Outreach tools with real HEP data: challenges and opportunities

Fifth Workshop on Data Preservation and Long Term Analysis in HEP

Fermilab, Batavia, IL

M. Bellis

Department of Physics
Stanford University

May 16^{th}, 2011

- **Tuesday, May 17^{th}, 16:00-18:00**
- **Parallel Sessions on DPHEP common projects**
  - *Outreach*
    - Tom Jordan, Quarknet and I2U2

Outline

Orientation question

- Are we a young field or a mature field?

Motivation

Why bother with outreach?

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- *Our responsibility.*
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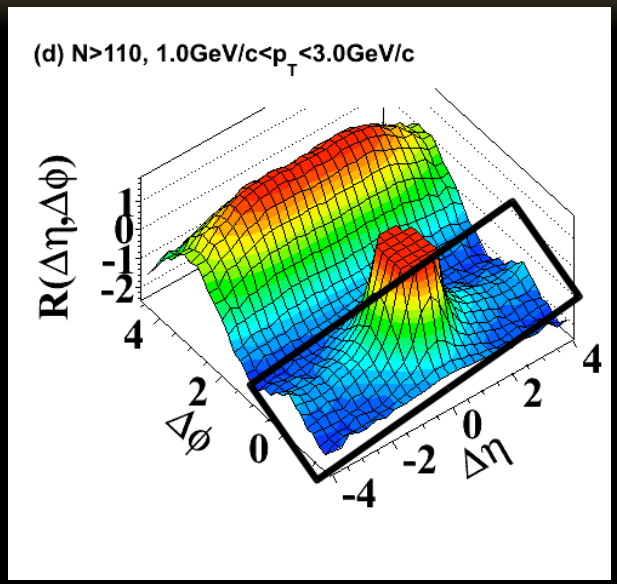
Why bother with training?

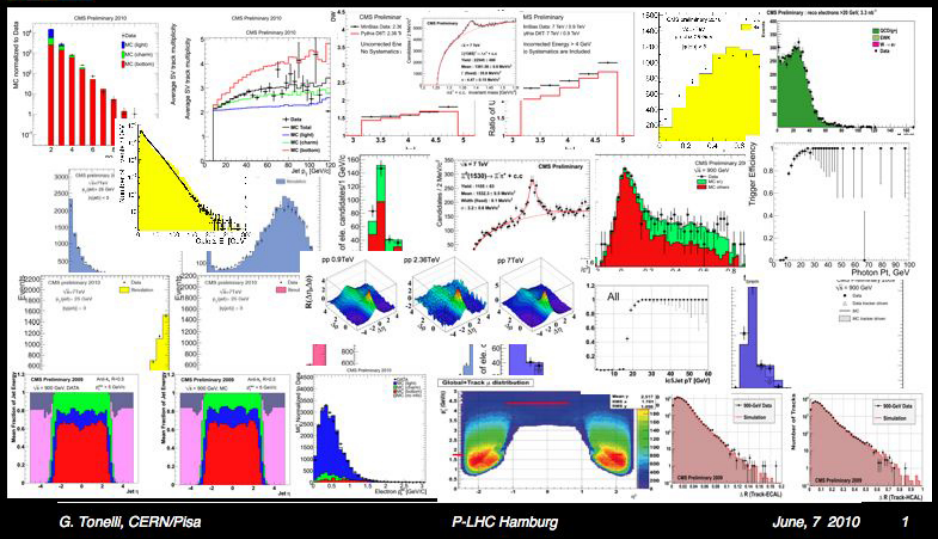
- Train new students/collaborators better.
- Encourage more (better?) communication between theorists and experimentalists.

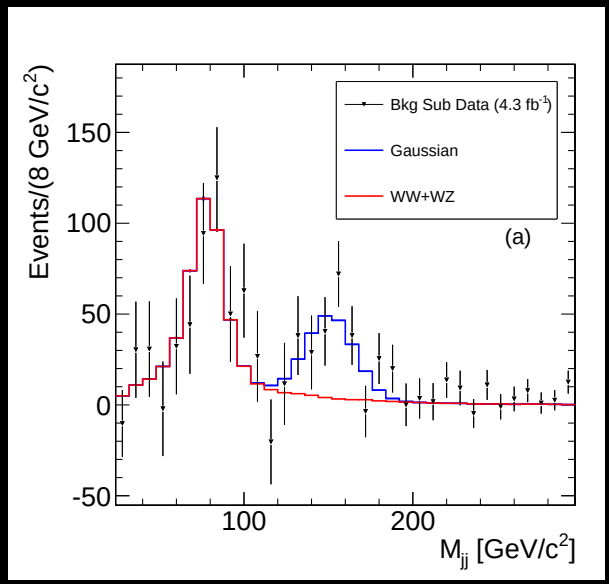
Tell people what we do.

- Particle physics complexity is increasing.
- New-physics or not, we have to explain these results to the general public.
- Citizen-scientist involvement is different than astronomy.



...and plenty of new results coming daily





Contribute to an educated workforce/society

A need for future analysts.

- **New York Times** (May 13^{th}, 2011)
- McKinsey Global Institute
- *"Big data: The next frontier for innovation, competition, and productivity".*

http://techcrunch.com/2010/03/16/big-data-freedom/

- http://www.mckinsey.com/mgi/publications/big_data/index.asp
- http://www.nytimes.com/2011/05/13/technology/13data.html

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From the McKinsey Global Institute study...

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- (From NYT article) The report points to the need for a sweeping change in business to adapt **a new way of managing and making decisions that relies more on data analysis**.

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- **"Every manager will really have to understand something about statistics and experimental design going forward,"** said Michael Chui, a senior fellow at the McKinsey Global Institute.

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How many particle physicists at grad student/postdoc level, go on to a complete career in particle physics?

Train new students/collaborators better

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  - **BaBar** (CP-violation $\Rightarrow$ $c\bar{c}$ spectroscopy)
  - **Tevatron** (E frontier, top physics $\Rightarrow$ b spectroscopy, $\mathcal{L}$/precision frontier)
  - **LHC** (E frontier $\Rightarrow$???)

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- SuperB at Fermilab? ILC at SLAC?
- Will LHC lose key developers over lifetime?
- Why do analyses take so long? (Computing expertise? Physics expertise?)

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- Will LHC lose key developers over lifetime?
- Why do analyses take so long? (Computing expertise? Physics expertise?)
- Can we teach the **integrated knowledge** better?
- DPHEP seems like the right place to learn **a lot** of physics.

Better communication between theorists and experimentalists

- Learn theory in classes.
- Learn experimental analysis in ???.
- *Experimental analysis school for theorists?*

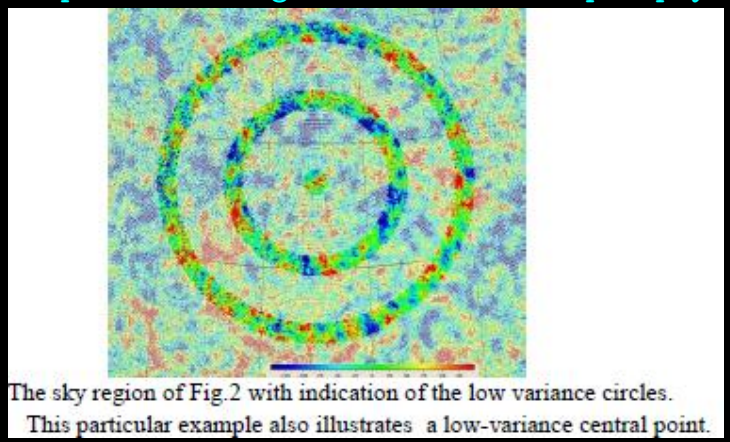
Better communication between theorists and experimentalists

- Learn theory in classes.
- Learn experimental analysis in ???.
- *Experimental analysis school for theorists?*
- Otherwise, folks may take it into their own hands...

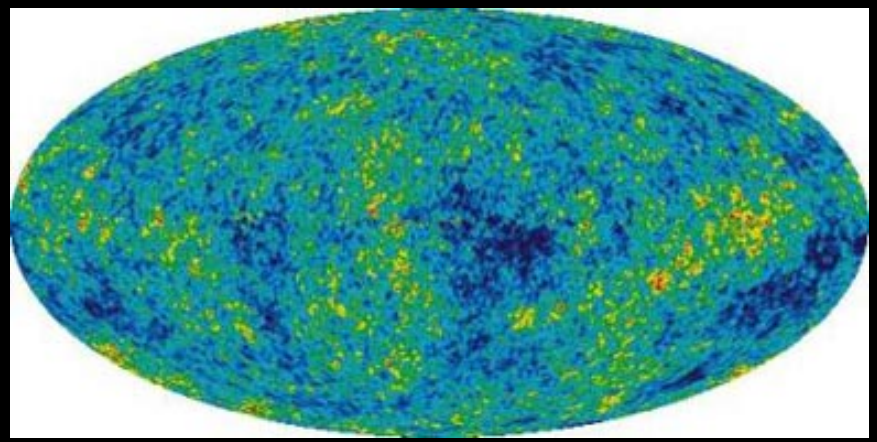
Gurzadyan and Penrose

"Concentric circles in WMAP data may provide evidence of violent pre-Big-Bang activity"

http://arxiv.org/abs/1011.3706http://physicsworld.com/cws/article/news/44388



The sky region of Fig.2 with indication of the low variance circles. This particular example also illustrates a low-variance central point.



http://www.nature.com/news/2010/101210/full/news.2010.665.html

Current models - not an exhaustive list

General outreach

http://www.cpepweb.org/

- *CPEP*
- Contemporary Physics Education Project.
- Demos and information.
- Classroom materials.

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- *CPEP*
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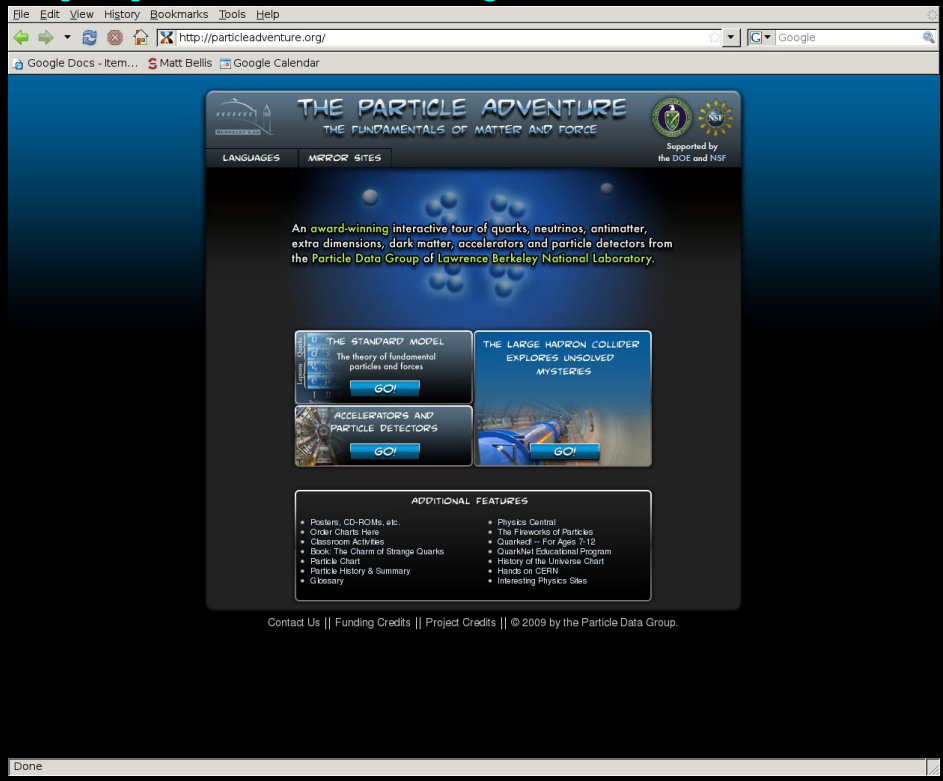
- Particle adventure.

http://www.cpepweb.org/
http://particleadventure.org/

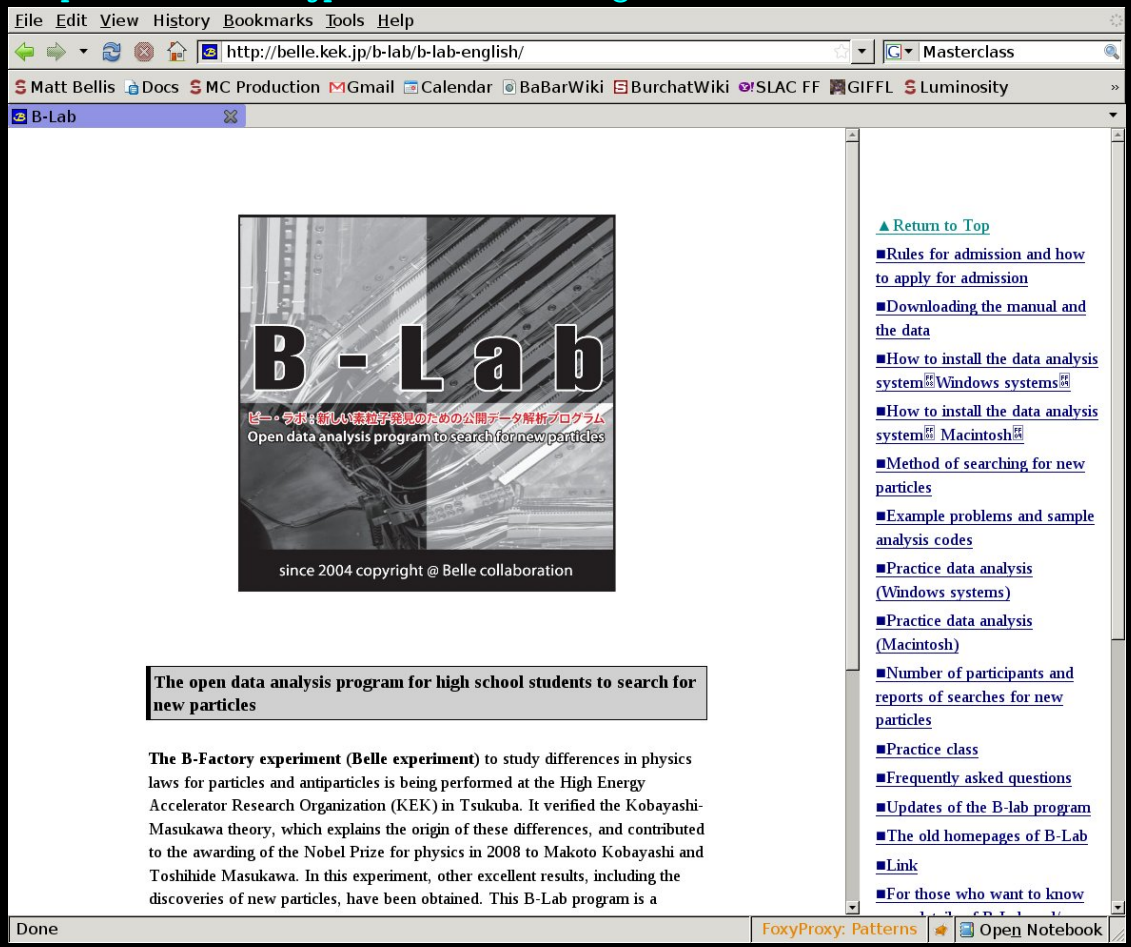


Current models - not an exhaustive list

K-12 models

- **B-Lab (Belle)**
- High school students.
- Summer.
- Basically organized by one emeritus professor.
- *Thanks to Takeo Higuchi for information.*

http://belle.kek.jp/b-lab/b-lab-english/



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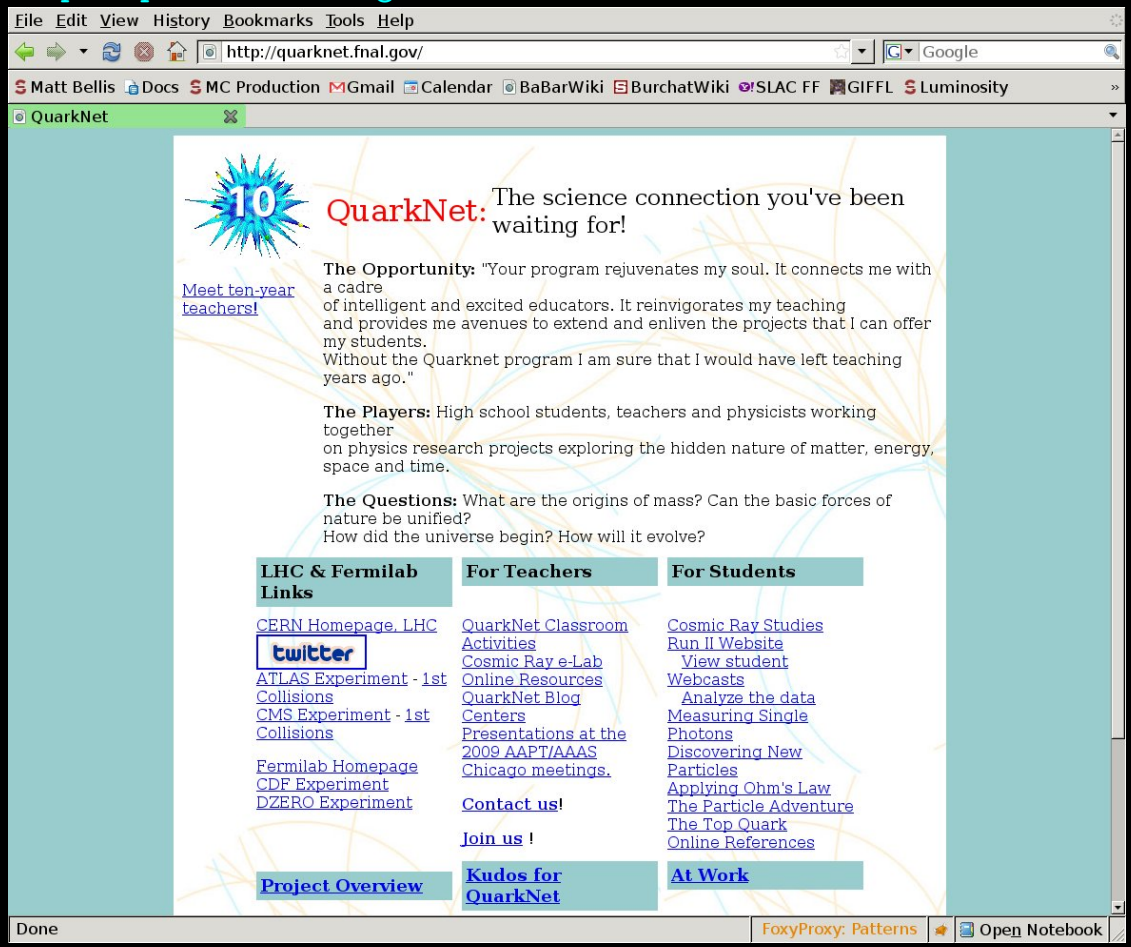
K-12 models

- **Quarknet (NSF/DOE, Fermilab)**
- Some local exercises.
- Links to other sites.
- Inhomogeneous, some old exercises.

