ESS-Bilbao contribution to the ILC-DR/BDS/DUMP subgroup

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- Intro to ESS-Bilbao
- ESS-Bilbao experience with PMQs
- Some activities related to ILC BD PMQs
- Information and contact

ESS-Bilbao


ESS bilbao
Who we are?
Public consortium of Central and Basque Governments; bringing knowledge and added value in particle accelerator and neutron scattering science and technologies; by leveraging its in-kind contribution to the European Spallation Neutron Source, in Lund (Sweden)
48 employees
age average: 40
29% women
71% men
Qualification
27% PhD
13% Post Graduate Degree
44% Master's Degree
8% Bachellor
8% Technician
Headquarters
R&D Center
AWF
Madrid Satellite
Polígono Ugaldeguren III
Zamudio (Bilbao)
Parque Tecnológico
Zamudio (Bilbao)
Polígono Industrial Júndiz
Vitoria-Gasteiz
Instituto de Fusión Nuclear
Madrid
EUSKO JAURLARITZA
GOBIERNO VASCO

ESS-Bilbao

In-Kind Contributions to ESS

MEBT

Accelerating element: complete subsystem that goes after the RFQ and integrates: design, manufacturing, diagnostics, control, assembly and testing.

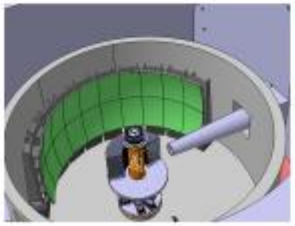
RF Systems

RF chains: 1 for RFQ and 5 for DTL.
Composed by klystrons, modulators, loads, waveguides, interlocks and LLRF

TARGET

The spallation process takes place when the accelerated proton beam hits the Tungsten bricks of the 11-tonne target wheel. This will produce neutron brightness for scientific experiments across multiple disciplines.

MIRACLES INSTRUMENT



Time-of-Flight backscattering instrument for polymer science, energy materials, and magnetism studies.
Prime contractors: design, manufacturing, assembly &cold commissioning

EUROPEAN SPALLATION SOURCE

EUSKO JAURLARITZA GOBIERNO VASCO

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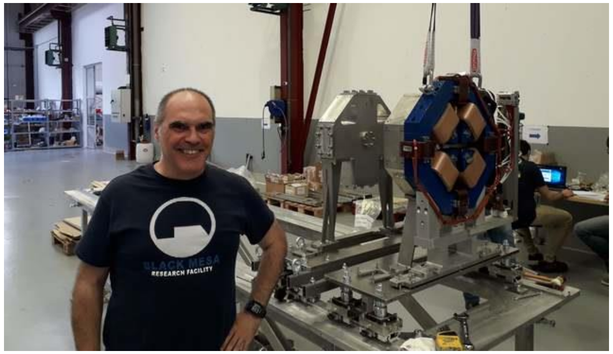
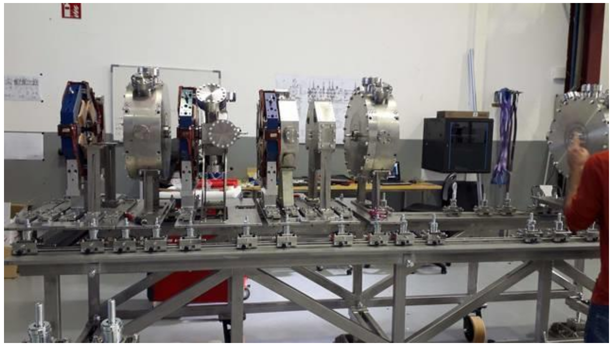
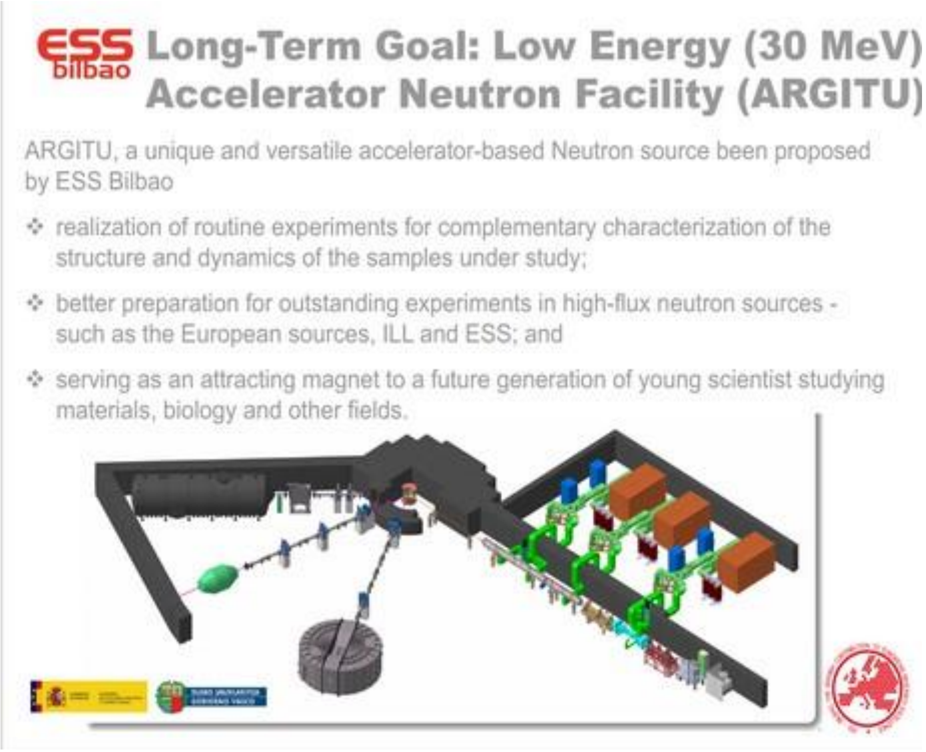
- **ESS MEBT: Designed, built and delivered!**


