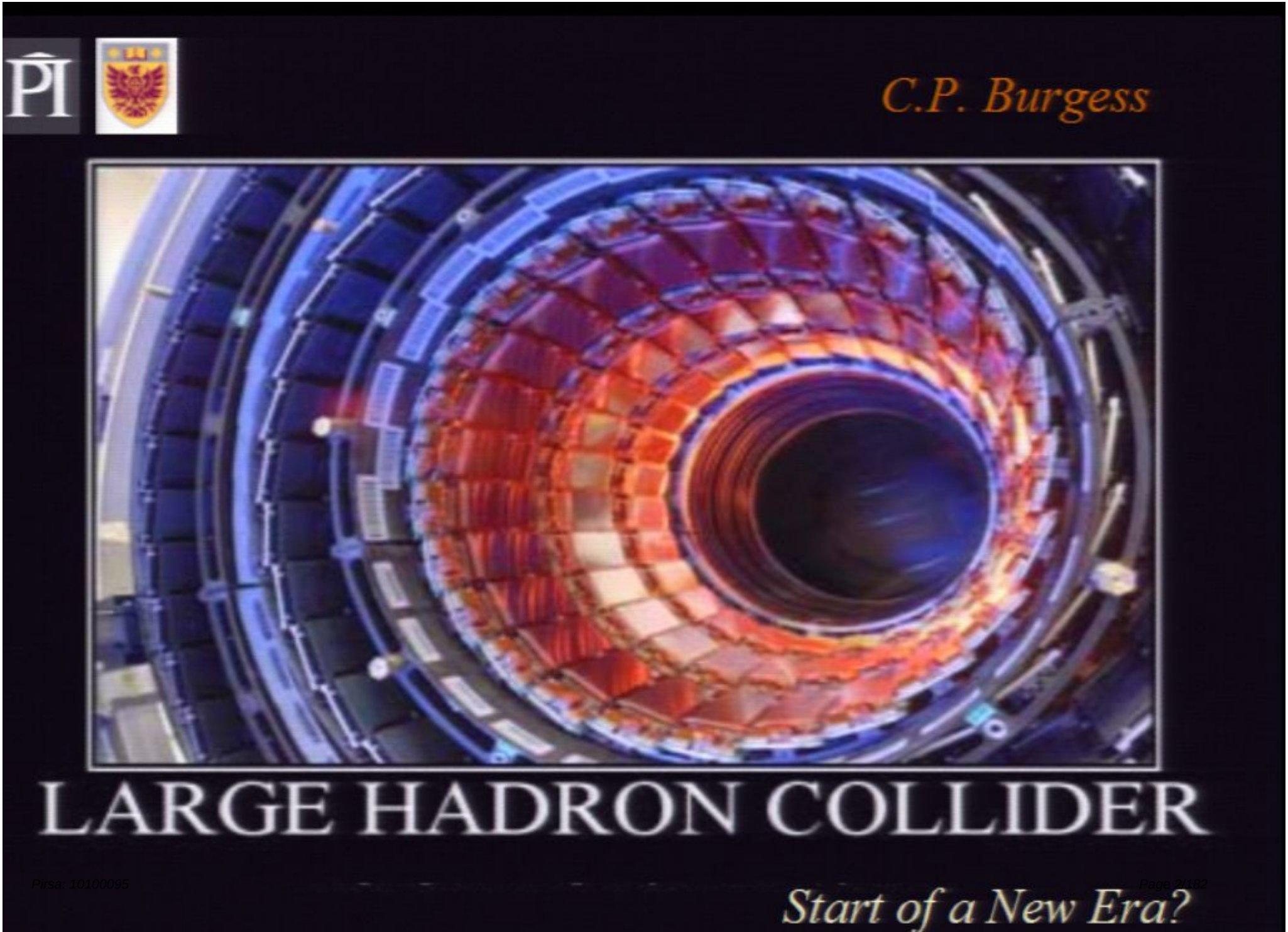
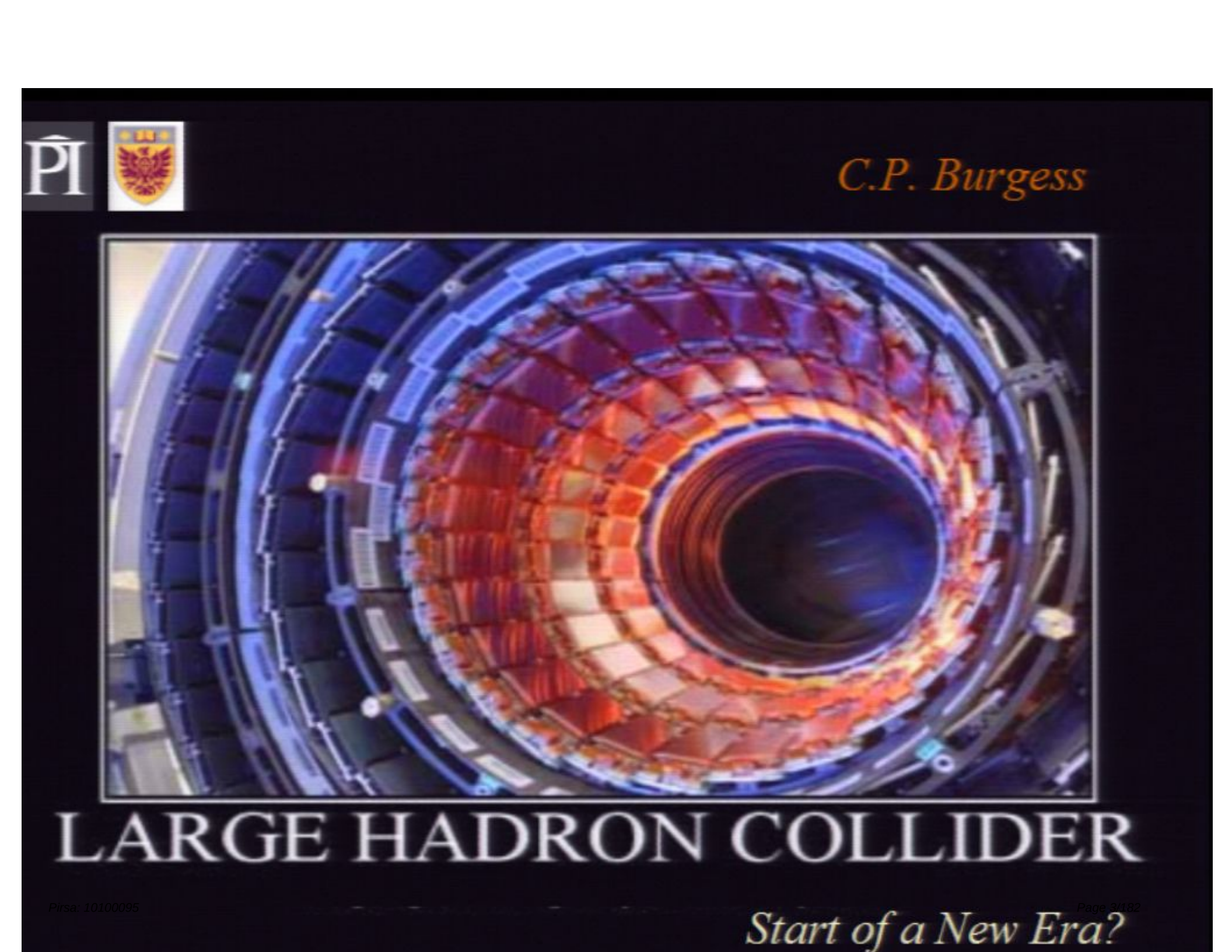
Title: LHC: Start of a new Era?

Date: Oct 22, 2010 10:30 AM

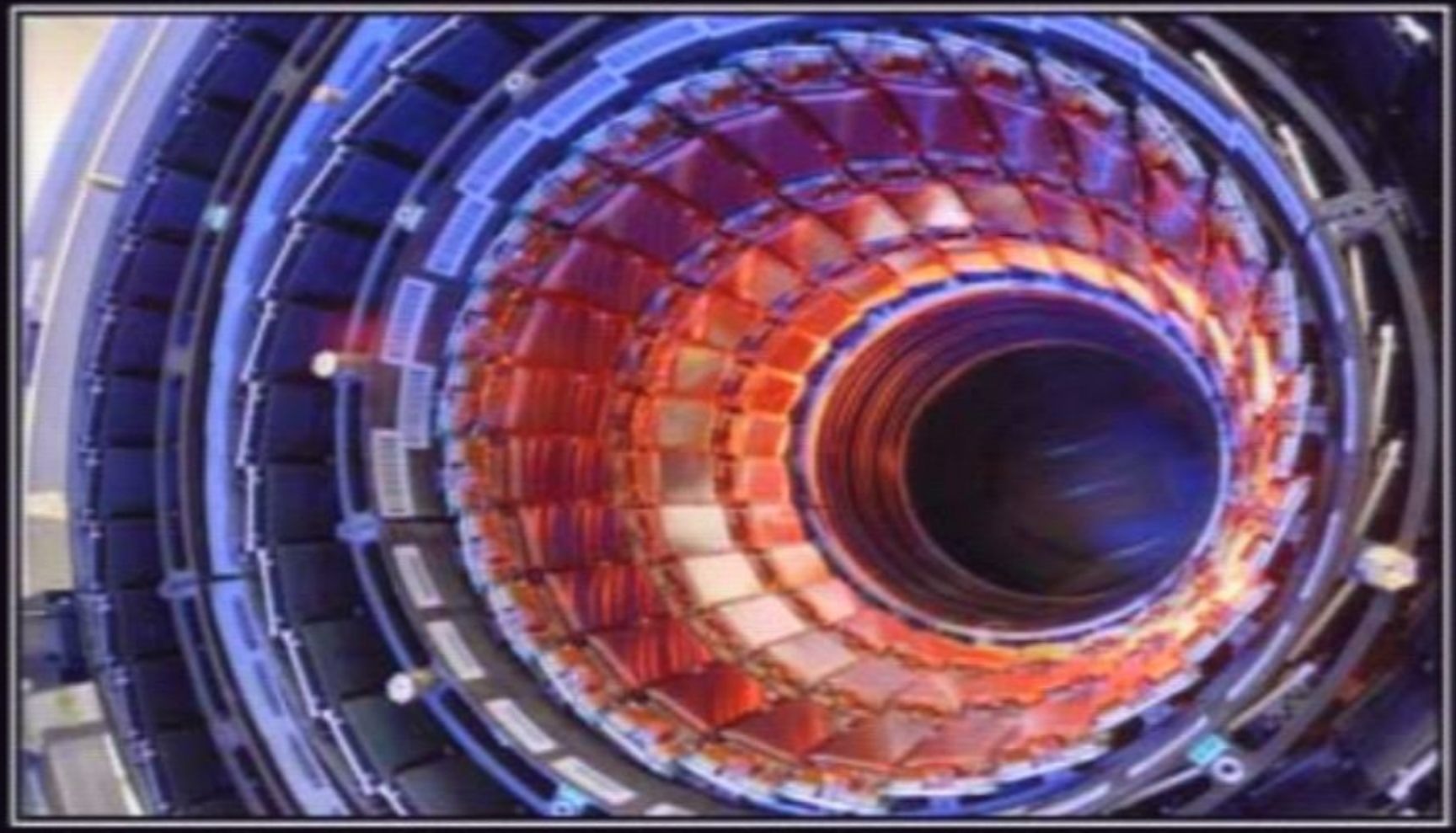
URL: http://www.pirsa.org/10100095

Abstract:





C.P. Burgess



LARGE HADRON COLLIDER

It's going to fucking kill you dead. May 2008.

http://skepticalteacher.files.wordpress.com

...or the End of the World?

