Making Masculinity in Plasma Physics: Machines, labour and experiments

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The aim of this article is to analyse masculinity and experimental practices among plasma physicists. The study is based on ethnographic field work with observations and interviews among experimental plasma physicists in a laboratory in the United States. Through daily practices and hands-on situations, the experimental plasma physicists defined their experimental work as strongly associated with masculinity. Both practices and discourses about working with the experiments were fringed with connotations of a craft, of strength and physical efforts. Together, the practices and discourses were used as marks of identity for the laboratory and for the group of physicists within.

Keywords: Masculinity, experimental plasma physics, experimental practice

Introduction

The aim of this article is to analyse experimental practices among plasma physicists as gender creating processes with perspectives from masculinity studies. The study is based on ethnographic field work with observations and interviews among plasma physicists in a laboratory in the United States. The physicists were followed in their daily work in the laboratories, at the office, during conference participations and research seminars.

I argue that perspectives from masculinity studies are central when analysing gender dynamics within scientific communities. Interpreting gender and specifically cultural aspects of masculinity contribute to the understanding of the domination of men by rank and number within the physics community and "science in general". The use of a masculinity perspective will enrich current understanding about the lack of women in science. I claim that the category of men needs to be analyzed as a political category within research communities. Furthermore, such an analysis enhances our conception of knowledge and power within academic communities on a local and global level.

Physicists are a well studied community. Anthropologists, historians of science, educational researchers and researchers in many other fields have played an important role in our understanding for the physicist community (Galison & Hevly (eds), 1992; Gusterson, 1996; McNeil & Sher, 1998; Ong, 2001 & 2005; Hasse & Trentemøller, 2008; Hasse, Sinding & Trentemøller (eds), 2008). One of the groundbreaking studies was Traweeks fieldwork among high energy physicists at SLAC at Stanford and KEK in Tsukuba. Likewise, Gusterson conducted a massive ethnographic fieldwork when

studying nuclear physicists in the Lawrence Livermore Laboratory in northern California (Traweek, 1988; Gusterson, 1998).

An ethnographer can contribute to critical analysis of culture and society by "studying up". This, Nader writes, includes powerful institutions and groups in society that enjoy influence, money, space and voice. Examples are scientists and cultural spaces of gender dynamics (Nader, 1974: 284-286; Pettersson, 2007: 26).

It is no exaggeration to say that science and physics are associated with men. Several feminist science studies scholars have documented and analyzed the ways in which physics is related with a certain gender (Cohn, 1987; 1987; Danielsson, 2009; Fox Keller, 2001: 9ff; Merchant, 1980; Quinn, 1995). A widely spread common image of the scientist is a portrait of Einstein, a mild modification of the crazy scientist but nevertheless a genius. Another variant is the controlled scientist in his lab, preferably someone like Louis Pasteur (De Meis et. al., 1993; Schummer & Spector, 2007: 224f).

Given the numbers in science education and physics education in the United States, the numbers of women registered at the post graduate programs in physics in 2005 are 1430 according to National Science Foundation (NSF).[1] The overall amount of post graduate student in physics is 13472.[2] This should be compared with the overall number of post graduate students in science and engineering, which 2005 were 478472. The numbers of female post graduate students in science and engineering were 206633. Given the quantity of women at the post graduate programs in S&E, the image of the scientist as a man is quite misleading (Whitten 2008, 103-105; Etkowitz, Kemelgor & Uzzi, 2000: 11).[3] Still, the percentage of male post graduate students in physics far exceeds the amount of female post graduate students.

The images of the gendered symbolic values in science are striking. At the same time, there is a paradox; research and science are arenas regarded as rational environments; neutral, unbiased and objective (see Ziman, 1996; 2000). An important part of this ideology is the ideal of objective research, a belief in gender neutrality and lack of gender biases (Rosser, 1989).

This article starts with an overview on gendered science and physics. The overview is followed by a discussion about men as politicised subjects in relation to science. I continue with a presentation of the plasma physics environment where I conducted field work. The ethnographic set up is followed by a section where I discuss the relationship between masculinity, machines, and embodiment in experimental plasma physics. Finally, I make an analysis on how the experimental setting with assumed physical efforts, danger, and dirt are used as marks of identity for the members of the laboratory.

Gendered Science and Gendered Physics

The idea of the physicist as a thinking male genius has been represented many times through images of scientists such as Isaac Newton and Albert Einstein. Even though many women were active physicists during the time before 2nd World War, for example in Vienna, to conduct physics is nonetheless represented as a discipline dominated by one gender category—men (Quinn, 1995; Fox Keller, 2001: 9ff; Bischof, 2006. Compare with Hoddeson & Daitch, 2002).

With successful women such as Marie Curie, there were several role models and examples of women who conducted physics. Despite these early role models, men have continued to dominate physics, and continued to do so after World War II (Whitten, 2008).[4] The interest in gender and science rose around the 1970s, in parallel

with the women's movement. Women scientist such as Rosalind Franklin and Barbara McKlintock were made visible by Sayre and Fox Keller (Sayre, 1975; Fox Keller, 1983).These studies made the important contribution by showing how science and technology through history, culture and society are strongly related with masculine connotations.