http://quarknet.fnal.gov/



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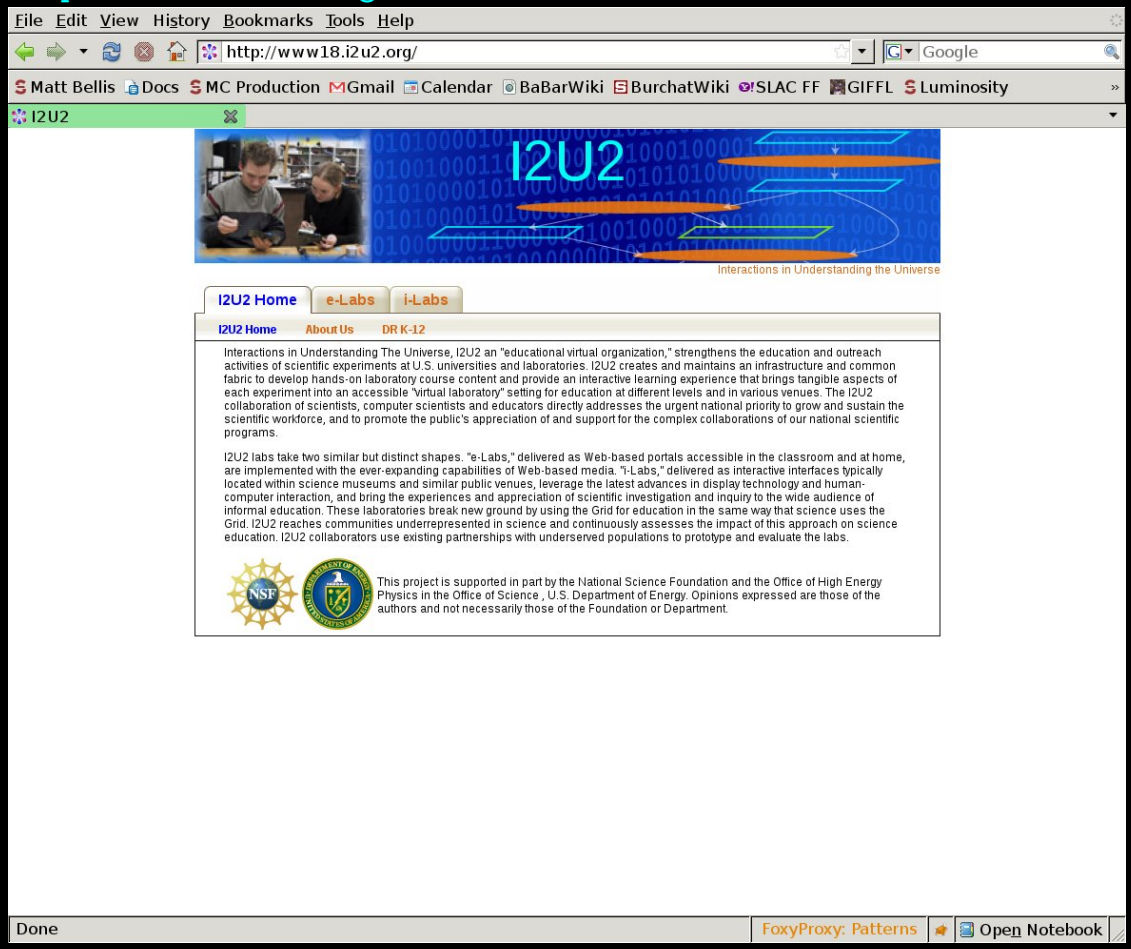
http://www18.i2u2.org/



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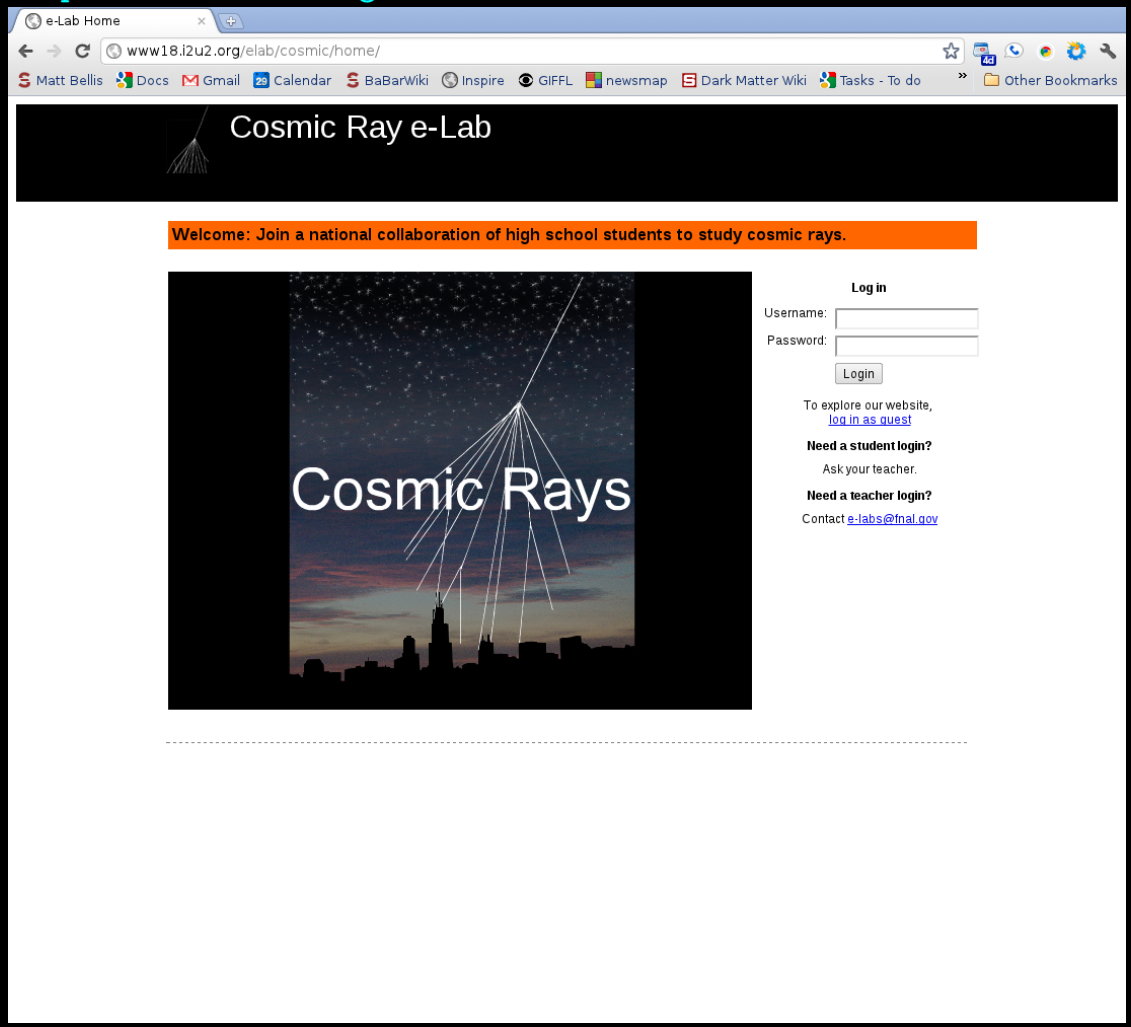

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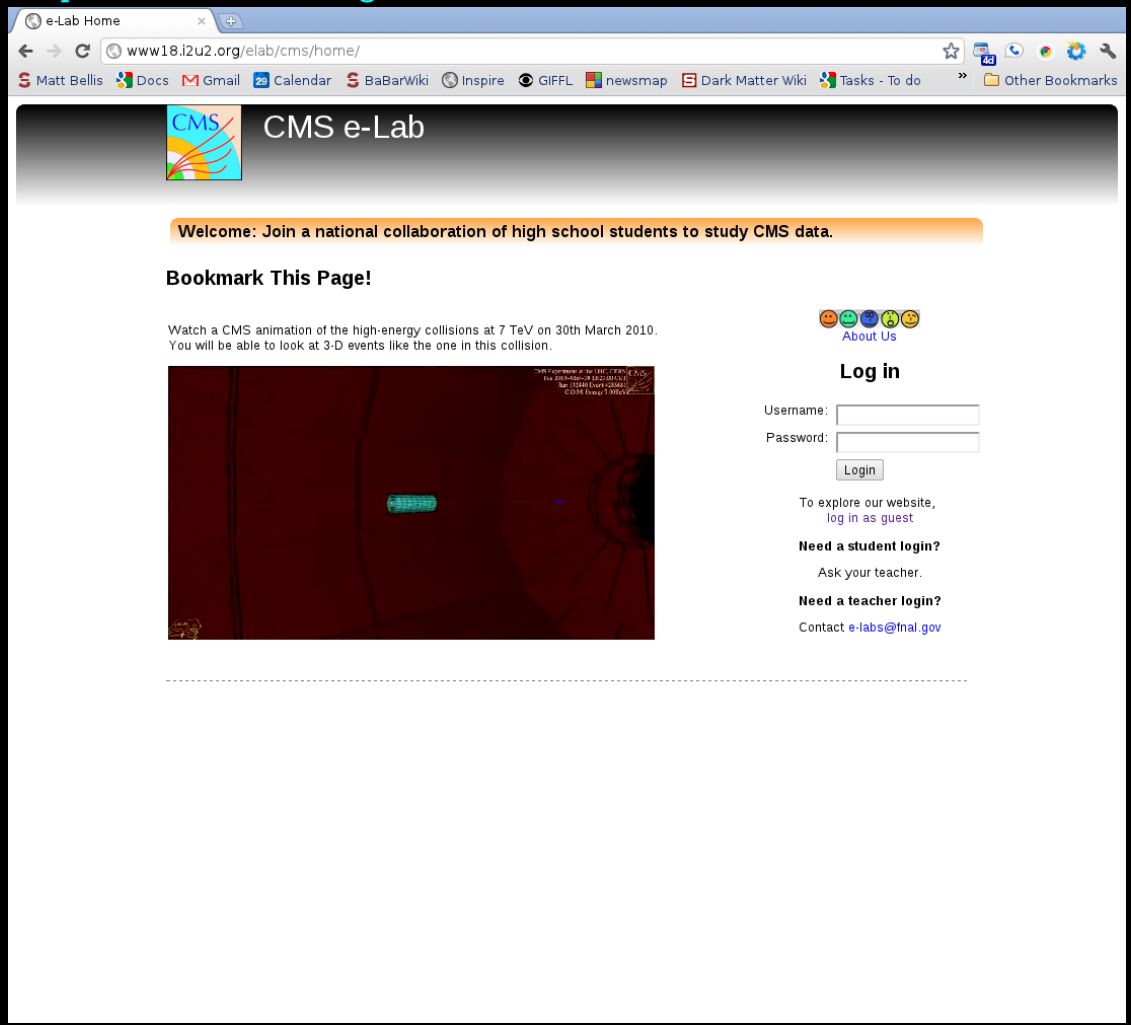

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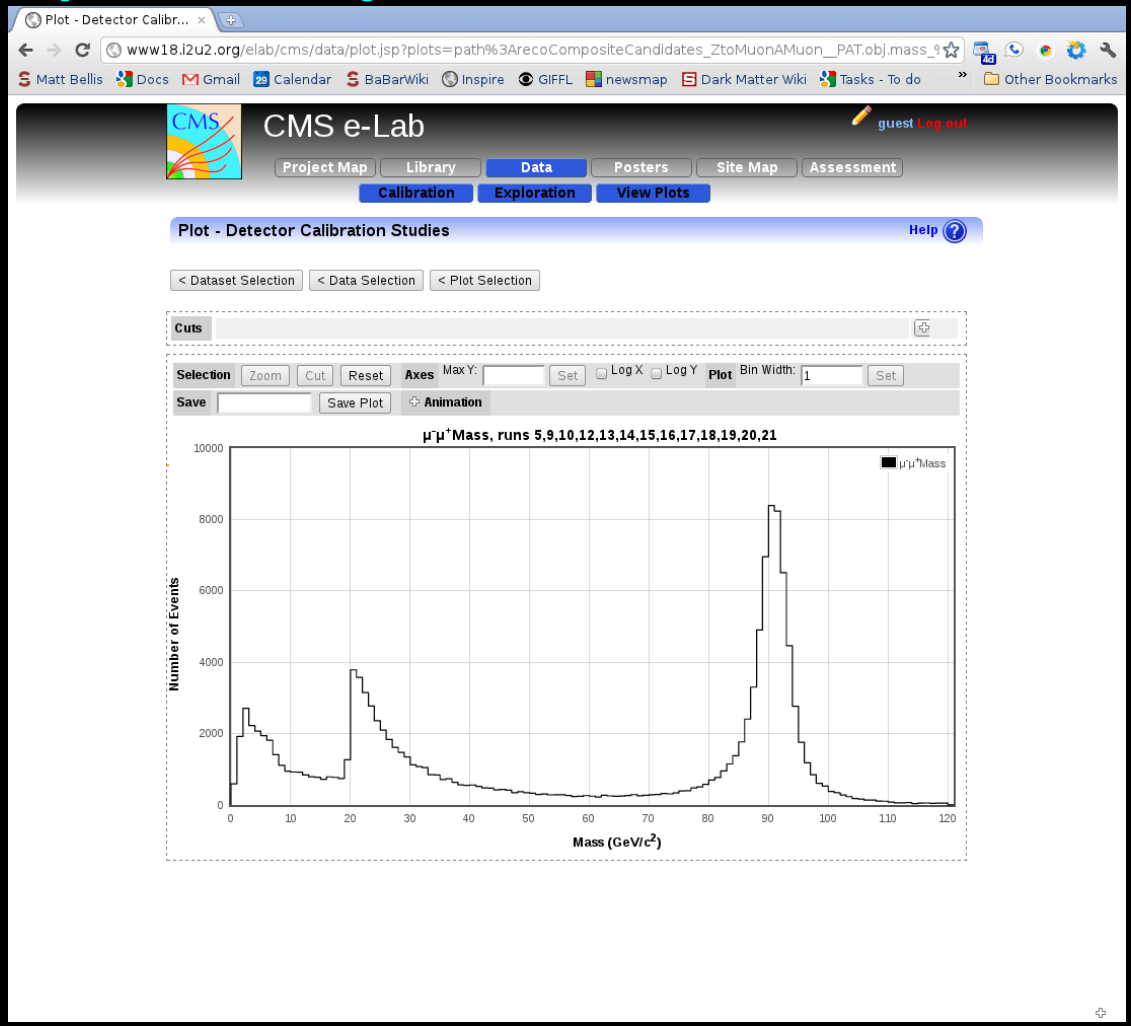

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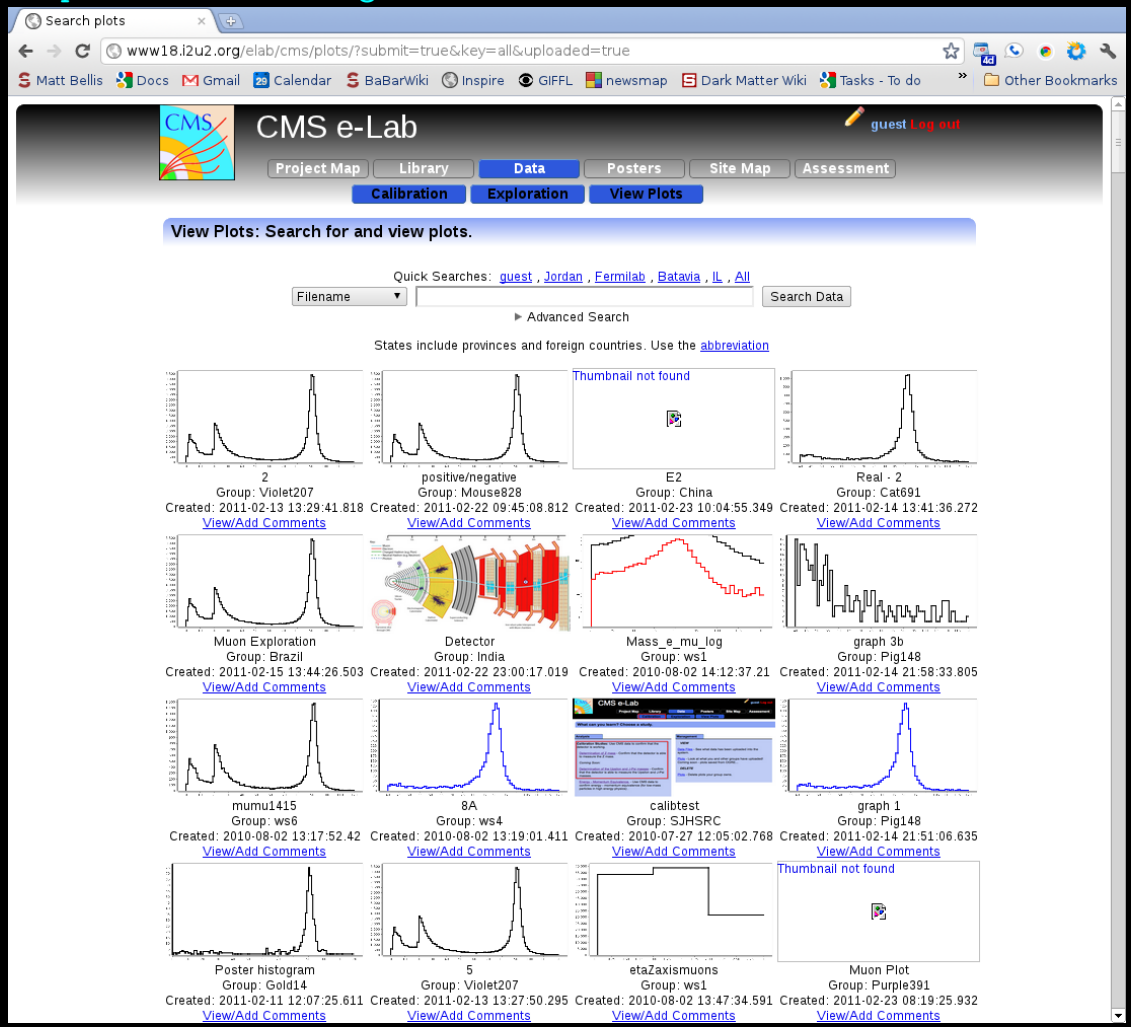

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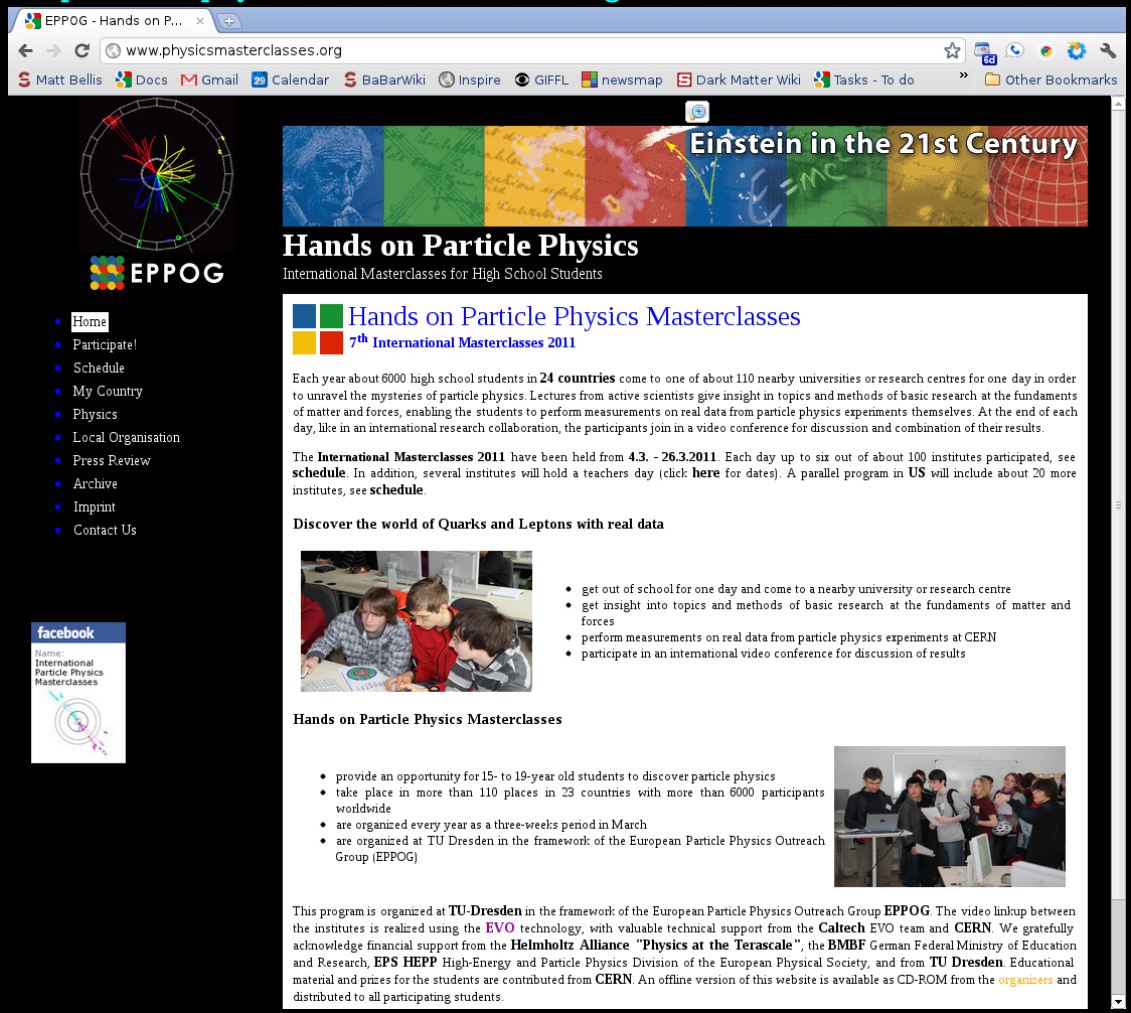
- **International Masterclasses for High School Students**
- Hands on Particle Physics

http://www.physicsmasterclasses.org/



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- 6000 students, 24 countries, 110 universities/research centers.