The Large Hadron Collider

Start of a New Era
or the End of the World?

C.P. Burgess

The Large Hadron Collider

Start of a New Era or the End of the World?

C.P. Burgess

Outline

- What is it?
  - *The machine and recent events*
- Why was it built?
  - *The Standard Model and its limitations*
- What might it hope to see?
  - *Problems*
- Outlook

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The Machine

- The Accelerator
- The Detectors

The Machine

- The Accelera
- The Detector

The Machine

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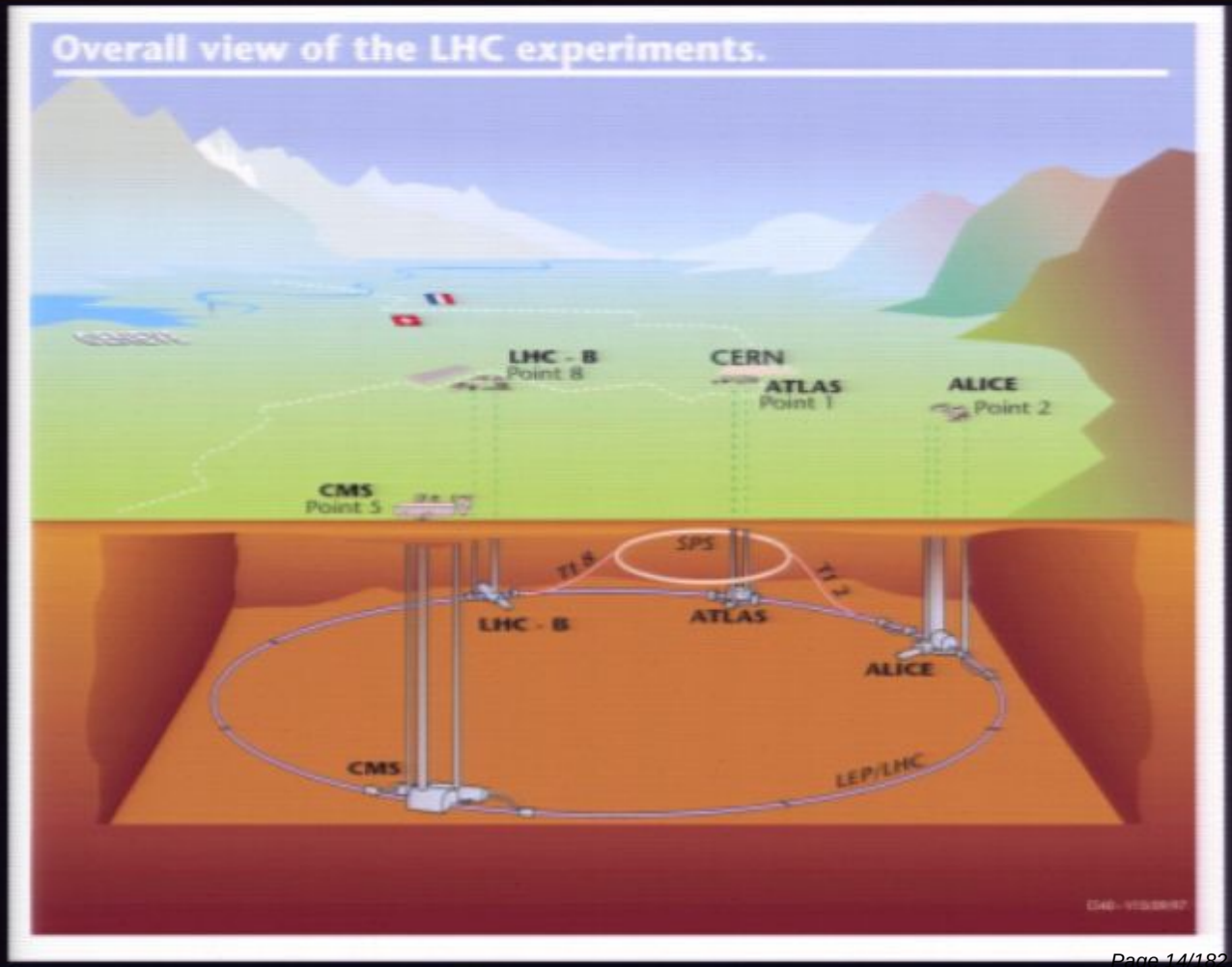
- The Detector



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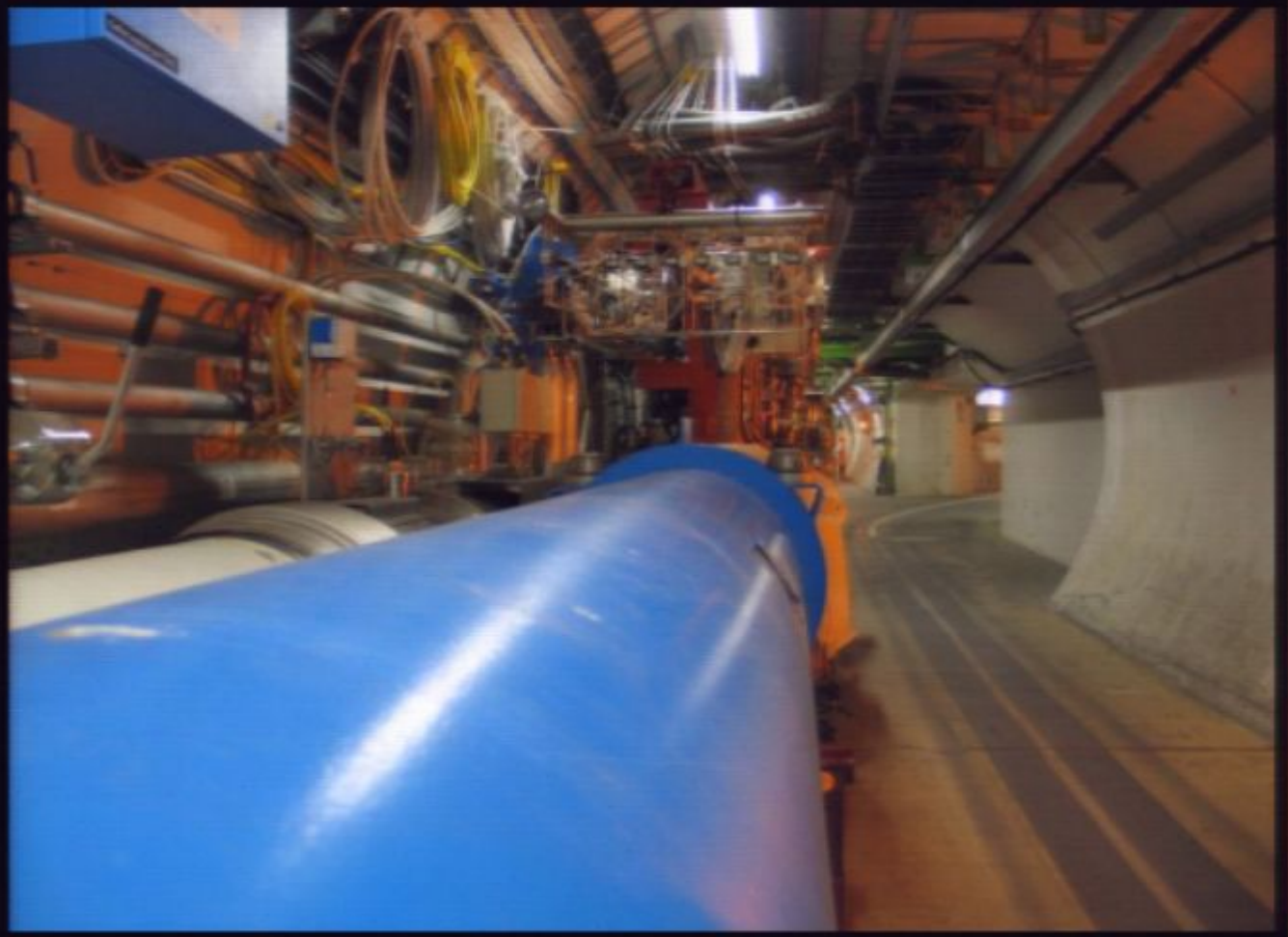

The Movie

- The Plot
- *Scenes at CERN*
- Scenes in Rome

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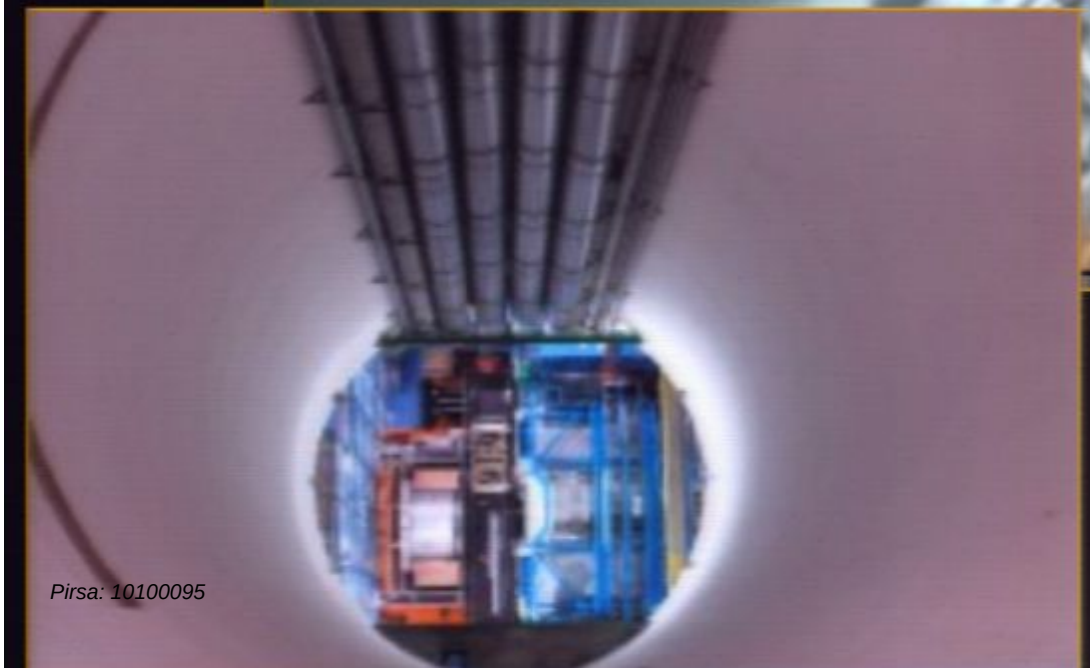