ESS-Bilbao

- **ESS-Bilbao in-house projects:**
  - Injector (Ion source+LEBT+RFQ)
  - RF Test Stand



Experience in PMQ

- Mainly comes from DTL PMQs.
- ESS-Bilbao DTL (past and forseen designs) is a clone of CERN-Linac4 DTL

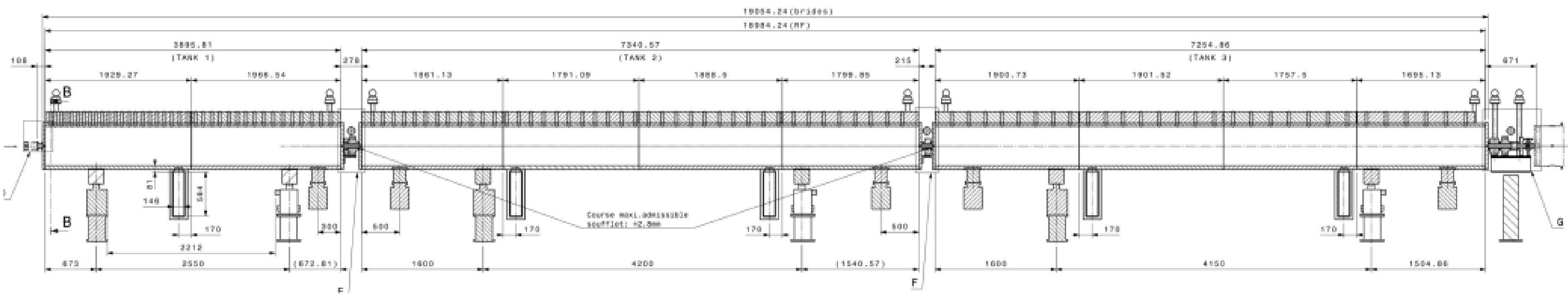


Figure 1.1: Drift Tube Linac layout, showing the three tanks.

