Multimedia Research

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Communicating about Technology and Research of the Large Hadron Collider: Interests, Knowledge, and Curiosities of Adult Science Center Visitors

Front-End Study in Support of *Secrets of the Universe*
for K2 Communications, Inc.
by

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Title page photo: http://cds.cern.ch/record/1295244 Aerial View of CERN/Large Hadron Collider, 2008

INTRODUCTION

The Large Hadron Collider (LHC)[1] is one of the world's largest experimental facilities, where thousands of scientists and engineers from over 100 countries collaborate to shed new light on the workings of our universe. More than 1800 U.S. scientists, engineers and graduate students have collaborated in LHC construction, operation and experiments. As LHC research, such as the discovery of the Higgs boson, continues to hit the news in future years, it will be important for educators in informal science institutions to understand how to engage their visiting public's interests and curiosities and shape their understanding regarding this leading edge research.

Secrets of the Universe NSF project. Recently funded by the National Science Foundation, the *Secrets of the Universe* project has at its core a giant screen (GS) film that will explore the fundamental laws of nature under investigation at the Large Hadron Collider.[2] The project involves a collaboration among K2 Communications Inc., University of California Davis Department of Physics, Stephen Low Company, and Franklin Institute. In addition to the 40-minute 3D documentary film, other project deliverables include a full dome planetarium film, an interactive theater lobby exhibit, website, mobile app, materials and professional development workshops for educators.

To support the development of the film and associated outreach components, the goal of the front-end study reported here is to discover what the adult science center public is interested in, familiar with, and curious about as relates to LHC technology and research. These findings are intended to help filmmakers and informal science educators understand what the visiting public brings into US science centers and to identify starting points for the film and outreach to explore what this audience may perceive to be difficult and esoteric content.

Background. Despite the importance of the Large Hadron Collider to the international physics community, very little is known about the public's awareness and understandings of the LHC and the nature of the facility and its research. Only the United Kingdom has published about efforts to engage their public with the LHC. To support promotion of the LHC in the United Kingdom, a 2006 UK study[3] with eight single-sex focus groups (N = 63) made several observations about the adult public's interest in LHC's research:

- It is important to communicate openly about the LHC work and the rationale for experiments.
- The main topics of interest were the Big Bang and origins of the universe.

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[1] http://home.web.cern.ch/topics/large-hadron-collider
[2] http://www.nsf.gov/awardsearch/showAward?AWD_ID=1322527&HistoricalAwards=false
[3] http://sciencecentres.org.uk/news/ecsite/ecsite_newsletter_69_winter_2006.pdf p. 10-11. Full report no longer available online.

- Antimatter and dark matter were not familiar topics and LHC's questions about such topics were not particularly interesting.
- Participants assumed that scientists already knew about matter, mass and how gravity works and wondered what we don't know and why we need to know it.
- Some raised concerns about safety of experiments and fear of unknown consequences, including possible environmental impact and military use.
- Participants supported fundamental science but were interested in the utility of the research, particularly beneficial medical applications.

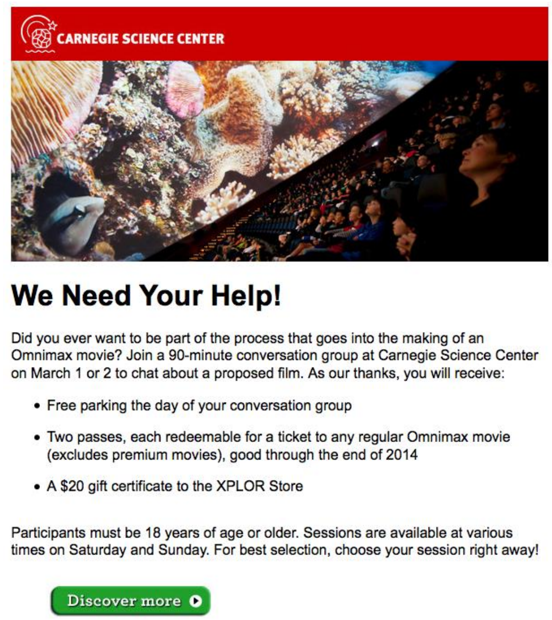
Front-end Study Design. This front-end study for the *Secrets of the Universe* project covers some of the same territory as the 2006 UK study but goes into more depth with 18 US focus groups about the LHC status as of 2014. The focus groups gathered quantitative data and qualitative discussion from adult science center visitors to address three overall research questions related to the Large Hadron Collider facility and experiments:

- **What is the extent of adult science center visitors' awareness of and familiarity with the Large Hadron Collider technology and research?**
- **What are the curiosities of adult visitors about the Large Hadron Collider facility and the scientific research?**
- **How interested are adult visitors in the Large Hadron Collider physical facility and research questions?**

METHOD

Sample

Focus group participants were recruited via emails to membership rosters of three science centers that are partners in the film project: Oregon Museum of Science and Industry, Portland, OR; Carnegie Science Center, Pittsburgh, PA; and Franklin Institute, Philadelphia, PA. Emails sent by the science centers invited adults to a 90-minute conversation to contribute to the making of a giant screen film. The film content was not mentioned in the invitation. Participation incentives worth up to $40 were offered, but specifics of the incentive varied by site. The Carnegie Science Center invitation is shown to the right.



Six focus groups occurred at each site, totaling 18 groups with 106 adult participants. Group size ranged from 2 to 9, with an average of 6 per group[4]. Demographics of the full sample follow:

- <u>Gender.</u> Half of the sample were women and half men.
- <u>Age.</u> Participant ages ranged from 19 to 83 years, with a normal distribution around a mean of 48.6 years. The men with a mean age of 51.5 were statistically significantly older than the women with a mean age of 45.7.[5]
- <u>Minority representation</u>. Minorities comprised 16% of the sample, which is higher than the 8% estimated minority attendance for giant screen films in US markets with GS theaters.[6]
- <u>Giant screen film experience</u>. Participants were very experienced with the GS film format. The majority (80%) reported having seen 3 or more giant screen or IMAX films in a museum or science center; 13% had seen 2 films; 6% had seen 1 film. One respondent did not know how many films had been viewed.

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[4] A snowstorm decreased full participation for the group of two participants.

[5] *t*-tests applied to two independent samples assess the difference between means, in this case the mean ages of male and female groups. $t(98) = 2.06$, $p = 0.04$.

[6] Kennedy, M.K., (2004). GSTA's 2003 worldwide viewer and nonviewer research programs: Key results and how to use them, *The Big Frame*, Winter, 40-59.

- <u>Interest in science discoveries</u>. As shown in Table 1 below, the majority (76%) of our sample is "very interested" in issues about new scientific discoveries. Our science center member sample reports higher interest than the national US population of whom 40% are "very interested."[7] Also, our sample of men are significantly more interested than women, with 89% of men "very interested" compared with 64% of women.[8] The national sample also shows a gender difference.

