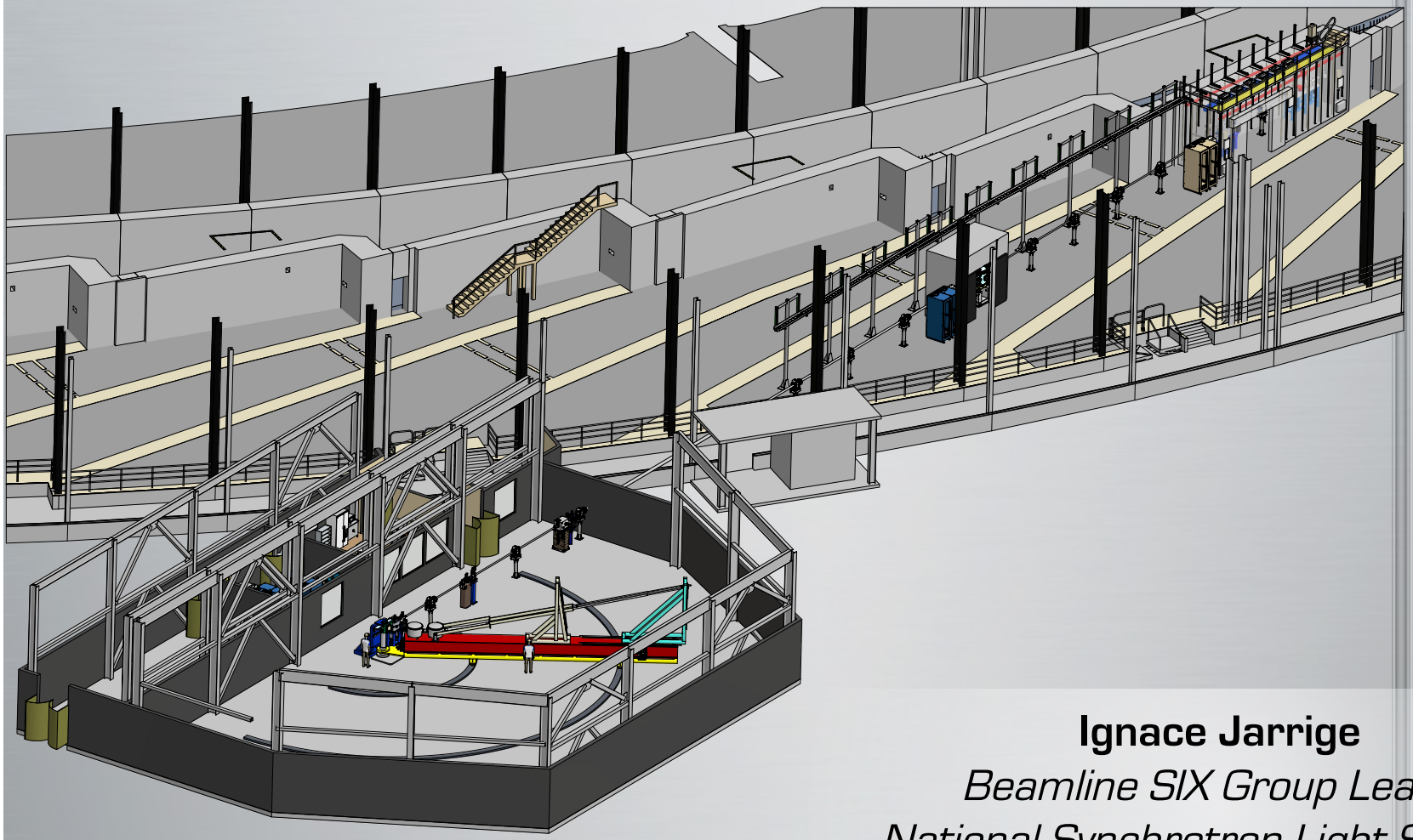
SIX: A Looong Beamline at NSLS-II to Probe Electrons

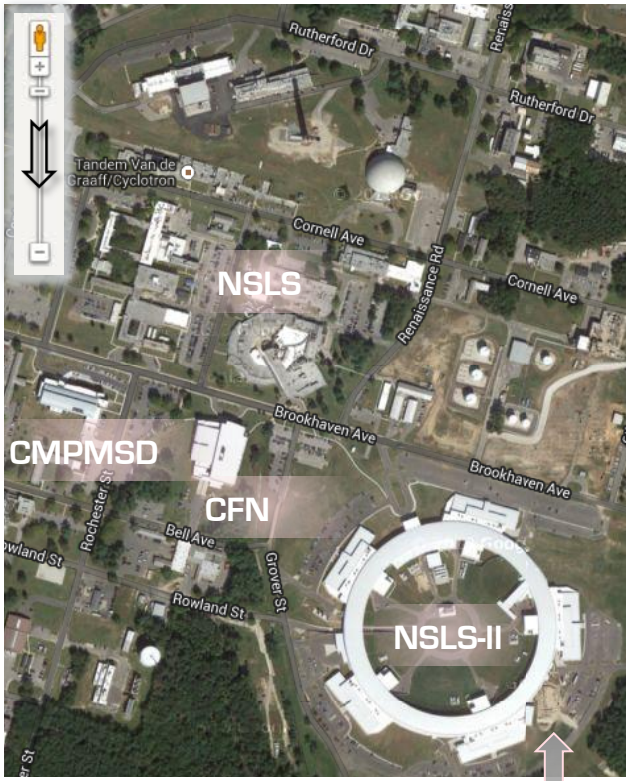


Ignace Jarrige
Beamline SIX Group Leader
National Synchrotron Light Source II
Brookhaven National Laboratory