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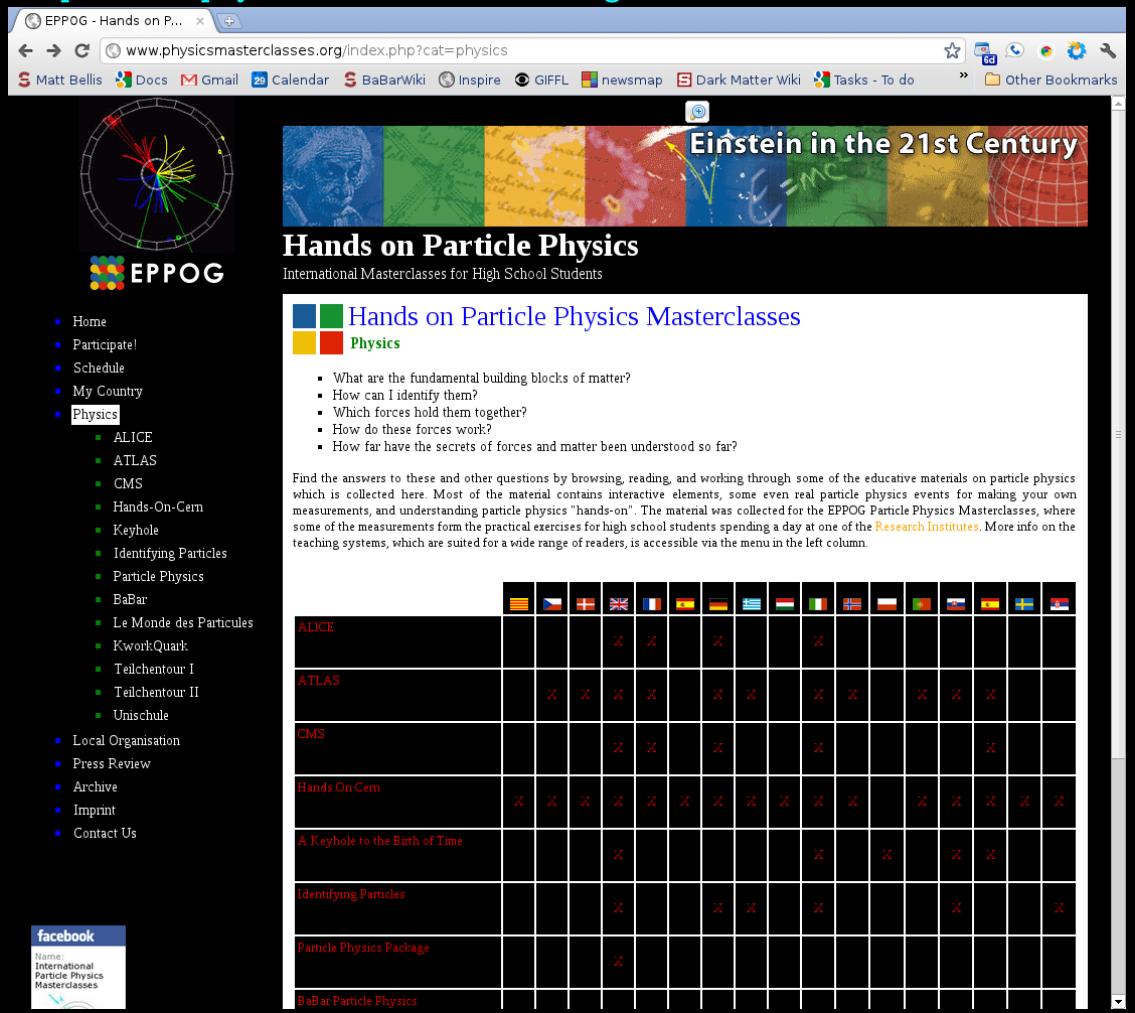

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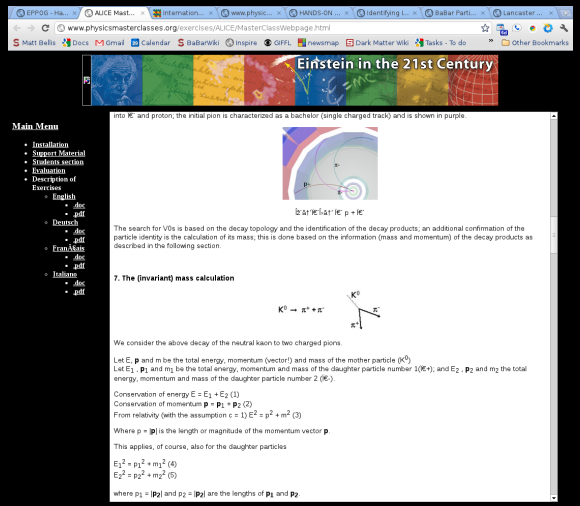
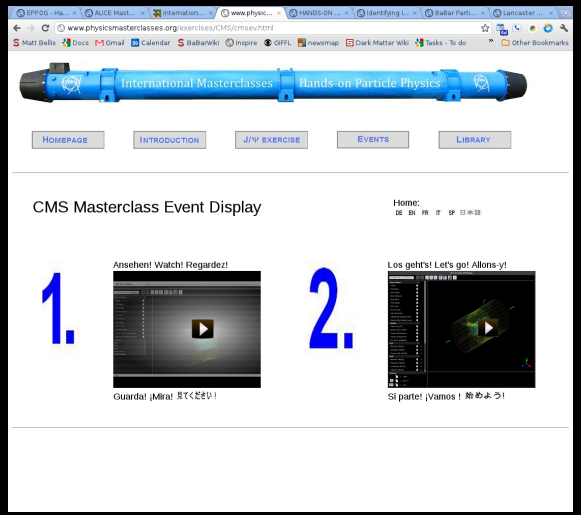
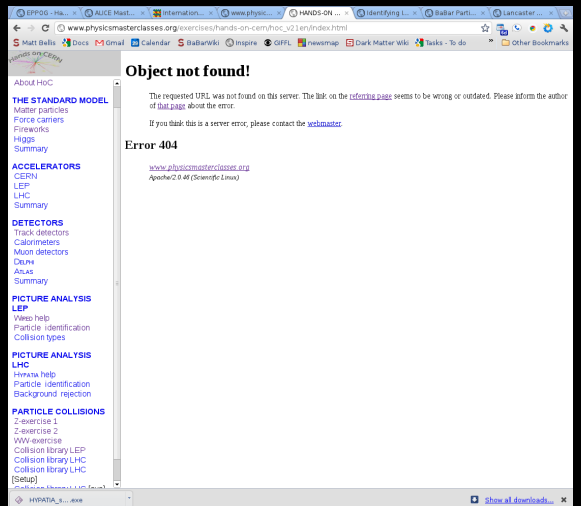
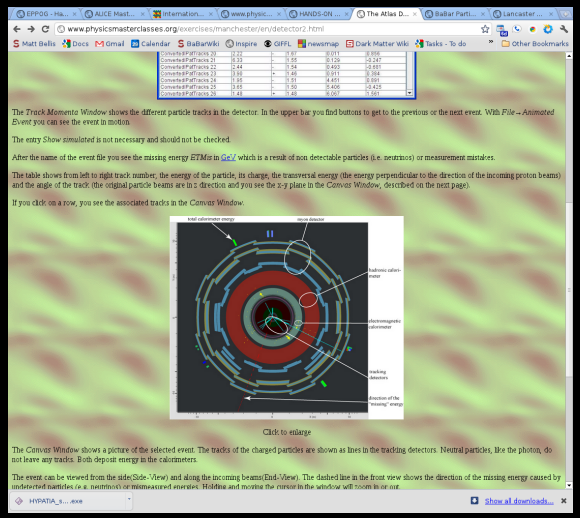
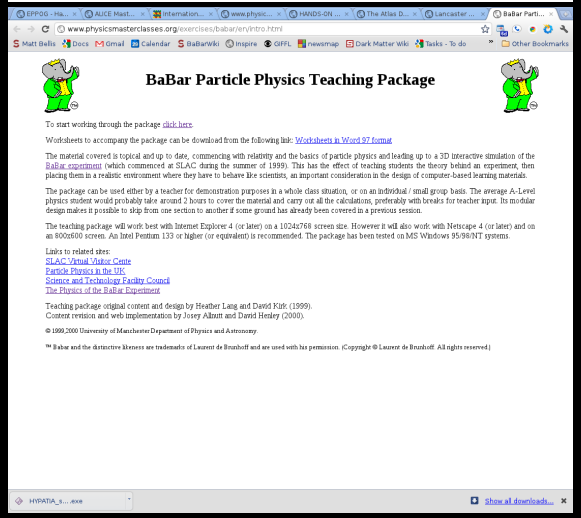
Masterclass, somewhat inhomogeneous, some old exercies.

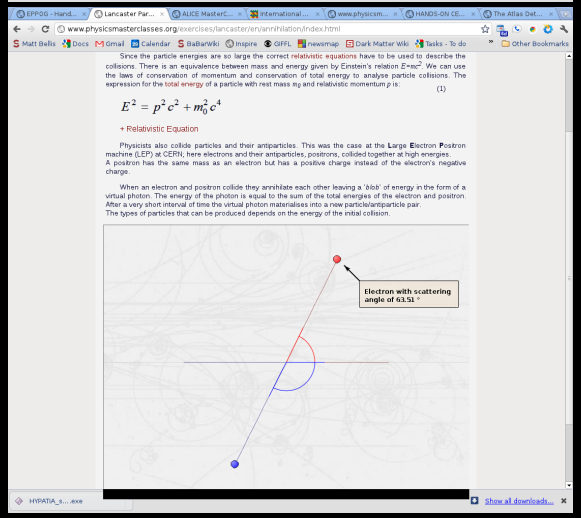












Is there something that the DPHEP effort brings to the table?

Data formats

- HEP analysis have benefitted from common analysis tools
  - ROOT, PAW, GEANTx

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  - XML, JSON
- Archival/Outreach needs are different.
  - Ease and stability over speed of access.

Revisit FITS

FITS (Flexible Image Transport System). Standardized in **1981**.

- http://heasarc.nasa.gov/docs/heasarc/fits.html
- Images *and* catalogs.
- Human-readable header.
- *Many* libraries! http://fits.gsfc.nasa.gov/fits_libraries.html
  - **FORTRAN** (1957)
  - **C** (1973)
  - **IDL** (1977)
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- Understand that our data is more complicated...

Previous attempts

This is not the first time we've discussed this...

- HEPEVT
  - Event record in a Monte Carlo-independent format.
  - LEP initiative.
  - http://cepa.fnal.gov/psm/simulation/mcgen/lund/pythia_manual/pythia6.3/pythia6301/node39.html
- StdHep
  - Common output format for Monte Carlo events.
  - http://cepa.fnal.gov/psm/stdhep/
- HepML
  - Unified XML format of information required for Monte-Carlo (MC) simulation in HEP.
  - https://twiki.cern.ch/twiki/bin/view/Main/HepML
- HepRep
  - Generic Interface Definition for HEP Event Display Representables (XML)
  - Wired.
  - http://www.slac.stanford.edu/~perl/heprep/index.html

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- Does the DPHEP effort provide an opportunity to contribute? Or confuse?

HepEdu

- Discussions within DPHEP: format for outreach.
- BaBar, Belle, H1.

HepEdu

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- First order attempt: text. Number of particles/tracks in the event
  index PID E px py pz for particle 0
  index PID E px py pz for particle 1
  index PID E px py pz for particle 2
  index PID E px py pz for particle 3

```
6
0     -13  1.313  0.407  1.241  0.075
1     -11  2.010 -1.813  0.039 -0.865
2    -211  0.474 -0.134  0.304 -0.308
3     211  0.480 -0.353 -0.112 -0.273
4    -211  1.003 -0.905 -0.369  0.176
5      22  0.212 -0.108  0.147  0.108
3
0     211  1.316 -0.414 -1.239  0.075
1    -211  2.014 -1.802  0.204 -0.865
2     211  0.474 -0.307  0.127 -0.308
```

HepEdu

- Discussions within DPHEP: format for outreach.
- BaBar, Belle, H1.
- Add parent/daughter information.

```
6
0      11  2.305 -0.369 -2.171 -0.678  -1 0
1    -211  0.578 -0.388 -0.059  0.400  -1 0
2     211  0.519 -0.084 -0.476 -0.129  -1 0
3     310  0.686  0.280 -0.164 -0.068  -1 2 4 5
4    -211  0.384  0.337  0.017  0.122   3 0
5     211  0.302 -0.057 -0.181 -0.190   3 0
```

Next steps...

- Formalize data description.
  - Abstract event information.
  - Abstract particle/candidate/track/jet information (4-vector).
  - Attach abstract information:
    - Vertex, detector hits, cut criteria.

HepEdu

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  - Python library (HepEduEvent?)
  - Examples (BaBar? H1?)
  - Converters. (XML? JSON?)
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  - Documentation.
- BaBar data? H1 data? LASS data?
- Is there funding for this?
- Could this supplement the Quarknet/Masterclass/I2U2 efforts?
- Where else would this help?

UC Irvine Machine Learning Repository

- Request from our collaborators to upload data.
- http://archive.ics.uci.edu/ml/index.html
- Center for Machine Learning and Intelligent Systems at the University of California, Irvine.
- http://cml.ics.uci.edu/
  - MiniBooNE particle identification Data Set already exists.
- Request is still being considered...

Would (Should?) ROOT be involved?

- Need a light-weight, standalone TFile library.
  - TString (TCharacter?)
  - TDouble, TFloat, TInteger (TTree?).
  - **That's it!**
- Libraries in C/C++ and Python almost already exist.
- In my opinion, this library should be separate from ROOT.
- Does DPHEP lend weight to this request?

Data for outreach

What data can we use?

- Issues with "ownership" of data.
- Non-trivial and may vary from institution to institution.
- Discussion of "outakes" within BaBar.
- Should we prepare for the eventual (inevtiable) FOI request?
- Ongoing...

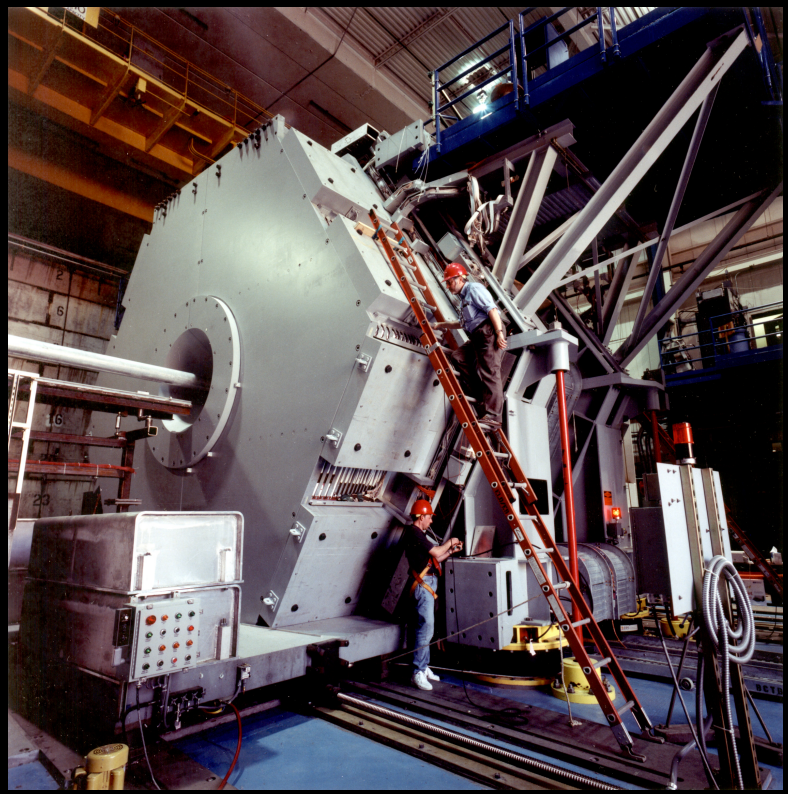
Particle Physics Wind Chime

Science Hack Day SF

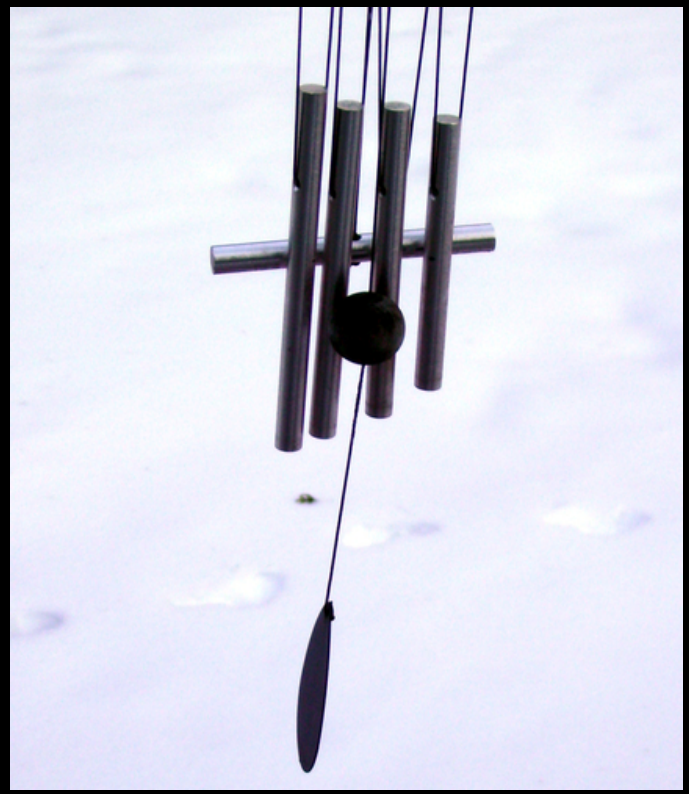
Organized by **Ariel Waldman**, David Harris et al.
Offshoot of SHD London, 2010. http://sf.sciencehackday.com/

From *tantek* on Flickr photostream.