Table 1. Interest in Issues about New Scientific Discoveries

Interest in new scientific discoveries	Front-end Sample (N = 106)	US Sample (N = 2256)
Very interested	76%	40%
Moderately interested	24%	45%
Not at all interested	0%	14%

- <u>Science attentiveness.</u> As shown in Table 2 below, our participants follow science and technology (S&T) news in the media "very closely" (31%) or "somewhat closely" (58%). Our sample reports higher S&T attentiveness than the national US population in which 16% follow "very closely" and 41%, "somewhat closely."[9] Our sample of men follow S&T news significantly more closely than women, with 42% of men "very closely" attentive compared with 21% of women.[10]

Table 2. Attentiveness to Science and Technology News in the Media

Attentiveness to S&T News	Front-end Sample (N = 106)	US Sample (N = 779)
Very closely	31%	16%
Somewhat closely	58%	41%
Not very closely	11%	19%
Not at all closely	0%	22%

[7] The written survey question asked: *There are a lot of issues in the news, and it is hard to keep up with every area. How interested are you in issues about new scientific discoveries?* This question is used as a telephone interview question in the biennial University of Chicago's National Opinion Research Center General Social Survey. The 2012 national population statistics are reported in NSF's Science and Engineering Indicators, http://www.nsf.gov/statistics/seind14/content/chapter-7/chapter-7.pdf

[8] With categorical data, chi-square tests whether there is a relationship between proportional distributions of the two variables, in this case: gender and interest in new scientific discoveries. χ^2 (2, N = 106) = 9.45, p = 0.009

[9] The written survey question asked: *How closely do you follow science and technology news either in the newspaper, on television, radio or the Internet?* This question is used as a telephone interview question in the biennial Pew Research Center for People & the Press Media Consumption Survey. The 2012 national statistics are reported in http://www.people-press.org/question-search/?qid=1818978&pid=51&ccid=50#top

[10] χ^2 (2, N = 106) = 9.15, p = 0.01

- Physics education. Most participants (84%) reported some physics education background. Participants' highest level of physics coursework was high school (42%) or college (38%, of which 2% were physics majors). Another 4% reported having taken graduate level physics coursework. Men were significantly more likely to have experienced college level physics coursework (71%) than women (30%), and women were more likely to have taken no physics courses (71%) compared with men (29%).[11]

Procedure

The early draft treatment for the giant screen film addressed both the physical facility of the Large Hadron Collider and the experiments that researchers are implementing; thus, the focus group procedure built on that structure and content. Project filmmakers, advisory scientists and educators reviewed a draft procedure that included both written survey questions and oral questions to elicit focused conversation. After revisions, the procedure was piloted with a group of men and a group of women, then revised, and reviewed again by advisors.

The 90-minute focus groups were moderated by this report's two authors. At the beginning of each group session, participants signed a consent form[12] and completed a survey with anonymous demographic questions, as summarized in the previous Sample section. The moderator then explained that the goal of the session was to learn about potential viewer interest, familiarity and curiosities with the proposed film content, that the content would be revealed gradually over the course of the conversation, and that the session would be mostly verbal, providing only brief descriptions of the content. Moderators reassured participants at various points in the conversations that the project needed to hear all viewpoints, from those familiar with the topics presented as well as those who had never heard of or were not interested in the content. Discussions were audio-recorded with no names mentioned during the session.

The group conversations began with eliciting ideas related to the project title, *Secrets of the Universe,* progressed to a discussion of methods used to explore *secrets* mentioned by the group, and then introduced the technology of colliders if a group had not done so themselves. These findings are presented in pages 7-8.

In response to brief verbal descriptions of four photos of the physical facility of the Large Hadron Collider, participants discussed their curiosities about the technology and rated their interest in written questions about the physical facility and how it operates. These findings and the associated photos are presented in pages 9-13.

[11] χ^2 (2, N = 106) = 12.93, p = 0.002.
[12] An external IRB reviewed the study design for protection of human subjects procedures.

The second half of the session presented very brief verbal descriptions of five research areas at the Large Hadron Collider including

1) conditions and energies during the very first instant after the Big Bang
2) what happened to antimatter after the Big Bang
3) dark matter and dark energy
4) multi-dimensional universe
5) why some particles gain mass and the discovery of the Higgs boson.

After each individual study area was described verbally, participants rated in the written survey their level of interest in and familiarity with the research and then discussed with the group their curiosities about the research area. These findings are presented in pages 14-28.

The closing survey question asked participants to comment on whether the work of the LHC scientists that they heard about is important and why or why not. These findings are presented in pages 28-29.

Groups were run with genders separated because of significant gender differences in physics coursework experience and interest in fundamental physics.[13] Also the previously referenced UK focus groups were single-sex. Participants were debriefed at the end of the sessions about why single-sex groups were implemented.

Data Analyses

The unit of analysis for the written survey data is the individual participant. These findings are presented as percentages of 106 participants in text, tables and charts. Appropriate statistical tests were implemented for all quantitative data. In this report, footnotes present a definition of a statistic when first used and also present the statistical test results. A statistical test that gives a p-value, or probability value, lower than .05 is reported as "statistically significant." This means that a difference is noted as significant only if it has a 5% or smaller likelihood of occurring by coincidence or chance.

Narratives from the transcripts of the focus groups were subjected to semantic content analysis, examining the frequency with which concepts, questions, and themes appear across groups, not within groups. Thus, the unit of analysis in the qualitative data is the group, not the individual participant. These findings are reported as the number of groups out of the total 18 groups in which one or more participants discussed a concept, question or theme.

[13] Flagg, B. N. (2001). Gender differences in interest in contemporary science topics. The Leading Edge: Enhancing the Public Understanding of Research. Boston Museum of Science. The Susie Fisher Group (October 2007). How did the Big Bang exhibition work within Antenna? www.lhc.ac.uk/resources/pdf/Big_Bang_Summary_Report.pdf. Note that one site inadvertently signed up two women to participate in a men's group. With agreement of all participants, the women joined the men in this group.

"SECRETS OF THE UNIVERSE" TITLE

Expectations of the film title

The title of the proposed giant screen film is *Secrets of the Universe.* To assess what audiences expected from such a film title, and to move the groups gradually into discussing the LHC content, participants were asked to suggest what "secrets or unknowns of the universe" they would expect to learn about from this film.

Of the 18 groups, 14 responded to the title with one or more topics that are addressed by LHC research, including the origin, evolution and expansion of the universe (10 of 18 groups); dark matter/dark energy (8); multiverse (6); antimatter (3); and quantum physics (3).

Adults in all 18 groups mentioned other "universe" topics, including objects in our solar system and beyond such as planets, exoplanets, stars, nebula, supernovae, galaxies, and/or black holes. Half (9) of the groups posited alien life as a 'secret of the universe' that the film might cover.

In response to the title, technology was brought up by 6 groups. Technology mentions included rovers, probes, Voyager, Hubble, and even one citing of the Large Hadron Collider. Additionally, the title reminded 6 of the groups of space-focused television series such as *Cosmos*, *Through the Wormhole*, and *Star Trek.*

Several participants in each of 12 groups also noted that the title could relate to non-space topics including religion, medical advances, oceans, sea life, earth's core, climate, UFOs, myths, microorganisms, conspiracies and psychological secrets.

As conversations progressed through the 90 minute sessions, a few participants returned to the title and suggested that it is too broad, unspecific or not closely related to the LHC technology or research:

> *It's a pretty broad title. It doesn't really tell me too much about it.*
>
> *It almost sounds like a general title, that there would be a series. "Secrets of the Universe" is so huge. It doesn't sound like a specific thing to me.*
>
> *This seems like a very broad title, and maybe that's intentional.*
>
> *When you said 'Secrets of the Universe,' my first thought was –boom – outer space. As we discuss it, the discussion is going more around to not outer space. It's things like where does gravity come from, what is the nature of the earth, that's a different kind of topic than what my first conception would have been.*

From the title that you gave, none of us thought of this direction [in response to study of antimatter]*. Perhaps you need a different title.*

Awareness of methods to study "secrets" of the universe

To determine whether participants associated the technology of colliders with the "secrets" discussed above, moderators read back to participants a list of those topics that they mentioned that most closely related to LHC research and asked the groups what methods scientists use to study and research the noted areas (such as antimatter, dark matter/dark energy, multiverse, origin and evolution of the universe). **Half (9) of the 18 groups suggested colliders: 77% of the male groups and 22% of the female groups.**

Also as methods to study such "secrets of the universe," half (9) of the 18 groups mentioned telescopes in general and the Hubble telescope in particular. Rovers and spacecraft were put forward by 7 groups. Six (6) groups noted that researchers also use radio telescopes; satellites; International Space Station; higher mathematics; or computers for simulations and modeling. Additionally, 5 groups focused on "brilliant minds" as a method to research secrets of the universe.