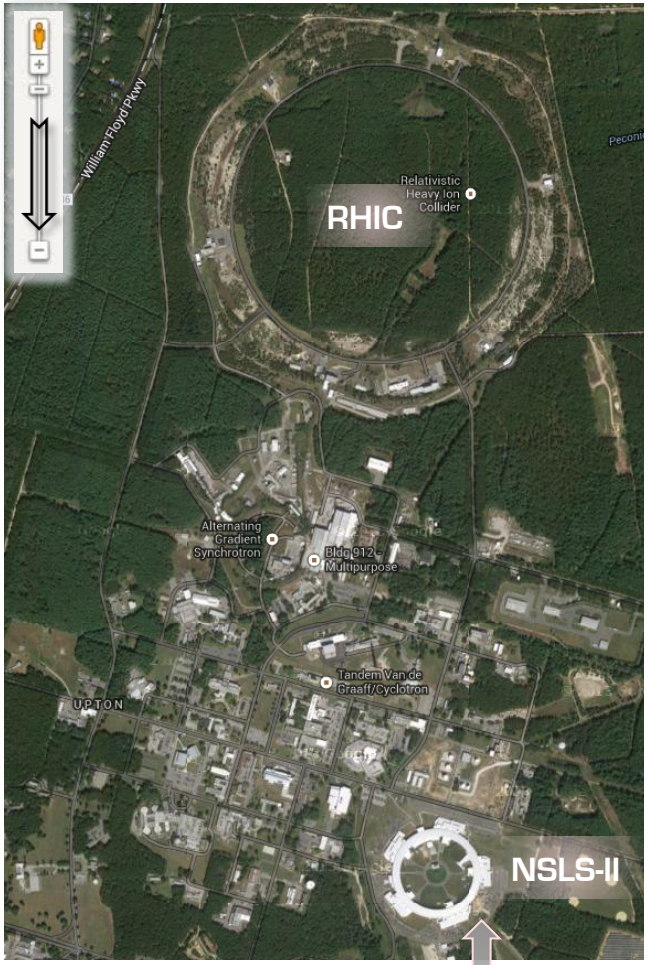
Community Advisory Council – January 9, 2014

Tell me Google Map... Where is SIX?

SIX



SIX

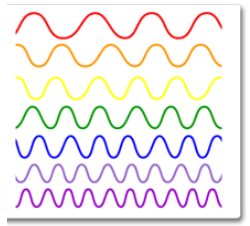


SIX

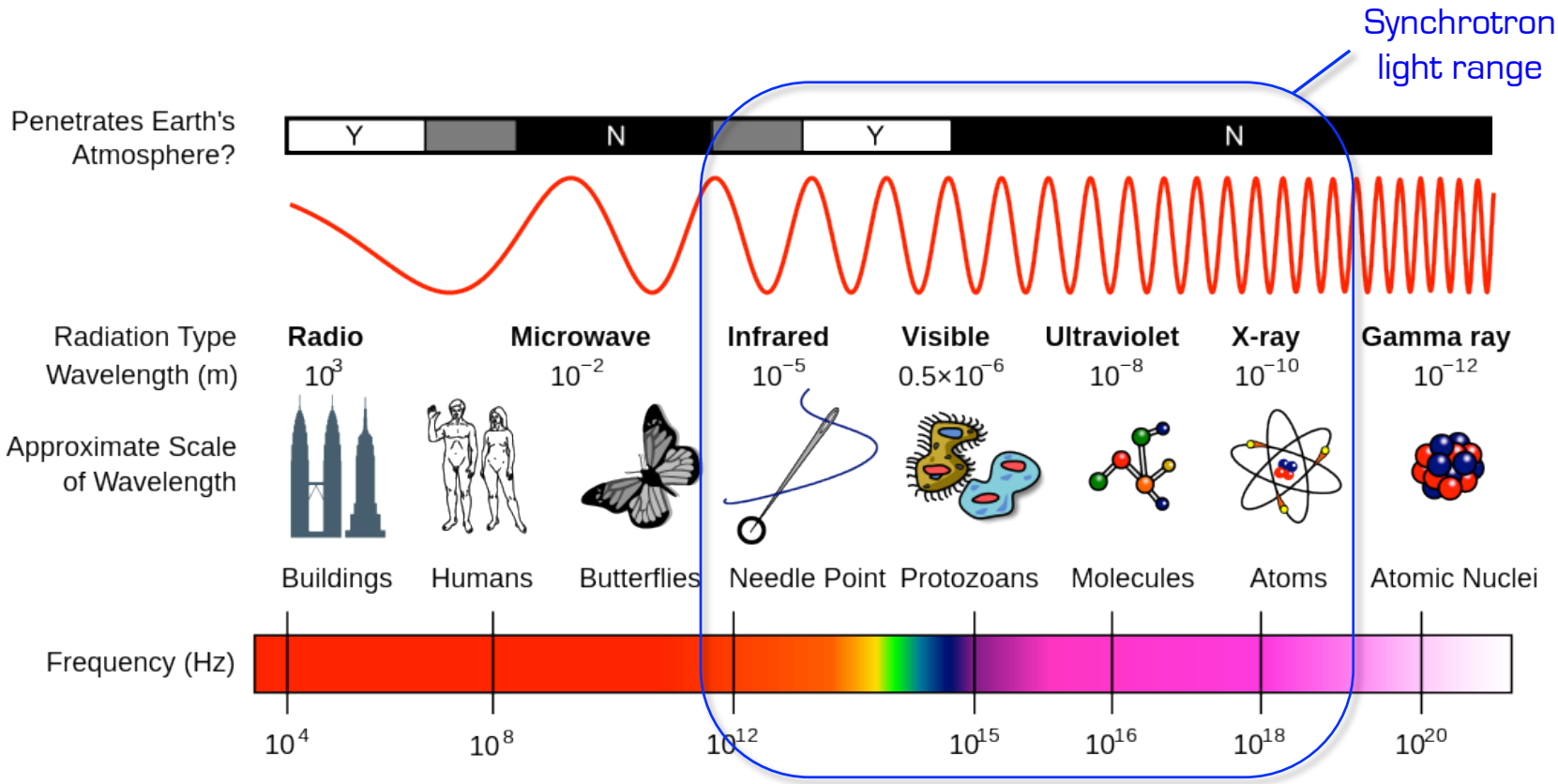
What is a synchrotron?