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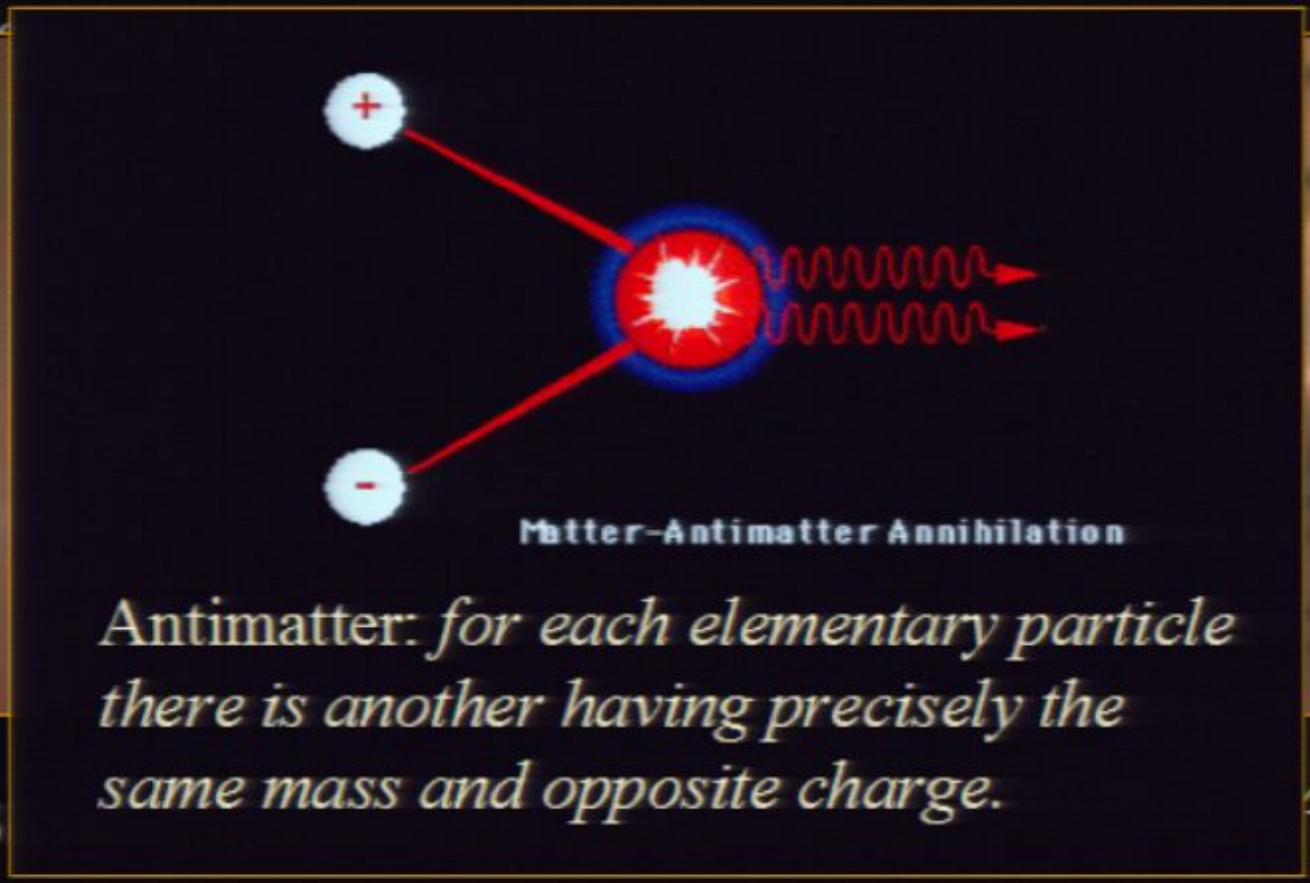

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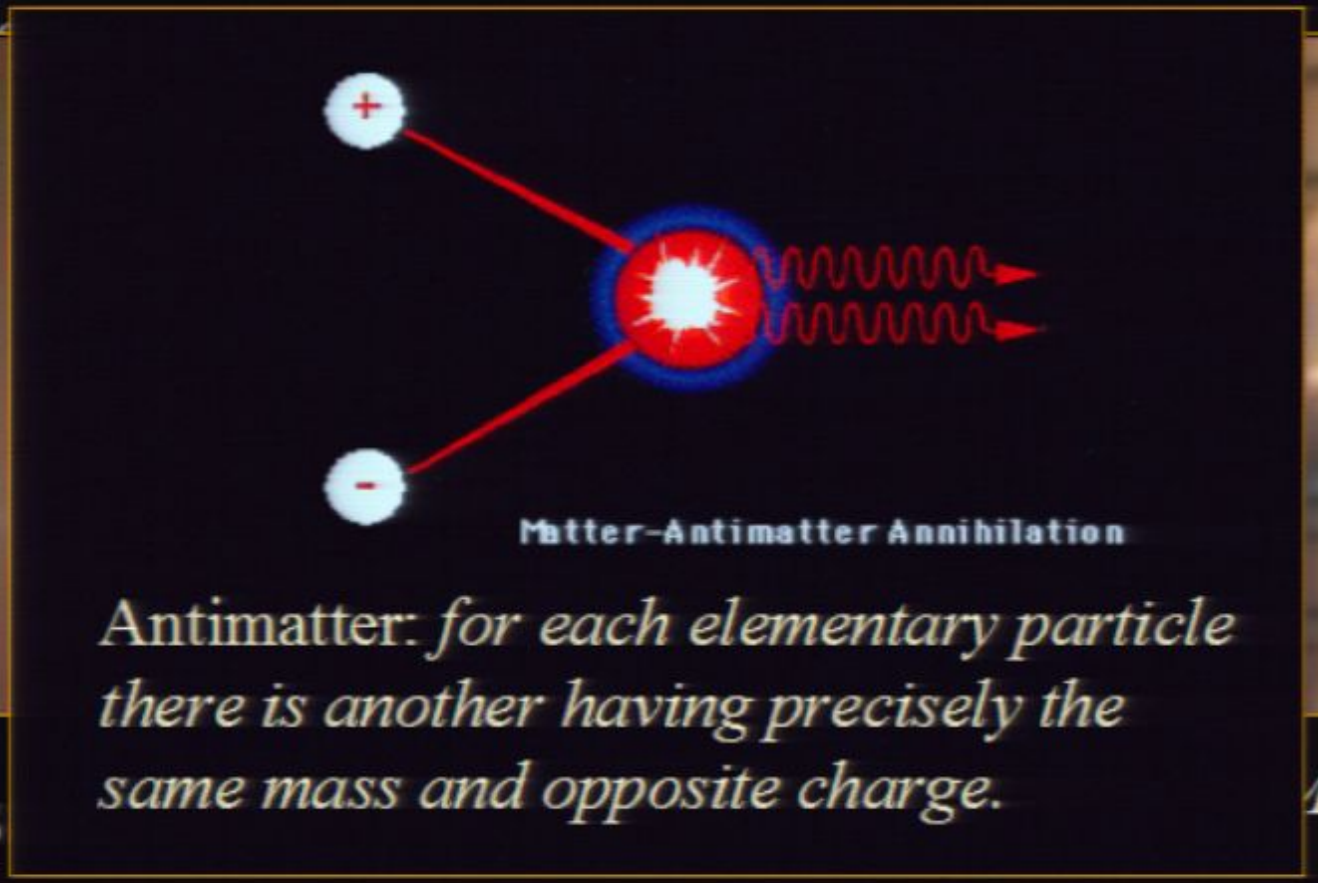

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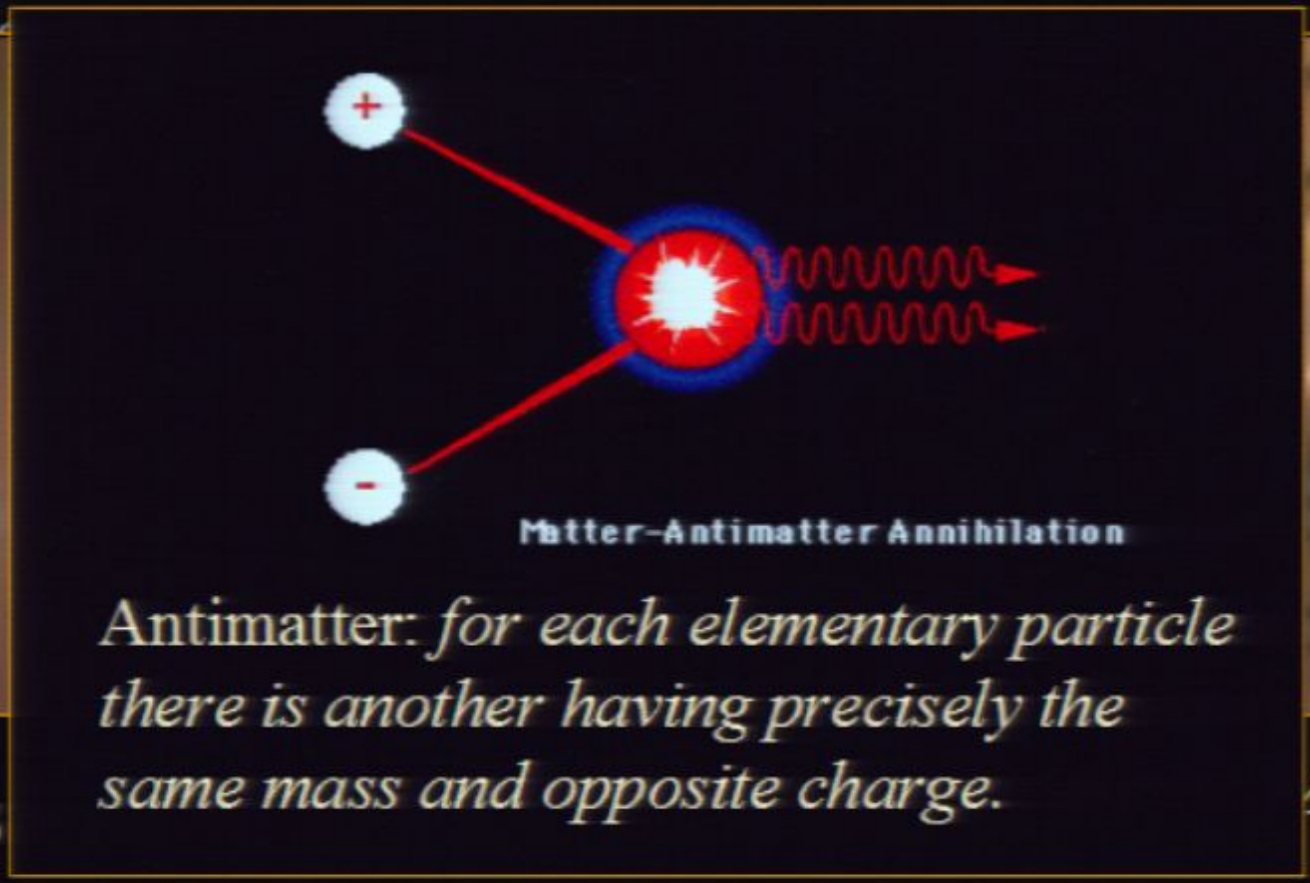