Whether participants mentioned colliders or not as a method to study secrets of the universe, moderators briefly introduced the collider technology, as follows:

> *There are research facilities called colliders or accelerators that run experiments to understand the universe, from the largest astronomical scales to the tiniest particles of matter. Have you heard of colliders? Can you think of any examples of such facilities that you may have heard about, seen or read about?*

A majority of the groups (15 of 18) gave an example of a collider "somewhere in Europe or Switzerland;" however, only 8 groups included someone who spontaneously mentioned some portion or all of the name: "Large Hadron Collider." A minority of the groups had also heard of a collider in Illinois (6), California (3), New Jersey (1) or the aborted construction in Texas (5).

TECHNOLOGY OF LARGE HADRON COLLIDER

Awareness of and familiarity with the Large Hadron Collider

Moderators told the groups that the giant screen film will be about *a research facility called the Large Hadron Collider* and then counted how many in each group had heard of the LHC. **Most (79%) of the men reported having heard of the LHC whereas significantly fewer women (40%) had heard of the facility**.[14]

To assess familiarity with the LHC technology, those who had heard of the LHC were asked what they could recall about *the physical aspects of this massive machine, anything about the actual facility.* **Most of the groups placed the facility in Switzerland or Europe (15 of 18 groups), and many described it as underground (11) in a circle (7) from 2 to 22 miles long (9). Fewer groups added that the LHC uses lots of power (4) and magnets (3).**

Curiosities about and interest in the Large Hadron Collider facility

Groups were then introduced to the physical facility via short verbal descriptions accompanying four 8x11 photos[15] that were passed around the table. The photos and descriptions elicited numerous comments and questions from the groups.

Moderator's verbal description for first photo: *The Large Hadron Collider is one of the largest research facilities in the world. At the LHC, they study the smallest particles in existence with one of the most complex machines ever built. Here is a photo of the facility superimposed on an aerial shot near Geneva, Switzerland. The collider has huge curved tunnels about 300' underground and about 17 miles in circumference.*

Most groups (13) were curious to know who is involved with the LHC facility; for example, what countries and what professionals were involved in the original design and construction; who operates and works at the facility currently; who has access to the data and findings.

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[14] Fisher Exact Probability Test tests whether two groups (e.g., males, females) differ significantly in the proportion with which they fall into two classifications (e.g., heard of LHC or not). Two-tailed Fisher Exact test, $p < 0.0001$.

[15] Photos from http://cds.cern.ch/collection/Creative%20Commons%20Images%20from%20CERN

Eleven (11) of the 18 groups were surprised by the location, wondering why the Geneva area was chosen and how aware the ground-level inhabitants are of the facility. **Ten (10) groups raised the issue of funding**, asking how much the facility and research costs and what is the source of support.

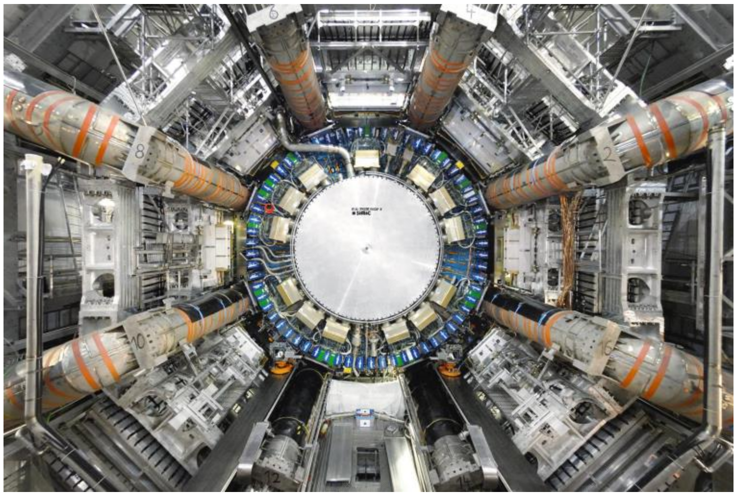
Moderator's verbal description for second photo: *Just to give you a sense of scale, here's a photo of part of the tunnel. The Large Hadron Collider was built to study the universe's tiniest particles. You learned in school about particles like protons and neutrons, but there are many many other much tinier particles that scientists study. In the tunnels, beams of particles are accelerated to almost the speed of light and guided in opposite directions so that they collide into each other with incredible energy. The incredible energy of the collisions produces hundreds of different really tiny particles. And some of these particles may be unknown to scientists.*

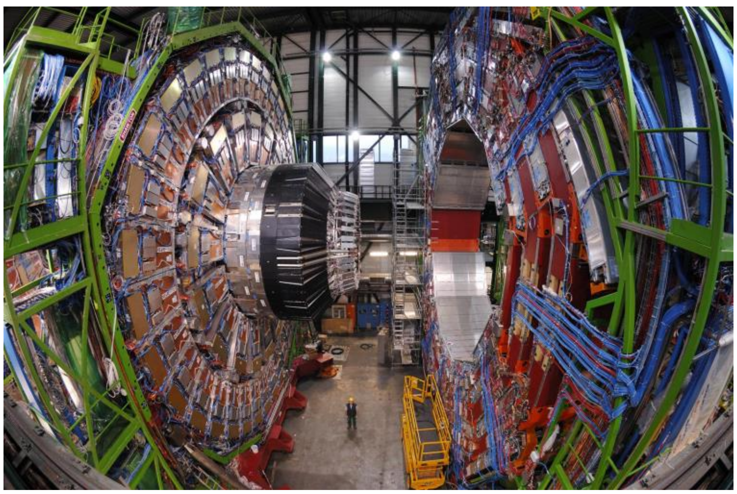
The tunnel photo and description elicited **concerns from 13 groups about worker safety and larger operational safety of particle collisions for the civilians, the workers, the scientists and the surrounding environment**, ranging from the practical: *How do you get air down there?* - to concerns about collisions: *What's going to happen when these collide? What is the safety for the folks above the facility?* – to health fears: *Do these people die of cancer and have three eyes? -* to gallows' humor: *I think this guy is going to be turned into one of the Stanley comic superheros*.

Twelve (12) groups were impressed with the massive size of the facility and tried to put the size into some sort of more understandable scale related to football fields, Manhattan, Hoover Dam, or auto or subway tunnels. The tunnel photo elicited strong interest in a giant screen immersive experience riding through the tunnel on the worker's track or even as a particle.

Twelve (12) groups asked questions about the particles themselves. The most frequently asked questions include: *What are particles? What particles are used? Where and how are they generated? How are tiny particles accelerated and controlled so as to collide? How much energy is needed? Why does the facility have to be so big if particles are tiny?*

Eight (8) groups were curious how the facility was powered, how much energy is used and how it is produced.





Moderator's verbal description of two final photos:
Look at the aerial photos. You'll see the names Atlas and CMS along the superimposed circle. These are the locations of a huge apparatus called a detector. A detector records the results of a particle collision. Here are photos of two of the giant detectors, ATLAS and CMS.

Eight (8) groups were intrigued with the detectors and asked questions such as *how the detectors measure particle collisions; why the enormous size to detect tiny particles; why different detectors; how do the detectors relate to the tunnel and the tube in the tunnel; what are the materials used; what do the colors and numbers mean.* A few participants suggested that the giant screen format could give the audience a real-life feel for the scale of the machines.