An extremely powerful source of light:

- A synchrotron produces extremely bright light which is used in research.
- The light comes in different ***wavelengths***, x-rays, ultraviolet, visible, infrared.

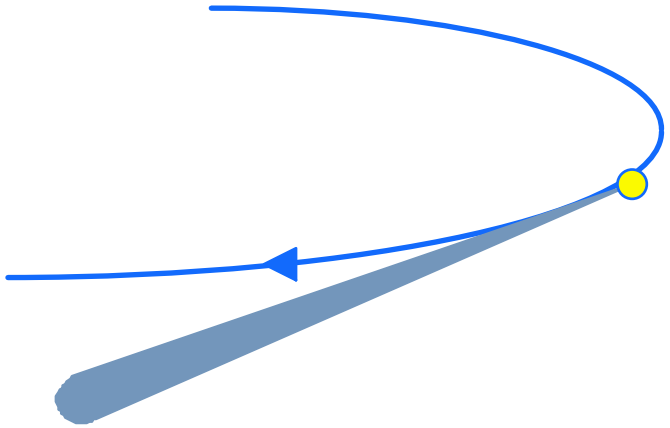


Providing many different 'colors':



What is a synchrotron?

Under the hood...



- Particles called electrons are accelerated to extremely high speeds, injected in the synchrotron ring to move in a large circle.
- As the electrons pass through magnets around the ring, they loose energy in the form of light, emitted as a narrow pencil directed forward.

- This light is channeled out of the ring into beamlines, where it is tailored to accommodate specific needs of the research conducted.
- All beamlines operate simultaneously.
- Each beamline is designed for use for a specific type of research.
- Experiments run throughout the day and night.