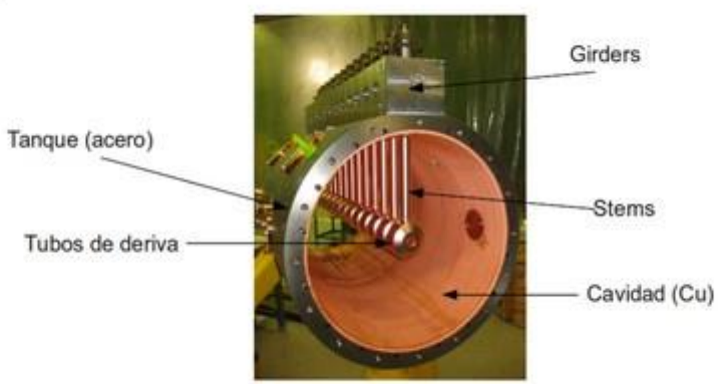
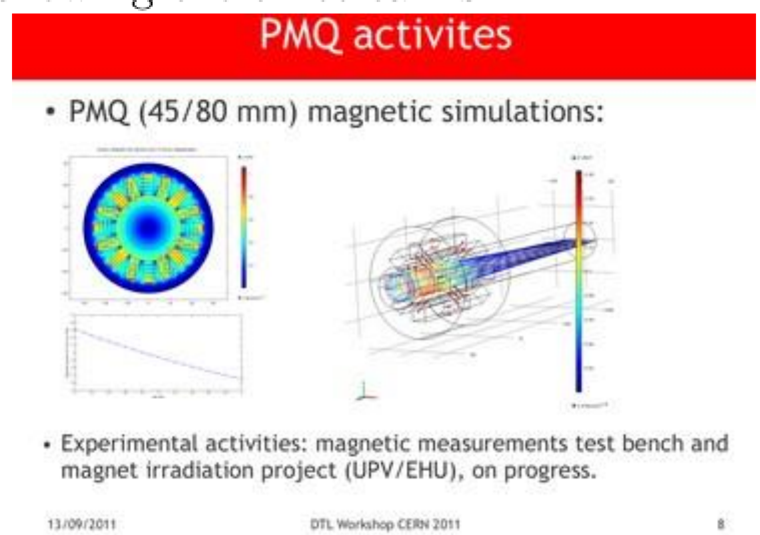
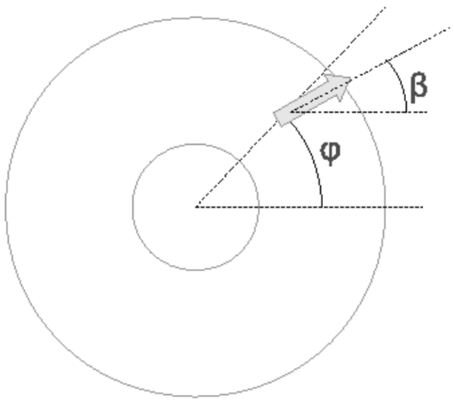


Figure 1.2: Linac4 DTL prototype.