Particle Physics Wind Chime



$\Rightarrow$



The goal

- In 24 hours hack a prototype.
- Map particle properties onto sonic properties.
- *Let users define their own mappings!*

particle type	pitch		
momentum			
momentum angle			
velocity			
detector x			
detector y		timbre	
detector z			
travel length			volume
detector type			

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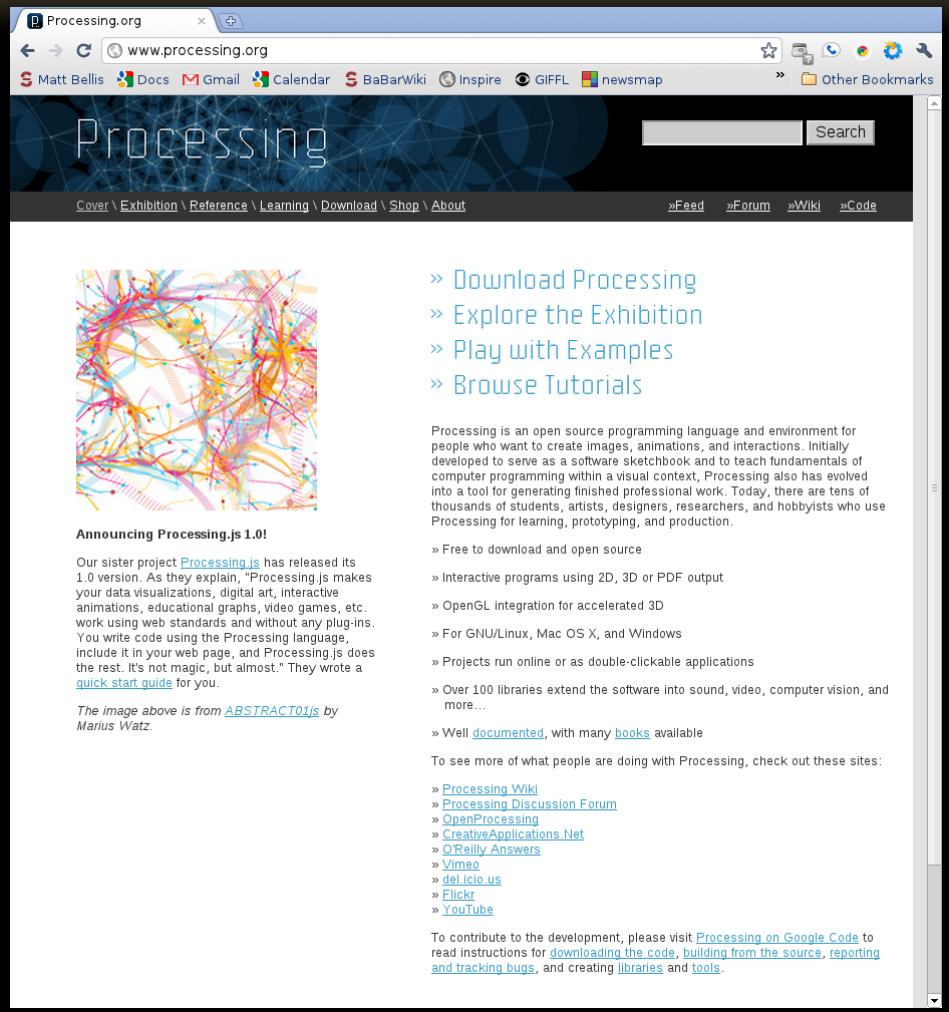

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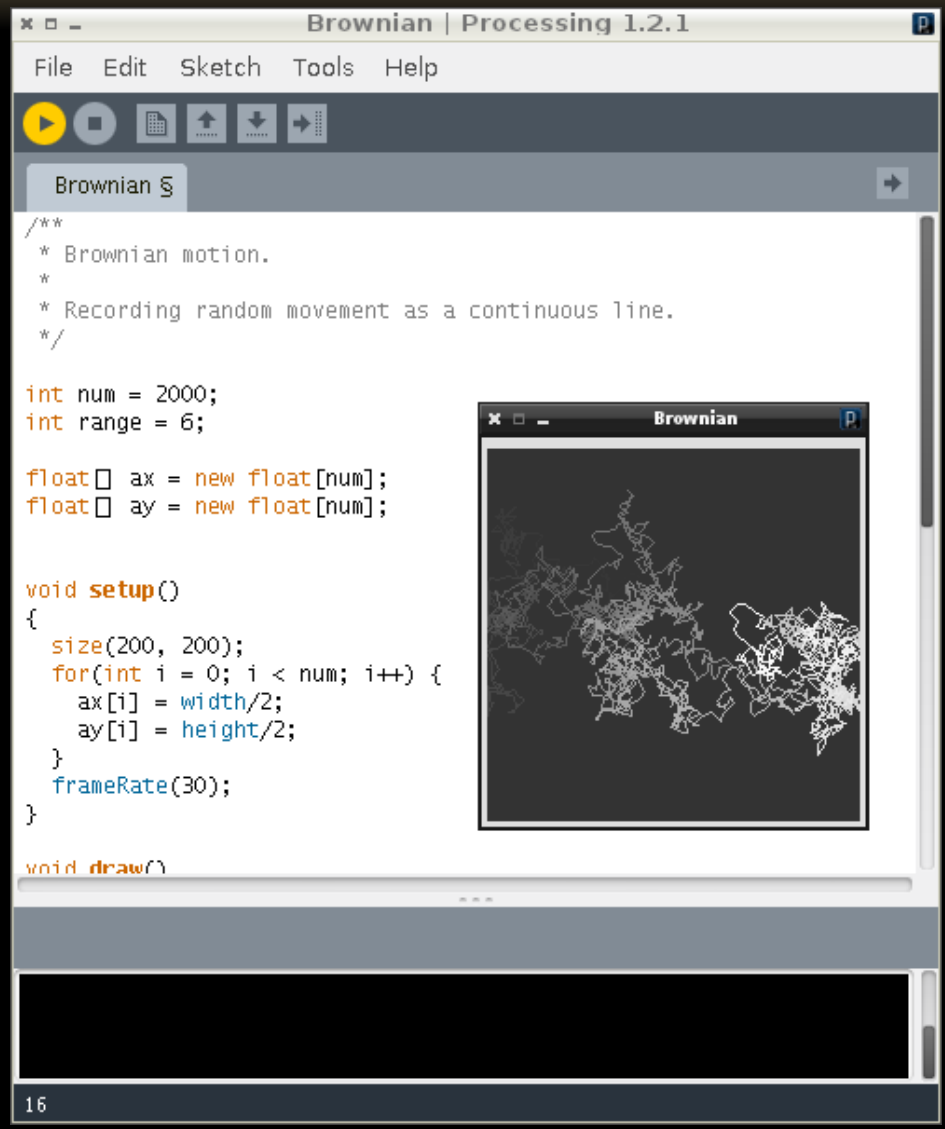

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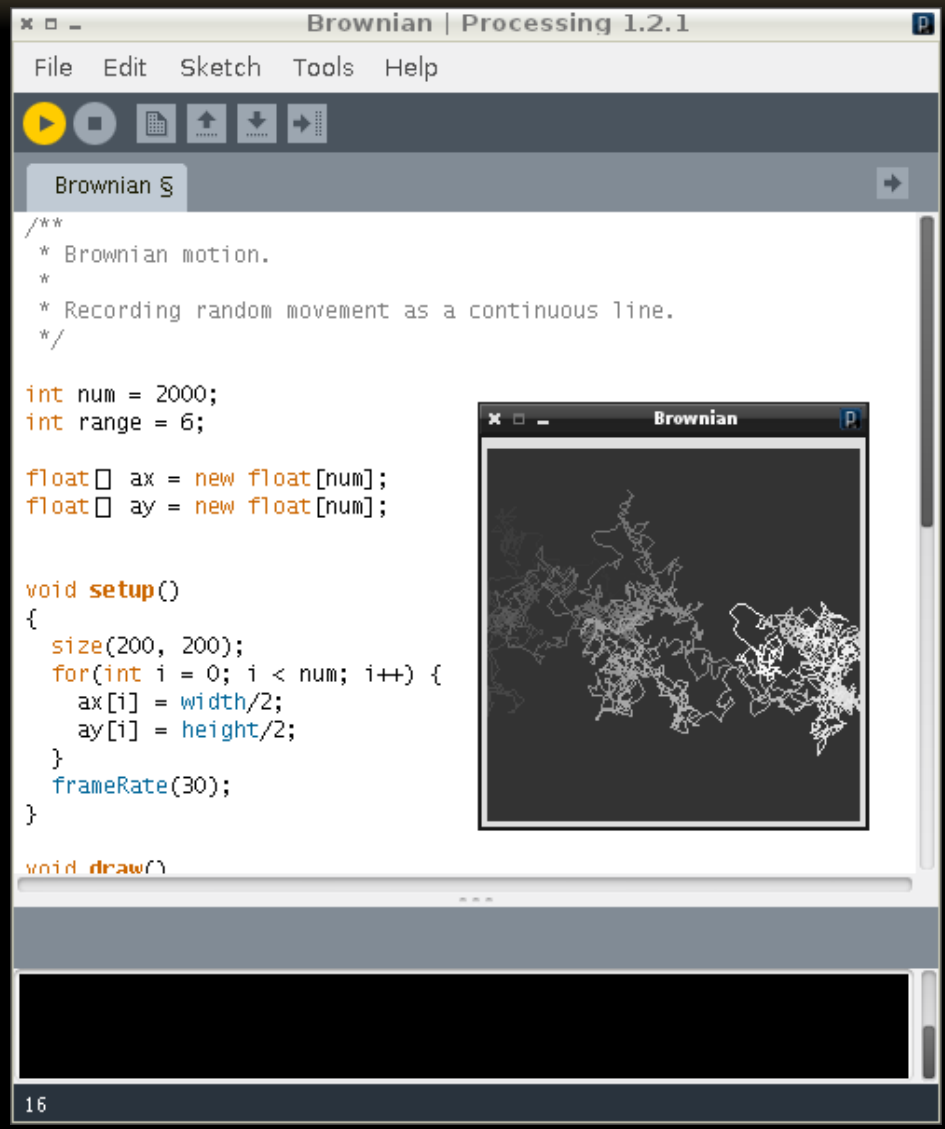

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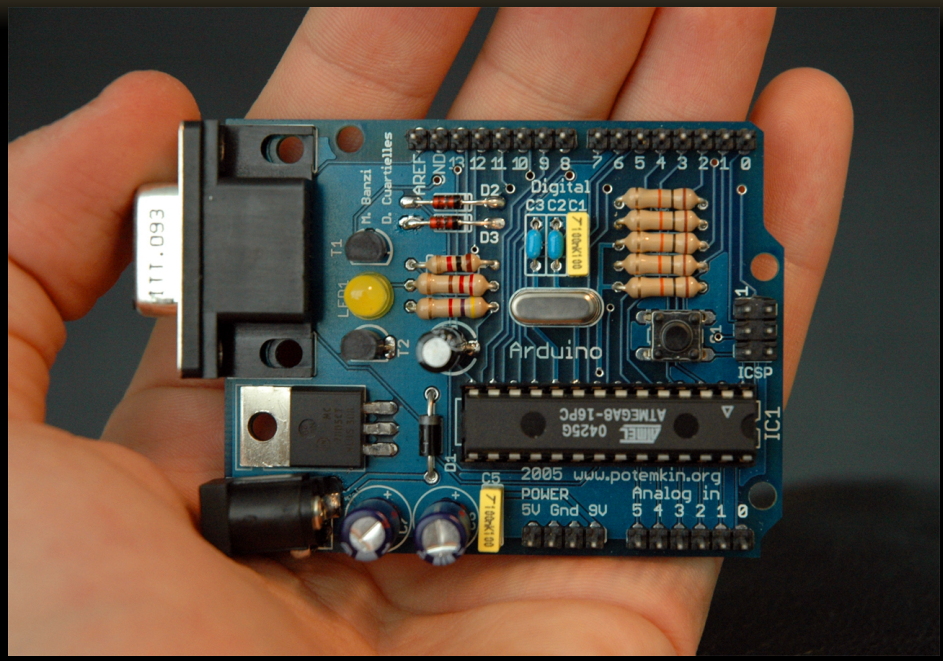

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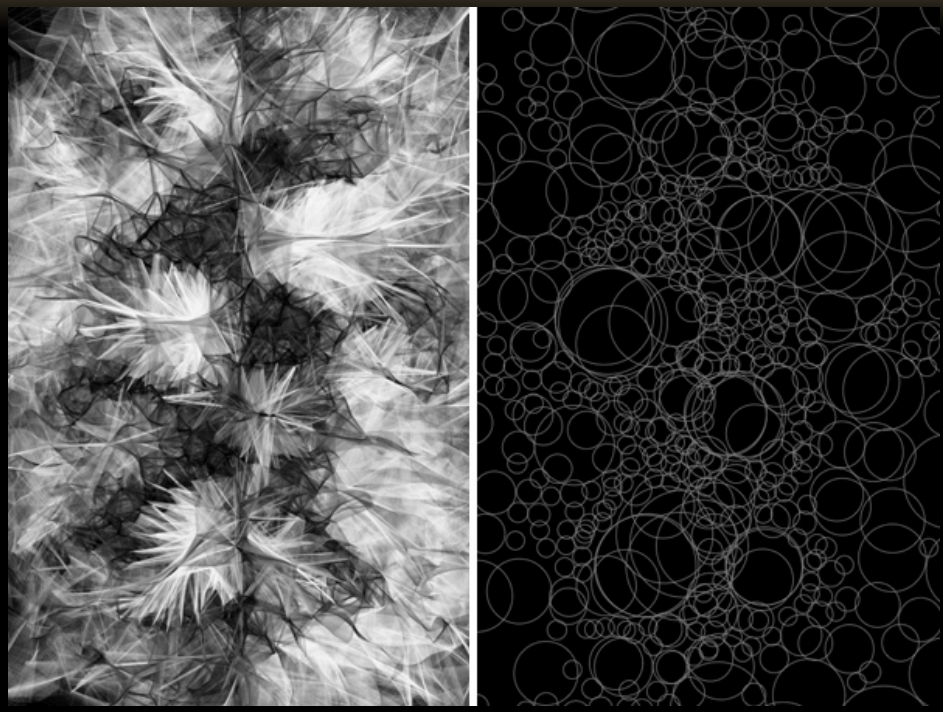
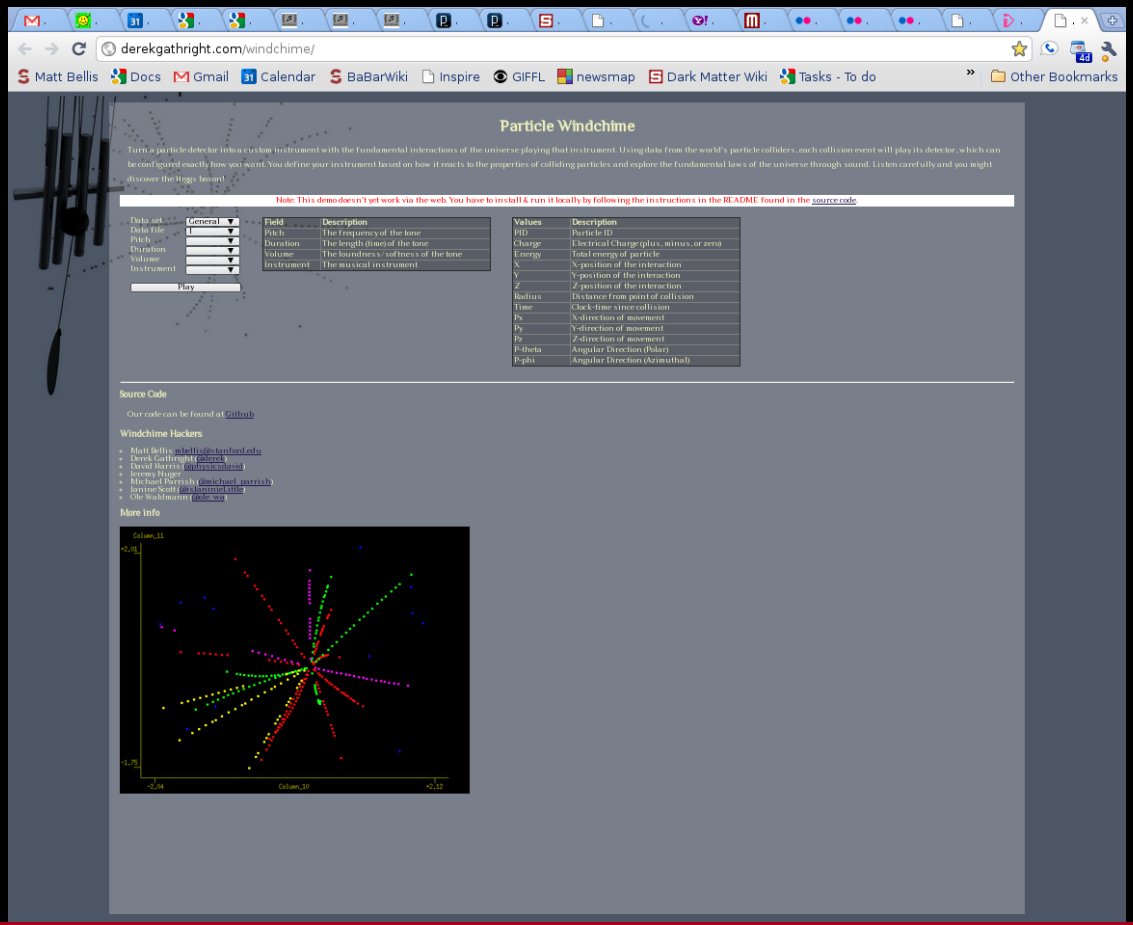
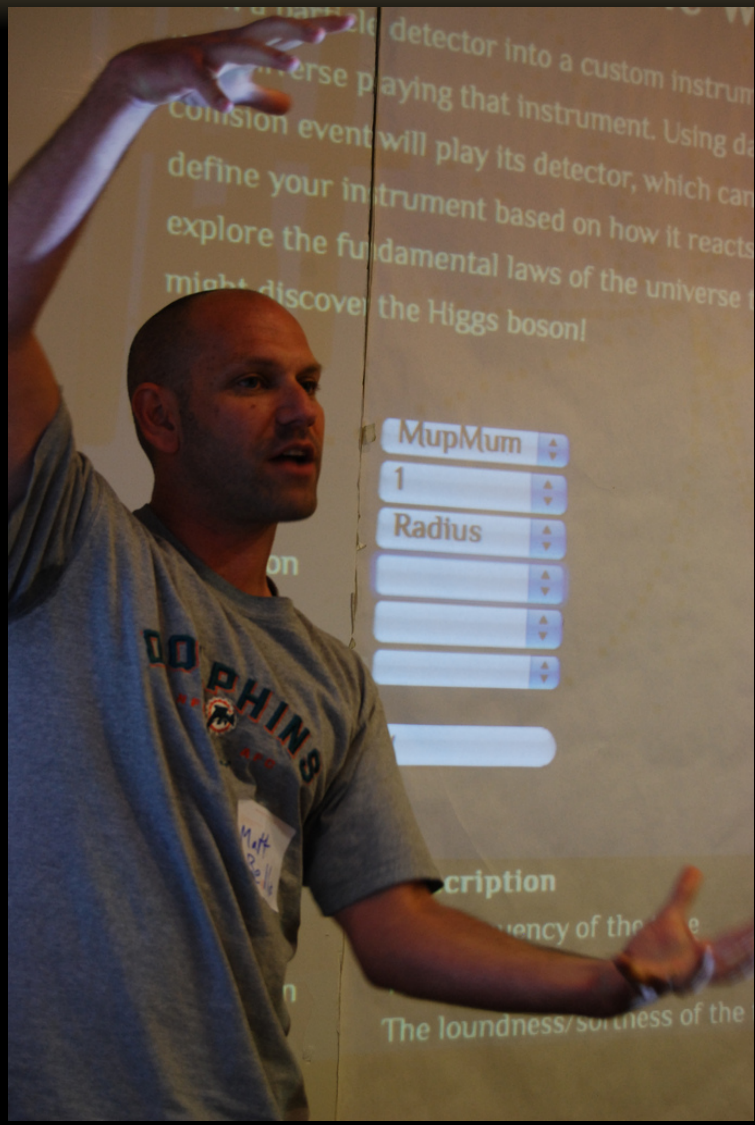
  `SoundCipher`, `controlP5`
- Arduino/Wiring
- **Can export apps for Windows, Mac and Linux!**



Science Hack Day SF

- Had a prototype working on a laptop, but not live website.
- Standard data format would've made things easier.
- *We won Best Use of Data award* and the *People's Choice award!*

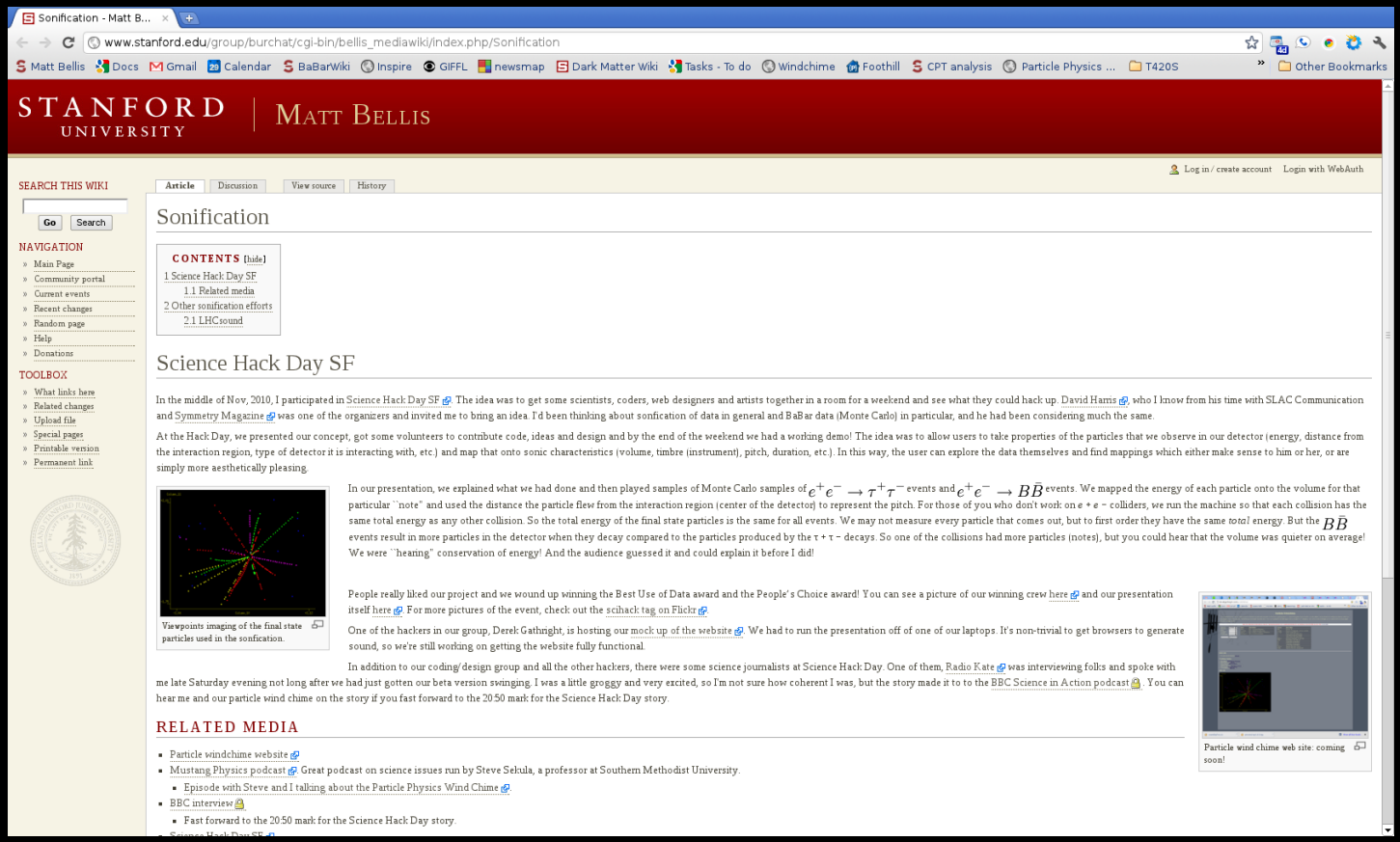




From *swissnex San Francisco* on Flickr photostream.