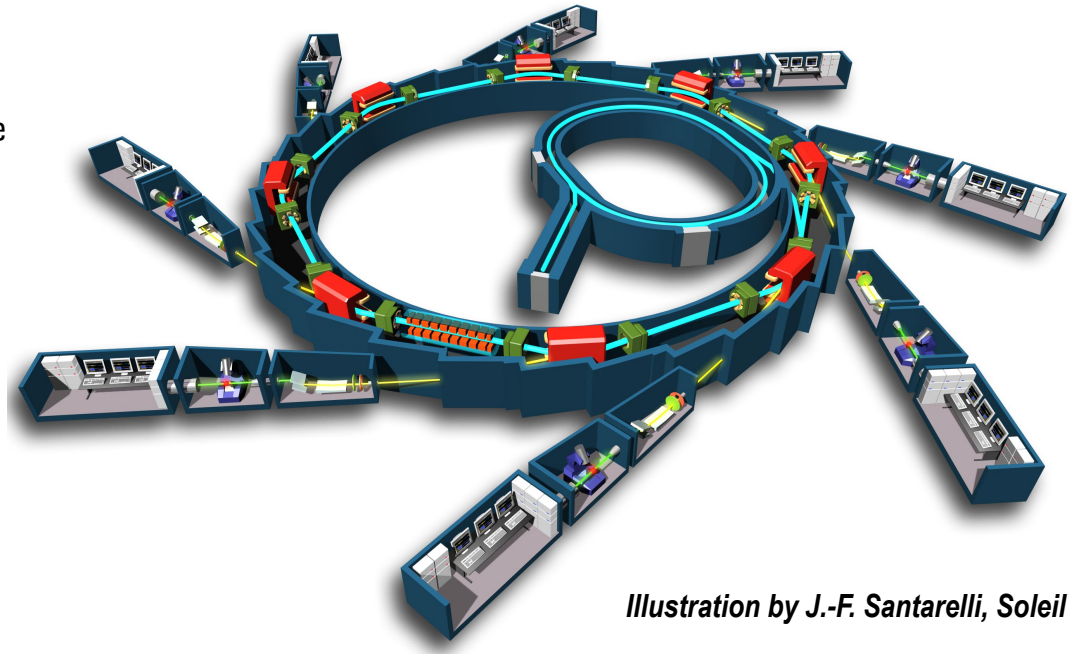
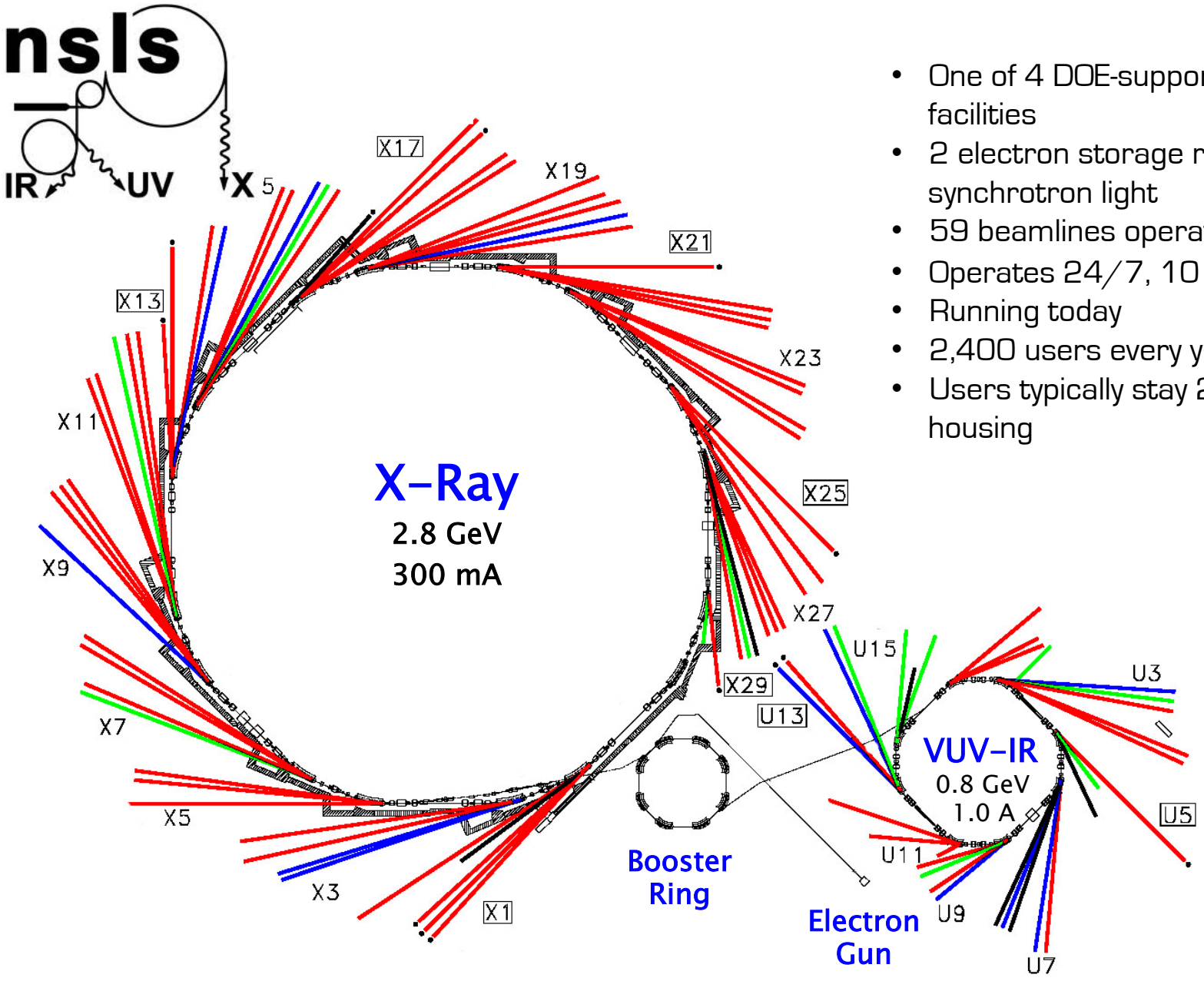


Illustration by J.-F. Santarelli, Soleil

What is a synchrotron?



- One of 4 DOE-supported synchrotron facilities
- 2 electron storage rings that produce synchrotron light
- 59 beamlines operate simultaneously
- Operates 24/7, 10 months per year
- Running today
- 2,400 users every year
- Users typically stay 2-4 days in on-site housing

For what research?

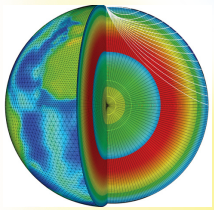
Light sources are used to explore pretty much any type of matter, so they have a wide range of applications:

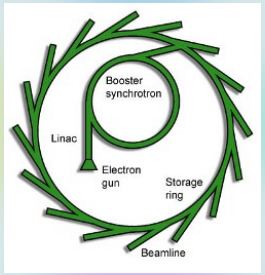
2003 and 2009 Nobel Prizes in Chemistry based on work performed at NSLS

Chemistry

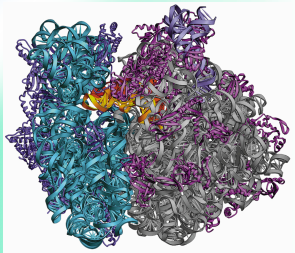
All these lines are blurred! Lots of interdisciplinary research (biophysics, physical chemistry, geophysics…)