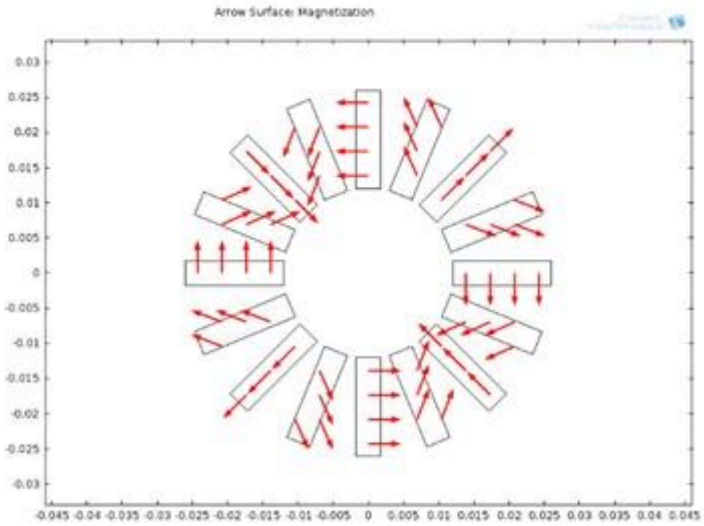


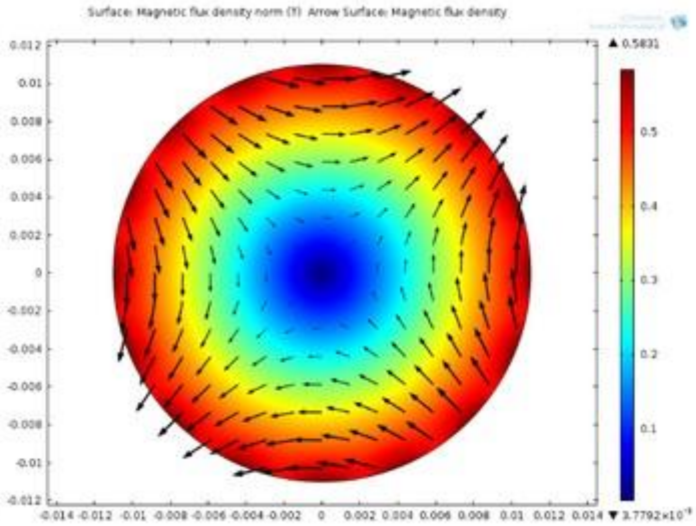
Experience in PMQ

- We made our design for PMQs, as they had different gradients.
- Standard Halbach arrays approach



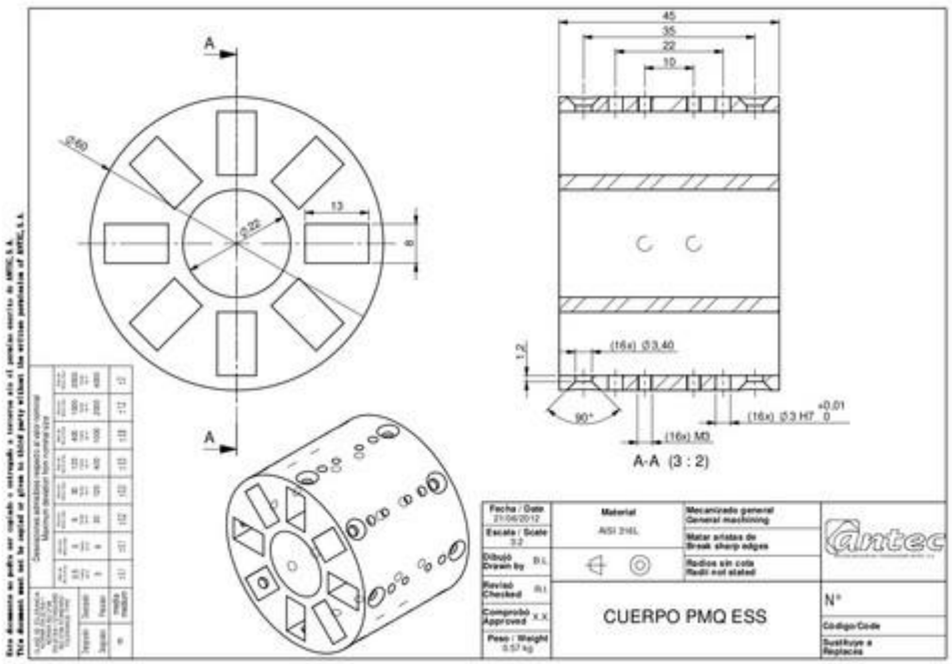
$$\beta(\varphi) = \varphi(N+1)$$





Experience in PMQ

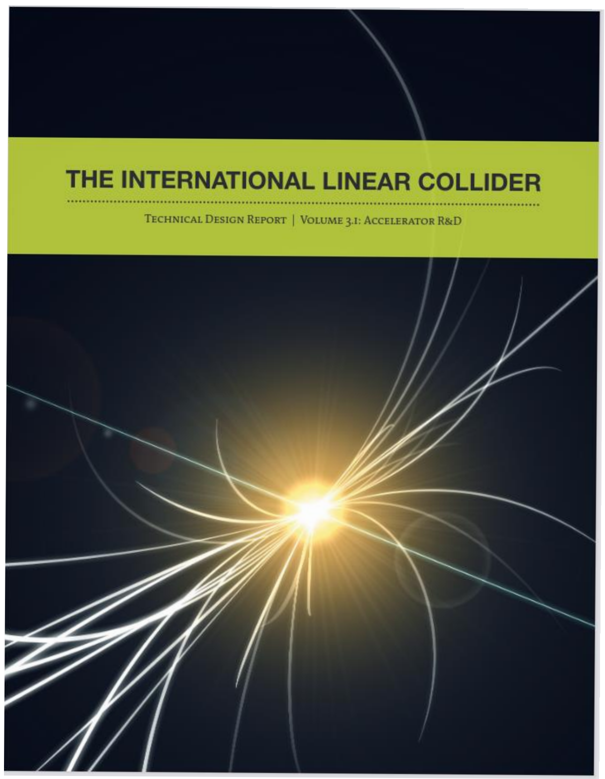
- Prototype fabricated for testing and irradiation experiments (in a project driven by UPV/EHU.