The following two conversation transcripts illustrate the themes of curiosity summarized above. A group of seven women raised questions addressing the themes of who is involved, location, funding, safety, size and particles:

What kind of people live there?
When did they build it?
How long did it take to build a facility of that magnitude? How dangerous it is? What safety precautions are they taking for the area?
Is it private? Do people who live there know about it? Or is it secret?
Underground sounds secret. Why is it underground?
Who funded it? There's a lot of money.
Why does it have to be so big if the particles are so small?
How many collisions is it recording? Thousands per minute or a few a day?
Is this a United Nations thing or a Swiss project?
Who gets the information?
Who pays for it?
Is it 24 hrs a day or 9-5 operation?
How do people go up and down – do their ears pop?

A conversation of seven men covered the themes of who is involved, funding, safety, size, power required, and particles.

What's a particle?
A lot of expense.
Who has access? Is it open to all?
What kind of power is required?
How safe is it?
Will it end up creating a black hole – that went around the news cycle for awhile, the earth will be swallowed up. [A few others in the group had heard this]
Any relation to developing fusion power, fuse two particles together to generate huge amount of energy?
I think the size is a great perspective. Why the size is necessary?
What are they looking to do? I'm assuming that atoms are not the smallest particle and they are trying to delineate the smaller particles.

After the general discussion of curiosities related to the LHC technology (summarized above), participants responded to a written survey to rate their interest in learning answers to pre-determined questions[16] about the physical facility. Table 3 presents interest ratings for nine questions.

All nine of the pre-determined questions about the LHC facility elicited moderate to high interest from a majority of the participants, but most appealing were questions about particle collisions – how do particles collide, how are they seen, what do they reveal to scientists.

Table 3. Interest in the Large Hadron Collider Physical Facility and Operation (N = 106)

Questions about physical facility and how it operates	Not at all Interested	Slightly Interested	Moderately Interested	Very Interested
What do scientists learn from the collisions?	2%	1%	7%	91%
How do scientists see and identify particles?	1%	3%	11%	85%
How does the LHC get particles to collide?	2%	2%	12%	84%
How does a detector work?	3%	5%	26%	66%
What does the inside of the tunnels look like?	3%	11%	21%	65%
Why is the LHC underground?	1%	15%	32%	52%
Why is it large?	4%	13%	32%	52%
How are detectors constructed?	1%	18%	33%	48%
Why circular?	6%	16%	36%	42%

[16] Various sources were drawn upon to produce these survey questions: the UK 2006 study, LHC outreach sites (e.g., http://www.stfc.ac.uk/646.aspx), and advisor suggestions.

The written survey also elicited additional questions that participants had about the LHC physical facility and its operation. These questions reflected the themes reported in the focus group conversations. **More than one-third of participants (N = 106) were interested in issues of safety and health, funding, and who is involved in the LHC.**

- Most participants (41%) focused on the **safety and health** of the LHC operation for workers, for people of Geneva, and for the environment.
- 39% of the adults were interested in **funding** issues: how much the LHC cost to build, to operate and maintain; and who provided the financial support.
- 36% wanted to know **who is involved** in originating the concept, in the construction and in the operation of the LHC: how many people; what are their professions, backgrounds, and countries; and who owns it.
- 18% asked why the LHC was built near **Geneva** and how aware the inhabitants above are with the facility and its operation.
- 16% were interested in how much **power** the LHC uses when operational and what generates the power.
- 15% asked **how long** it took to construct the facility.
- 14% were interested in the **particle beams**: their source, size, type; and control of their movement and collision.
- 10% were concerned with how much is **secret vs. public** about the facility, its operation and its research findings.

RESEARCH OF LARGE HADRON COLLIDER

Awareness of research at the Large Hadron Collider

After conversing about the LHC physical facility, moderators moved on to why the Large Hadron Collider was constructed and the kind of questions that scientists want to answer using the LHC. Participants first presented their own understanding about why scientists want to study the results of particle collisions. **A majority of groups (10) proposed that LHC research focuses on the origin and evolution of the universe and general exploration of the fundamental nature of matter.**

Frequently mentioned research, noted by 10 groups, relates to the **origin and evolution of the universe**, with 6 groups including mention of LHC scientists **recreating conditions of the Big Bang**; for example:

To explain how the universe came about.

What was at the very beginning, how do you end up with hydrogen particles being formed, how did matter originate?

How did the universe form and all that followed.

How and why did the universe come into existence? What came before the Big Bang? At the instant before the Big Bang, our entire universe was compressed into a single particle. What was that particle? What did it look like? What was it made of? What caused it to do what it did?

I thought they wanted to reconstruct the Big Bang. I thought that was the initial purpose.

What they are trying to recreate is what happened already, whether it happened by God's influence or on its own. We're trying to redo it and understand it.

Ten (10) groups also spoke about research **exploring the fundamental nature of matter**; for example:

If we are ever going to achieve fast than light travel, time travel, manipulation of gravity, antigravity or artificial gravity, and so forth, these are things which we are only going to get to based on a very good understanding of the fundamental principles that govern the universe. The way to get to that understanding is to understand the nature of the subatomic particles that are being investigated in machines like this.

One of the big things is the real composition of matter.

What matter is made of.

Understanding more what the universe is made of, understanding basic parts of matter.

Eight (8) groups became more specific in their explanation of why scientists study the results of particle collisions, mentioning **Higgs boson** (6), **dark matter** (2) or **antimatter** (1); for example:

> *Trying to find one of the missing particles, the Higgs boson.*
>
> *Discovery of the Higgs Boson.*
>
> *Like that Higgs boson particle was mathematically shown like 60 years ago. A lot of the stuff they're colliding is with the goal of seeing these particles that they believe to be there or like have existence.*
>
> *Because that instant of when they have the collision, they form these particles that die off so fast that you can only see them in that second of time, and they believe 97% of what's around us is formed by that particle that exists only for that moment of time, so that's what they're trying to study.*
>
> *Humans are always on a quest. The first question is what gives mass, and that was what the Higgs was all about. The two big questions now are where is dark energy and dark matter.*
>
> *Dark matter, what's gravity, how is it formed and how is it related to mass.*
>
> *Antimatter was a big one, I think. Kind of hard to explain. There's a lot of things they've observed that they can't explain because it doesn't conform to their initial theories. Now they're trying to figure out alternative theories that explain why things don't line up the way they should.*

Seven (7) of the groups focused on **new forms of energy** as a research topic at LHC; for example:

> *My understanding is it's something to do with energy and the ability to create energy.*
>
> *They could bring new forms of energy.*
>
> *I'm assuming that it's to do with energy…this might be to find ways to be more efficient.*
>
> *Energy comes to mind – renewable forms along lines of nuclear I am thinking.*
>
> *I think the Holy Grail…I forget whether it's fission or fusion. Is it a fusion reactor?*

Interest in and familiarity with specific study areas

After hearing what participants knew or speculated about why LHC scientists study the results of particle collisions, moderators read brief descriptions of five areas of study. After each verbal description, participants rated their interest in and their familiarity with the study area and then discussed their questions of curiosity about the research topic. Below are the research descriptions as presented verbally to the groups:

- *The Large Hadron Collider recreates conditions and energies that existed during the very first instant of the universe after the Big Bang.*