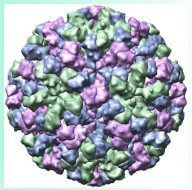
Geology

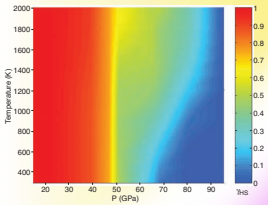


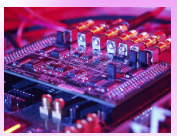


Biology









Physics

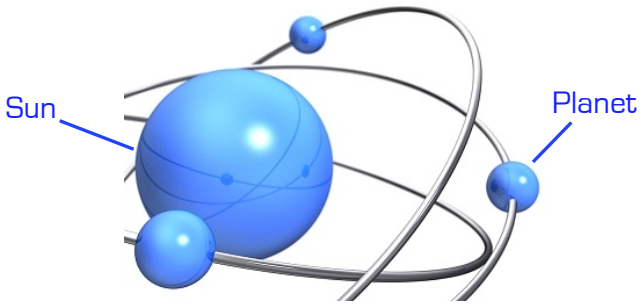
NSLS-II

- Will bring best scientists to do experiments not possible today
- World's finest capabilities for x-ray imaging and high-resolution energy analysis
- X-rays 10,000 times brighter than current NSLS
- Under construction at Brookhaven Lab, about 90 percent complete
- $912-million project, early completion in September 2014, funded by U.S. Department of Energy
- Your tax dollars at work, thank you for your investment in science

SIX: Designed to look at what?

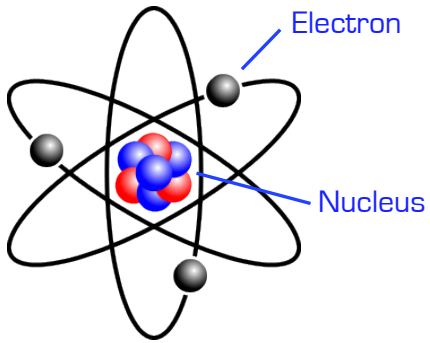
- ***Electrons!***
- ***What are they:*** All matter is made of atoms, which are themselves like tiny solar systems (a billionth in size), with a nucleus and electrons rotating about the nucleus in orbits:

From the solar system....

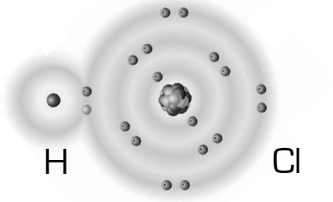


Size/1000,000,000

...to a lithium atom

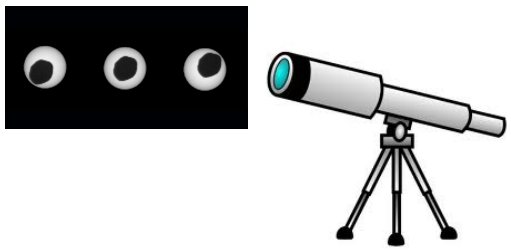


- ***What do they do:*** Electrons have an electric charge and a magnetic moment, they confer the ***electric*** and ***magnetic*** properties of matter. Atoms, to bond with each other, share electrons:

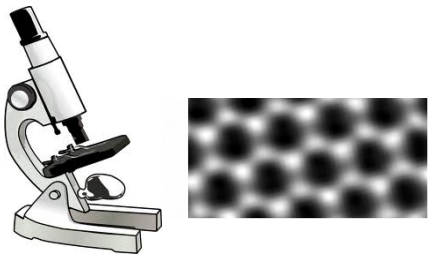


- ***The researcher's tool box:***

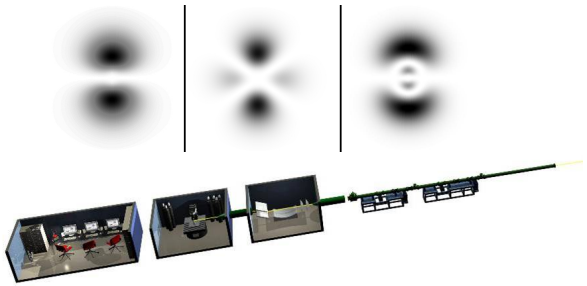
Telescope for the solar system...



Microscope for atoms...



Beamline for electrons



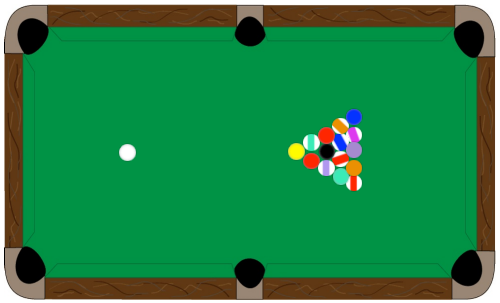
Soft Inelastic X-ray scattering: What technique?

The goal of the SIX beamline is to let us play billiards with light and electrons!

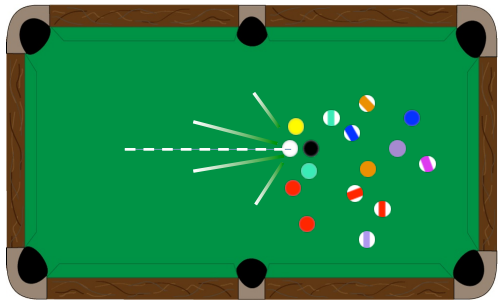
- **The setup:**

- **The process:**

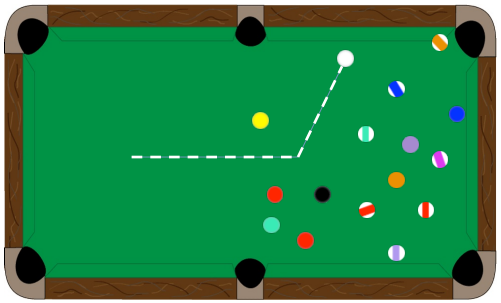
Our sample is a set of balls. Imagine that we want to find out their number and color, but have no mean to look at them directly.