For a long time, feminist theory has contributed with groundbreaking analysis on science and technology studies. For example, Harding and Haraway have critically deconstructed the aura of neutrality within science and technology. As Sandra Harding argues, the "women question" in science, has been transformed into a "science question in feminism." (Harding, 1986, 2008; Haraway, 1991, 1998. Also see Haraway, 1997).

Cohn, Fox Keller and Merchant have for example studied the practice of science and how gender is present through language, contests, domination, direction and ideology (Cohn, 1987a; 1987b; Fox Keller, 1985; Merchant, 1990). These were central contributions to the understanding of science and technology from a gender perspective. Since then, gender studies have expanded.

Earlier feminist research on women, gender and science and technology has made a crucial work to analyze a subordinated category (women) within the field of science and technology. Traweek, for example, underlines how "gender is a difference that makes a difference" in relation to the low amount of women and high amount of men within particle and high energy physics community (Traweek, 1988: 117). Traweek also points at how traditional sex roles in the broader society continue to determine the division of labour in science. Ideas regarding the female brains capability of conducting science, restrictions in experimental facilities for health reasons, and the importance of social activities outside work, all includes gendered aspects to women's disadvantage in scientific work (Traweek, 1988). What is thus missed in theses analysis of science and technology is the analysis of how the male dominated physics culture is sustained.

The crucial and pioneering work on making women visible as a political category has been a base for the possibility of making men as a political category (Mac an Ghail & Haywood, 2007: 29). It is important to recognise the social and cultural basis of knowledge production when examining the generation of knowledge about men (Ashe, 2000: 128). Mac an Ghaill & Haywood highlight a risk for a tension in parallel approaches of both feminist studies and studies of men and masculinities (Mac an Ghail & Haywood, 2007: 2).

This tension is not directly a crisis of women's and men's cultural and social practices. Rather, gender as category provides a lens through which the assumed crisis is perceived and mediated (Mac an Ghail, & Haywood, 2007: 2). With a risk of creating dichotomy, it is even more important to see masculinity studies and feminist studies as frameworks for interplay. Rather, we should ask what sort of masculinities or femininities we make visible/examine/analyse.

Men as Political Category

As the history and the scientific environments for physicist are so dominated by men, masculinity studies are a useful approach. A critical perspective on the development of masculinity studies raises the issue of men *again* being in focus in studies of science and technology. To a large extent, men and men's "discoveries" have been highlighted in the history of science. Hearn emphasises that studies of men is not a new discipline. Most work about humans is about men. To make men an invisible gender category is a

structured way of not beginning to talk and question men's power in relation to women, children, and young people and indeed other men" (Hearn, 1998b: 786). It is also a way of making men represent normality.

The words "the personal is political" is a phrase related to the 1970s women's movement. The phrase is also stressed by Whitehead. "Men" is a political category as women (Whitehead, 2008: 45-47; 59-61). He continues,

> in presenting the case for seeing men as political category it is equally important to draw attention to how such a category is sustained, not only by men's supposedly instrumental desire for power over women, but through the more subtle and arguably more profound conditions of discursive associations [...] (Whitehead, 2008: 60).

And that is, Whitehead argues, the dominant privileged knowledge's that serve to reify what he call "historically transitory" category of men (Whitehead, 2008: 40; Hearn, 1998). As women, *men are also a gendered category*. Therefore, spaces dominated by men and men as gender category need to be further analysed.

As a result of choosing to analyze men as political subjects, that also allows a deeper analysis of the gendered domination in science and technology. The development of masculinity studies encourages science and technology to focus on the main practitioners within the field as well as the minorities; men and women and their relational making of gender. Analyses of men and masculinities as a subject of politics, for example works such as Hearn and Connell are crucial contributions for further understanding the gender dynamics in culture and society (Hearn, 2006; Hearn & Parkin, 2001; Connell, 2005; Connell & Messerschmidt, 2005; also see Edwards, 2006).

A major concept analysed within masculinity studies is hegemonic masculinity (Connell, Lee & Carrigan, 1985). The concept of hegemonic masculinity was later revised by Connell and Messersmidt to integrate a model of multiple masculinities. According to Connell, masculinity concurrently refers to a context or place, where the subject is positioned within contexts of power (Ashe, 2005: 145; Connell, 1995: 71). An example would be academic institutions, like scientific laboratories. Also, it includes the practice of subjects within that place and the effects of those practices on 'bodily experience, personality and culture" (Connell & Messerschmidt, 2005).

Furthermore, Connell argues that masculinity is not predetermined, neither pre-cultural. It is a relational term. Also, Connells write, no masculinity arises except in a system of gender relations (Connell, 1995: 71). Masculinity is therefore a formation of practices, culturally organized in arenas of power between men and women. According to Connell, hegemonic masculinity is heterosexual, aggressive and competitive, and homosocial (Connell, 1997: 8).

Connell points out that hegemonic masculinity is a historically mobile relation. However, he writes, "the global movement for the emancipation of women combined with a 'historical collapse of the legitimacy of patriarchal power' in ways that established the gender order in rich industrialised countries" (Connell, 1995: 85). The concept "hegemonic masculinity" has served as a "symbolic icon for the more general increase in interest in the study of men, critical or otherwise" (Hearn, 1996: 202). A raised critique highlight the issue of whether if it is at all appropriate to talk

about a hegemonic masculinity, since it defines a state which no man in practice can embody (Wetherell & Edley, 1999: 337; Jefferson, 2002.)