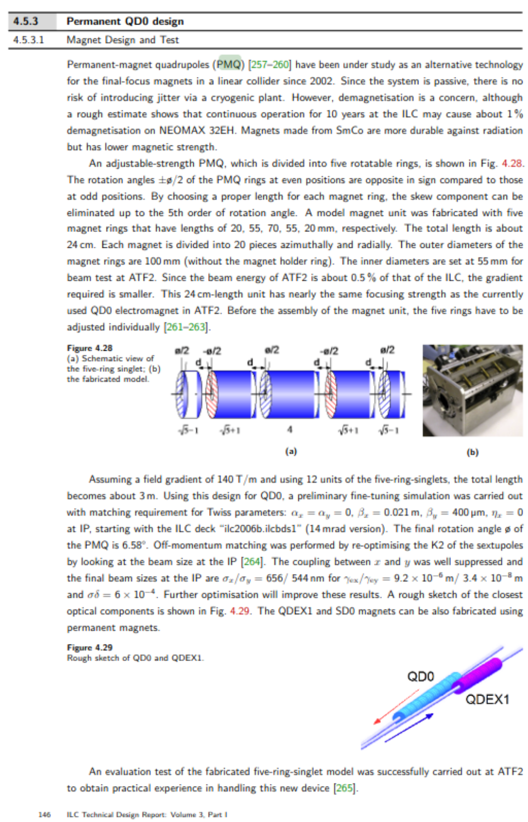


- Testing unfinished due to early project ending.

Activities for ILC - BD

- Magnetic calculations with QD0 magnet, as described in TDR





4.5.3	Permanent QD0 design
4.5.3.1	Magnet Design and Test

Permanent-magnet quadrupoles (PMQ) [257–260] have been under study as an alternative technology for the final-focus magnets in a linear collider since 2002. Since the system is passive, there is no risk of introducing jitter via a cryogenic plant. However, demagnetisation is a concern, although a rough estimate shows that continuous operation for 10 years at the ILC may cause about 1 % demagnetisation on NEOMAX 32EH. Magnets made from SmCo are more durable against radiation but has lower magnetic strength.

An adjustable-strength PMQ, which is divided into five rotatable rings, is shown in Fig. 4.28. The rotation angles $\pm ø/2$ of the PMQ rings at even positions are opposite in sign compared to those at odd positions. By choosing a proper length for each magnet ring, the skew component can be eliminated up to the 5th order of rotation angle. A model magnet unit was fabricated with five magnet rings that have lengths of 20, 55, 70, 55, 20 mm, respectively. The total length is about 24 cm. Each magnet is divided into 20 pieces azimuthally and radially. The outer diameters of the magnet rings are 100 mm (without the magnet holder ring). The inner diameters are set at 55 mm for beam test at ATF2. Since the beam energy of ATF2 is about 0.5 % of that of the ILC, the gradient required is smaller. This 24 cm-length unit has nearly the same focusing strength as the currently used QD0 electromagnet in ATF2. Before the assembly of the magnet unit, the five rings have to be adjusted individually [261–263].

Figure 4.28
(a) Schematic view of the five-ring singlet; (b) the fabricated model.

Assuming a field gradient of 140 T/m and using 12 units of the five-ring-singlets, the total length becomes about 3 m. Using this design for QD0, a preliminary fine-tuning simulation was carried out with matching requirement for Twiss parameters: $\alpha_x = \alpha_y = 0$, $\beta_x = 0.021$ m, $\beta_y = 400\,\mu$m, $\eta_x = 0$ at IP, starting with the ILC deck "ilc2006b.ilcbds1" (14 mrad version). The final rotation angle ø of the PMQ is 6.58°. Off-momentum matching was performed by re-optimising the K2 of the sextupoles by looking at the beam size at the IP [264]. The coupling between x and y was well suppressed and the final beam sizes at the IP are $\sigma_x/\sigma_y = 656/\ 544$ nm for $\gamma_{\epsilon x}/\gamma_{\epsilon y} = 9.2 \times 10^{-6}$ m/ 3.4×10^{-8} m and $\sigma\delta = 6 \times 10^{-4}$. Further optimisation will improve these results. A rough sketch of the closest optical components is shown in Fig. 4.29. The QDEX1 and SD0 magnets can be also fabricated using permanent magnets.