We hit the cue ball (incoming light from beamline) which hits the set of balls and sends them around the table. We have disturbed, or excited our sample.

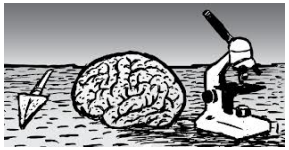


Upon impact the cue ball is deflected and looses speed. By measuring the deflection angle and speed of the cue ball after impact, we can find out about the number and color of balls

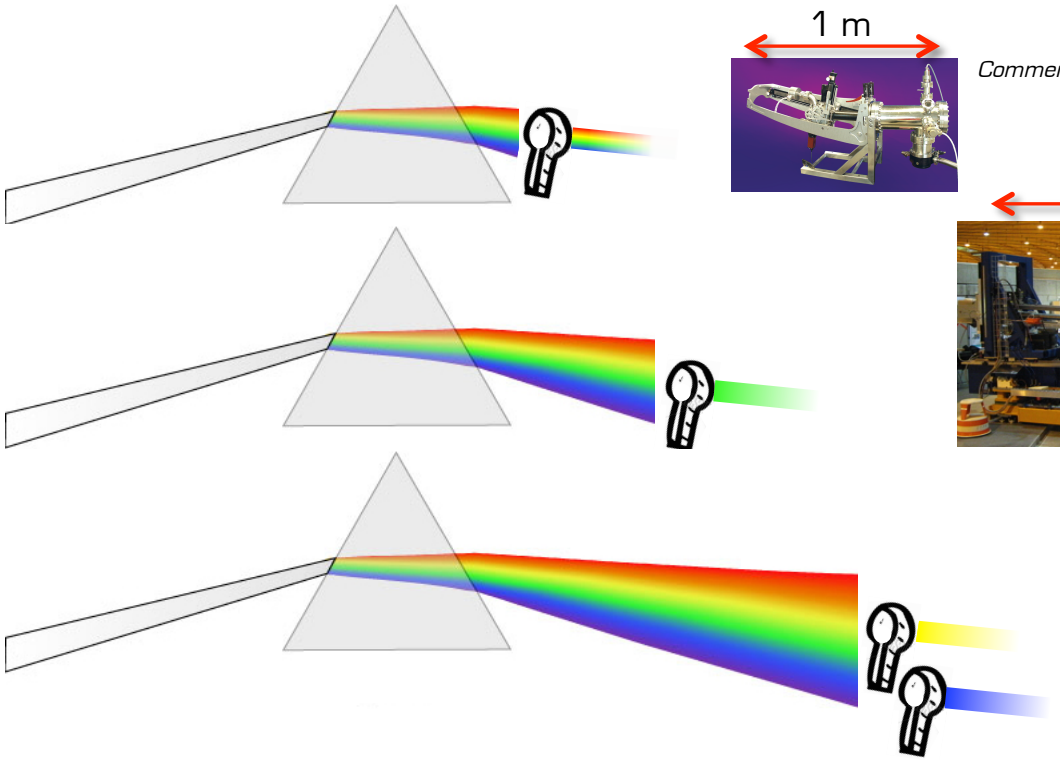


Why SIX needs to be bigger (and costlier) than a billiard table

- ***The more accurate the measurement, the finer our understanding about matter.***
  Without a world-leading instrument, most often impossible to do world-leading research!



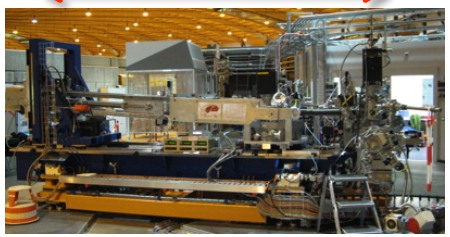
- ***Ongoing world-wide race to improve the 'color' resolution of instruments*. How?**
  - ***First ingredient:*** To split the colors, focus, deflect the beam of light, need ***perfectly flat mirrors***... within the growth rate of a fingernail per 0.1 s!! Polishing takes up to a year, only 1 or 2 companies in the world are able to do it.
  - ***Second ingredient:*** Looking through a finite aperture, the more the colors split up, the easier it gets to pick up one particular color. ***Needs distance from the rainbow splitter!***