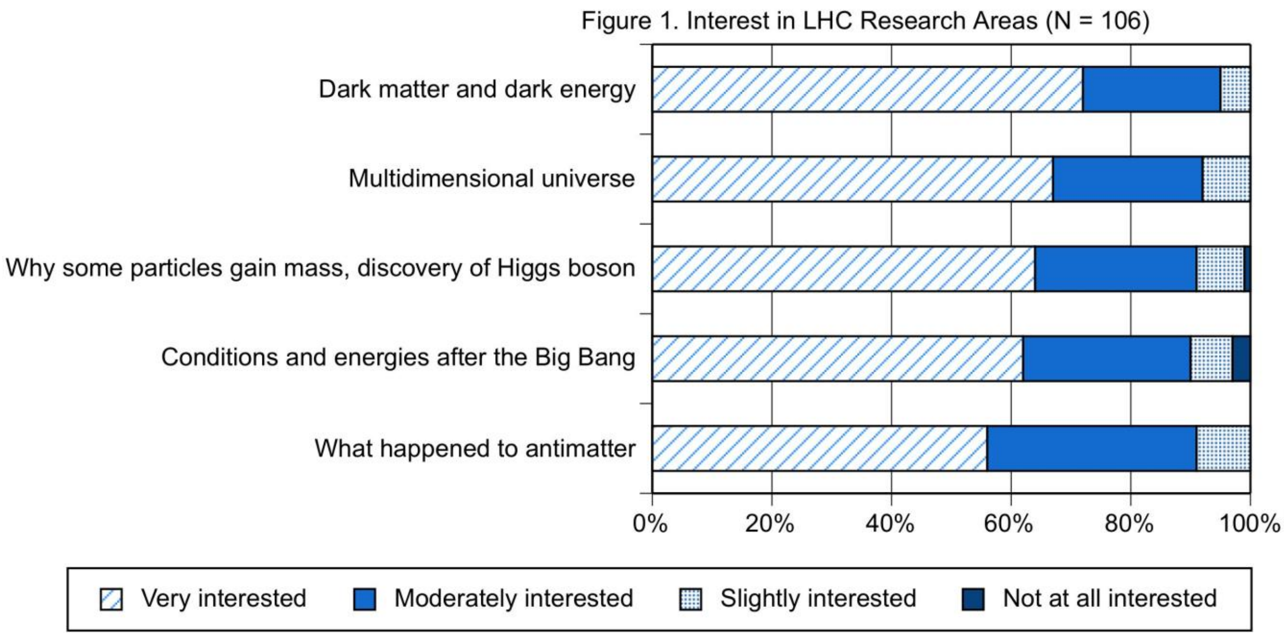
- *The Big Bang created equal amounts of matter and antimatter, but antimatter then disappeared. Large Hadron Collider experiments are exploring what happened to the antimatter.*

- *Scientists have concluded that only about 4% of the Universe is made of visible matter as we know it. The remaining 96% is made of matter and energy that we do not yet understand and is referred to as Dark Matter and Dark Energy.*

- *We generally experience the world in three dimensions. Think of this room- we have the dimension of length, the dimension of width, and the dimension of height.Many scientists think the Universe has many more dimensions, maybe even 10 dimensions. Research at the Large Hadron Collider may allow us eventually to see evidence of multiple dimensions.*

- *One purpose of the Large Hadron Collider is to carry out experiments that may confirm or not confirm theories about how the universe works. Scientists at the LHC have been testing a theory about why some particles gain mass, by looking for a fundamental particle they thought was responsible -- a particle called the Higgs boson -- which you may have heard the media call 'the God particle.' In the LHC particle collisions, scientists looked for and recently confirmed the existence of the Higgs boson.*

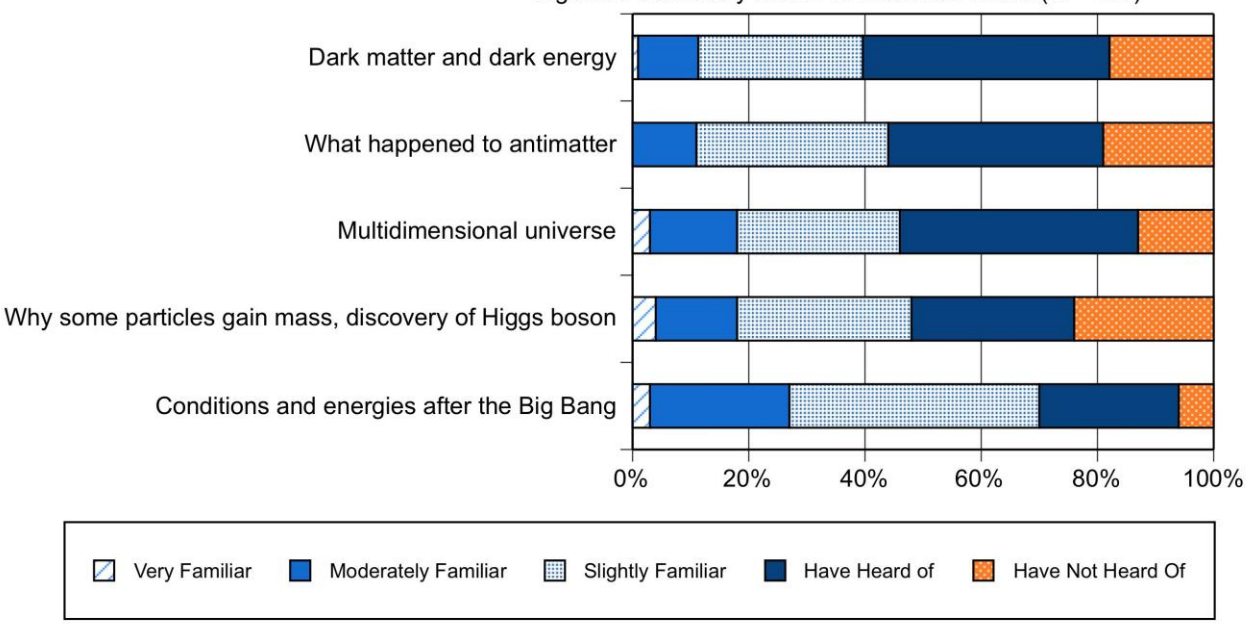
Figure 1 presents the participants' ratings for interest for each study area. **A majority of the adults were "very interested" in each of the study areas**, ranging from 72% very interested in dark matter/dark energy to 56% very interested in antimatter research. How closely a participant reported following S&T news was significantly associated with interest in the conditions after the Big Bang and dark matter/dark energy. [17] Also participants' level of interest in new scientific discoveries was significantly associated with interest in what happened to antimatter after the Big Bang.[18]



[17] Big Bang χ^2 (6, N = 106) = 22.06, p = 0.001; Dark matter/dark energy χ^2 (4, N = 106) = 9.96, p = 0.04
[18] χ^2 (2, N = 106) = 11.11, p = 0.004

Figure 2 shows that **a majority of the adults had heard of all five of the topics, if only through science fiction references, but only the Big Bang topic was at least "slightly familiar" to a majority (70%) of participants.** One-quarter (24%) of the sample had "not heard of" Higgs boson, and one-fifth had "not heard of" antimatter (19%) and dark matter/dark energy (18%). Men rated their familiarity higher than women for research about dark matter/dark energy, antimatter, and Higgs boson.[19] Familiarity with all topics except the Big Bang was higher for those who expressed more interest in new scientific discoveries.[20] Familiarity with Higgs boson was significantly higher for those who more closely followed S&T news.[21]

Figure 2. Familiarity with LHC Research Areas (N = 106)



[19] Dark matter/energy χ^2 (4, N = 106) = 11.54, p = 0.02; Antimatter χ^2 (3, N = 106) = 11.02, p = 0.01; Higgs χ^2 (4, N = 106) = 16.48, p = 0.002;

[20] Dark matter/energy χ^2 (4, N = 106) = 11.65, p = 0.02; Multi-dimensional universe χ^2 (4, N = 106) = 10.15, p = 0.04; Higgs χ^2 (4, N = 106) = 22.17, p = 0.0002;
Antimatter χ^2 (3, N = 106) = 19.34, p = 0.0002;

[21] χ^2 (9, N = 106) = 29.56 , p = 0.0003

Curiosities about research at the Large Hadron Collider

After hearing each study area description and rating their interest and familiarity with the research, participants posed their questions of curiosity about the research. Groups asked similar types of questions across all five research topics, yielding nine themes of curiosity. **The major themes of curiosity that more than half of the groups have about the LHC research include: (1) what are the basics of the phenomena? (2) how do researchers know something happened or something exists? and (3) what difference does the research make to our lives and world? Less frequent but still important themes of curiosity ask: (4) how are the researchers exploring the issue? (5) is the research safe? (6) what does the phenomena look like? (7) why do this research? (8) how does the research relate to other known information and theories or other LHC research? and (9) what motivates the researchers?**

Example questions of curiosity are presented below illustrating the range for each theme and for each of the five research areas. Note that individual quotes are from different groups, although they may sound as if they are from one conversation because groups had similar questions.