Connell and Hearn argue that the analysis of men's identities has to be located in both public and private spheres of gender power (Hearn, 1992; Connell, 2004). According to Ashe, the new politics of masculinity "is rooted in the claim that the social, political, and economic conditions of late capitalist societies". This has exerted pressure on men's traditional roles and identities, producing "men less secure than their fathers were about their place and function in society" (Ashe, 2000:1)

Such argument may lead to an illogical loop, where traditional gender values are both denied and confirmed. Ashe point out that many men within the academy may–theoretically–support feminist theory or equality policy, however, not in practice (Ashe, 2000:76). This is also highlighted by Braidotti, who writes that "academic men have appropriated feminists' thoughts in ways that are largely instrumental" (Braidotti, 1987: 234-235).

To be able to understand the relationship between physics and masculinity, we need to examine the relationship between everyday work and skills considered central within a scientific community such as in this particular case local plasma physicist community. In the following text, the reader is introduced to the ethnographical setting, an important frame for the content of the main discussion on how to understand how masculinity is produced at the studied field; the laboratory and the plasma physicists.

Ethnographic SetUp

A thorough description of my field site provides a necessary framework for my following analysis of the relationship between physics and masculinity. I started to conduct fieldwork during fall 2007. My fieldwork was situated in a large university laboratory in plasma physics at a large university campus in the United States. A university laboratory is smaller compared to the Big Science laboratories but may still maintain large experimental facilities like tokamaks and accelerators.[5]

A reason I chose to study plasma physicists in this laboratory is the reasonable size of the lab and the staff. Big science facilities like SLAC or CERN are enormous plants, both regarding the actual size and geographical site, but also regarding the number of people working there. The university based laboratory simplified my fieldwork and made it easier for me to conduct observations of all of the lab members and their experimental work.

The physicists who work in the lab define themselves as experimentalists, not theoreticians. Most people at my field site conduct experimental basic plasma physics, a few conducts a more experimental fusion oriented physics. Plasma physics is the science of ionized gases, which are considered to be the fourth state of matter. Plasma can be produced through the raise of temperature of a substance until a reasonable high fractional ionization is obtained (Bellan, 2008; Bittencourt, 2004).[6] The majority of the physicists in the lab work with a plasma column (referred to The Device in this text), but also with an electric tokamak and the tokamak DIII-D.[7]

In this article, references to "the lab" refer to a general cultural space, which includes both the office space in one campus building and the actual laboratory and a workshop in another campus building. Central for this article is a building with devices and rooms for plasma processing, laser experiments and a huge hall with a workshop with machines and experimental devices.

The Device is situated in the basement in one of the buildings. To get to the basement, you can walk down the fire stairs. However,

the elevator is frequently used whenever the physicists need to attend the Device in the basement. From the elevator, you walk in to a corridor. To your left, you can enter a room for laser experiments. Along the corridor wall, there are murals; people portrayed as silhouettes. From the left, you see two persons standing in colors similar to a sunset. They wear clothes that make you think of epochs of Johannes Kepler or Isaac Newton, and stand in front of a massive sunset or a solar corona.

To the right of the two youths, there is a mural of two person's upper bodies. One of them is portrayed with the formula $E=MC^2$, "that's Einstein, obviously" one of the senior informants says. The other might be Nikola Tesla or Hannes Alfvén, he suggests, since that person is portrayed with a tool that seems to measure waves. The last set of murals portrays three persons. One sits next to a computer and it is hard to make a gender definition. Another person is portrayed with attributes as skirt silhouette and longer hair (a women?), and the other a person with trousers and shorter hair (a man?). They are situated together with The Device. The person with the longer hair holds a pen and a notepad in her hand. The person with trousers is standing nearby. Their gazes are both toward The Device with a gas like red-purple background. Plasma? Universe? A nebula?

Behind these murals is The Device Control Room with computers and screens, showing the data taken by The Device. The room is filled with cabinets, computers, and plasma screens. Outside, in the corridor, there are signs to the different rooms and next to the doors. "DANGER–HIGH VOLTAGE" one of the signs informs. Another sign warns of eventual laser use: "DANGER: INFRARED LASER IN USE. BEAM IS INVISIBLE. EYE PROTECTION REQUIRED WHEN LIGHT IS FLASHING". "DANGER. LASER IN USE" is lit in red next to the flashing lamp above the door. A shelf with glasses for laser protection greets the visitor before entering the double door to The Device hall.

The noise hits you when entering The Device hall: first, a general cacophony, but then, within the mixture, a distinct, rhythmic sound from a pump, slightly in front of you to the left. You stand in a passage with The Device 10 steps straight ahead. On the immediate right, there are tubes with different gases with labels like "NITROGEN COMPRESSED" or "HELIUM COMPRESSED". To the left, there is a table and small wagons with boxes of nuts and screws in different sizes. They are flanked by two ladders and a cabinet with a carbon box full of orange earplugs in small plastic bags.