Figure 4.29
Rough sketch of QD0 and QDEX1.

An evaluation test of the fabricated five-ring-singlet model was successfully carried out at ATF2 to obtain practical experience in handling this new device [265].

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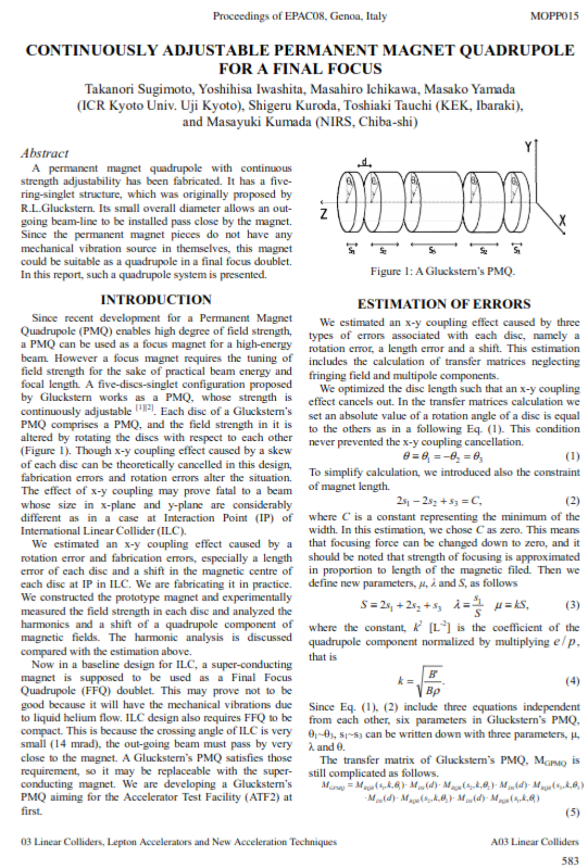

Proceedings of EPAC08, Genoa, Italy MOPP015

CONTINUOUSLY ADJUSTABLE PERMANENT MAGNET QUADRUPOLE FOR A FINAL FOCUS

Takanori Sugimoto, Yoshihisa Iwashita, Masahiro Ichikawa, Masako Yamada (ICR Kyoto Univ. Uji Kyoto), Shigeru Kuroda, Toshiaki Tauchi (KEK, Ibaraki), and Masayuki Kumada (NIRS, Chiba-shi)

Abstract

A permanent magnet quadrupole with continuous strength adjustability has been fabricated. It has a five-ring-singlet structure, which was originally proposed by R.L.Gluckstern. Its small overall diameter allows an out-going beam-line to be installed pass close by the magnet. Since the permanent magnet pieces do not have any mechanical vibration source in themselves, this magnet could be suitable as a quadrupole in a final focus doublet. In this report, such a quadrupole system is presented.

Figure 1: A Gluckstern's PMQ.

INTRODUCTION

Since recent development for a Permanent Magnet Quadrupole (PMQ) enables high degree of field strength, a PMQ can be used as a focus magnet for a high-energy beam. However a focus magnet requires the tuning of field strength for the sake of practical beam energy and focal length. A five-discs-singlet configuration proposed by Gluckstern works as a PMQ, whose strength is continuously adjustable [1][2]. Each disc of a Gluckstern's PMQ comprises a PMQ, and the field strength in it is altered by rotating the discs with respect to each other (Figure 1). Though x-y coupling effect caused by a skew of each disc can be theoretically cancelled in this design, fabrication errors and rotation errors alter the situation. The effect of x-y coupling may prove fatal to a beam whose size in x-plane and y-plane are considerably different as in a case at Interaction Point (IP) of International Linear Collider (ILC).