- **What are the basics?** A majority of the groups wanted basic explanations of the phenomena being researched.

Multidimensional universe (16 of 18 groups):

What are the other dimensions?
What does that mean? I understand height, width, and even time to a certain perspective, but that's only four. What are the other six?
I want to know what the ten dimensions are, and why not eleven?
I would want to know the basic theory of it.
Explain a ten dimensional postulation of space.
Are you talking parallel universe?
Is there a model that shows what it looks like, how does it work, how long have they been working on this, what steps have they made, what information have they gained?

What happened to antimatter (15 groups):

For me, antimatter is a hard concept. What is it?
Why can't we see it, or detect it, where is it, and I don't know enough about the science of it to be firm in my acceptance that it really exists.
What caused it to disappear?
Where did it go when it disappeared? Is it exempt from the laws of matter that matter isn't destroyed?
Did it disappear or can we just not measure it?
What is where the antimatter used to be?
Does matter go back and forth between matter and antimatter?
They say that antimatter and matter will annihilate each other, so why aren't we seeing massive energy releases when this happens? Do they never meet?
What happens when antimatter meets matter? Does it turn into another matter?

Dark matter and dark energy (14 groups):

Explain it so we can understand it. What is dark matter? What is dark energy?
I'd like an analogy. Use another system to explain it.
Why can't we see it?
What is its purpose?
If it's out there in that huge scale, is it also in here, in between the particles that we know as matter? Is there also dark matter here?

Big Bang and subsequent conditions and energies (11 groups):

I'd want some kind of review of what the Big Bang was supposed to have been and what preexisted the Big Bang. I'd want some elementary reminders.
Is the Big Bang theory correct?
Is the fact that the universe is expanding – is that irrefutable evidence of the Big Bang?
How was matter created out of nothing?
What started our universe? How did it transform?
Are the laws of physics different at that point?
Can they say with certainty when the Big Bang occurred?
How many of the elements that we know now were present at that time? What elements existed in that first instant and what happened to them after that?

Discovery of Higgs boson (10 groups):

Why is it important that particles have mass?
Why don't some particles gain mass?
Do particles stop gaining mass?
Does it lose mass too? Does it go back and forth?
What is the Higgs boson?
How did Higgs and Boson come up with it?
How is this particle responsible for giving mass to other things?
If you add a Higgs boson to another, what do you have –two of them or something different? How do these particles come together? How do particles become what they become, how is matter transformed?
Does it attach to the proton or the electron? Or does it spin around on its own? Or is it just like vacuum? What is it? Where is it?
How many of these have they found? How often is it repeatable?

- **How do the researchers know?** Questions raised in the groups related to how do scientists know that dark matter and dark energy make up 96% of the universe, that antimatter disappeared, what the conditions after the Big Bang were, that multiple dimensions exist, and that Higgs boson exists.

Dark matter and dark energy (14 of 18 groups):

How do they know what they don't know? You can't identify the types of matter that are out there, so how do they get 96%?
How do they know the percentages?
What do they think is dark matter?
Is there a basis outside of theory? Have we developed some sort of detection?

What happened to antimatter (8 groups):

How do they know it was equal amounts [of matter and antimatter after the Big Bang]?
How do we know that antimatter actually existed and that it disappeared?
If it disappeared, how do they know that it ever existed?

Big Bang and subsequent conditions and energies (8 groups):

You're saying we are recreating conditions – how do you know what conditions were like then?
How do they know they're recreating the conditions after the Big Bang. How sure are they – give a good explanation of what leads them to believe they have it right.
How can you say this happened when you're just doing it out of some kind of mathematical postulations?
How do you know that what you are looking at happened before?

Multidimensional universe (7 groups):

How do they know there are other dimensions?
In order to know ten dimensions, have they seen something or proven it in some form?
If you can't see it, touch it, smell it, feel it, how do you know it's there? Is it just a math problem?
How do they know it's there? This one is further outside the scope of an IMAX film. What is the evidence that shows that this is a possibility?

Discovery of Higgs boson (2 groups):

How did Higgs come up with the premise of its existence and how its existence relates to what it does in the universe as a subatomic particle
What is the evidence that they used to support the existence of this particle or other particles?

- **What difference does the research make to our lives?** Groups were curious what implications or practical applications the research findings might have; for example:

Dark matter and dark energy (9 of 18 groups):

This all seems so esoteric…is it anchored in any way to our day to day lives …what's relevant to my life or how could it be relevant?
How does dark matter affect us? Is it affecting us now?
What are the effects they expect on us as people? Do they think they'll find sources of energy? Or just to learn more?
If there's 96% of it out there, can we use it for something?
How does the study help society or us or the world?
Is there a benefit to understanding it?

What happened to antimatter (8 groups):

What can we use it for, if we know how it works?
What are the uses of antimatter?
What can be commercialized? Can it be turned into something awesome?
Could we use it as an energy?
Can we get rid of the power plants and use antimatter?
Is it applicable to space travel, time travel, energy?

Discovery of Higgs boson (7 groups):

Is there any benefit to it?
What's in it for me? It's all great in theory, but how are they going to use this information?
Does this bring us closer to faster than light travel? Does this bring us closer to suspend gravity or intensify it? Where are we going with this discovery? How can we use that information?

Big Bang and subsequent conditions and energies (7 groups):

I would want to know what they expect to gain from that knowledge. Will it help us going forward?
It seems to be speculation. I can't see spending a lot of time and effort and money on that. How is it going to improve people's lives? How does understanding the way past be of benefit to us?
There's kind of a disconnect between astrophysicists and everyday life. You're walking around drinking your latte, and you're like 'why does it matter to me?'

Multidimensional universe (3 groups):

Is that knowledge useful? What can we do with that knowledge?
You have to justify it by showing the application. Science for science's sake is not a positive necessity.
Is it possible that by seeing these dimensions that are heretofore unknown, or knowing that they exist, can enlighten us to seeing more of our own world?

- **How are the researchers exploring the issue?** In this theme, participants' questions related to methodology and procedure:

Dark matter and dark energy (8 groups):

I am curious to hear what the current theories are and how they are testing them.
How are they going to use the LHC to find and analyze the dark matter?
How do you detect it?
Where are they looking for dark matter?
How does math give them answers about this stuff?
What groups are studying dark matter?

Multidimensional universe (5 groups):

How do they study that?
How does the LHC purport to figure this out?
How is the collider going to help them discover these dimensions?
Is it testable? What are the tests being done?

What happened to antimatter (4 groups):

What is their process of investigating it?
How do you observe it?
If it disappeared, how are they recreating it?
Does this machine create the antimatter?
When you say they created some antimatter, is that something that they could keep indefinitely or is it going to disappear?