The Device itself is almost 20 meters long and produces quiescent, highly ionized plasma in which the ions can be strongly magnetized. The machine dominates the room with its 80 tons of steel. Bright lilac and yellow color is painted on the "pancake magnets" placed at 6-inch intervals along the machines length. It looks like a huge caterpillar, and organic being, fed with ions, heat, electricity and lasers, pierced with measuring tools.[8]

The characteristics of the entire hall indicate that it is this device that is in the center of the activities. Everything revolves around The Device. You see huge power supplies along the wall, tables with diagnostics and antennas, mobile shelves and trays with computers and oscilloscopes. A loud noise is always present, a rhythmic, pumping thud, and the constant stream of buzzing sound from a huge air con, hanging from the ceiling.

From the beginning, the physicists had a generous attitude toward my presence in their environment; they gave me access with my own key and door code to their work space as well as an office space with chair, desk and internet connection. The physicists were patient answering my

question about their experiments, the machines and equipment, instructing how to use the espresso machines but also telling me about their life outside physics.

While doing fieldwork, I was present during ordinary workdays observing experiments, and workshop labor. I sat in during seminars, office work and meetings. The field note data include not only my observations but also conversations and shorter interviews with physicists visiting The Device as visiting researchers. I also conducted fieldwork during the 50th Plasma Physicists' Conference in Dallas, Texas, where I made observations throughout the conference events, and conducted shorter interviews with eight physicists.

The deep interviews were conducted with 15 persons in the lab with the length ranging from two to five hours. The interviews were recorded with a mini disc. The key informants participating in the deep interviews were professors, senior and junior staff scientists and post graduate students. Two of them were women, 13 were men. The interviews took place in a meeting room at the lab. It was a more neutral space than an office, without phone or computer to distract. Most interviews were conducted in one long sweep including small breaks. However, for some people, it was hard to find several hours in a row, why the interviews were conducted in two or three parts.

Before the interviews I had a set of questions that I wanted to ask the informant. I also told the interviewee that she or he was free to develop any thread or start any theme they thought was important for the interview. The list of question included details about their work and practices, but also about gender. Based on my observations of the physicists work, the machines, and the low amount of women in the lab, my curiosity of gender relations and plasma physics was triggered.

To approach a subject like "gender" can sometimes involve a controversy. To be able to detect gender issues among the physicists, I had to rethink how I approached the topic. Asking interviewees "Why are there so few women in plasma physics?" did not result in an immediate response, or willingness to discuss the matter. Instead, I had to change the angle of my inquiry. The question "Why are there so many men in plasma physics?" was better understood and triggered more reflections. The reluctance to talk about the lack of women, but at the same time willingness to problematize the presence of men is in itself an interesting result.

In the above text I have made a presentation of the physical environment where my field work mainly was conducted. Given the aim with this article, the description provided necessary context for the following analysis of the topic of masculinity.

Why a Gender Gap in Plasma Physics?

Plasma physics is a research field dominated by men. In a study presented in 2000, the amount of women is described as "woefully small" (Lucas & Post-Zwicker, 2000). The authors refer to one of the major plasma physics laboratories in the US, where 2% of the members were women and underrepresented minorities. As Lucas and Post-Zwicker point out, the percentage of women in other STEM (science, technology and medicine) fields is higher, for example, in computer science (Lucas & Post-Zwicker, 2000). A closely related field, astronomy, has a higher amount of women as faculty members and post graduate students compared to physics (Ivie & Ray, 2005).

At an everyday level, gender was considered to be a non-existing factor, not important in the daily work within the laboratory. Yet, there was awareness of the relationship between plasma physics, the experimental environment and the large

amount of men and the small amount of women. Female physicists who were themselves engaged in highlighting women in plasma physics were also intrigued by the absence of women but did not reflect upon the causes.

During my field work at an annual meeting for the division of plasma physics in Dallas, I attended a reception "Women in Plasma Physics", dedicated to female physicists within the field. According to one of the organizers, the low amount of women in plasma physics was a mystery, but she did not have any hypothesis why it was so. The majority of my informants in the lab was likewise puzzled and did not come up with any automatic response or explanation at first.

However, one of the informants pointed at the educational context as a pipeline into or from physics. He also mentioned what he called an assumed relationship between boy's "natural talents" for the sciences and its consequences. By the time the boys and the girls are in *high school*, he said, a selection process has already started. And by that time, girls have already been taught that they are bad at math and physics.

> The boys are good at it and already know that they are good at it! Like… It has nothing to do with who they are! [Laugh] Necessarily! It's just that assumptions get made and that's what they get taught! So, by the time you're taking Calculus, you know, higher level science, math, physics, calculus as a high school oral, as you should be if you're gonna become a physicist… you have already weeded out half the girls who had the skills! Because even though they had the skills, they got told that they didn't or that they weren't as good as the guys.

One of the post graduate students within the lab made critical reflections on the relationship between gender, expectations and physics in general. According to him, assumptions about boys' and girls' "natural relationship" to the sciences "is made *first*, then the feedback is given, and the children learn this [in schools]."