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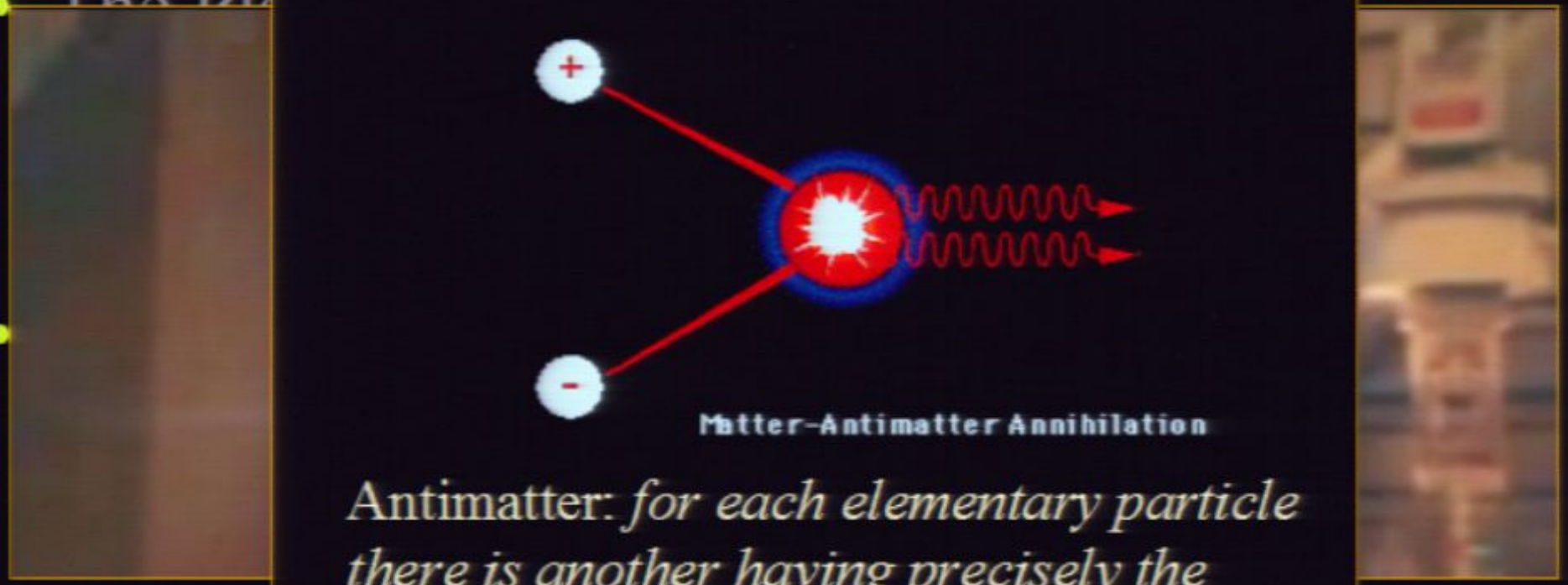

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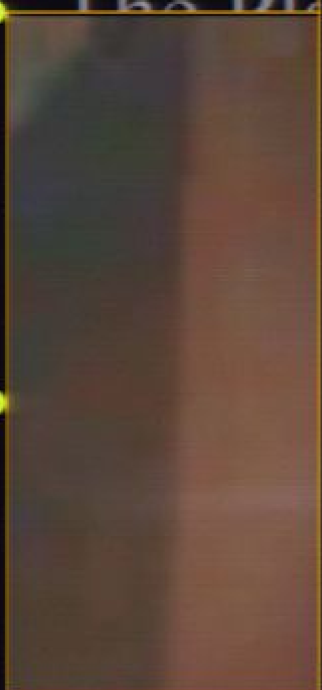

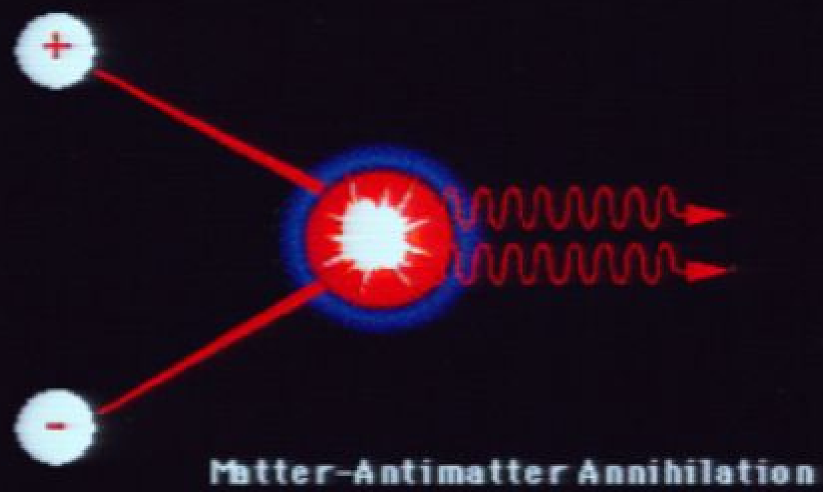

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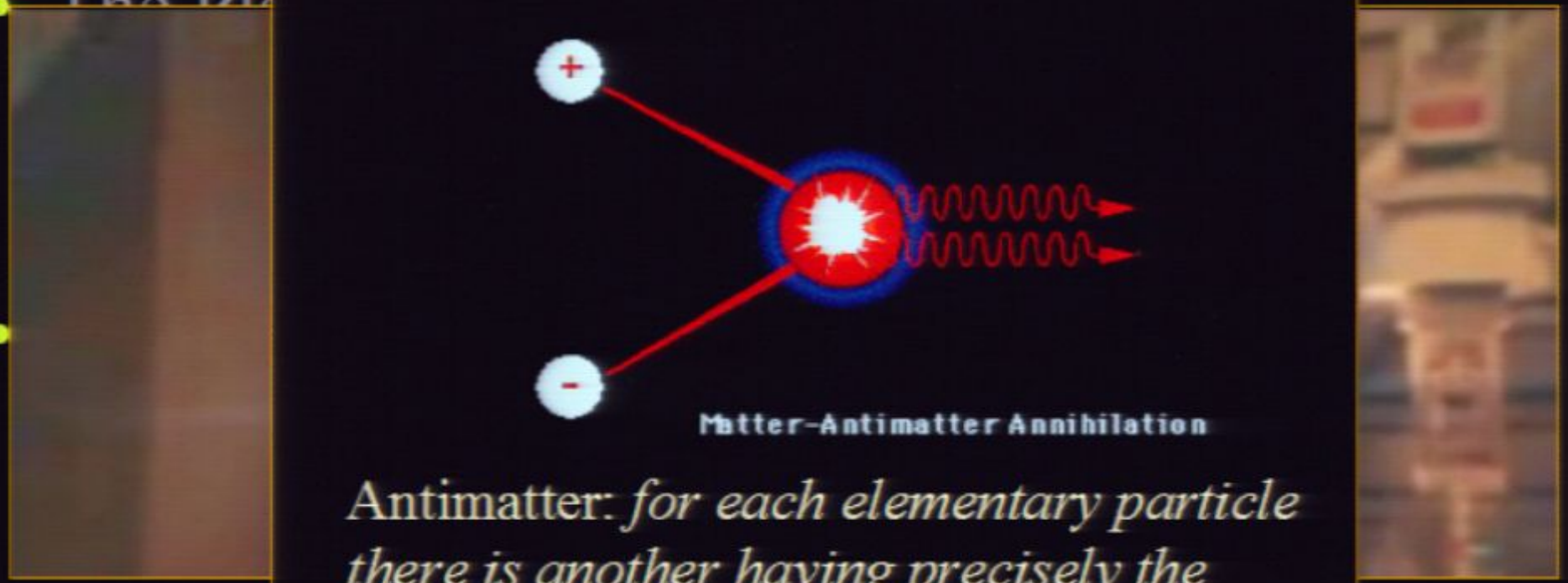

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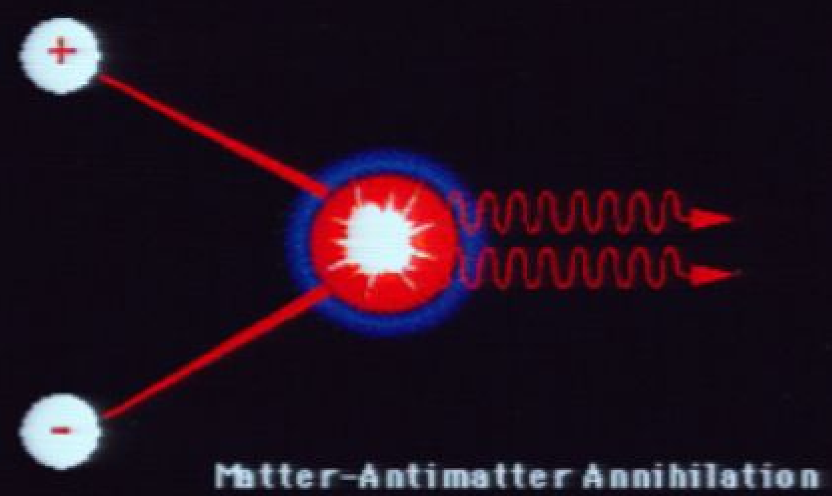