1 m

Commercial spectrometer

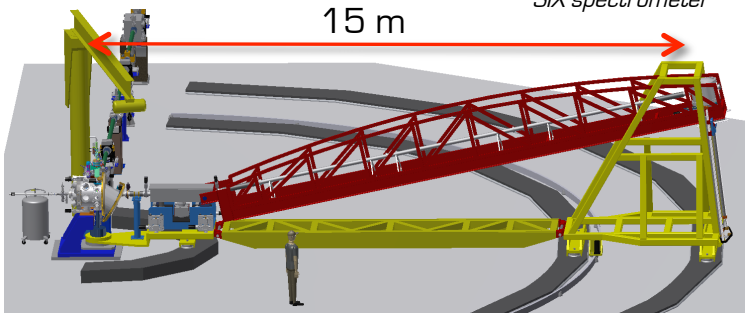
5 m



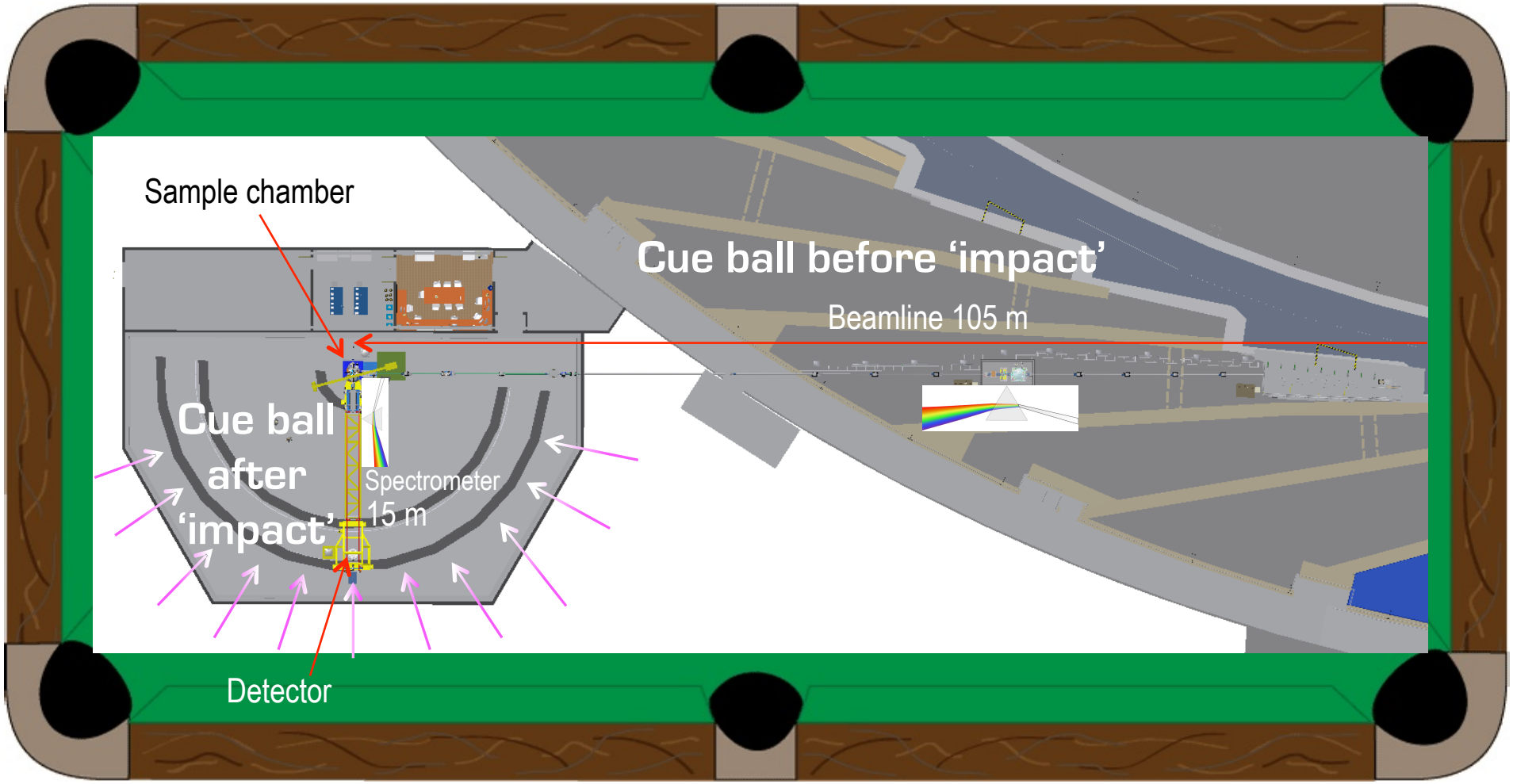
ADRESS spectrometer, Swiss Light Source

SIX spectrometer

15 m



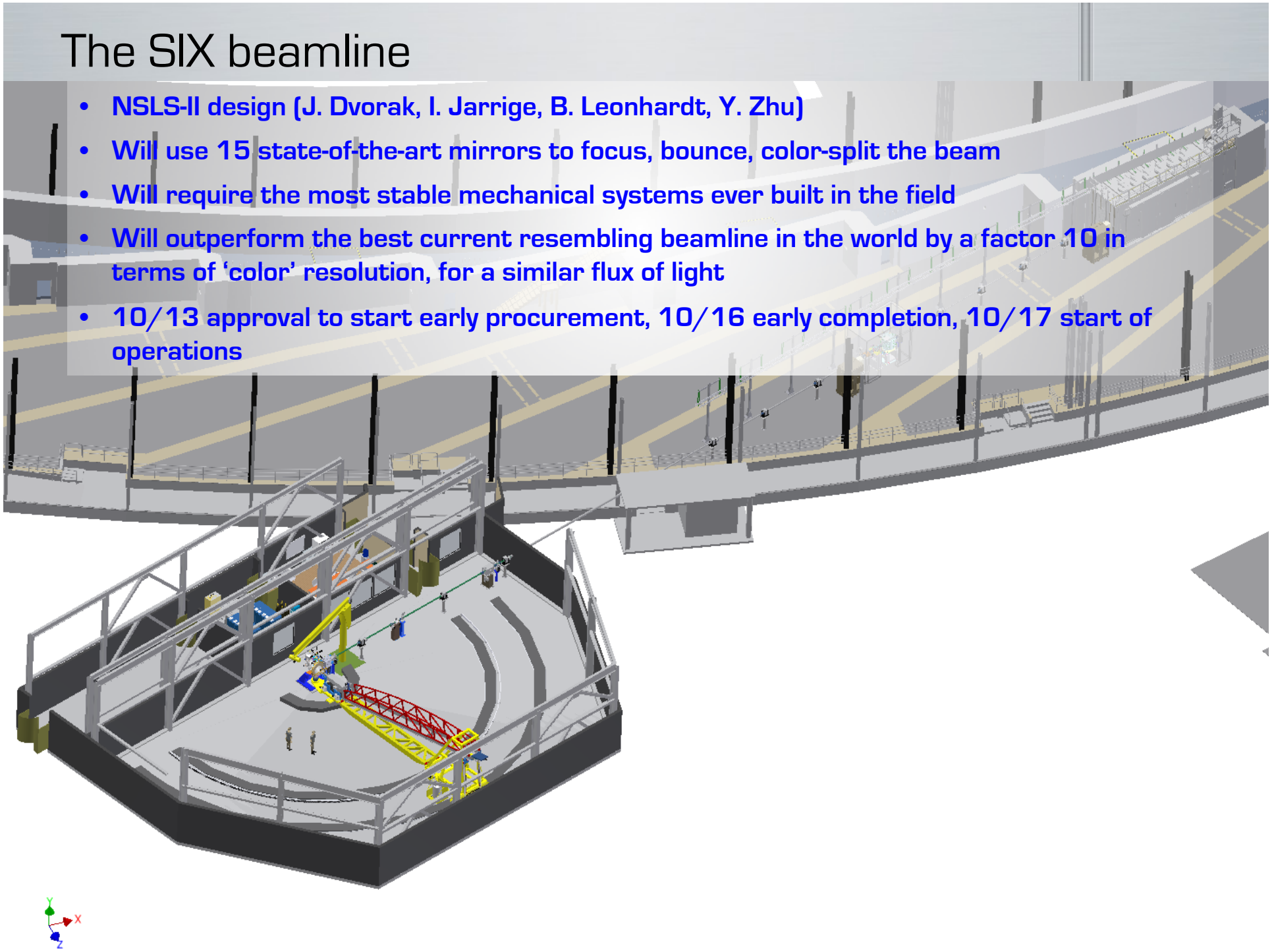
But really… how big?



- *Total length 120 m does not fit in NSLS-II's experimental hall*
- *15-m long spectrometer needs to rotate from (120° range) to measure deflection angle, bringing the building footprint to 9000 square feet*
- *Spectrometer splits light in the vertical, brings roof height to 22 feet*

The SIX beamline

- NSLS-II design (J. Dvorak, I. Jarrige, B. Leonhardt, Y. Zhu)
- Will use 15 state-of-the-art mirrors to focus, bounce, color-split the beam
- Will require the most stable mechanical systems ever built in the field
- Will outperform the best current resembling beamline in the world by a factor 10 in terms of 'color' resolution, for a similar flux of light
- 10/13 approval to start early procurement, 10/16 early completion, 10/17 start of operations



The SIX external building

- **BNL design (T. Joos, O. Dyling et al.)**
- **Engineered for low vibrations (28” thick slab isolated from ‘the rest of the world’) and high thermal stability (±0.3°)**
- **Contractor: Construction Consultants of Long Island (Riverhead, NY)**
- **Contract: $3.55M**
- **05/13 start of contract, 08/13 footings, 09/13 floor slab, 11/13 steel, 02/14 weather tight, 06/14 construction complete**

The SIX external building

The SIX external building in photos

The chronology of the construction, in photos...