There were also voices uttering ideas about women's ability to conduct science and physics. During an interview, one of the senior physicists openly expressed his doubts about women's abilities to conduct science from a biological perspective. According to him, the female brain simply is not capable of dealing with physics. Women do not have a "natural" ability for science, and referred to young children he had been observing: "Boys learn science and math fast, while girls struggle with the same," he concluded.

During my fieldwork, only few persons referred to possible biological causes openly. However, the relationship between gender and talent in science and physics was sometimes uttered in daily conversations. These comments referred to women being incapable of conducting a god job in physics or their capacity of doing a job in a correct way. Such comments created uneasiness among the few female physicists in the lab. Not only did the comments disqualify their capacity to conduct physics; they also realized that no one openly would argue that women are incapable of science face to face.

Several of the informants expressed a wish for more gender diversity within the field. However, they also emphasized what they considered was an artificial construction of gender equality through affirmative action. The risk of promoting affirmative action could jeopardize the overall quality of the students and scientists. There was a uniform voice against positive discrimination in order to make plasma physics look more

diverse: the most import thing, after all, was to attract the most talented students in physics, they said. Affirmative action would weaken the recruitment base and thereby the discipline's reputation. To argue for affirmative action was by the informants considered to be "politically correct". Moreover, it was considered to be an interference of social values into the sciences.

Given the informants ideals regarding the educational system, biological causes and affirmative action, we need to consider the environment in where the plasma physicists conducted their research and experiments. In the following part I shall discuss how physics as an activity was defined among my informants. We shall see which activities were in the core of the lab and central in the physicists' definition of basic and necessary knowledge for doing good physics and in what respect this is related to masculinity. And how can we understand this in terms of identity work? [9]

Men and Machines

Skills bounded to science, gender and biology is a long debated question. As Rossier points out, scientific beliefs about gender change over time. As have beliefs about women (and men) and scientists changed (Rossier, 2008). This includes ideas about talent, knowledge gain and abilities in relation to gender.

However, a persistent stereotype of gender lies in the relationship between men and machines. In Mellström's study of masculinity cultures, he has analyzed the relationship between men, embodiment, symbolism and identity. Especially, he focuses on men's "masculine homosocial bonds that are being mediated through the interaction of men and machines" (Mellström, 2003: 17; see also Landström, 2006: 33). The social bond between men and machines that Mellström discusses is interlinked with Faulkner's research on gender, machines and technology. Faulkner argues that the relationship between gender and technology is constructed at a symbolic level in everyday practice (Faulkner, 2001).

When analyzing an arena such as the plasma physics laboratory in my fieldwork, the relationship between homosociality and machines becomes crucial for understanding the gender dynamics and thereby the ways in which practices in experimental plasma physics are gendered. As mentioned, ideas about men's brain and "natural" ability to conduct physics were clearly articulated. But the existence of a symbolic relationship between the practice involving machines, experimental plasma physics and gender was also articulated by junior and senior physicists.

The informants used a well known notion of men, machines, technology and tools; the notion of "boys and their toys". One of the informants even pointed at a "sort of this culture of *boys and their toys*! In plasma physics". Plasma physics as experimental science was talked of as a scientific field with exclusive high power equipment and powerful machines. Relationships between men and machines were talked about with references to everyday life as the work in the lab, as a connection interlinked with each other. "Physics–*plasma physics*–is about *big high power toys*. Which is sort of a classical *male thing* in this country" said a junior physicist (see Horowitz, 2001; Adler, 2007).[10] One of the informants called upon a connection between motor vehicles as toys and advanced power equipment as relational aspects of men and machines.

> *Boys are brought up in big trucks*! And *tractors*! Once you drive a car, you want a *big fast thing*! You know. If that's your kind of *THING*, well, then you're actually going to be *pulled in to plasma*

> *physics*! 'Cause there's *some REALLY HIGH POWER, SEXY, EXOTIC EQUIPMENT IN THERE*!

When the informants recounted their own path into experimental plasma physics, the point of departure in their stories were early interest for machines, tools together with electricity and power. Some informants were mentioning what can be described as bonding acts with a father or a grandfather. Important aspects of these stories were how the father or grandfather and child walked in to the garage or down to the cellar. The informants described these occasions as initiations into the fascinating world of technical equipment where radios, amplifiers and cars were rebuilt and reconstructed.

> From the beginning I've always liked *ELECTRONICS* and TOYS and… and my grandfather took me to the basement and we built kits with electronics. From *very, very small [age]* I was exposed to this stuff all the time. So when *I* walk in to a place like that [The Device hall] for the first *time*, I am immediately assessing "oh, I know what *that is*, I know what *this is*" or "how can I do *this*". I learn the stuff *fast* […].

The early fascination for tools, machines and technology was mentioned by both men and women in my interviews. But in the daily discourses about necessary abilities for conducting plasma physics and about how physics was supposed to be conducted in general there was an ideal always present. As shown in earlier work by Traweek, the naming of the machine and work is indeed a way of gendering scientific practices (Traweek, 1995). Using metaphors such as "sexy" and "exotic" is also a direct way of masculinizing the discourse on the technology applied.

To bond with the machines and the technology used in the lab and to "show off" that bond during, for example, job interviews was regarded as important by both senior and junior staff. One junior physicist said:

> I mean, when I *first* found out about this place I got a tour, sort of the traditional; 'these are the magnets, this is the vacuum chamber', you know! I had the components pointed out for me briefly.