Science Hack Day SF

https://www.stanford.edu/group/burchat/cgi-bin/bellis_mediawiki/index.php/Sonification



Sonification - Matt B...

www.stanford.edu/group/burchat/cgi-bin/bellis_mediawiki/index.php/Sonification

Matt Bellis | Docs | Gmail | Calendar | BaBarWiki | Inspire | GIFFL | newsmap | Dark Matter Wiki | Tasks - To do | Windchime | Foothill | CPT analysis | Particle Physics ... | T420S | Other Bookmarks

STANFORD UNIVERSITY | MATT BELLIS

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Sonification

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2 Other sonification efforts
2.1 LHCsound

Science Hack Day SF

In the middle of Nov, 2010, I participated in Science Hack Day SF. The idea was to get some scientists, coders, web designers and artists together in a room for a weekend and see what they could hack up. David Harris, who I know from his time with SLAC Communication and Symmetry Magazine was one of the organizers and invited me to bring an idea. I'd been thinking about sonfication of data in general and BaBar data (Monte Carlo) in particular, and he had been considering much the same.

At the Hack Day, we presented our concept, got some volunteers to contribute code, ideas and design and by the end of the weekend we had a working demo! The idea was to allow users to take properties of the particles that we observe in our detector (energy, distance from the interaction region, type of detector it is interacting with, etc.) and map that onto sonic characteristics (volume, timbre (instrument), pitch, duration, etc.). In this way, the user can explore the data themselves and find mappings which either make sense to him or her, or are simply more aesthetically pleasing.

Viewpoints imaging of the final state particles used in the sonfication.

In our presentation, we explained what we had done and then played samples of Monte Carlo samples of $e^+e^- \to \tau^+\tau^-$ events and $e^+e^- \to B\bar{B}$ events. We mapped the energy of each particle onto the volume for that particular ``note" and used the distance the particle flew from the interaction region (center of the detector) to represent the pitch. For those of you who don't work on e^+e^- colliders, we run the machine so that each collision has the same total energy as any other collision. So the total energy of the final state particles is the same for all events. We may not measure every particle that comes out, but to first order they have the same *total* energy. But the $B\bar{B}$ events result in more particles in the detector when they decay compared to the particles produced by the $\tau^+\tau^-$ decays. So one of the collisions had more particles (notes), but you could hear that the volume was quieter on average! We were ``hearing" conservation of energy! And the audience guessed it and could explain it before I did!

People really liked our project and we wound up winning the Best Use of Data award and the People's Choice award! You can see a picture of our winning crew here and our presentation itself here. For more pictures of the event, check out the scihack tag on Flickr.

One of the hackers in our group, Derek Gathright, is hosting our mock up of the website. We had to run the presentation off of one of our laptops. It's non-trivial to get browsers to generate sound, so we're still working on getting the website fully functional.

In addition to our coding/design group and all the other hackers, there were some science journalists at Science Hack Day. One of them, Radio Kate was interviewing folks and spoke with me late Saturday evening not long after we had just gotten our beta version swinging. I was a little groggy and very excited, so I'm not sure how coherent I was, but the story made it to to the BBC Science in Action podcast. You can hear me and our particle wind chime on the story if you fast forward to the 20:50 mark for the Science Hack Day story.

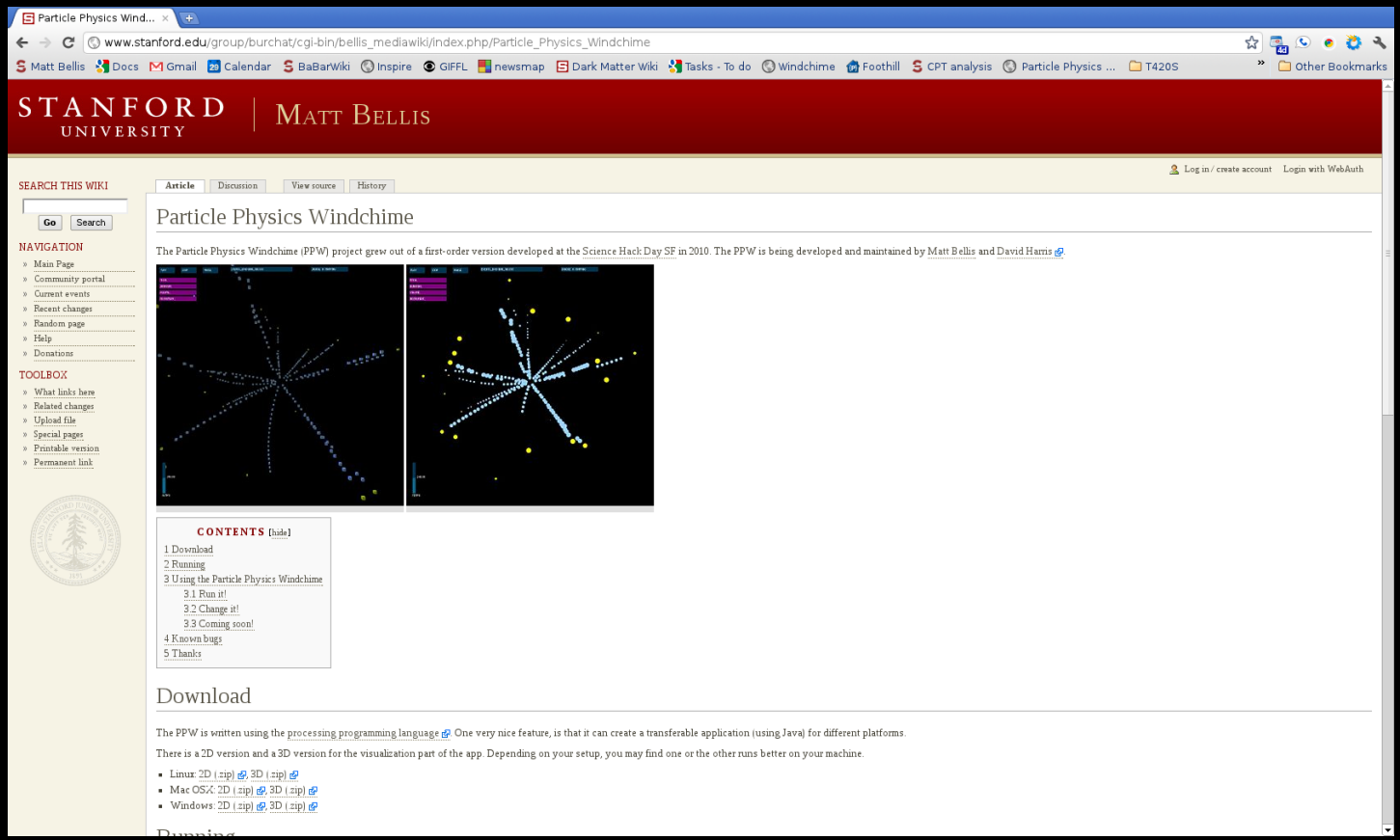
Particle wind chime web site: coming soon!

RELATED MEDIA

- Particle windchime website
- Mustang Physics podcast. Great podcast on science issues run by Steve Sekula, a professor at Southern Methodist University.
  - Episode with Steve and I talking about the Particle Physics Wind Chime
- BBC interview
  - Fast forward to the 20:50 mark for the Science Hack Day story.
- Science Hack Day SF

Science Hack Day SF

http://www.stanford.edu/group/burchat/cgi-bin/bellis_mediawiki/index.php/Particle_Physics_Windchime



Not the only ones doing this

- **LHCsound**
  - *Lily Asquith*, currently at Argonne National Lab.
  - http://lhcsound.hep.ucl.ac.uk/
  - Composers Desktop Project (MacOSX, Windows)
  - Produce .wav/.mp3 files.
- **QCD Audio**
  - Katharina Vogt, currently at Institut fur elektronische Musik und Akustik, Austria.
  - http://iaem.at/Members/vogt
  - http://qcd-audio.at/
  - SuperCollider (MacOSX, Windows, Linux)
  - Produce .wav/.mp3 files.
- Probably many more out there!
- Confluence of desire and good tools.

Let's see/hear an example!

Sound from particle physics data!

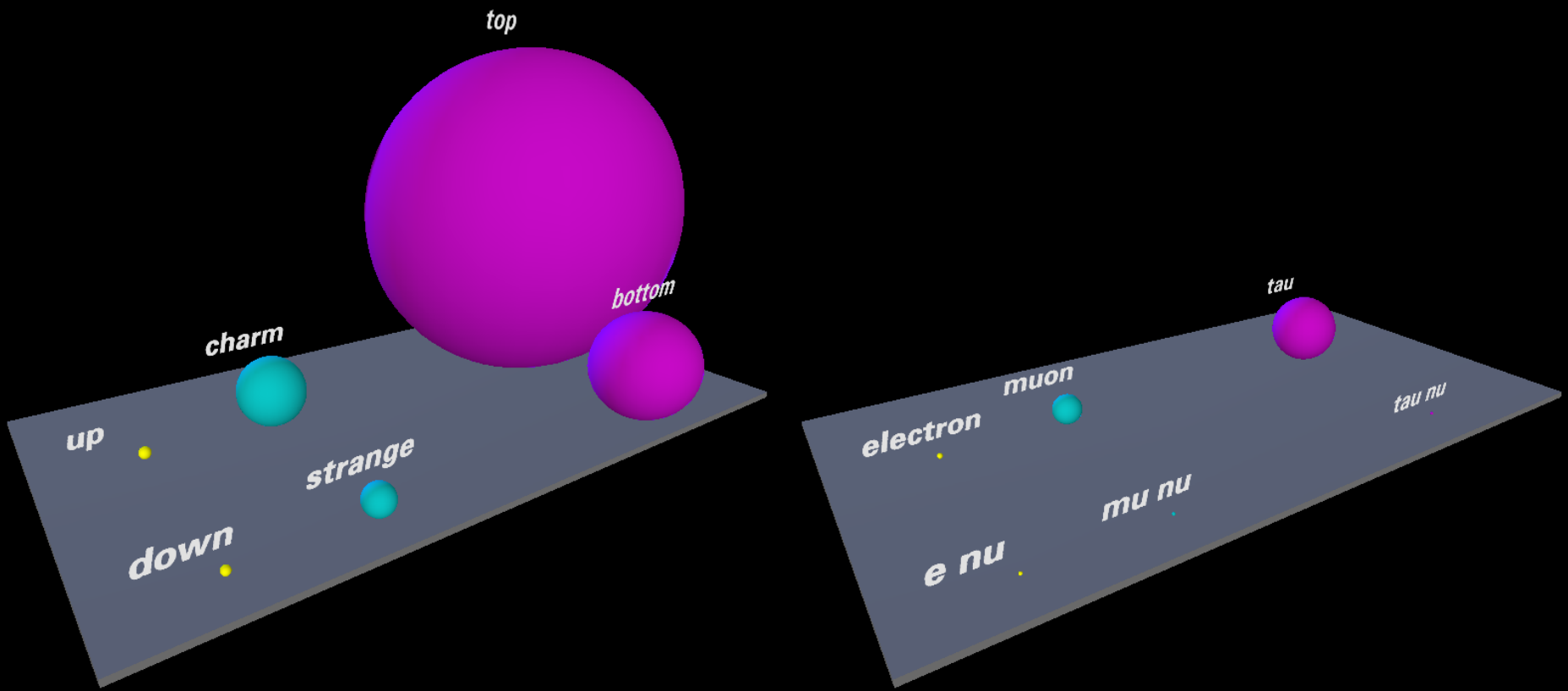
Much excitement stemmed from *context* of the sounds.

Try it yourself!

http://www.stanford.edu/group/burchat/cgi-bin/bellis_mediawiki/index.php/Particle_Physics_Windchime

The Standard Model - Quarks and leptons

This is the invisible world we are trying to make manifest.



Wind Chime as teaching tool

Public-ish talks

- Demo at Southern Methodist University seminar
- Stanford Center for Computer Research in Music and Acoustics (CCRMA)
  - Research in signal processing.
  - Asked about getting some of our data!

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Can teach with this!

- Which fermion/antifermion pair produce the most particles?
  - Why?
- What type of particle is produced most often?
  - Why?
- Can you find a way to "hear" conservation of energy?"

Can use this for exploratory learning.

We have something running!

Is it interesting?

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Stealth motives

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Killer app for all ages to learn programming.

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Art $\Longleftrightarrow$ Science

Summary

- Ideas and enthusiasm for outreach, education and training.

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- Continued development of Wind Chime project with BaBar data.
- Do other experiments want to "hear" their data?
- Develop HepEdu format, tools. (probably dependent on funding)
- DPHEP organization provides a formal framework.

Thanks for your time!

Backup slides

Linux with persistence

Contribute to an educated workforce/society

From the McKinsey Global Institute study...

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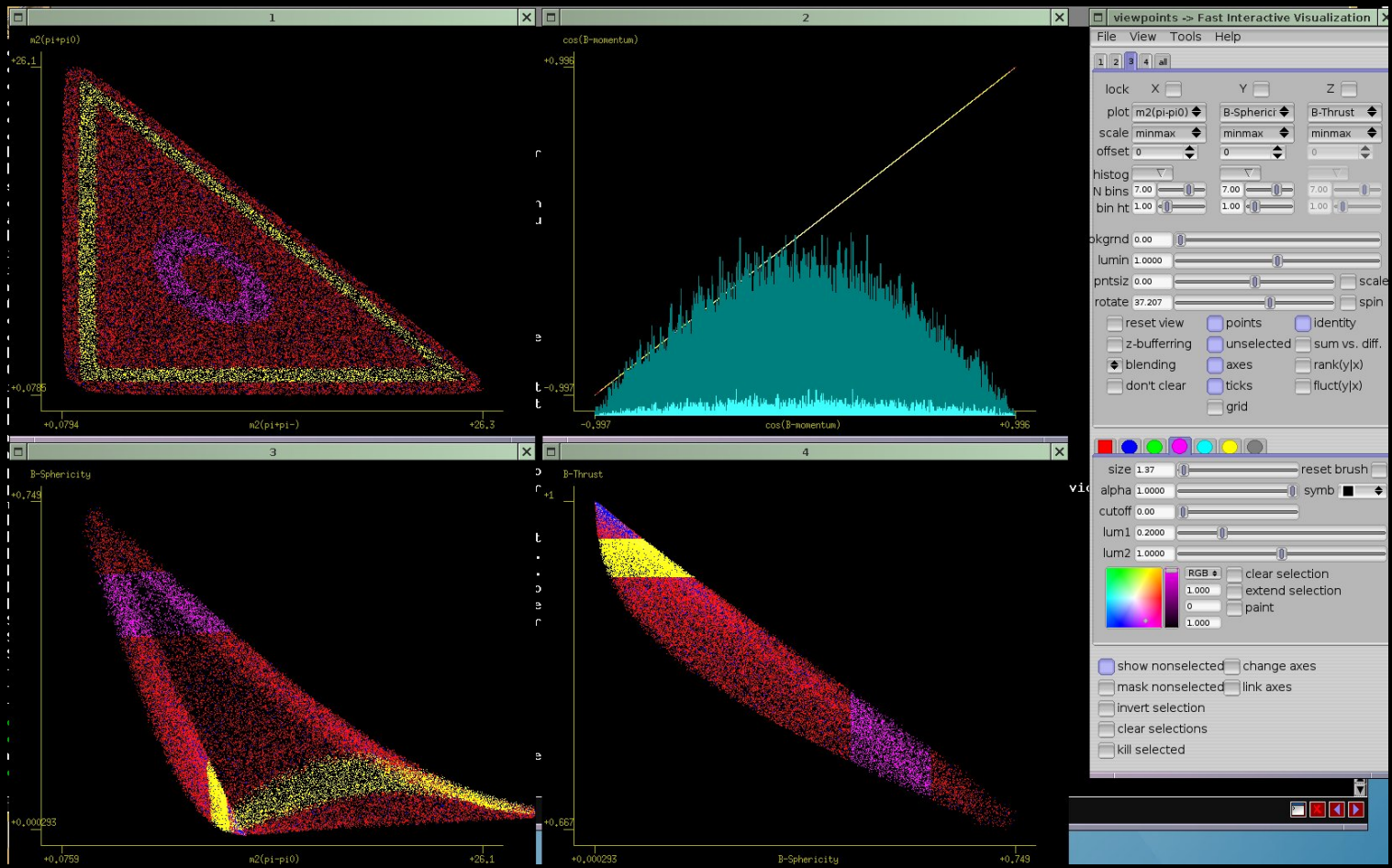
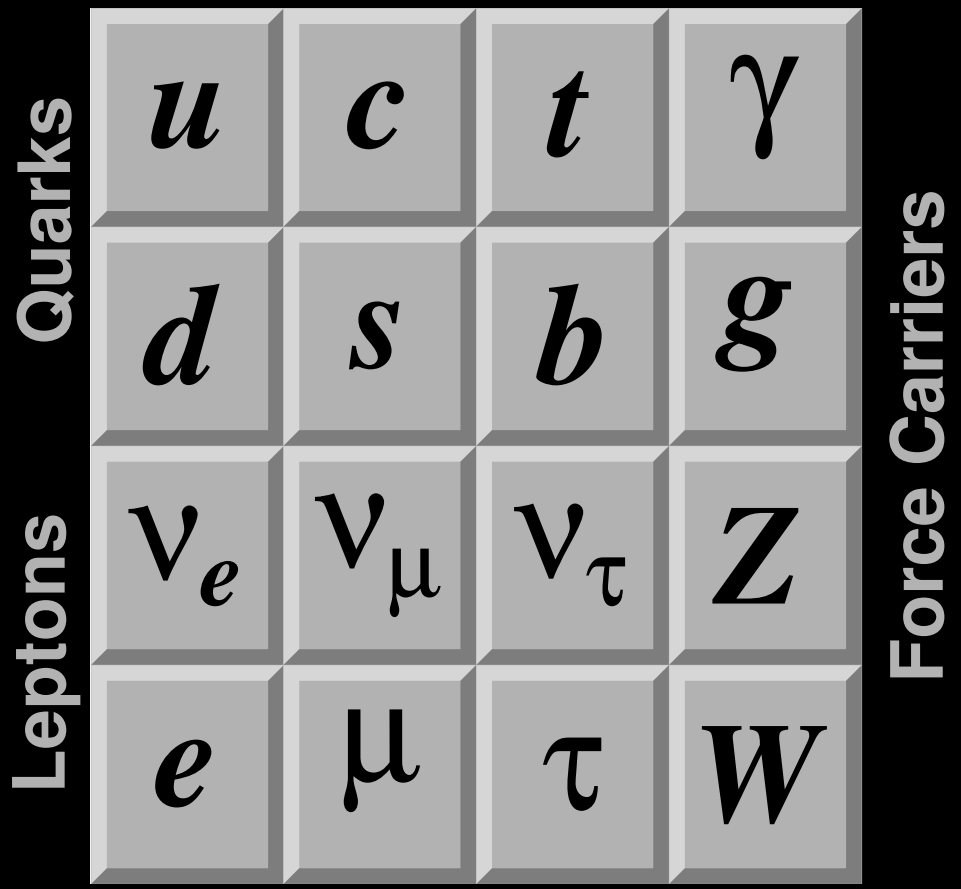
- Managers, according to the McKinsey researchers, must grasp the principles of data analytics and be able to ask the right questions.
- **"Every manager will really have to understand something about statistics and experimental design going forward,"** said Michael Chui, a senior fellow at the McKinsey Global Institute.