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The Movie

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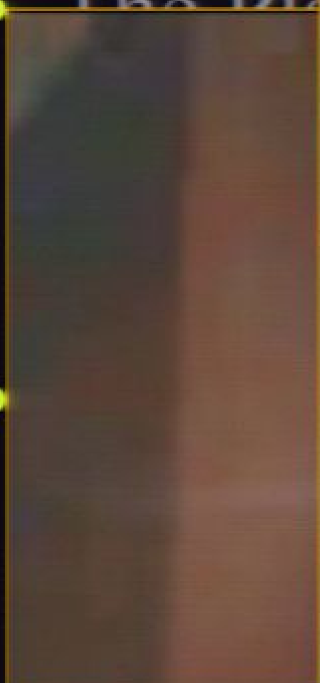
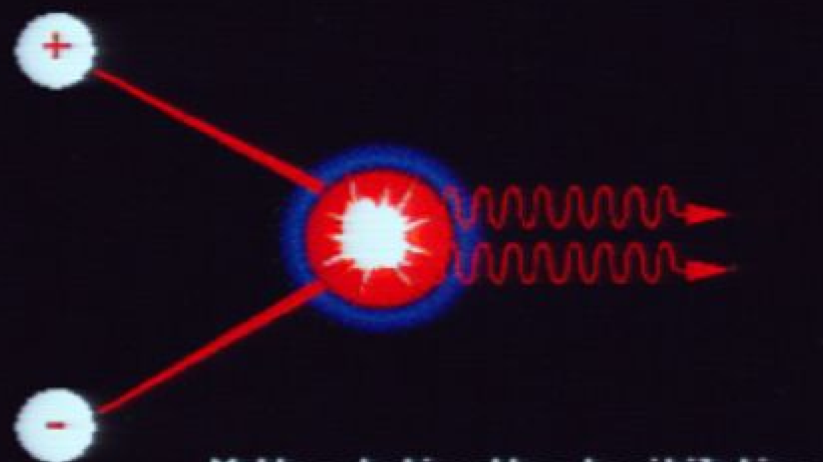
- Scenes … Iovie





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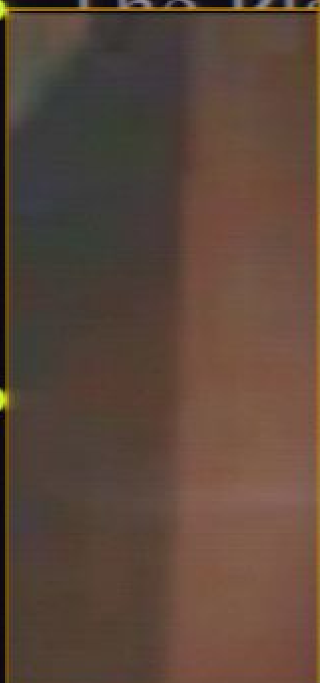

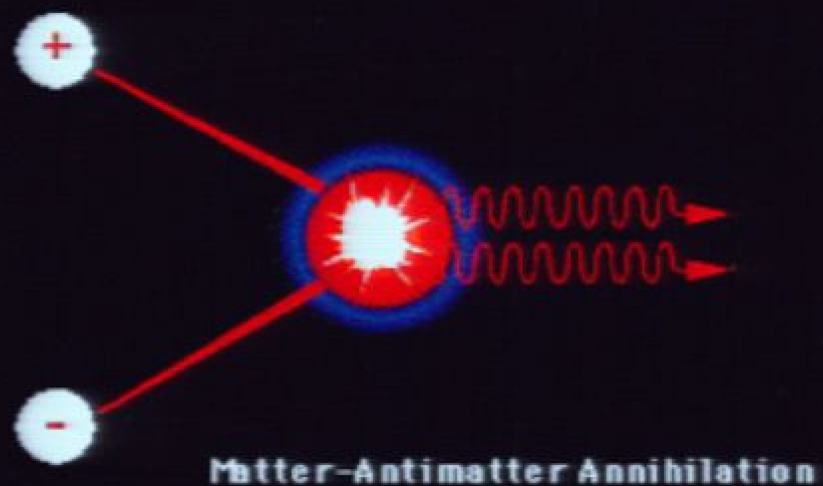

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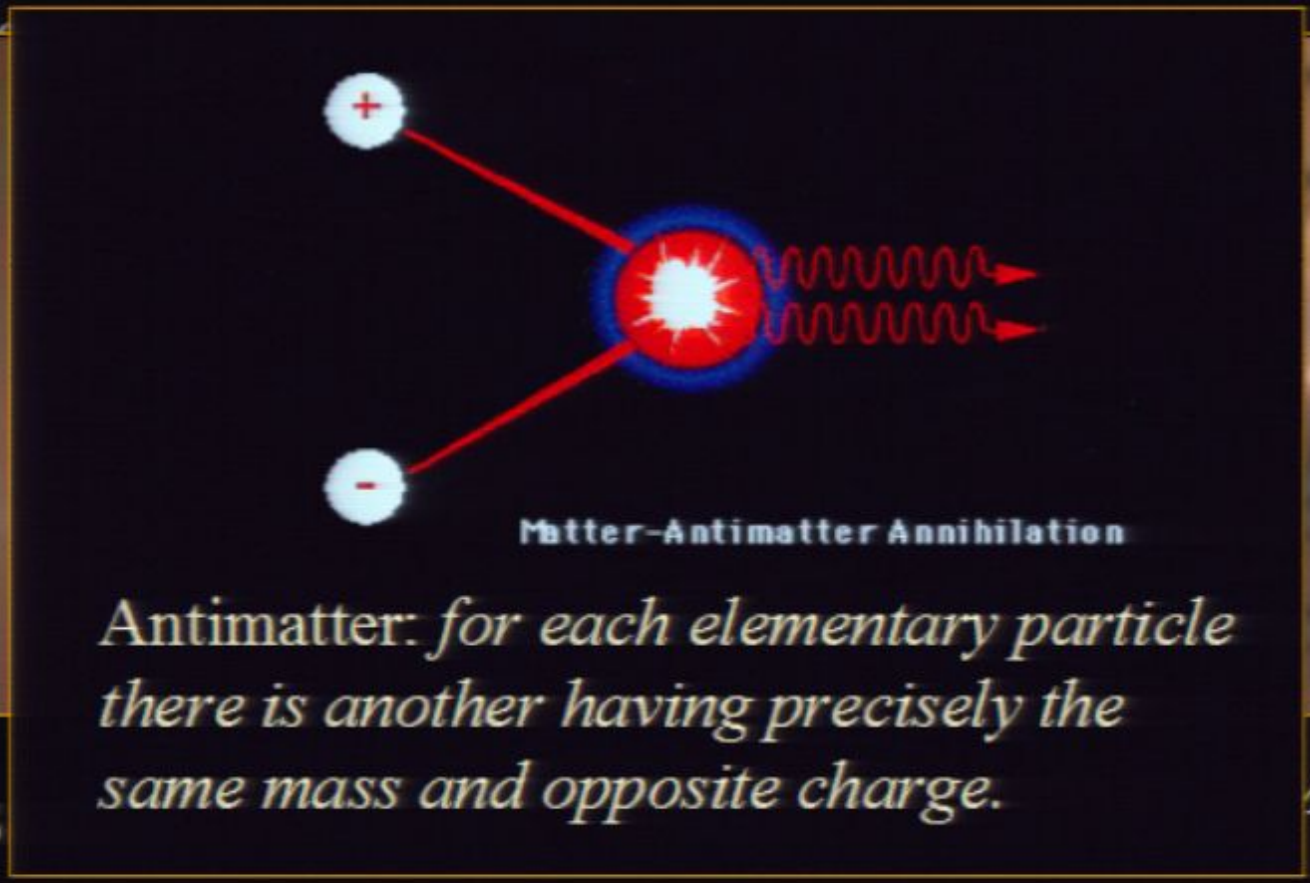

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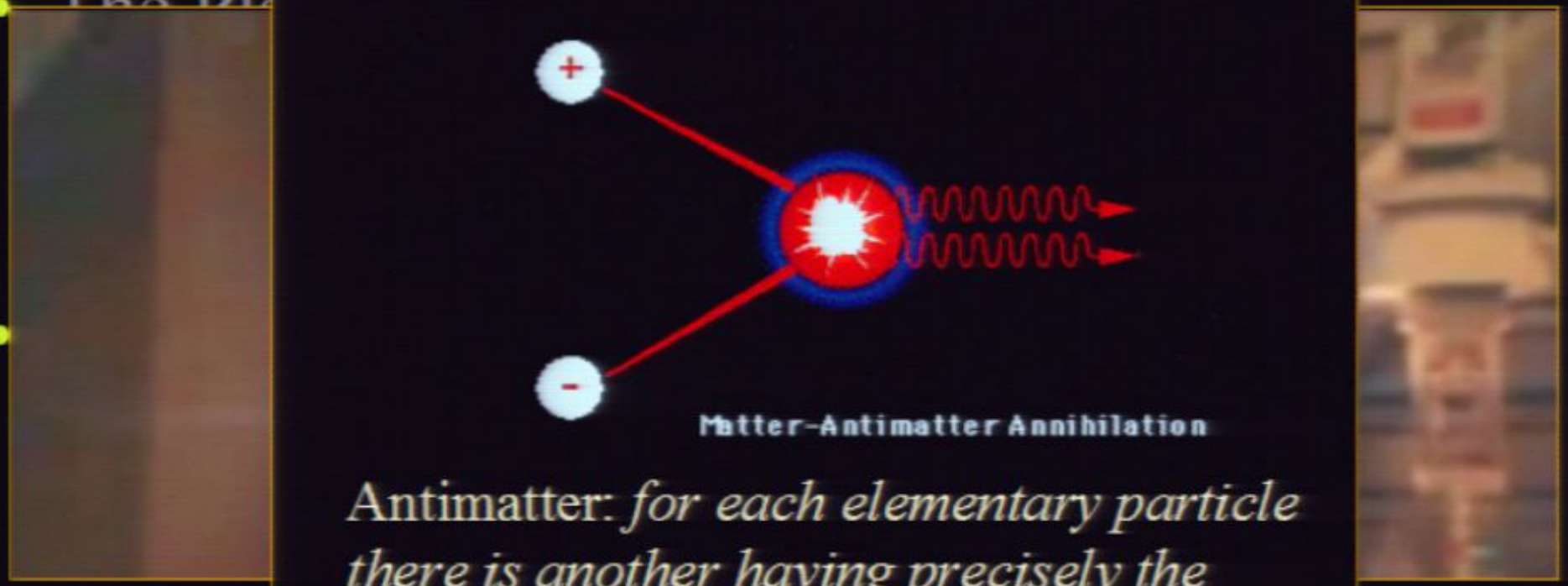