Through such hiring processes, the junior physicists said, you could also bond with the head of the lab and the other members of the lab. One of the post graduate students describes his first visit to the lab as a visit for an already initiated experimentalist. The meeting with the machine was an act of recognition and gave him what he considered to be an immediate "contact, I had the right vocabulary. So I said 'Oh! So those are the magnets! Right! That's what contains the plasma!" This process was verified by the head of the lab and senior lab members. Theoretical merits were important and letter of recommendations informative, but not compared to what could be observed when a job applicant walked in to the actual Device Hall, and furthermore, commented on the machines capacity, diagnostics or measuring tools.

The idea of machines as toys for boys and an assumed relationship between men and machines work as a gendered framing for the experimental work in the lab. The concept of "boundary work" can illustrate how the relationship between men and machines is defined as act of recognition in hiring processes. As single component, it is thus hard to define this relationship as a specific

act of masculinity. However, when studying how the physicists value and practice the experimental work, masculinity is actively created in relations to the machines. Here, both the gendering of the machines as well as the definition of physics is boundary work aiming at coordinated identity work among the physicists within the laboratory.[11] It remains to be asked how this is defined at a practical level and how it is associated with masculinity.

Building Machines to Make Physics

Physics is not only about theoretical knowledge and formulas. Physics is about skills, building and constructing. Those are the words of my informants. To be able to work as an experimental physicist, *all* of my informants said, you must be able to master building and constructing. You also need practical knowledge in electromagnetism and you need to learn how to run high power machines on your own. "Hands-on" knowledge is essential.

According to the informants experimental physics is not about theory and math. It is *foolish* to take that standpoint, said a senior member in the lab. "Sure, you need to do your math, but you cannot conduct experiments if you cannot build your machines and devices." Actively contributing to an environment with tools and machines is contrasted with physicists' working in theory. The latter is described as work distanced from reality, missing knowledge how an experiment is set up, how the equipment is built and how an experiment is run for collecting "real" data and being able to control one's experimental setting.

As stated before, the machine experience and previous knowledge of each lab member is carefully examined and it has to be eventually demonstrated during hiring processes. The candidates' previous experience of experimental physics is valued in terms of having hands-on experience of constructing and building. "You can see if the person is used to building, what the candidate knows about machines, when the candidate moves around, asks questions and talks about The Device", said the head of the lab.

A person with experience of building experimental devices and machines is defined as a highly valuable co-worker in the lab. For sure, academic rank and title is considered to be important; rank decides the possibility to supervise post-graduate students. However, the hands-on knowledge and skills to build is what really makes a fellow physicist specifically precious. Here in the lab, you do *labor*, said the head of the lab. That means to get greasy and dirty, to lie under machines and to lift heavy things. With labor, he refers to bodily work, and not necessarily activities related to intellectual work. Moreover, it relates to working at a shop floor, and as such several physicists talk about it as manual work (see Meyer, 2001).

Equipment needs to be constructed and occasionally new machines need to be built. When planning a run of experiment, the aspect of constructing and building is considered to be natural. During my fieldwork, a group of physicists started to repair a tokamak[12] that had not been used actively for a couple years. An early task was to restore the machine's cooling system made of copper pipes. The actual work that needed to be done was to bend, cut and forge hundreds of feet of copper pipes.

A post-graduate student was appointed to the task. He did not have any similar experience on building cooling systems before, but he started off with the work under the guidance of the head of the lab. The work that went on in the workshop was defined as a "dig in" or "sink-or-swim" situation, where the performance of showing handiness and initiative was an important part of the

post-graduate program. The work included days at the shop floorto cut the copper pipes, forging the pipes together, making calculations on how to continue with the implementations of the entire system, planning test runs with the tokamak, and then writing a poster about the machine and possible experiments.

In a recent study of physicists in Estonia conducted by Velbaum et al., the physicists describe their work as that of a blacksmith. Here, the blacksmith metaphor relates to technical issues, engineering and "experimenting in a direct sense". The physicists refer to themselves as "physicist-as-smiths" and identify themselves with "manually-thinking-jobs", engineers and dockyard mechanics (Velbaum et. al., 2008: 178 ff.). Although not fully discussed in the article, the metaphors presented in Velbaum et.al, refer to highly masculininized fields of work, even heavy and dangerous.

Given the demands of being an experimental plasma physicist with practical skills, the practical work included handling tools from stationary saw blades and drilling machines, and cutting tools, to soldering irons, screw- and nut drivers and wrenches. The emphasis on the practical work can be interpreted as a boundary work toward other fields of physics, claiming the uniqueness of both being a plasma physicist and an experimentalist.

The boundary work of experimental plasma physics is also a gender making process. The shop floor environment in the lab and the demands of building machines carried elements of danger. Accidents *could* happen, hurting people working in the lab as well as the machines. These elements of danger added another dimension to the attempts of understanding the gendered aspects of the environment of the experimental plasma physicists. The combination of conducting physics not only as labor but eventually as dangerous activity, raises another dimension of masculinity.