Current effort

http://astrophysics.arc.nasa.gov/~pgazis/viewpoints.htm
http://www.slac.stanford.edu/~bellis/viewpoints_demo.html



Elementary Particles



Three Generations of Matter

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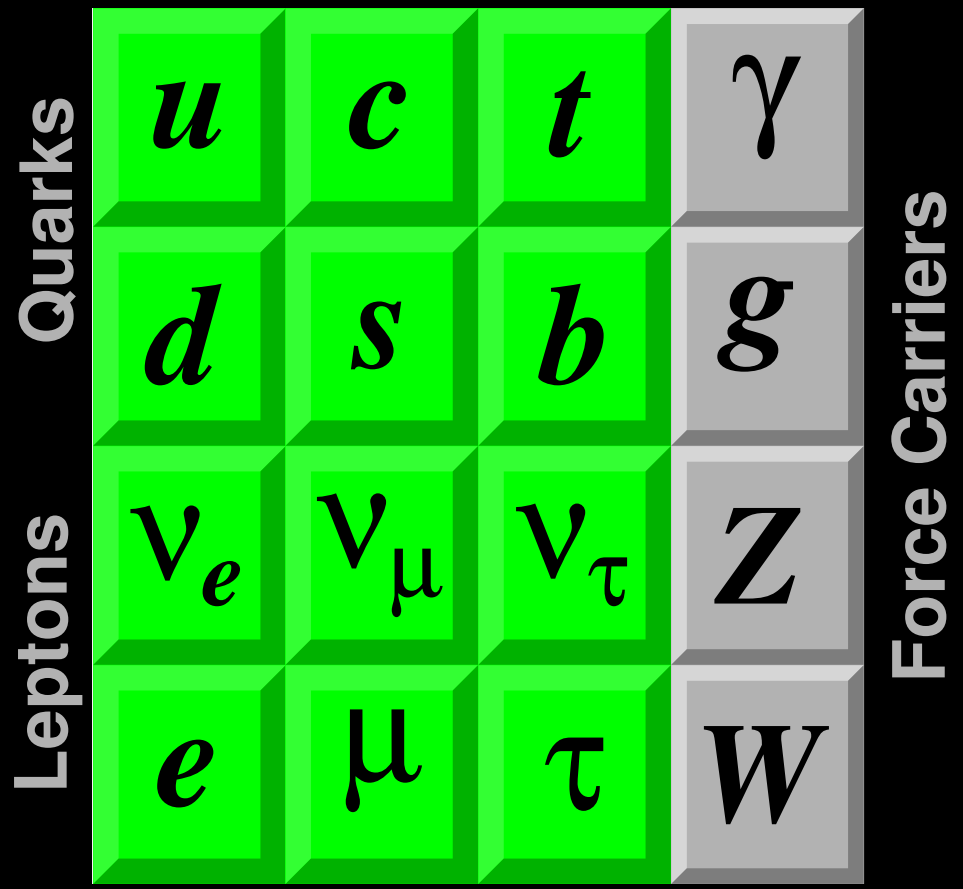

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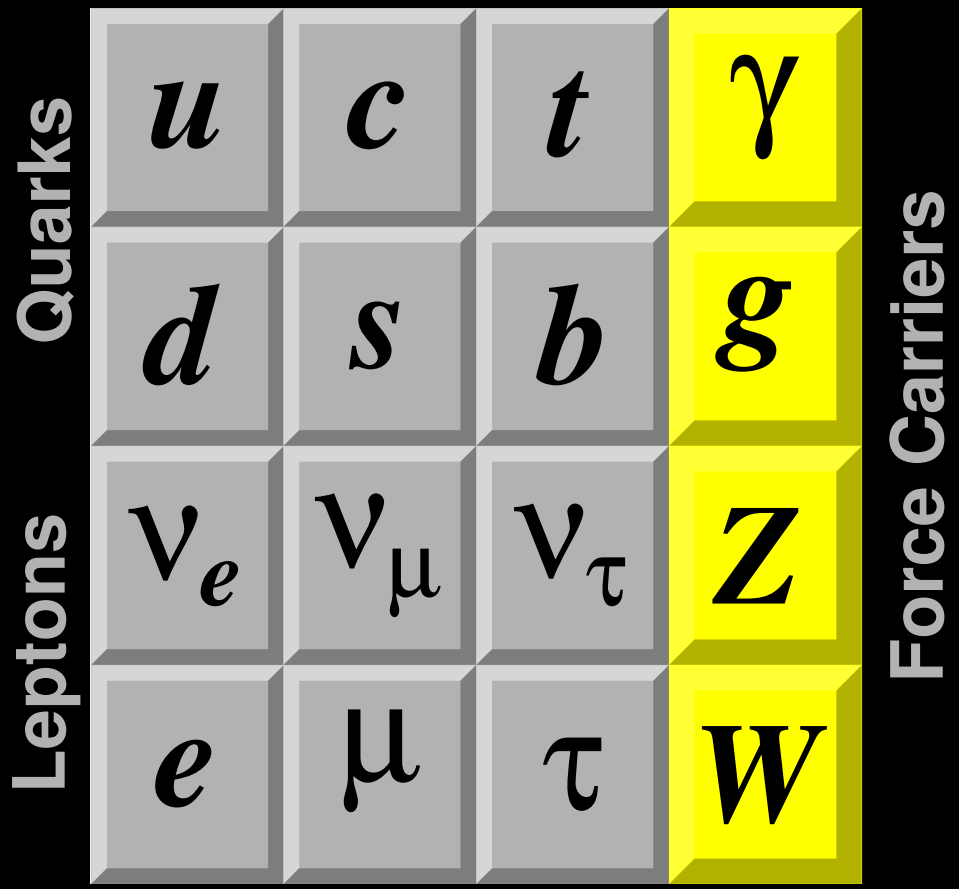

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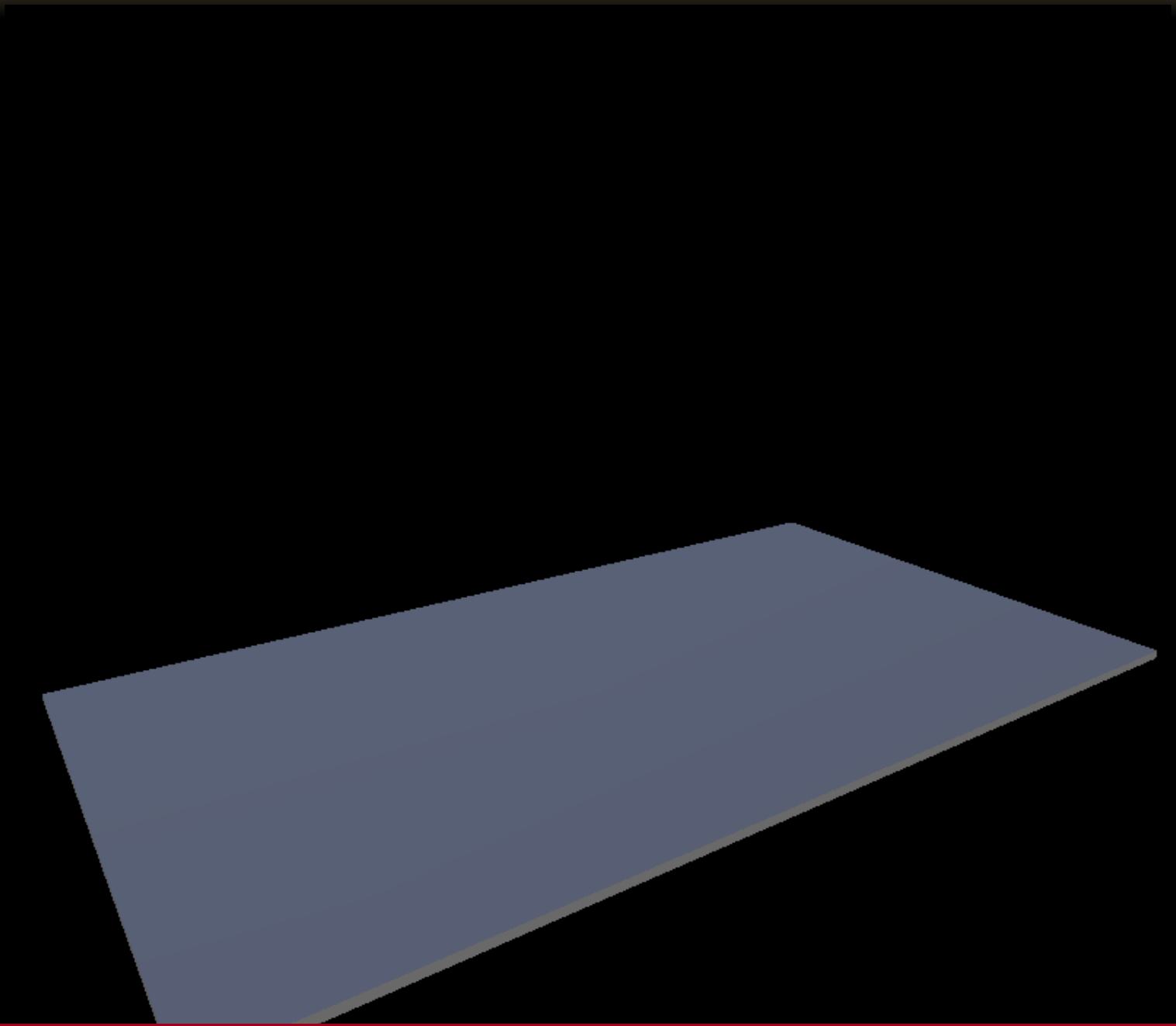

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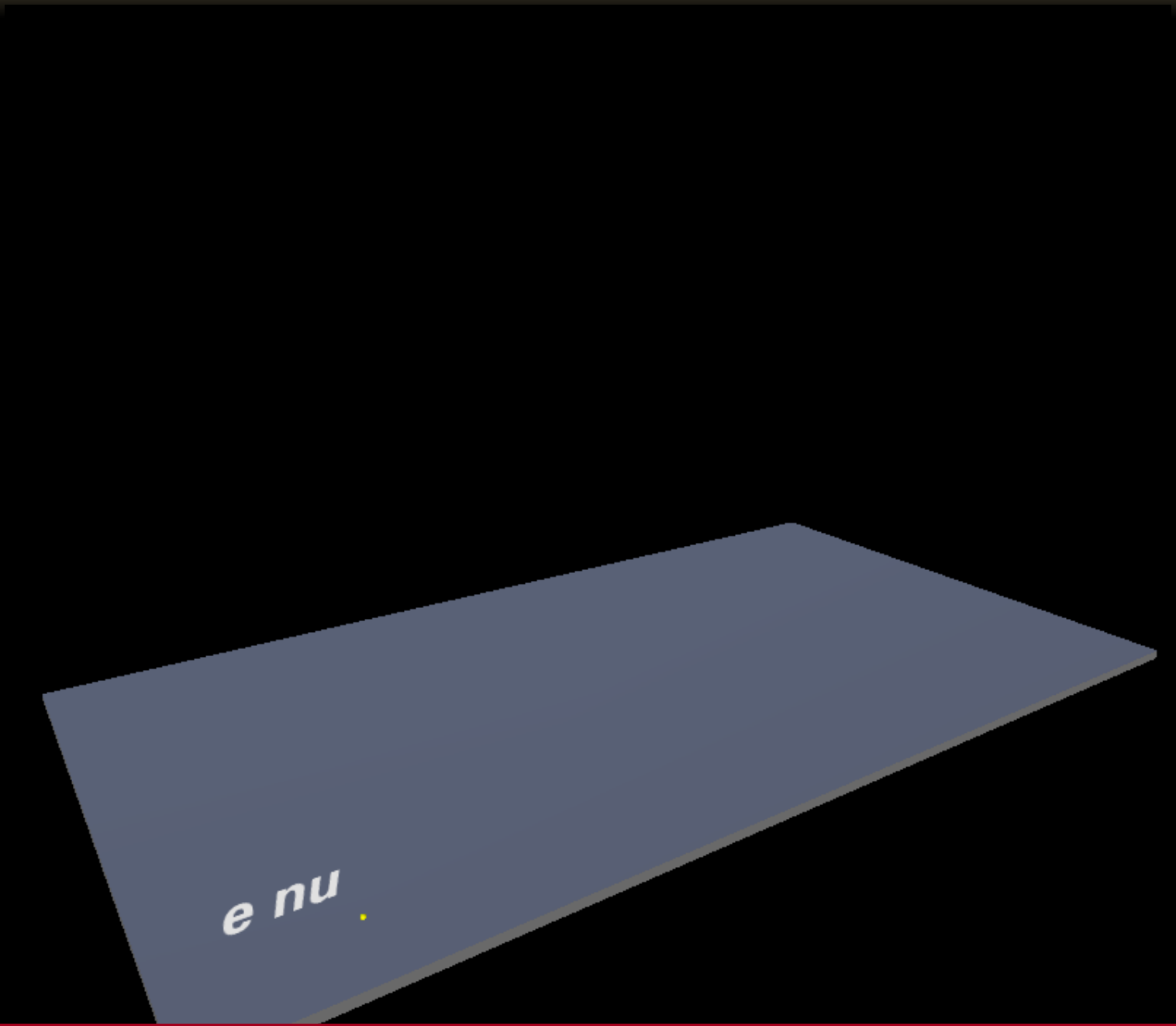

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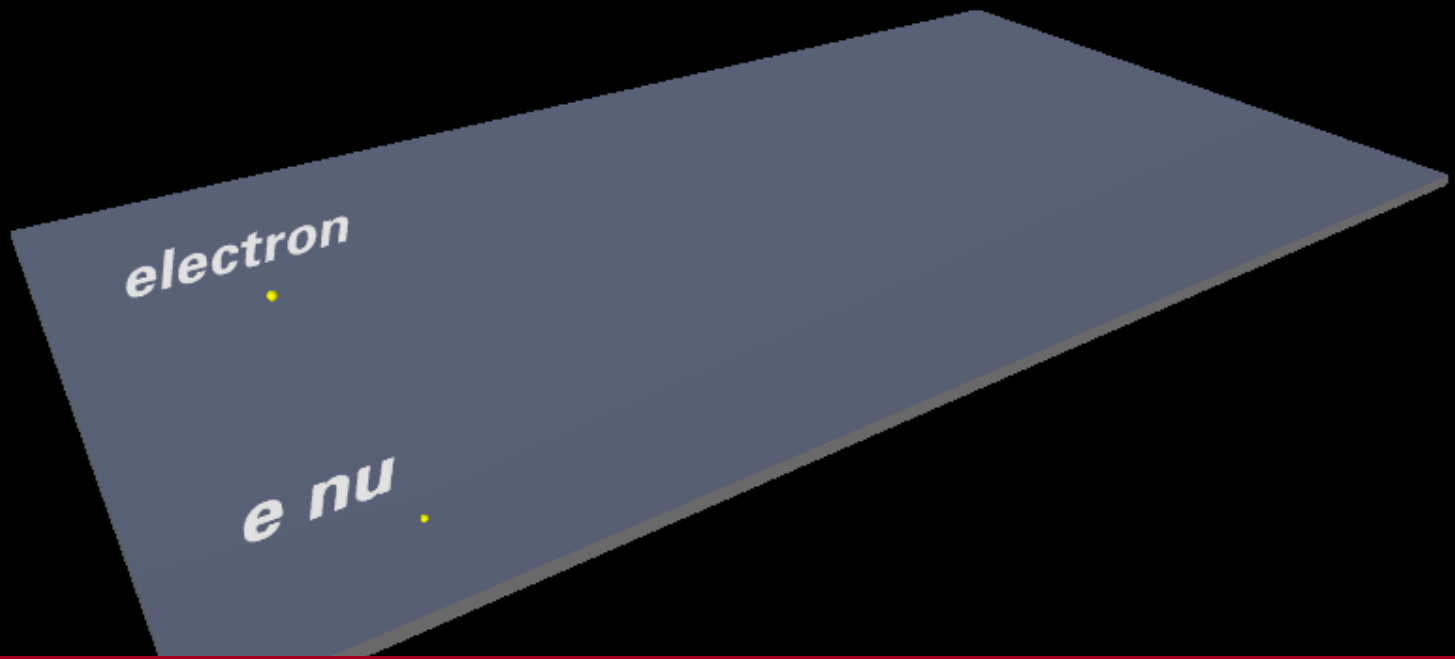

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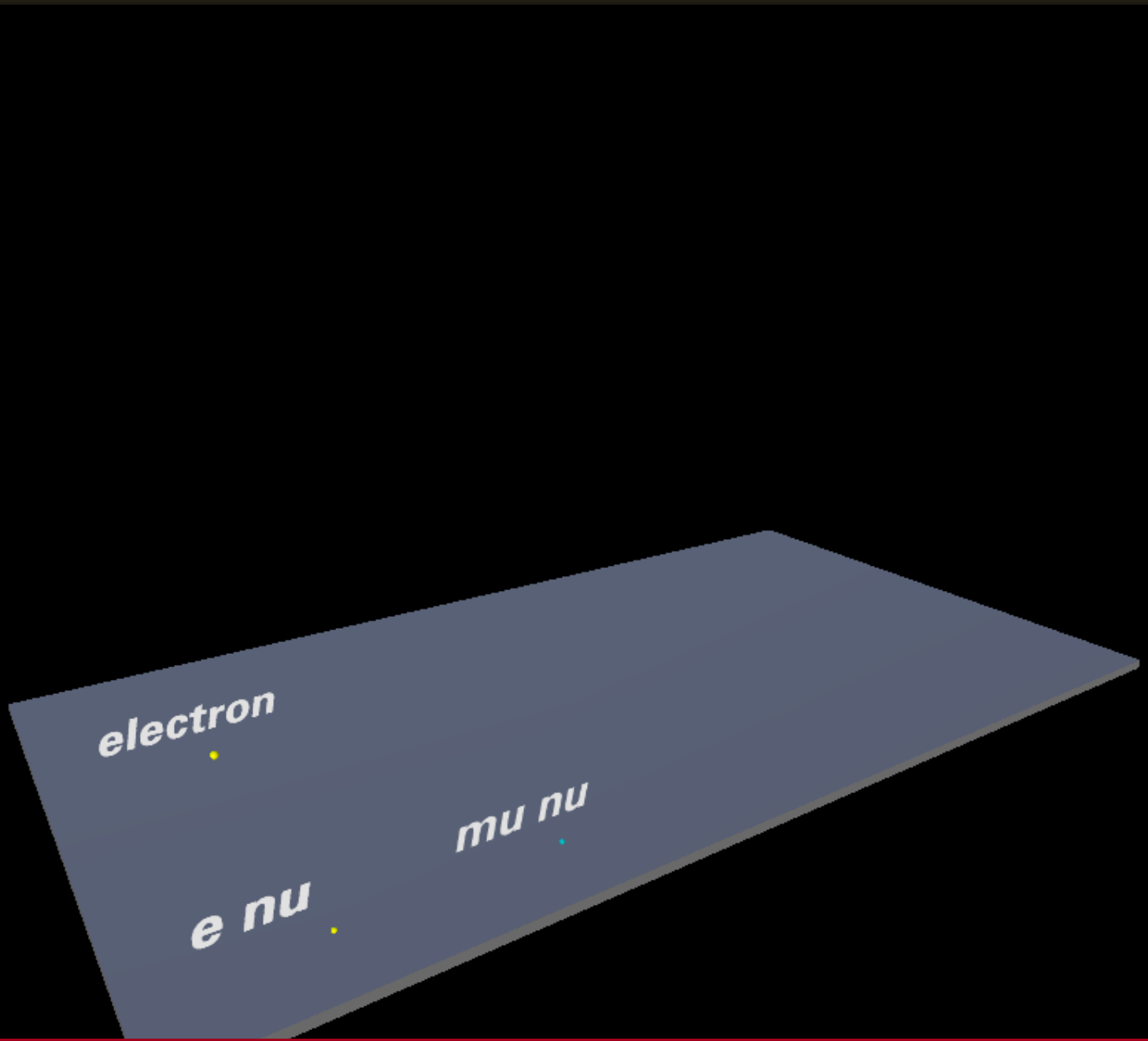

