responsible for BPM mechatronics and PSI for the front end electronics and digitalization.
- There are two different time of CBPM one for undulator intersection and the other for the beam line position.
- Two simulations shows that the monopole mode and the dipole mode inside the CBPMs cavities.
- The mechanic characteristic of beam CBPMs cavities was introduced to underline that the RF – proprieties are linked to mechanical tolerances. Were also introduced the characteristic resonance frequency load and crosstalk important to reach a decay time of 6.7ns. About were shown the statistics characteristics on a production of 122 undulator cavity BPMs and on 30 BPM cavities.
- Has been introduced the electronic principle. The amplitude detection has a lower quality factor due to the high bunch repetitions (222ns).Has are used attenuators there is the problem that each attenuator has a di9fference that must be correct , otherwise there is the risk to introduce an error in phase.
- After the accelerating structure there are two FLASH .On FLASH1 is performed a beam based measurement: Are used all BPM except one under test and is predict the position of each bunch to this BPM .On FLASH2 CBPMs and two button BPMs are used to measure the difference between BPM under-test and the others. Building-up beamline of E-Xfel started in 2014 will end in 2016.

Dr. Nathan EDDY

"RF and digital signal processing of HOM and cavity BPM signals"

- The aim in RF measuament s from a beam is to measure both amplitude and phase so it is used the complex notation.
- As it is necessary a signal processing and the use of DAQS (analog digital convertion) the most important characteristics to take into account are : The drift that is undesired the accuracy (indicate by effective bits) performances flexibility and others.
- The problems that characterise a digital to analog conversion are:
- The aliasing (that can be a desired or un undesired effect), quantitation and sample clock jitter. All this effect can cause noise and a lost in the DAQ performances shown by the SNR signal to noise ratio .Explication of aliasing frequency effect and of the jitter.Esplication of the quadrature Down- conversion do to shift signal in frequency and send more signal togheter in quadrature after followed by a decimating low pass filter to demodulate the signal.
- Introduction on a single side –band signal Mixer used to supress one side band by shifting in frequency. Explication of HOM Downmix Electronics that use the structure previously introduce :SSB MIXER ADC RF AND IF.
    - Slides that shows the final HOM Multi-Channel Downmix Electronics and the labview interface developed for it. Dedicated multi-channel downmix electronics have been developed for the 3.9GHz module installed in FLASH and A three channel 15GHz prototype is almost complete.

Mrs. Natalia Galindo Munoz (CERN)

"EM field alignment of the CLIC accelerating structure with help of WFM signals"

- The accelerating structure to be used in CLIC has been described. It consists of 24 coupled cells where the mode TM010 at 12 GHz is excited to accelerate the particle beam, 2 coupling cells for input and output power, damping waveguides with RF absorbers of high order modes and 4 wake field monitors to detect the misalignment of the structure with respect to the beam.
- The concepts of pre-alignment with respect to external fiducials and beam-based alignment have been presented. These steps are crucial for limiting the emittance growth, which imposes tight manufacturing tolerances for the components of the structure.
- The accelerating structure has to be fiducialized within 7 µm with respect to its electromagnetic center and the wake field monitors have to provide an accuracy of 3.5 µm. Two methods are being investigated to achieve these goals. One consists in using a stretched wire as an excitation and is suitable to prove the required accuracy for the wake field monitor. The second one uses the wire as a perturbation and is suitable for the fiducialization.

- A schematic of the test bench has been showed. This will be the same bench used for the BPM.
- Simulations concerning the second method have been presented. The scattering parameters have been studied as a function of the excitation frequency for different models of the structure. The results confirm that the wire creates a large enough perturbation to be sensed by the detecting devices.
- <u>Discussion</u>
    - Even though in principle also a dielectric wire is suitable, a conducting wire (copper) will be used as the same wire is to be used also for magnetic measurement of the main beam quad.
    - Despite the simulated method is more sensitive at lower frequencies, the alignment frequency will be tuned at 17 GHz so that the technologies currently available can be used.

Dr. Andrea Mostacci (Sapienza University of Rome e INFN-Roma I (IT))

<u>*"Stretched wire measurements and impedance matching"*</u>

- The theoretical basics of the use of a stretched wire to measure RF properties and the issues arising from the presence of transmission lines with different characteristic impedance have been presented.
- Both simulations and experiments in the EPA machine have shown the effectiveness of a stretched wire in simulating the beam when a pulse in sent into the wire itself.
- The problem of impedance mismatching has been introduced. Here matching sections are required to change impedance to the value required in the measured line in order to minimize reflections.
- One diagnostic technique for impedance mismatching, the Time Domain Reflectometry, where impedance mismatches are separated in time, has been described.
- Resistive matching networks allow the desired impedance matching to be obtained. The working principle of this technique has been described and illustrative examples have been shown.
- If the working frequency is such that the parasitic effects in the resistors become dominant, then solutions based on tapers con be adopted. However, tapers can generate string reflections at low frequency. This drawback can be overcome by using the technique of time domain filtering.
- <u>Discussion</u>
    - As far as the measurement system is calibrated, the type of connection to the analyzer (differential or single ended) should not affect the accuracy in measuring the impedance of a line.
    - If possible the measurement setup can be also vertical, in order to improve mechanical stability and avoid wire sagitta.

Dr. Reidar Lunde Lillestol (CERN/Uni. Oslo)

<u>*"Wake field monitors conception, installation and measurements in the CTF3 TBM and TBTS"*</u>

- Transverse wakes generated by beam offset in the accelerating structures can kick the beam, determining emittance growth. Wake field monitors can detect this misalignment with the aim of minimizing the offset.
- The structure of the CLIC Test Facility 3 has been described, with the-two beam test stand, now replaced by the two-beam module, where 4 accelerating structures are located and two wake field monitors for each structure.
- Measurement of wake fields performed on the two-beam test stand and first results on the two-beam module have been presented. In the first case, the wake field monitor gave a good resolution and revealed a horizontal misalignment of the structure. In the second case a background signal is present in the measurement, which is hard to compensate as it is different between the data sets.
- A new solution based on Electro-Optical Modulators for the front end of the wake field monitor will be probably tested in this year on the two-beam module.
- <u>Discussion</u>
    - The measurement on the two-beam module at 24 GHz presented a quite huge amount of noise. This depends on the working frequency, in fact such a noise was not found at 18 GHz.

Reported by G. Severino and D. Caiazza