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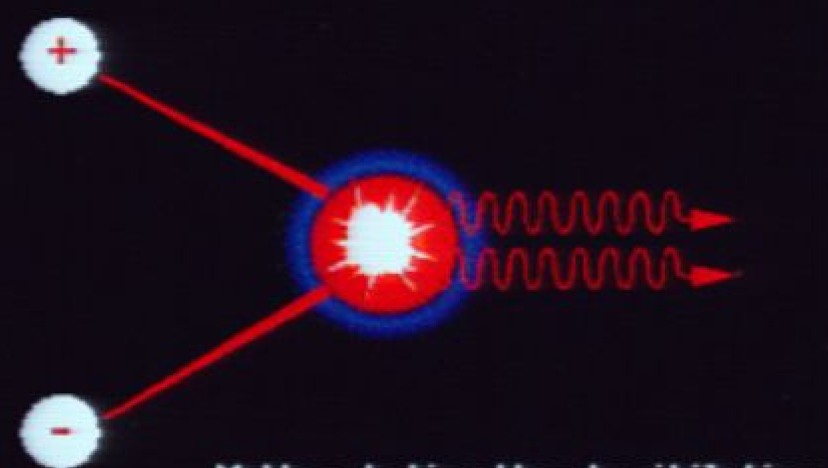

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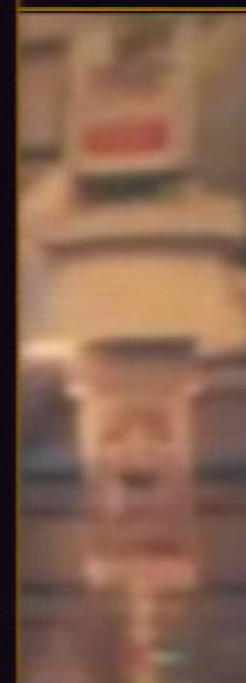

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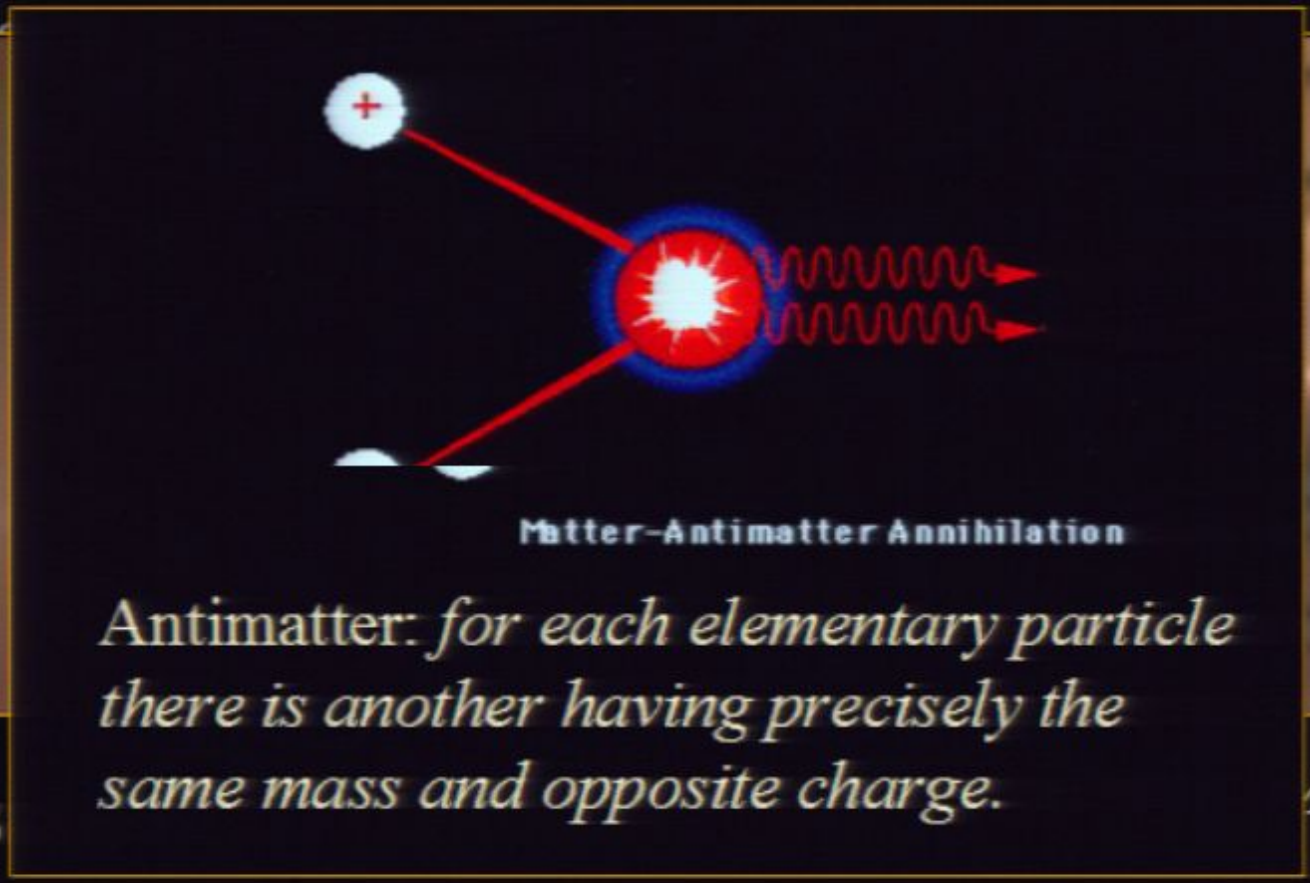

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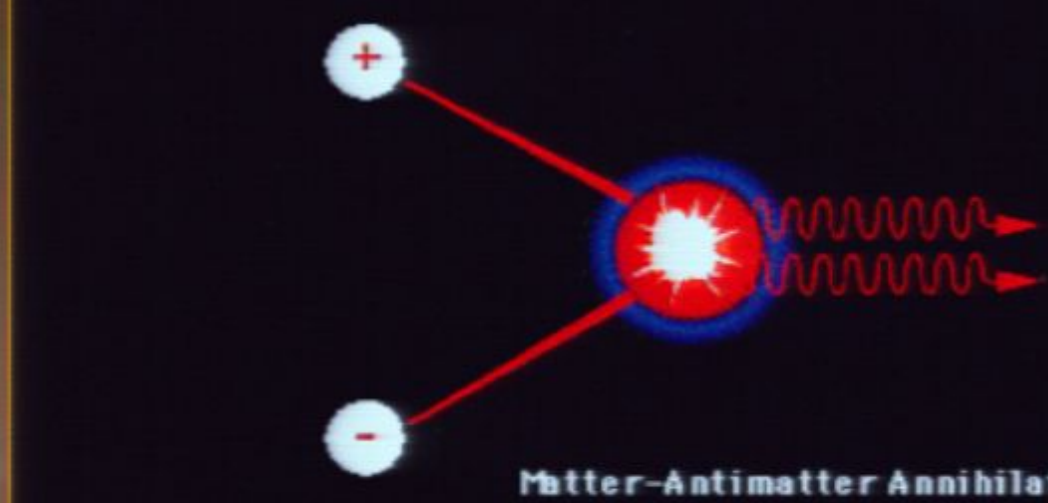

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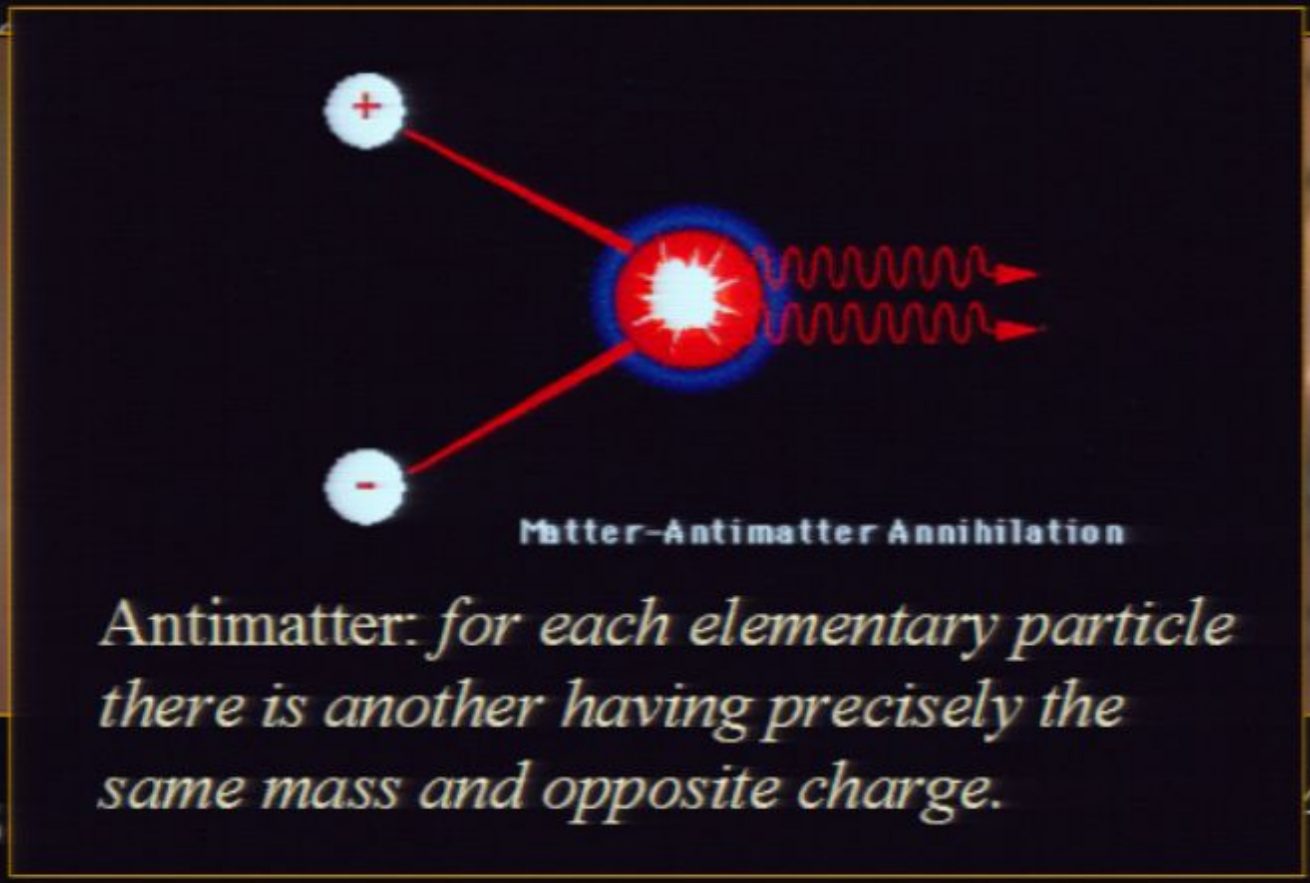