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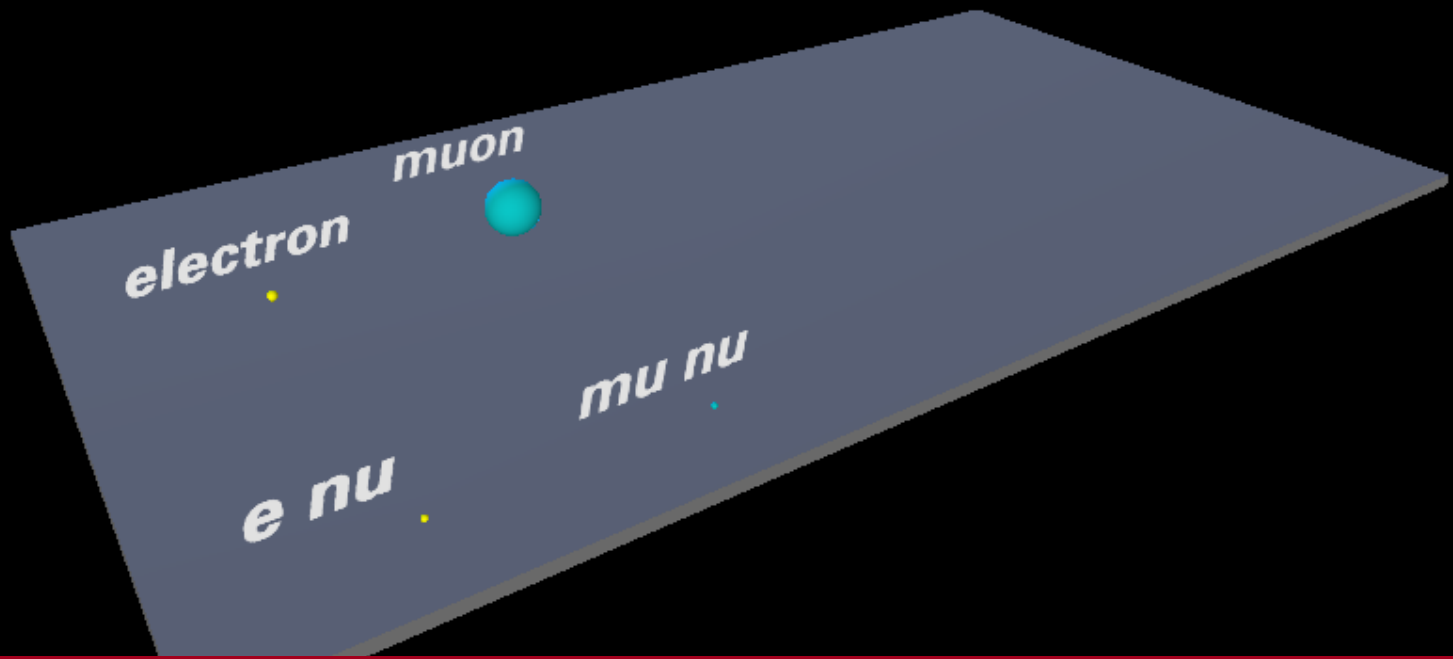

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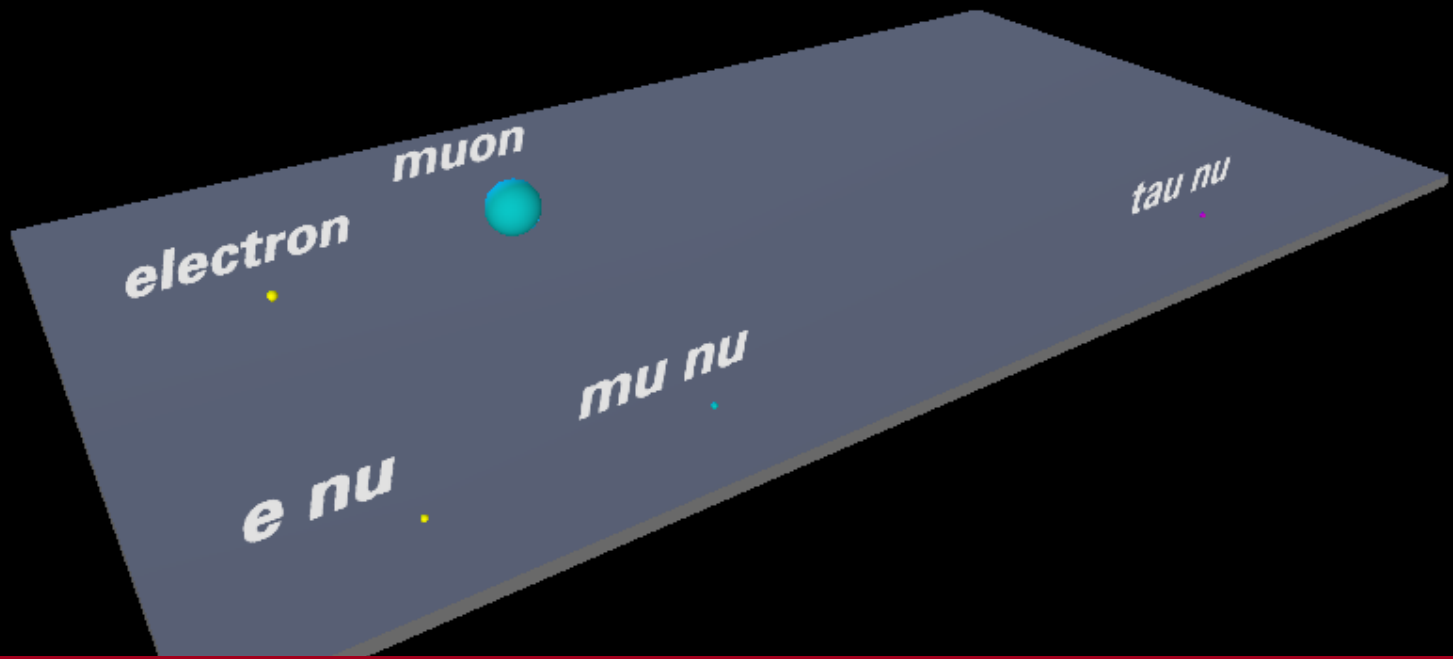

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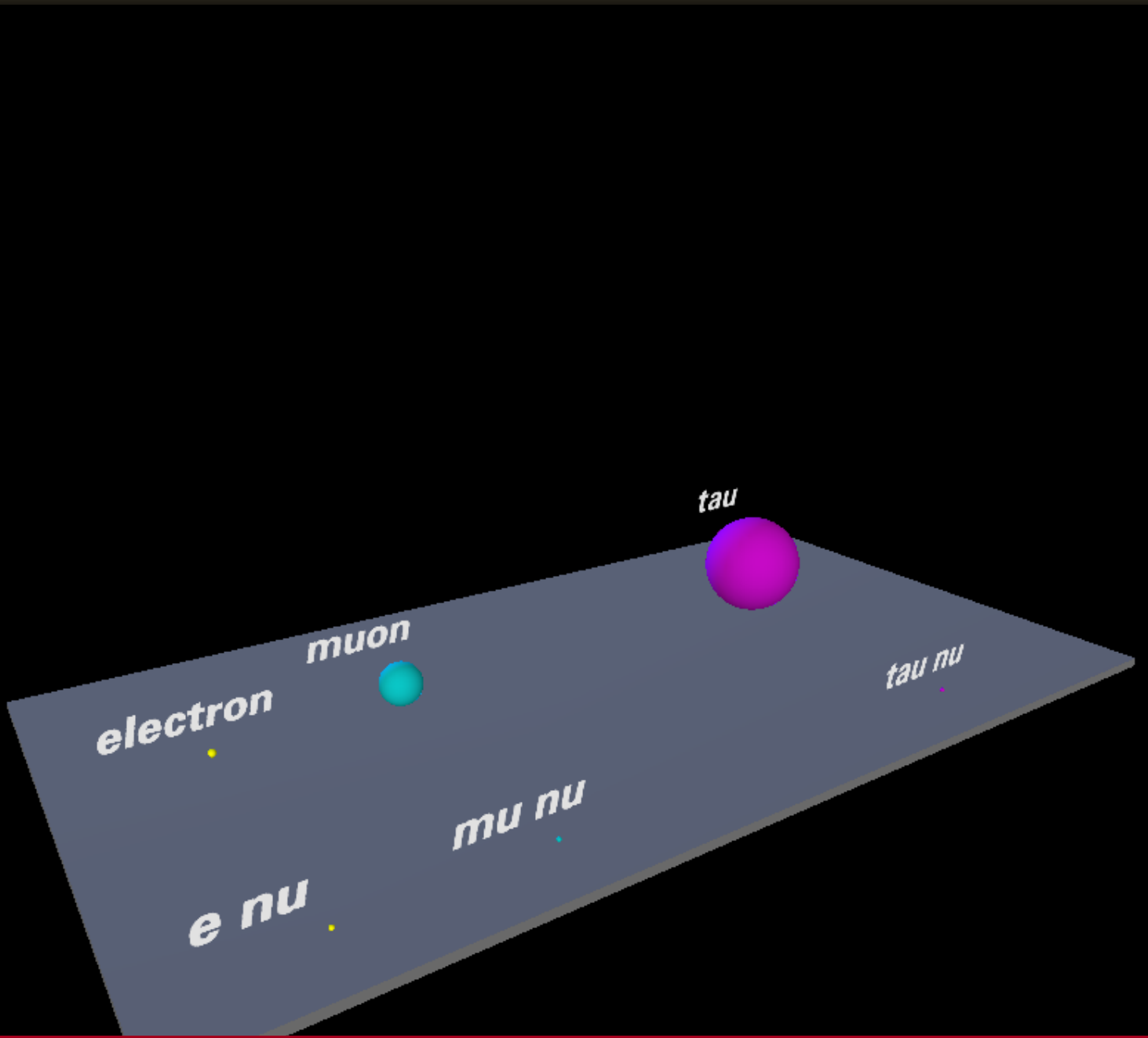
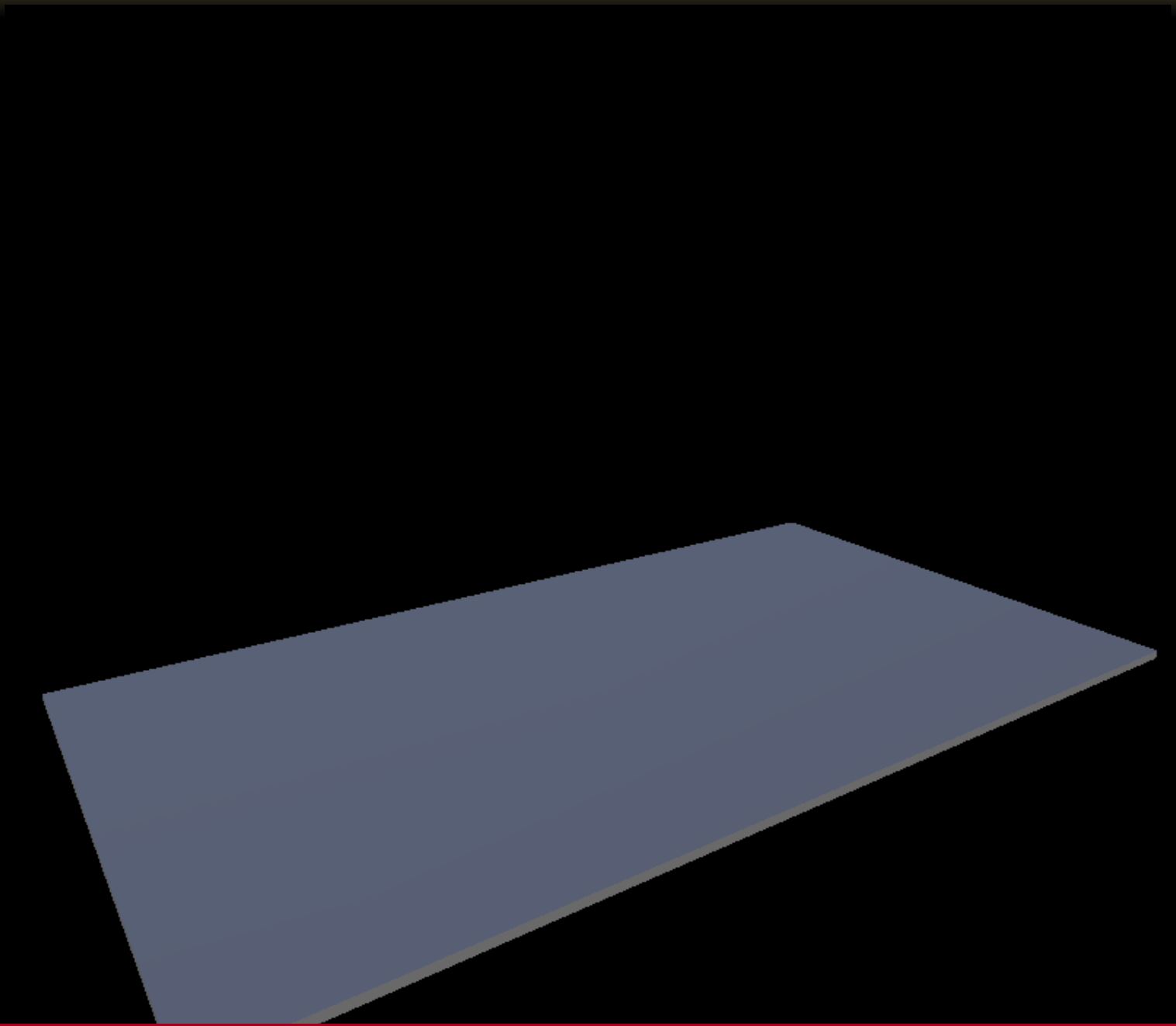
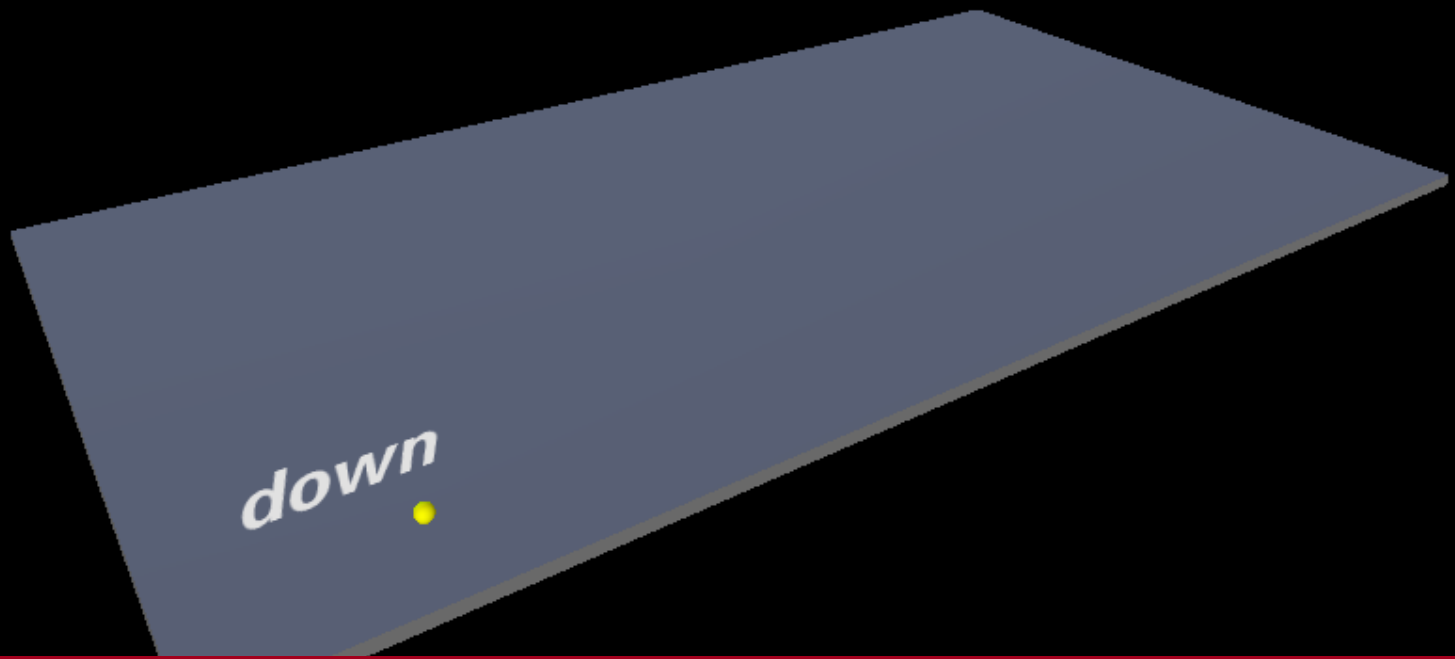
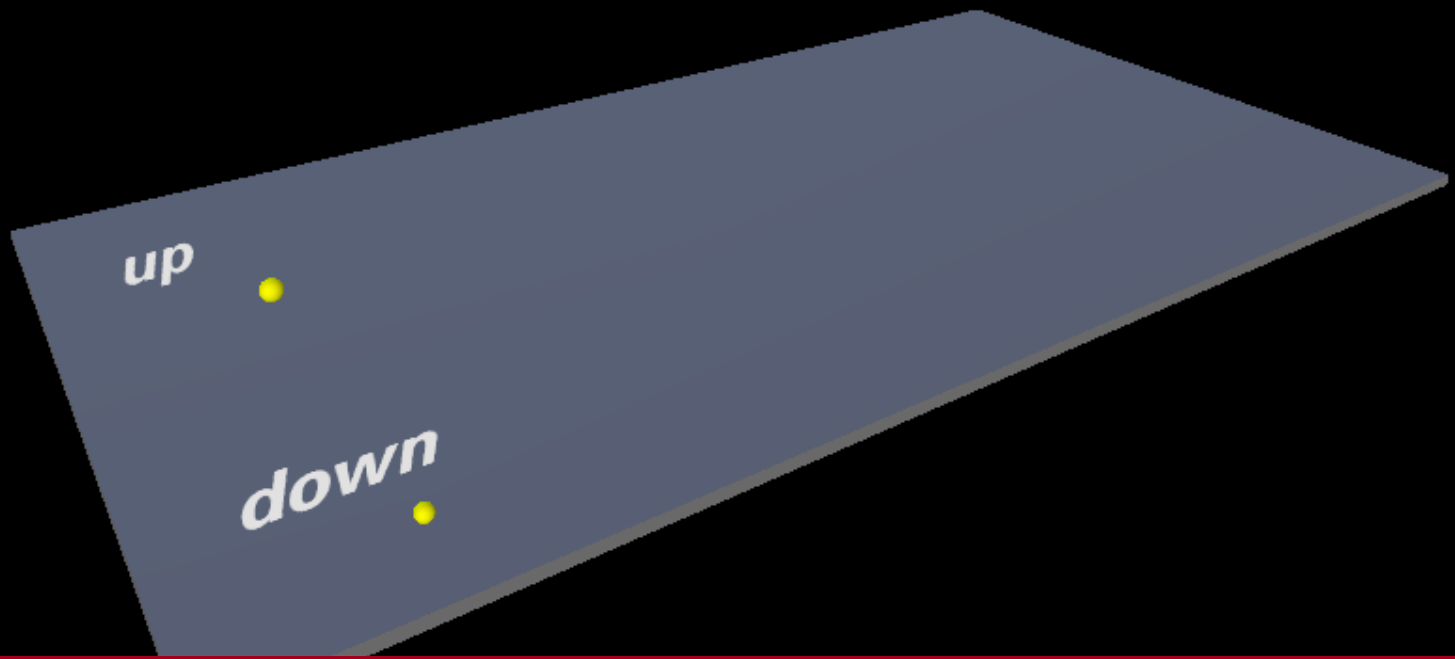