Discovery of Higgs boson (4 groups):

When these guys start out shooting particles, do they start with just water? What is it that they load into this gun to shoot these particles?
How did they find it?
Did they actually find it or just evidence it exists?
Was there a specific target in mind, saying we know there is this kind of particle, let's find it? Or was it accidental?
At what point is it deemed a success? Is existence itself a success?

Big Bang and subsequent conditions and energies (2 groups):

Why can the machine only do it after, why can't they get to the universe when it was born?
What particles are they throwing at each other?

- **Is the research safe?** Groups brought up issues of safety and possible consequences of the research activity; for example:

What happened to antimatter (7 groups):

What safety precautions are in place?

Is this something that we should recreate? If it went away, maybe we should not create it.

If they do create some of that, how do you contain it? How dangerous is it? What are the impacts on the surrounding area? When you look at science fiction movies, that's one of those things that you don't mess with.

Does the risk outweigh the benefits or not?

Dark matter and dark energy (4 groups):

How dangerous is it? Can the earth disappear into it?

Is there anything dangerous?

I just want to know how it affects me, so I can move through it without hazard. Show me what it is, show me the hazards.

Big Bang and subsequent conditions and energies (4 groups):

Does it happen identically to the initial Big Bang…and could they be creating the scenario that we live in right now. Could they start it all over again?

I think of that as a very potentially destructive force, and I hope this isn't headed in that direction. No destructive military purposes.

What do you do about the oops factor?

Are there health issues?

Multidimensional universe (2 groups):

There's all kinds of ethical questions about it. What would they use the data for?

Whoever controls this has a great amount of power. How do they use it?

Discovery of Higgs boson (1 group):

Once they figure out how to control this particle, this process, who will be allowed that technology? If they understand how particles achieve mass, then could they not begin to create? Is it playing God? Will it harm me?

- **What does it look like?** Groups were curious to know how these phenomena might be presented visually, particularly in the giant screen format. A few tried to describe some visual scenarios.

Multidimensional universe (6 groups):

I'm fascinated about the idea of other dimensions, but what's it gonna look like in the IMAX format.

What would be the entertainment?

So much of this feels over my head. A better way of visualizing it would be useful.

I find the idea fascinating, but I have trouble visualizing it.

Flies see so many different areas, the prism effect, but flies can filter into a single view, and this is in comparison to how we view the world vs. how a fly would view it. The things that we miss because we aren't equipped to see them, not just visual, but every sense, even ones we don't have.

Discovery of Higgs boson (4 groups):

What does it look like?

How do you visualize that?

Very abstract. How do you get the concept across visually?

Can they get a visual representation when two particles collide?

What happened to antimatter (3 groups):

How can you show it visually?

How can you visualize it without giving false information?

How visual will this be? You want something that will strike you on the big screen.

Big Bang and subsequent conditions and energies (3 groups):

I'd like a visual of it. What was the heat like?

Was it light, dark, red, dry – what were the conditions?

Dark matter and dark energy (1 group):

I can almost visualize having the Earth and showing the things you see every day, and taking [out] *the pixels of the 4% you see every day and see what is the 96% left, and where the rest of it goes?*

- **Why do this research?** Groups wanted to know the purpose of the work; for example:

What happened to antimatter (5 of 18 groups):
What's the purpose of it?
Why should we care about it?
Why are we trying to recreate something that we lost?
I'd first want to know why they're doing this.

Discovery of Higgs boson (5 groups):
Why do they think it's so important?
Why is it important? I don't have trouble gaining mass.
Will this finding accelerate what they are trying to do there?

Big Bang and subsequent conditions and energies (4 groups):
What is the ultimate outcome – just knowledge acquisition?
Why do you want to know this?

Dark matter and dark energy (3 groups):
Why does it matter to know about them?
Does it matter if we don't know what it is?
Why are they studying dark matter and dark energy?

- **How does the research relate to other known information and theories, or other LHC research?** Participants were interested In making connections with prior knowledge or among research areas presented in the focus groups; for example:

Dark matter and dark energy (8 groups):
We understand conventional energy but how does it [dark energy] *compare?*
Are black holes related to this?
How do we know that dark energy and antimatter are different? Are they different?
Does dark matter and dark energy relate to the expansion or acceleration of the universe?
How might this relate to string theory? How does it relate to multidimensional aspect? Did dark matter leak in from an alternate universe?
Is there a relationship to space, time, distance, wormholes?

Multidimensional universe (3 groups):
How does that connect to other things? Is it related to the Big Bang?
What happens in black holes? Is that related to the other dimensions? Black holes is a conversation starter; I haven't heard of these other things.
Is string theory related?
Are they [other dimensions] *related to time travel?*

Discovery of Higgs boson (2 groups):
Does this particle tie back to the Big Bang? If so, how?
Human beings grow and somehow you pick up mass. Is there any relationship of what they are finding to human beings?

Big Bang and subsequent conditions and energies (1 group):
How does the work that they are doing relate to background microwave radiation – reinforce that, contradict it, shed more light on it?

- **What motivates the researchers?** Some were curious about the scientists themselves and their motivations; for example:

Big Bang and subsequent conditions and energies (2 groups):
What inspired you, encouraged you? What sparked your interest?
What made them decide to get into this field? What got them into it? What sparked their interest in this question?

Discovery of Higgs boson (2 groups):
I saw an interview with Dr. Higgs, and how he came up with this idea and how scared he was of telling other scientists if they'd reject it. I think some of that human engagement really helped me understand and get excited about these discoveries and what the Higgs boson is.
I really want to know what they want, what their big dream is.

What happened to antimatter (1 group):
What was so exciting that a group of people decided to put so much money, time and effort into this? If there's a movie, there must be something out there that is so exciting to them; what is it?

Content-Specific Curiosities. In addition to the general themes of curiosity presented above, some research areas elicited content-specific questions.

- Discussion about the term "God particle" appeared in 11 of the 18 groups. Participants wondered why the Higgs boson was called by that term, and a few groups discussed whether the term should be used in the film or not; for example:
  Male group:
  If It's been published and talked about, then certainly explain why it's called the God particle.
  It has to do with how particles gain mass, what has that to do with the name God particle?
  The concept I have is that God created what we currently consider our personal universe. This is what created matter I guess. If it's a term that has been put into science writers' literature, then I am interested in putting it into my frame of reference.
  There is a responsibility in being careful in explaining and not stepping on toes. Explain briefly where the God particle term came from and move forward.

  Male group:
  Anytime you introduce God into the conversation, you split the audience. Separate God and science.
  I don't know the background of why they called it that, but you should separate.
  I agree.

- For the study area of conditions and energies immediately after the Big Bang, 8 groups asked what happened before the Big Bang. Only one group brought up issues of religion related to the Big Bang.

- The antimatter area generated discussions in 6 of the groups about science fiction including *Star Trek's* warp drive and Dan Brown's *Demons and Angels* book and movie.

- Related to the research on multidimensional universe, groups mentioned paranormal phenomena (4 female groups) or referenced science fiction (6 groups) including *Flatland*, *Dr. Who, Superman, Jules Verne, Buck Rogers, Star Trek Deep Space Nine, Men in Black,* and *The Adventures of Buckaroo Banzai Across the 8th Dimension*.

IMPORTANCE OF LARGE HADRON COLLIDER WORK

After hearing brief descriptions of the work that scientists at the Large Hadron Collider are doing, participants were asked in their written survey if they thought this work is important and why or why not. **Participants recognized the importance of the LHC work to our science knowledge base but wanted to know how the work is relevant to their lives and society.**

- 41% of participants felt the **LHC work is important insofar as it may contribute to the well being of society in some fashion**; for example:

It's important to know what the discoveries will lead to and be used for.

It's important, hopefully assuming that it will lead to something concrete to help with the real world problems.