Strength, Dirt and Buzzing Noise

During my fieldwork, I collected repeated stories about manual work, defined as dangerous, challenging and dirty. Some stories of the making of machines were told on an everyday level, for example, the risk of making laser experiments and entering The Device hall without using safety equipment like safety glasses. Others stories worked like a fellowship code: those who participated in the labor and articulated these stories carried a sign of respect, of being genuine, and of being a part of the inner lab affinity (Nye, 2005: 1048).[13]

One repeatedly told story about danger and the necessity of physical strength was about the construction of The Device in the 1990s. At that time, the hall for The Device to be was only an empty cellar with unpainted concrete and no equipment. To be able to build a machine there, everything needed to be transported down with the elevator. As I many times went up and down in that elevator during the field work, both physicists and technicians told me an anecdote regarding the construction phase. While building The Device, the weight of the magnets for the new device had to be transported down to the cellar with the elevator. But because of the heavy weight of the magnetic coils, the elevator subsequently broke down.

The story did not only contain an element of danger, but also hard physical work, muscles, sweat and strength. The content also focused on the inconvenience of moving the magnet coils but also on the physical work when transporting the different machine pieces. Lack of technical support and the smaller size of the lab were described as in stardust. The physicists who were working with The Device construction emphasized how they at that time in the lab had to do all the "dirty work" themselves, how they had to bend steel, drag, carry and construct the iron bars, the magnetic coils

and put all the pieces together. One of the senior physicists talked about the 1990s with nostalgia, where technical support was unthinkable given the budget. At that time, the physicist said, the lab was not "spoiled" with extra staff in the work shop or machine maintenance.

"I love to get my hands dirty!" was a repeated sentence by the informants during the interviews. Dirt symbolized the manual work, the labor, and was considered to be a part of the job. Dirt was also pointed out as a reason why men were more interested in experimental work compared to women. The environment in itself with the daily hands on practices was better matched with a more general, societal expectation of men and "what sort of labor men deal with". Hence, the laboratory environment was suited to men, said one of the senior researches. The work context in the lab considered to be closely related to what in the entire society is considered to be masculine, he concluded.[14]

Technological environments have been described as unsuitable for women based on the perception of environments with technology as "extra heavy". In the engineering industry for example, women and their bodies are perceived as inappropriate, unfit to heavy work, such as carrying, assembling and forging together pieces of machinery (Ek-Nilsson, 1999: 160-161, see also Pettersson, 2007: 171. Compare with Frank Fox, 2006). Resemblances between how the lab is discussed and physics are defined in the lab and an image of a factory for blue collar work is striking.[15]

Given that the work in the lab is considered to be "labour", the work is mainly for people with muscles, who are not afraid of danger, can stand dirt and grease and are not afraid to "dig in" (see Iacuone, 2005). The hands on work, the elevation of danger, physical efforts and strength are all features of how masculinity is made among the experimental plasma physics.

Alongside with the machines comes noise. It is a part of the entire setting of larger experimental physics, say the informants. The Device hall is framed by high noise level with pumps and a huge ceiling fan and air condition machine that transport the heat from The Device. Wearing ear plugs is common. Altogether, the noise is also a part of a masculine culture, says one of the informants.

One of the junior physicists pointed to the lab as a place with action and machines, "loud and exciting".

> And I think that *is* that… that the atmosphere is gendered and there are assumptions that are made about […]. I don't know exactly how to analyze *why* that environment is so unfriendly to women. Or is unfriendly to women, why women might be *put off* by it or whatever, but… whether it's just *machismo* or if it's something more settled.

Both practices and discourses about working with The Device are fringed with connotations of a craft, of strength and physical efforts. The stories are used as marks of identity for the lab and for the group of physicists. They are important element of the boundary work of experimental physics in one hand and of masculinity on the other. Through the daily practices, hands-on situations, and definitions of physics as labor, masculinity is staged. Experimental plasma physics is then defined as an activity for men. The boundary work of physics as experimental work thus becomes a process of gender identification, both at a symbolic level and at a direct everyday level.[16]

The discourses about the experimental work are double: on the one hand an ability that is embodied through brain and biology, on the other, referred to as a

socially constructed situation, interlinked with a general apparatus of gender ideals and stereotypes in what is referred to as the surrounding society. A "double masculinity" has been developed, where scientific development connotes ideals of masculinity that emanates around the turn of the last century, hand in hand with the contemporary spirit of geographical and scientific exploration. As Connell writes, the ideals represent the man of reason, the engine of progress (Connell, 2005: 164 ff; See also Ek-Nilsson, 1999: 160-161).

Conclusions

In this article I have discussed how perspectives from masculinity studies can be used to understand the construction of gendered research cultures in experimental plasma physics. To be able to critically study the gender dynamics within the sciences, we do not only need to analyse women's accomplishments and struggles within such male dominated disciplines as experimental plasma physics. Men and cultures dominated by men within academic disciplines and research communities should also be analyzed as political categories and political subjects.

In order to understand why physics in particular is still dominated by men, the cultures and actions that are associated with masculinity are analyzed. Through the daily practices and the hands-on situations, the experimental plasma physics as labor is associated with men and masculinity, and performed in a context that abundantly speaks of a masculinized environment. The discourse about the gendered brain capacity and physics is further transferred to an embodied understanding of skills for physics.