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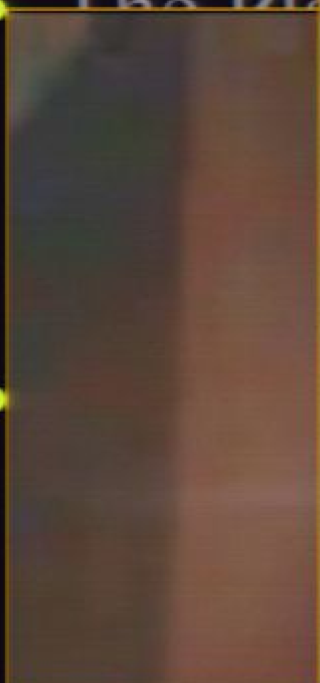

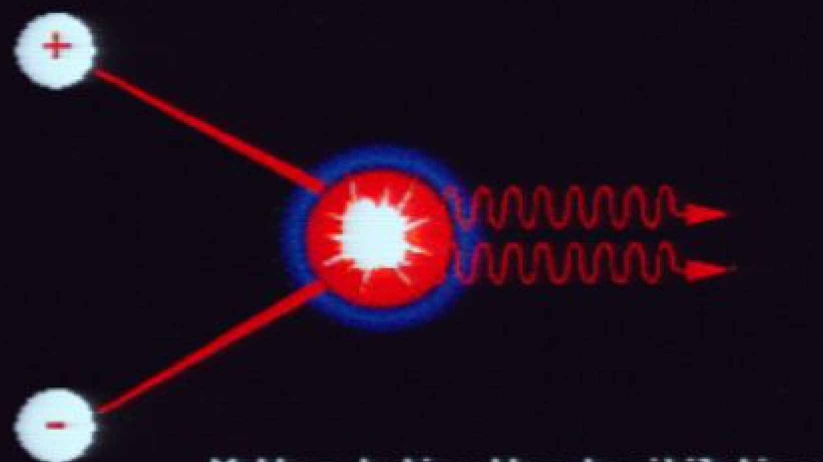

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- Scenes … Movie

The Movie

- The Pl

Accelerators make as much antimatter as matter whenever particles collide.

- *Scenes*
- Scenes

The Movie

- The Pl

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Left to itself antimatter annihilates with matter, so is very difficult to collect and contain (but would be a powerful bomb).

- *Scenes*
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The Movie

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- *Scenes*

- Scenes

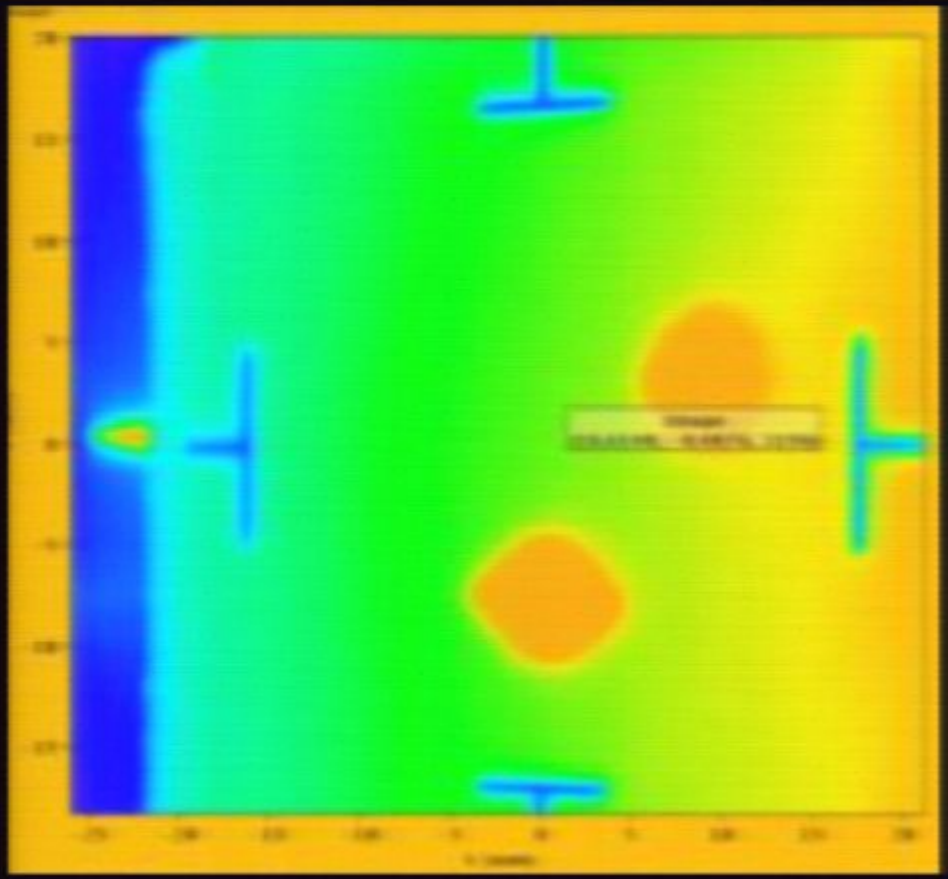
Accelerators make as much antimatter as matter whenever particles collide.

Left to itself antimatter annihilates with matter, so is very difficult to collect and contain (but would be a powerful bomb).

Each collision produces only a handful of antiparticles; years of effort were required to accumulate enough to make a few atoms of anti-hydrogen (destroyed after use).

The Machine

- The Accelera
- The Detector



Recent events

The Machine

W. Trischuk

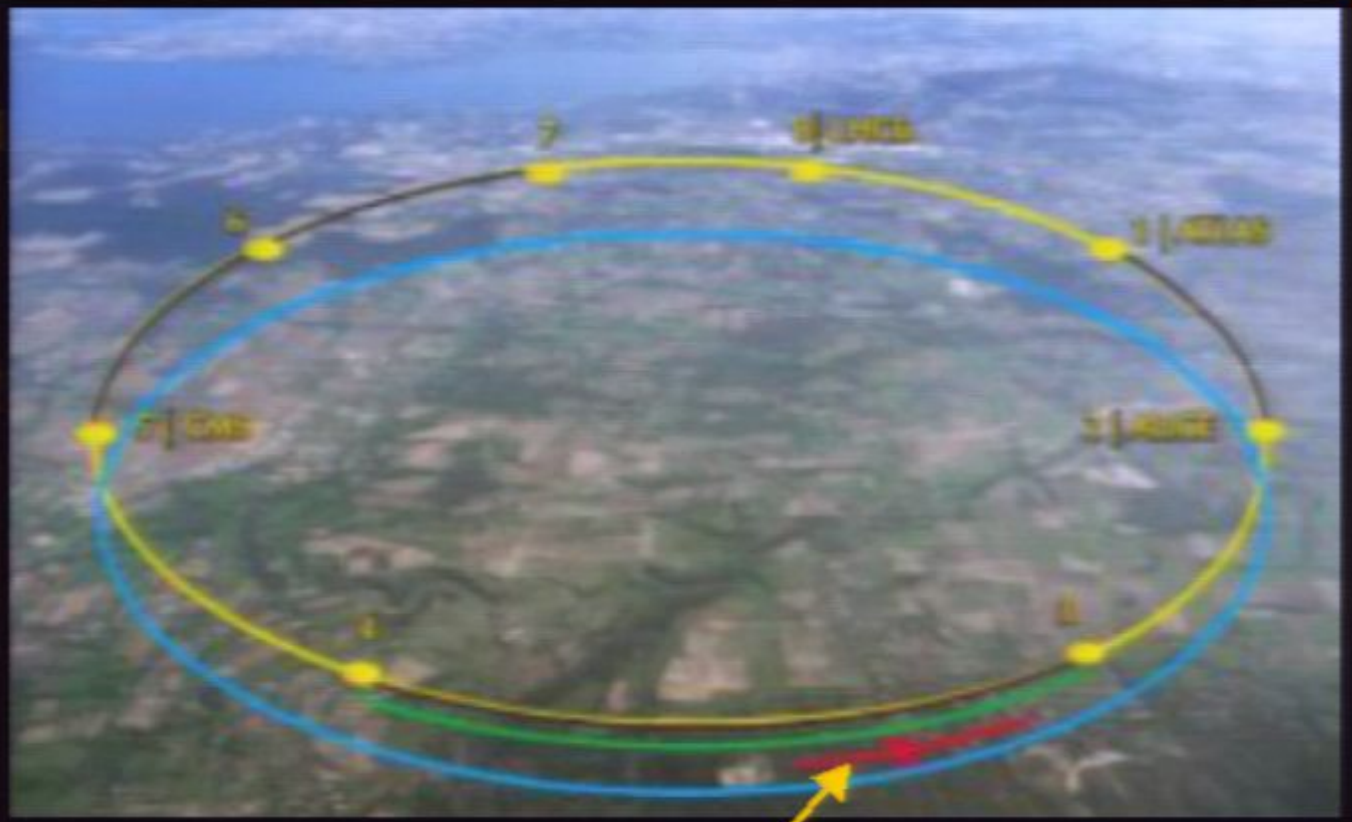
- The Accelera
- The Detector

mechanical damage

The Machine

W. Trischuk

- The Accelera
- The Detector



The Incident

The Machine

W. Trischuk

- The Accelera
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1200 superconducting magnets