It is important if they can show practical applications. Most people won't agree with the size and cost if there is nothing but esoteric theories to come from it. We have so many needs on our planet, how does the LHC address them?

What practical applications could come from this knowledge. If we can somehow use the info gained from the LHC for good, it will be important. If we can't, it's not a high priority compared with other problems in the world.

I believe it is important for our understanding of the basics of life and materials and energy. This gives us the chance to improve what we do now and find new ways to improve life and transport.

Yes, because it could create new forms of energy.

Until I see a practical application of the results and it moves society forward, I would say no. but I would hope they prove it is.

I'm not sure until we can see if the outcome actually helps us make progress in real life. Just to satisfy curiosity about origin of universe doesn't seem worth it.

It is important if useful practical information can be found by the research. It is a very interesting topic, but I would like to see this investment pay off with things that benefit the world.

- 38% of participants asserted that **fundamental research is important for understanding our world and universe and that humans will always explore their curiosities**; for example:

It is very important to understand the world around us.

I think that it is very important. We as humans need to explore all aspects of the world around us.

It is, since it is an endeavor to push out knowledge and understanding…so many discoveries have been serendipitous, and it's exciting to push the frontiers and make all the connections, whether in our generation or for future generations to make.

Advancement of basic science is essential for advancements in all other areas.

I think any new discoveries are important even if we do not fully understand their relevance.

I think exploration is important, whether it's in the physical or theoretical arena. We should try to continue to understand the universe in which we reside. My sense of curiosity was awakened by this conversation. I don't know why it's important but we may discover things that need to/should be discovered.

Yes, inquiry/curiosity should always be promoted. That is how we progress as a human race.

- 22% combined the above two categories, recognizing **LHC's work as important in its contribution to our scientific knowledge but also emphasizing that it is important to understand and communicate its use and relevance to our lives**; for example:

We can learn how matter began. Knowledge is never bad, however, how it is used is what counts.

Very important – it tells us about ourselves and our world/universe but does it have any practical application?

It helps explain some of the mysteries of the universe. I would like to see practical applications of what they are doing, though.

I think that the work can be vital if not only working to explain how we got here- "big bang" but where we are going. Are there implications of the research that can sustain society?

Yes, it is pushing our understanding of the universe. Will lead us to other questions that will improve people's lives.

I am not sure. I don't know what the applications are, but I'd be curious to know what they are. I think research is important for research sake. Any scientific discovery can be important on some level.

I do because it helps explain some of the mysteries of the universe. I would like to see practical applications of what they are doing, though.

DISCUSSION

Engaging public interest

Adult audiences are typically more easily engaged with content that is somewhat familiar to them already, so a film about the Large Hadron Collider has an uphill battle. A majority of our male participants had heard of the LHC but not a majority of the women. Even so, familiarity beyond name recognition was low; knowledgeable participants in a majority of groups could only recall that the facility was underground, someplace in Europe or Switzerland. Participants were surprised by the location and wondered about the safety and health of the LHC operation for workers, for nearby citizens, and for the environment.

In response to still photos of the LHC interior, adults were impressed with the massive size of the facility, suggesting that the giant screen format was most suitable for communicating the real-life scale of the tunnel and detectors and for immersing viewers in its operation. Operationally, participants were most interested in the particles: What are particles? What particles are used? Where and how are they generated? How are tiny particles accelerated and controlled so as to collide? How much energy is needed? Why does the facility have to be so big if particles are tiny? How are particles detected and identified? What do scientists learn from particle collisions?

Whereas United Kingdom research about the Large Hadron Collider in 2006 found that their public was interested in the Big Bang and origins of the universe and not particularly interested in dark matter and antimatter, our US science center members of 2014 showed a different pattern of interest. Participants were most interested in dark matter and dark energy, multidimensional universe, and Higgs boson. Interest was lower but still high in the Big Bang topics relating to conditions and energies after the Big Bang and what happened to antimatter. Yet some participants felt that the Big Bang is *old news*.

Although participants were not encouraged to “play producer” during the conversations, some groups were curious and skeptical as to how the abstract phenomena they were hearing about might be presented visually and credibly in the giant screen format.

Some of the LHC research topics reminded participants of science fiction media. Referencing such media in the film or outreach may provide hooks to attract the audience (e.g., *Star Trek*), but care should be taken that such references do not reinforce misconceptions (e.g., probability of warp drive).

Raising awareness and understanding

Adult audiences will bring to the theaters a very low awareness of LHC research. Those few of our participants who had some awareness mentioned that LHC scientists are recreating conditions of the Big Bang, looking for the Higgs boson, and/or exploring the fundamental nature of matter. With respect to the five specific topics described verbally to the groups, only the Big Bang was at least "slightly familiar" to a majority of adults.

To address their lack of familiarity, a majority of the groups wanted basic explanations of the phenomena being researched (e.g., *what is antimatter*) as well as background in support of scientists' claims underlying the research (e.g., *how do scientists know that dark matter and dark energy make up 96% of the universe*). These two themes of the basics of the phenomena and how do researchers know something happened or something exists were raised most frequently for all five of the research areas described to participants. Superficial treatment of many topics may leave viewers less satisfied than deeper coverage of fewer research areas.

The majority of our participants recognized the importance of LHC work for understanding our universe but additionally wanted to know how the work is relevant to their lives and society. (e.g., *Is that knowledge useful*). Describing potential payoffs of LHC research is critical to satisfying the audience's question of how the research investment is justified beyond that of satisfying human curiosity.

To a lesser extent, adults were also curious about how scientists are exploring the research questions (e.g., *how do they study that)*; the purpose of the work (e.g., *why is it important)*; what the possible implications and consequences are of such activities (e.g., *is there anything dangerous)*; and how the research issues relate to each other and/or other known research (e.g., *how does that connect to other things).*

Gender differences are important to consider in the development of a science film, particularly one dealing with fundamental physics. Reflecting national statistics, our women reported significantly less interest than our men in new scientific discoveries, significantly lower attention to science and technology news, and significantly less exposure to physics coursework. Compared to the men, significantly fewer women were aware of the LHC and significantly fewer women were familiar with research about dark matter/dark energy, antimatter and Higgs boson. However, there were no gender differences for interest in the research areas or curiosities about the LHC research. Data from giant screen theater demographics indicate that men are just as likely as women to make the decision in film selection;[22] however, women are somewhat more likely to attend giant screen films,[23] so paying attention to gender issues may impact a film's box office success as well as its educational impact.

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[22] Giant Screen Theater Association Addendum to GSTA's 2003 worldwide viewer research program.

[23] Viewers comprise 57% women vs 43% men as reported in Kennedy, M.K., (2004). GSTA's 2003 worldwide viewer and nonviewer research programs: Key results and how to use them, *The Big Frame*, Winter, 40-59.

Film title: *Secrets of the Universe*

The group conversations began with discussion of what science center members expected from the title, *Secrets of the Universe*. Although three-quarters of our groups responded to the title with topics that are explored at the LHC, the title also elicited “outer space” topics like black holes and planets in all groups as well as “non-space” topics in two-thirds of the groups. As such, the title is not effectively evocative of the proposed film content.

Study limitations

The participants in this front-end study represent US science center members who are experienced with the giant screen film format. Compared with the US public as a whole, our groups are more interested in science discoveries and attentive to science and technology news. As such, our sample may be imperfectly representative of the full range of the future film’s adult audience and thus generalization of the findings may be limited. Additionally, because of the very early status of the project, the front-end procedure presented verbal descriptions of potential film content, relying on participants’ previous knowledge and imagination to a much greater extent than if audiovisual materials were presented. Nonetheless, the front-end study identifies starting points for development of the film and associated outreach, to be clarified and assessed during future evaluation phases of the project.