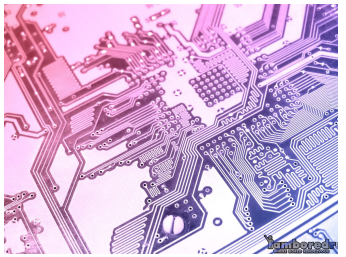
What scientific challenges for SIX? Energetic!

- ***High-temperature superconductivity: Make it hot***
  - Superconducting copper wires = zero resistance, can move power over long distances without any loss
  - But need LOTS of liquid nitrogen to be chilled to superconduct
  - Crucial to ***understand superconductivity and design room-temperature superconductors***

The LIPA-DOE Holbrook Superconductor Project: 600-m long cable, powers 300,000 homes, needs 13,000 gallons of LN_2

- ***Lithium and fuel cell batteries: Long live***
  - Ageing is the result of several physicochemical processes
  - Study mechanism of lithium, hydrogen and oxygen ion transport in batteries
  - ***Understand how to improve efficiency and lifetime***

- ***Spintronics for Computing: Making memories***
  - Magnetic processing of information, rather than charge, yields smaller, faster data storage
  - Spintronics transistors to create ultra-fast, low-consumption computer chips
  - ***Understand the nature of magnetic properties to help the design of future devices***

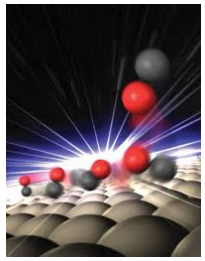


Conclusions

- *X-rays are not just for looking at broken bones*

We watch,

atoms and electrons,



poke and control

...without breaking them

- *SIX is a big tool to look at small things that have a big impact*

We look at the tiny things

That control the bigger phenomena

- *SIX to do clean science for a cleaner future*

Synchrotron light is clean...

...But why stop there?

At SIX, clean energy is our ultimate goal!