The Standard Model - Quarks

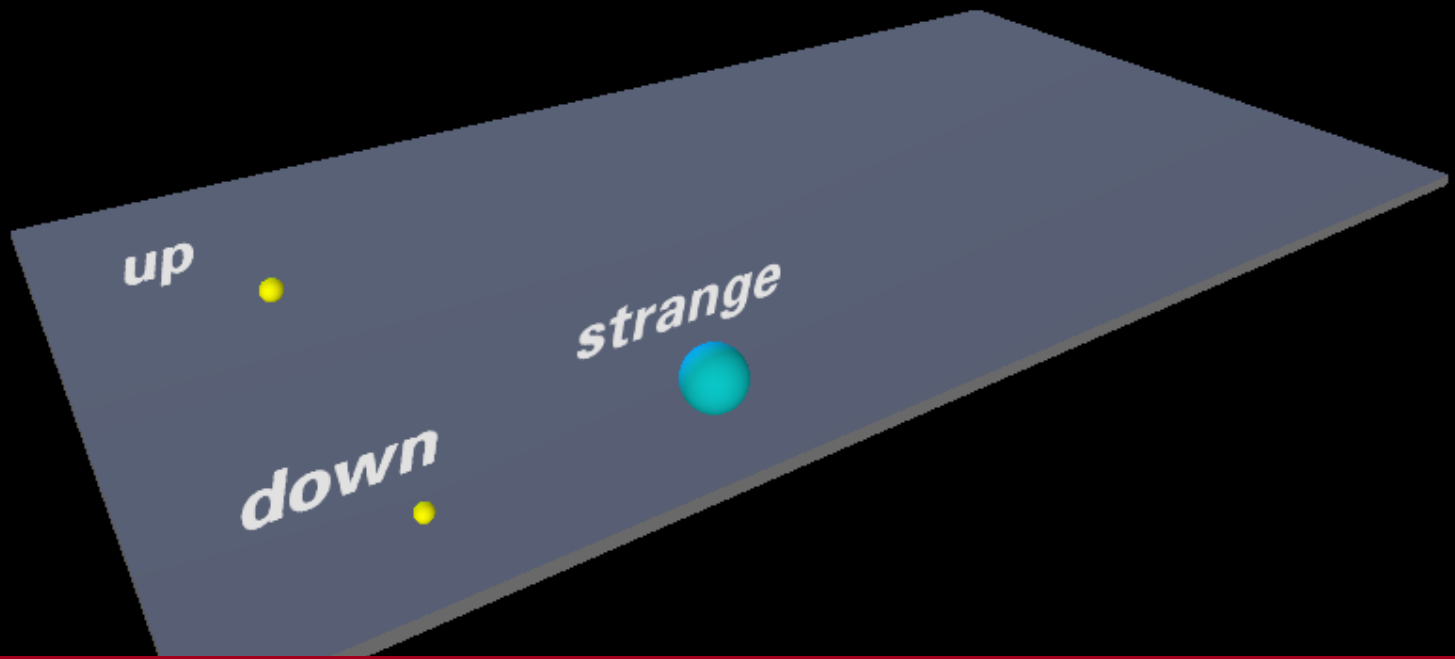



down

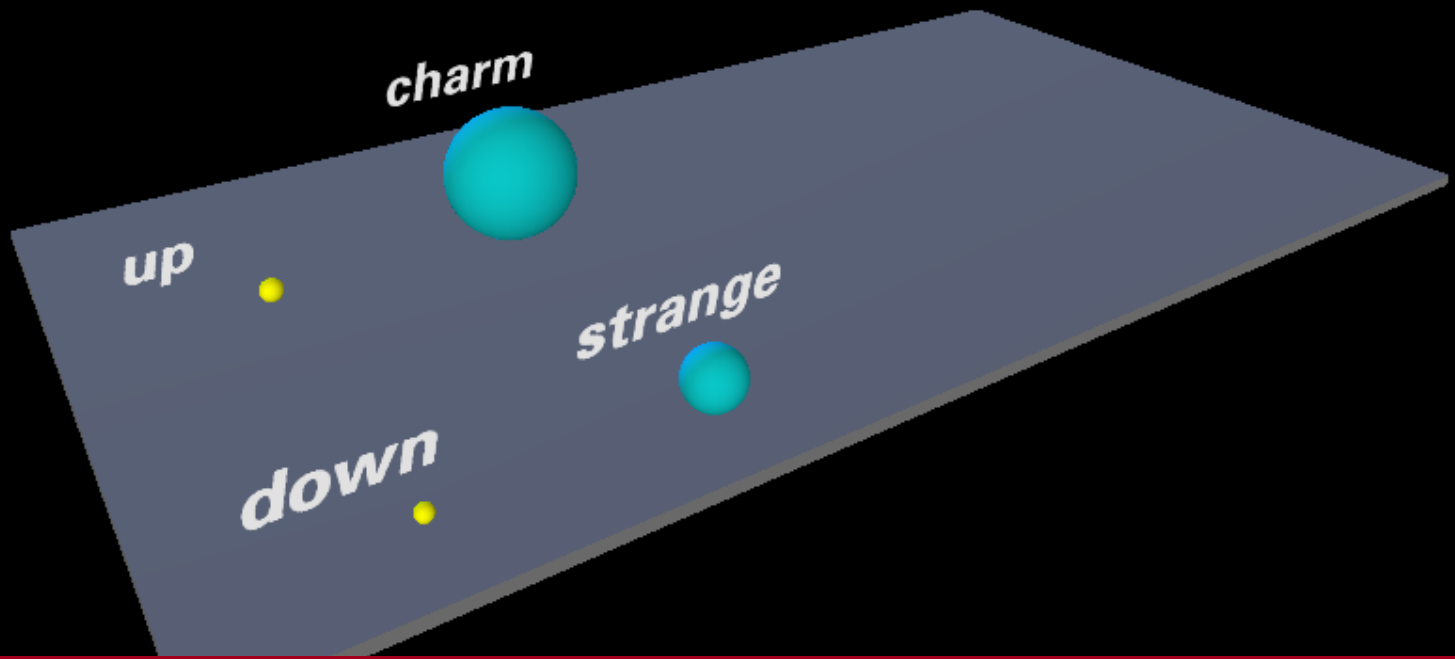
The Standard Model - Quarks



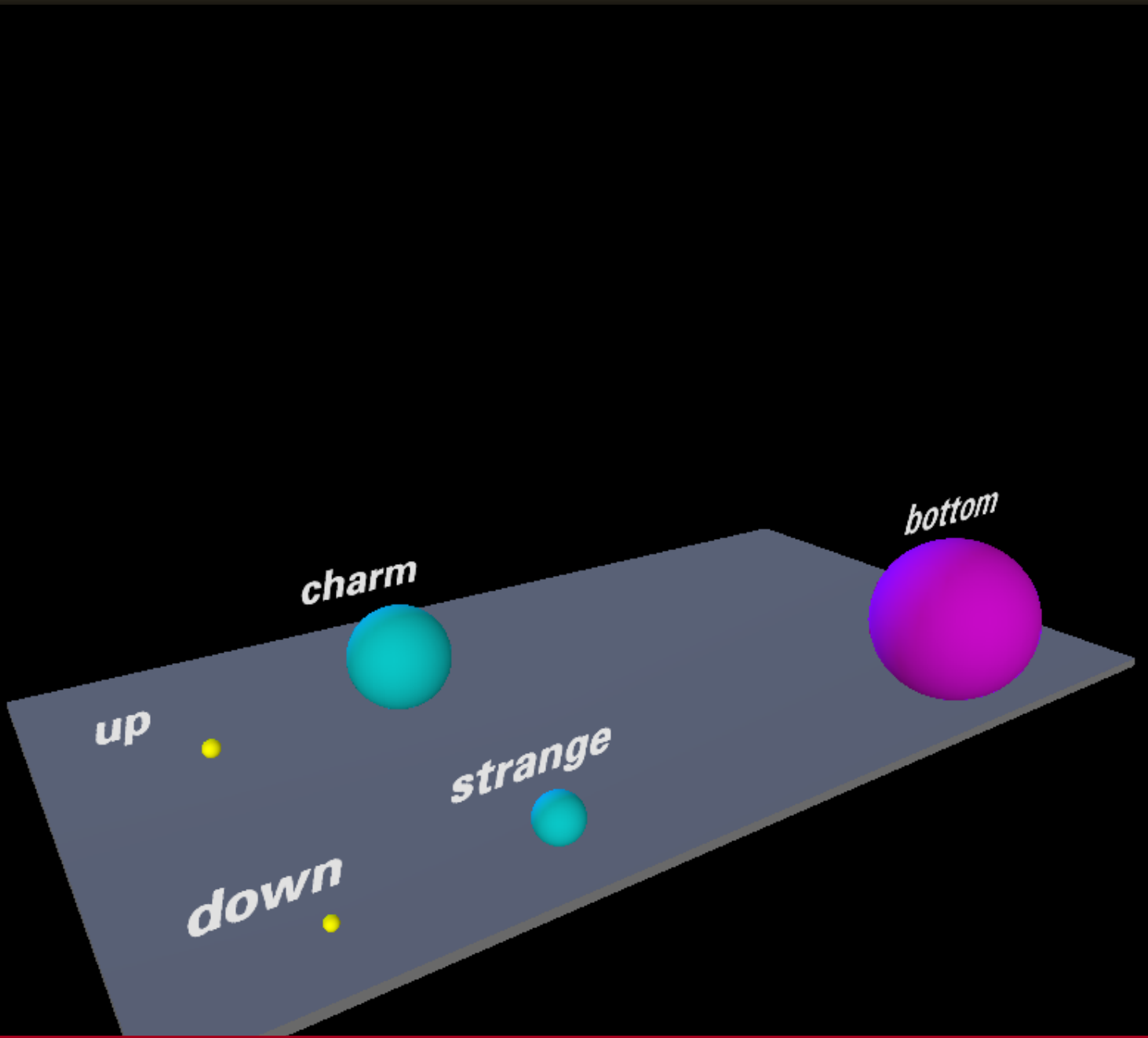
The Standard Model - Quarks



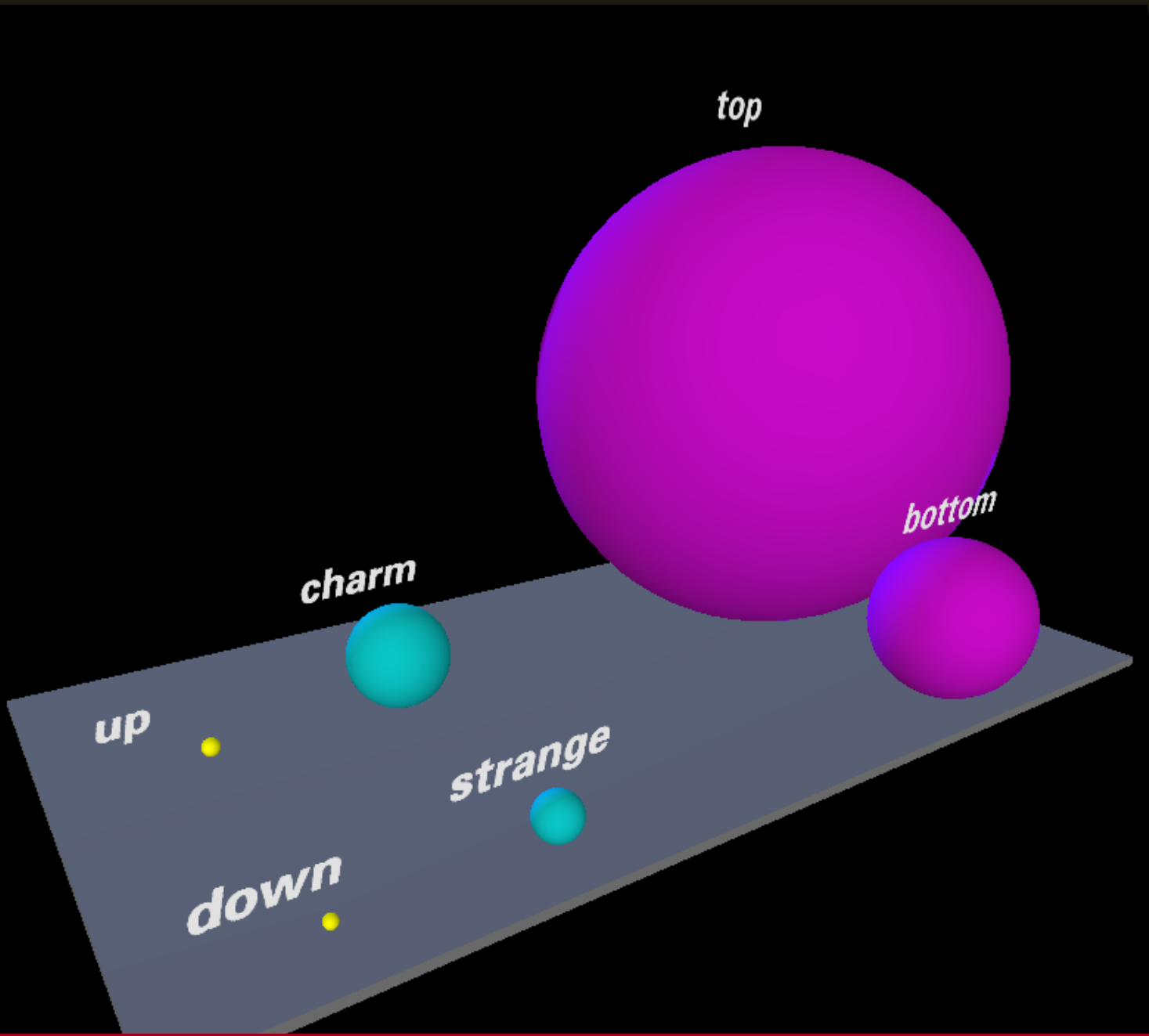
The Standard Model - Quarks



The Standard Model - Quarks

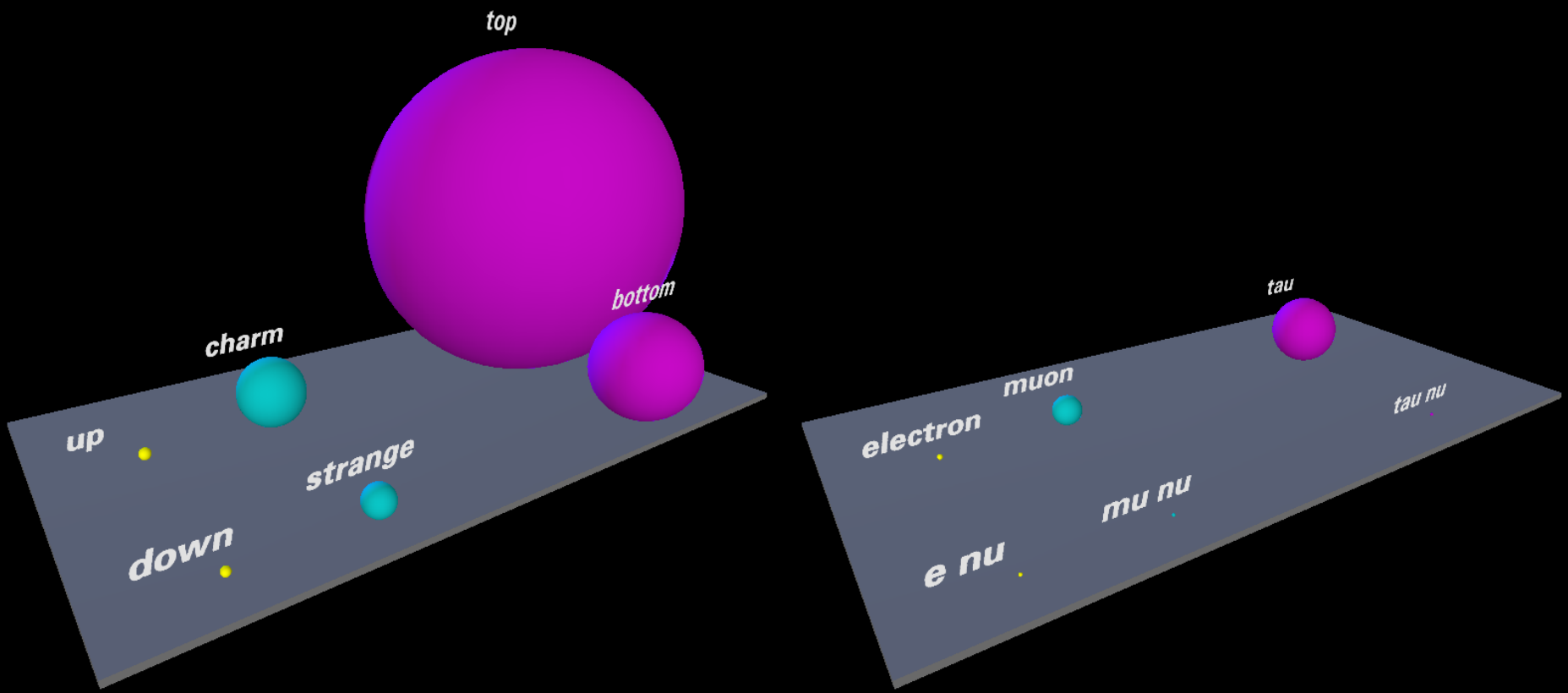


The Standard Model - Quarks



The Standard Model - Quarks and leptons

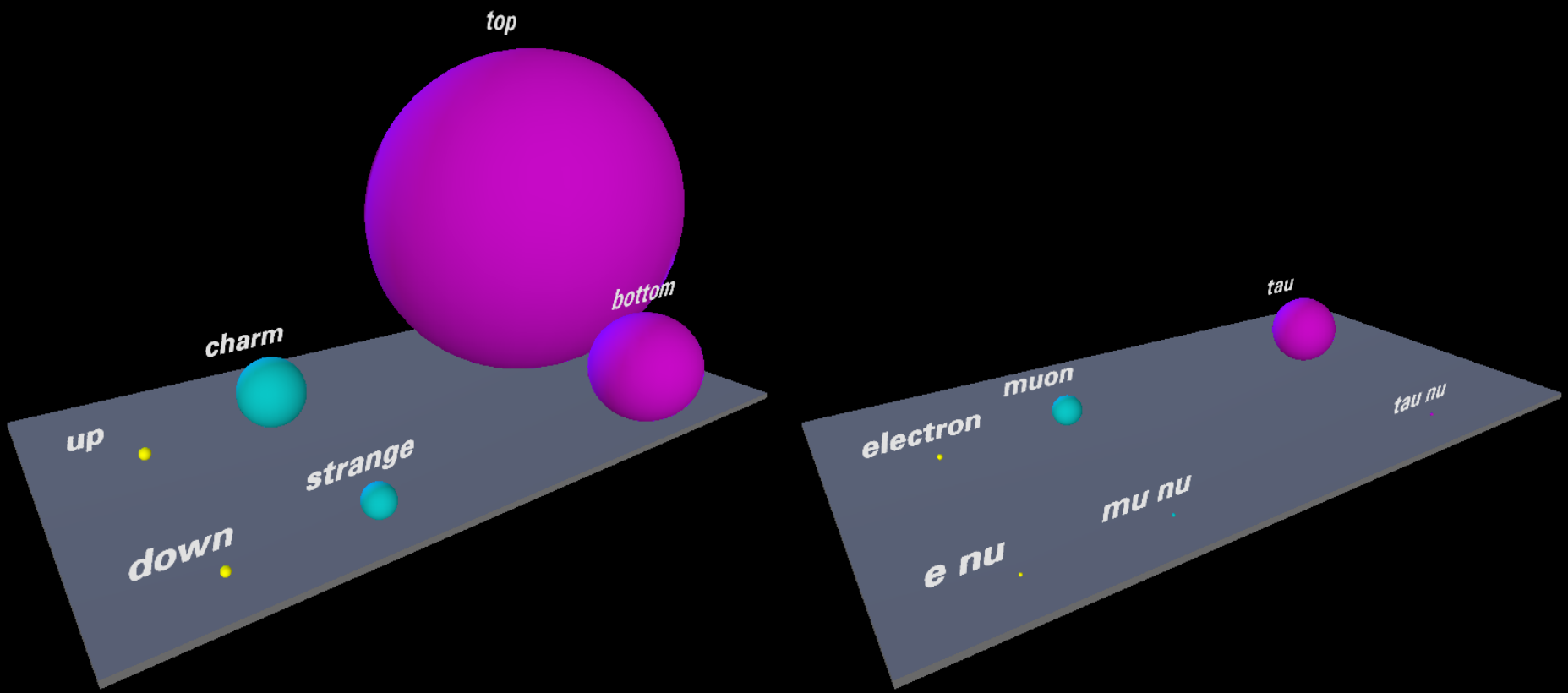
Lots of phenomena! *Mixing, virtual particles, conserved quantities, violation of conserved quantitites, group theory*



The Standard Model - Quarks and leptons

Lots of phenomena! *Mixing, virtual particles, conserved quantities, violation of conserved quantitites, group theory*

Quarks don't live free. Most of these live for less than a second.



The Standard Model - Quarks and leptons

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Our world. **How do we learn about all of this?**