We estimated an x-y coupling effect caused by a rotation error and fabrication errors, especially a length error of each disc and a shift in the magnetic centre of each disc at IP in ILC. We are fabricating it in practice. We constructed the prototype magnet and experimentally measured the field strength in each disc and analyzed the harmonics and a shift of a quadrupole component of magnetic fields. The harmonic analysis is discussed compared with the estimation above.

Now in a baseline design for ILC, a super-conducting magnet is supposed to be used as a Final Focus Quadrupole (FFQ) doublet. This may prove not to be good because it will have the mechanical vibrations due to liquid helium flow. ILC design also requires FFQ to be compact. This is because the crossing angle of ILC is very small (14 mrad), the out-going beam must pass by very close to the magnet. A Gluckstern's PMQ satisfies those requirement, so it may be replaceable with the super-conducting magnet. We are developing a Gluckstern's PMQ aiming for the Accelerator Test Facility (ATF2) at first.

ESTIMATION OF ERRORS

We estimated an x-y coupling effect caused by three types of errors associated with each disc, namely a rotation error, a length error and a shift. This estimation includes the calculation of transfer matrices neglecting fringing field and multipole components.

We optimized the disc length such that an x-y coupling effect cancels out. In the transfer matrices calculation we set an absolute value of a rotation angle of a disc is equal to the others as in a following Eq. (1). This condition never prevented the x-y coupling cancellation.

$$\theta = \theta_1 = -\theta_2 = \theta_3 \qquad (1)$$

To simplify calculation, we introduced also the constraint of magnet length.

$$2s_1 - 2s_2 + s_3 = C, \qquad (2)$$

where C is a constant representing the minimum of the width. In this estimation, we chose C as zero. This means that focusing force can be changed down to zero, and it should be noted that strength of focusing is approximated in proportion to length of the magnetic filed. Then we define new parameters, μ, λ and S, as follows

$$S = 2s_1 + 2s_2 + s_3 \quad \lambda = \frac{s_1}{S} \quad \mu = kS, \qquad (3)$$

where the constant, k^2 [L^{-2}] is the coefficient of the quadrupole component normalized by multiplying e/p, that is

$$k = \sqrt{\frac{B'}{B\rho}}. \qquad (4)$$

Since Eq. (1), (2) include three equations independent from each other, six parameters in Gluckstern's PMQ, θ_1~θ_3, s_1~s_3 can be written down with three parameters, μ, λ and θ.

The transfer matrix of Gluckstern's PMQ, M_{GPMQ} is still complicated as follows.

$$M_{GPMQ} = M_{RQR}(s_1,k,\theta_1)\cdot M_{DR}(d)\cdot M_{RQR}(s_2,k,\theta_2)\cdot M_{DR}(d)\cdot M_{RQR}(s_3,k,\theta_3)$$
$$\cdot M_{DR}(d)\cdot M_{RQR}(s_2,k,\theta_2)\cdot M_{DR}(d)\cdot M_{RQR}(s_1,k,\theta_1) \qquad (5)$$