The emphasis on experiments and physics as labor can be interpreted as a boundary work towards other disciplines of physics. Through defining "real physics" as experimental physics as labor, gender is also included in the boundary work process. Embodied abilities and the desired hands-on skills of an experimental physicist in the lab are acts of masculinity. I do not argue that developing a masculine identity is an active strategy among the lab members. However, the ideals in relation to the hands-on situation bare noteworthy masculine signifiers of gender, as even the lab members are highlighting.

At the field site, physics as labor was a taken as a for granted norm. To be able to problematize the norms, one needs to focus on how the norms are co-constructed with gendered expectations. It is important to emphasize that these processes are not practiced only in physics. Boundary work not only results in work that unites or automatically fuses those involved together. Boundary work can be as rife with controversy and power struggles as any other cultural effort. A continuously important issue for further studies of physics and science is how and why certain actions or lack of thereof become gain a symbolic value in relation to gender and how this coexists with for granted expectations but also challenges and breaks of gendered patterns.

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Notes

[1] http://www.nsf.gov/statistics/wmpd/pdf/tabd-2.pdf

[2] http://www.nsf.gov/statistics/wmpd/pdf/tabd-1.pdf

[3] Also see discussion on the lack of women in science in Etkowitz, Kemelgor & Uzzi, 2000: 11f.

[4] For a general overview discussion on gender and science after WWII, see Rose, 2001: 53ff. See Wajcman on women hidden from history of science and technology, Wajcman, 1993: 29ff.

[5] Big Science is characterized by large-scale instruments and facilities, supported by funding from government or international agencies, in which research is conducted by teams or groups of scientists and technicians, http://www.britannica.com/EBchecked/topic/64995/Big-Science

[6] The word "plasma" refers to the Greek word for "formed" or "molded". Plasma is one of the four matters; solid, liquid, gaseous and plasma. What distinguishes the four matters is the strength of the bonds that holds the constituent particles together. Plasmas can also be generated by ionization processes that raise the degree of ionization, much above its thermal stability value. One of the features that differs the behavior of plasma in relation to the other 3 matters is the existence of "collective effects". Given a range of electromagnetic forces, each charged article in the plasma interacts concurrently with a significant number of other charged particles. This activity results in significant collective effects dependable for the affluence of physical phenomenon that takes place in plasma (Bellan, 2008; Bittencourt, 2004).

[7] Fusion is an activity that is going on in the core of the sun, where hydrogen nuclei collide and fuse in to heavier helium atoms. Today, research on fusion is for example focused on fusion as energy. In a fusion reactor, like a tokamak, hot plasma can be controlled through magnetic fields. In the tokamak, light elements can fuse and produce energy through the plasma, http://www.iter.org/sci/whatisfusion.

[8] A langmuir probe is a measuring device to determine the electron temperature, electron density, and electric potential of plasma, see Anthony et.al., (1991).

[9] Women in physics inhabits a position that Haraway calls the "inappropriate/d other", a metaphor borrowed from Trin Minh-ha. To be an inappropriate/d other does not necessarily aim at someone who is outside. Haraway define the position of an "inappropriate/d other" as someone who is critical, and who diffracts. To be an "inappropriate/d other" is to not entirely fit in to the taxonomy of the given cultural space. Also, as such, you become dislocated from the available schemas that specify actors and narratives; in this case the culture of plasma physics and its environment (Haraway, 1991: 188-189; 2004: 70-71; Also see Pettersson, 2007: 51). Also compare with Valian's discussion on gender schemas and expectations among female academics in Valian, 1999.

[10] The relationship between "boys and their toys" has also been highlighted in the management literature, for example in Adler, 2007, where men and "toys" a.k.a. "gadgets" are interlinked. Also see Meyers, 2001 for discussion on the relationship between toys, masculinity and the automobile shop floor.

[11] In Star and Griesemer's study, a schedule of collecting, reporting and classify vertebrates circulates as a boundary object amongst a varied number of users. The group of people involved in collecting the vertebrates–scholars, professional trappers and amateur volunteers–is bound to a common quest: To assemble an array of vertebrates native to the state of California, see Star & Griesemer, 1989.

[12] A tokamak is a doughnut shaped reactor with a toroidal magnetic field. Most tokamaks are used to produce thermo nuclear fusion reactions, see for example Federici et.al., 2001.

[13] See Nye's presentation of how men are prevailing embodied codes of masculinity, see Nye, 2005: 1048.

[14] Health risks were not discussed, neither men's nor women's. There was for example no risk for pregnant women to be present in the lab or close to The Device or the laser.

[15] The metaphor "labour" is easily transferred in to the lab as a concept related to working class, factory work and shop floors. Here, the use of "labour" is detached from any derogation regarding class or social status. The blue collar worker and manual labour is instead used as heroic representations of "real work", compare with Beasly 2008.

[16] It is thus important to emphasize that acts of gender or masculinities are made differently within a group like physicists. In Hasse et. Al. "new masculinities" is highlighted a characteristic of "men who want to spend more time on their family, just as many women do" (2008: 127). These men become a variant of an inappropriate/d other/ness because they are unwilling to fulfill a career path and expected work load by male physicists (2008: 98, 124ff).

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