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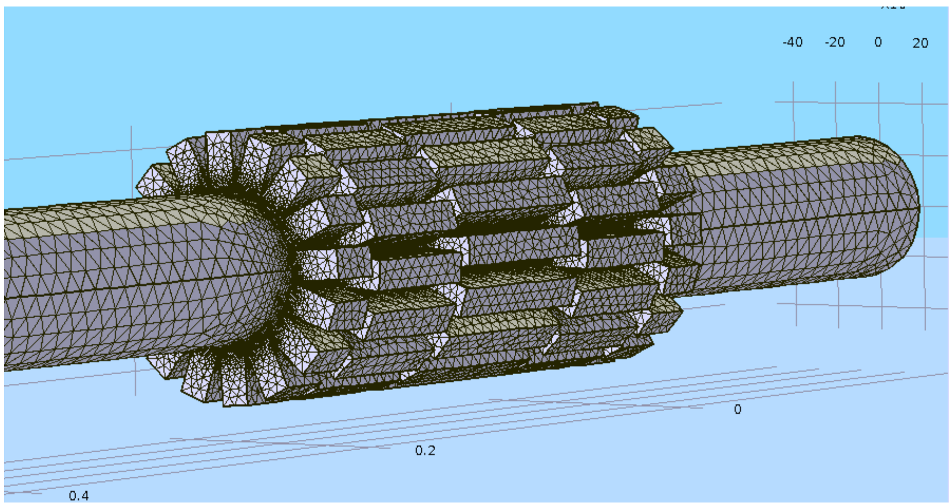
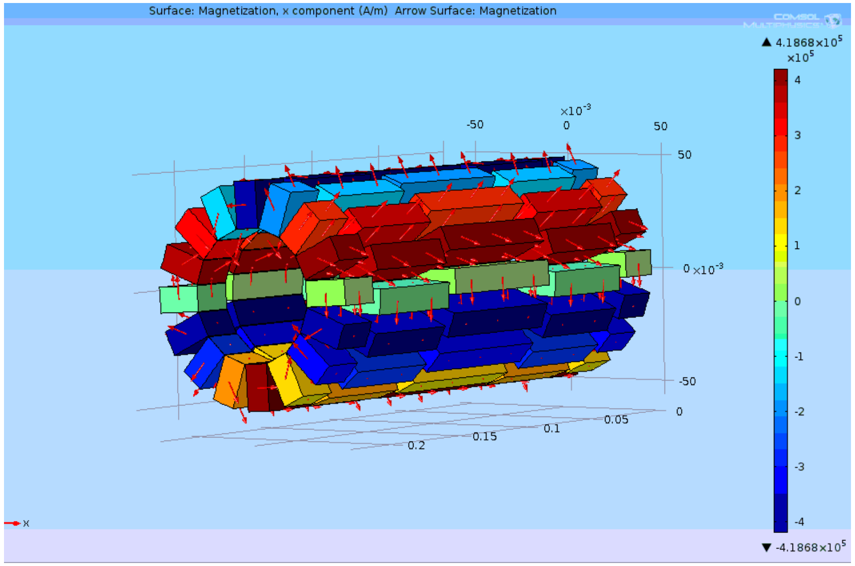
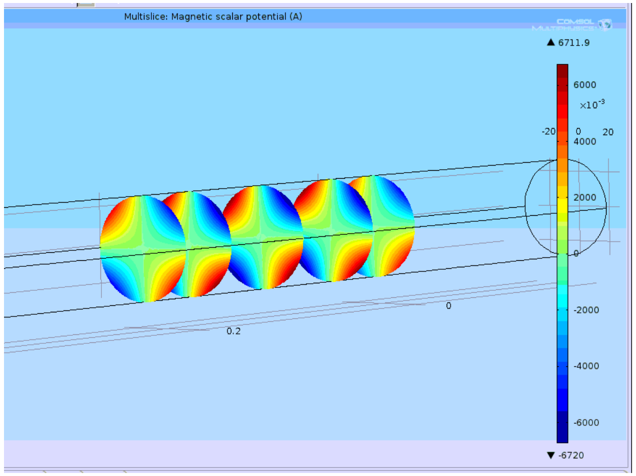
Activities for ILC - BD

- Magnetic calculations with QD0 magnet, as described in TDR, to grasp an idea of how it operates







- Simulations scripted for parametric optimization and beam dynamics

ESS-Bilbao capabilities

- **ESS-Bilbao capabilities related to these activities:**
  - Simulation and design of accelerator cavities and magnets
    - Main tool: COMSOL Multiphysics (for electrostatics, RF, magnetic devices, thermo-mechanical, CFD) + MATLAB scripting.
    - ELCANO home code for cluster calculations
    - Additional tools: Ansys mechanical; home made codes for specfic problems: CAD production and meshing, simulation (FeniCS)
  - Beam dynamics: GPT, Toutatis, Tracewin…
  - Local workstations + access to university/research centers HPC clusters
  - Experience in design and coordination of fabrication and measurement of magnets

ESS-Bilbao

- **ESS-Bilbao contacts:**
  - Juan Luis Muñoz (jlmunoz@essbilbao.org)
    - Accelerator Physics and Technology senior researcher, electromagnetic+... design and simulation
  - Ibon Bustinduy (ibustinduy@essbilbao.org)
    - Accelerator Division Head, acc. Physics
  - Estefanía Abab (eabad@essbilbao.org)
    - Collaborations and projects
  - Fiamma G. Toriello (fgtoriello@essbilbao.org)
    - Management office