The Machine

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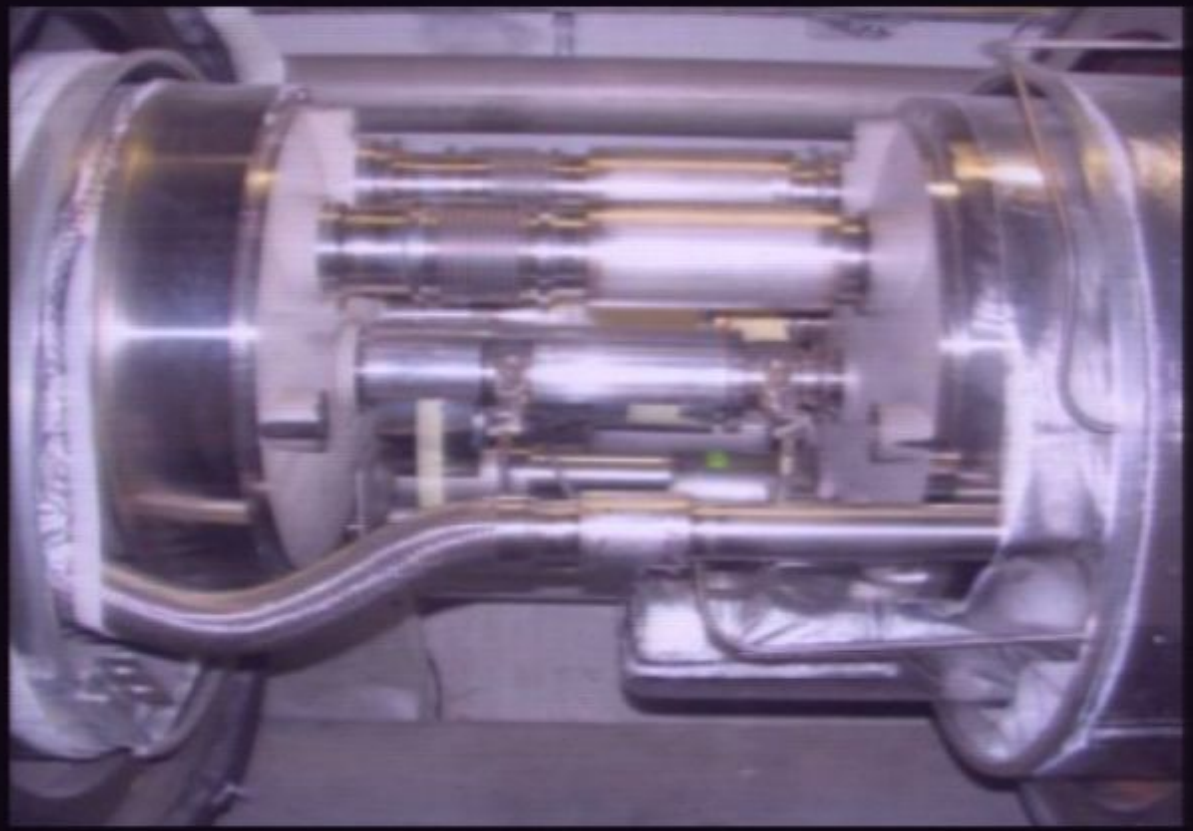


dipole interconnect

The Machine

W. Trischuk

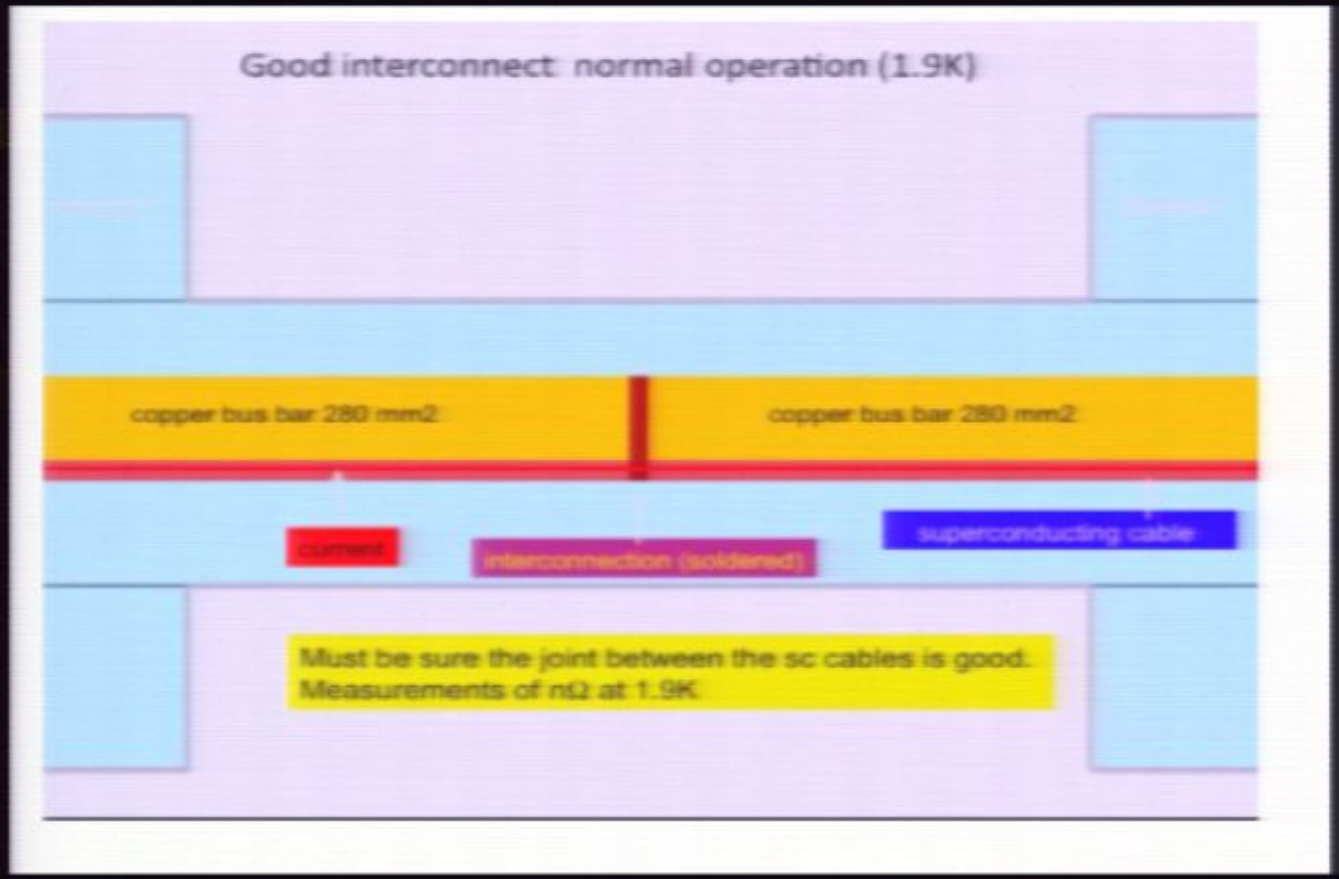
- The Accelera
- The Detector

dipole interconnect

The Machine

W. Trischuk

- The Accelera
- The Detector

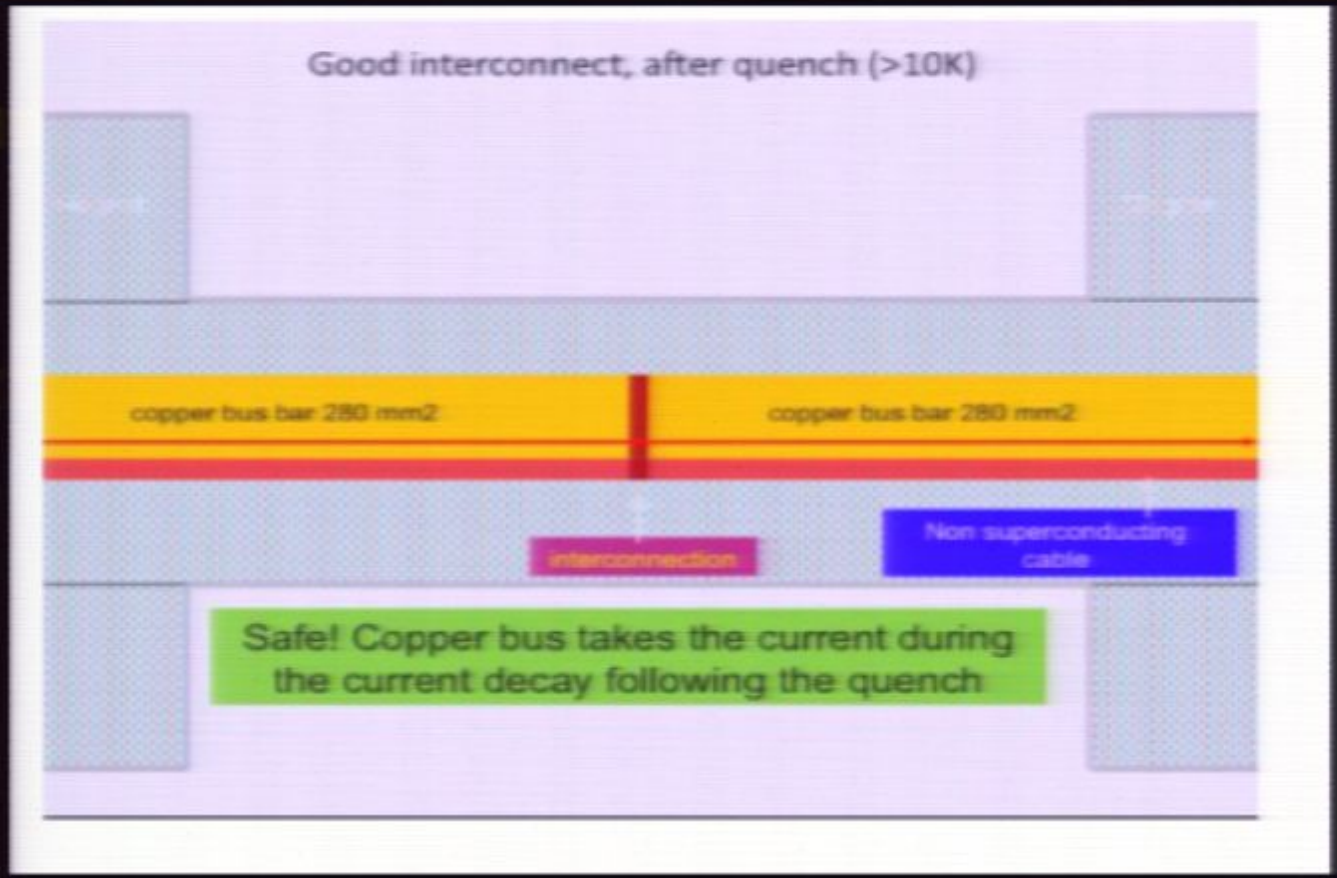


schematic connection

The Machine

W. Trischuk

- The Accelera
- The Detector



schematic connection

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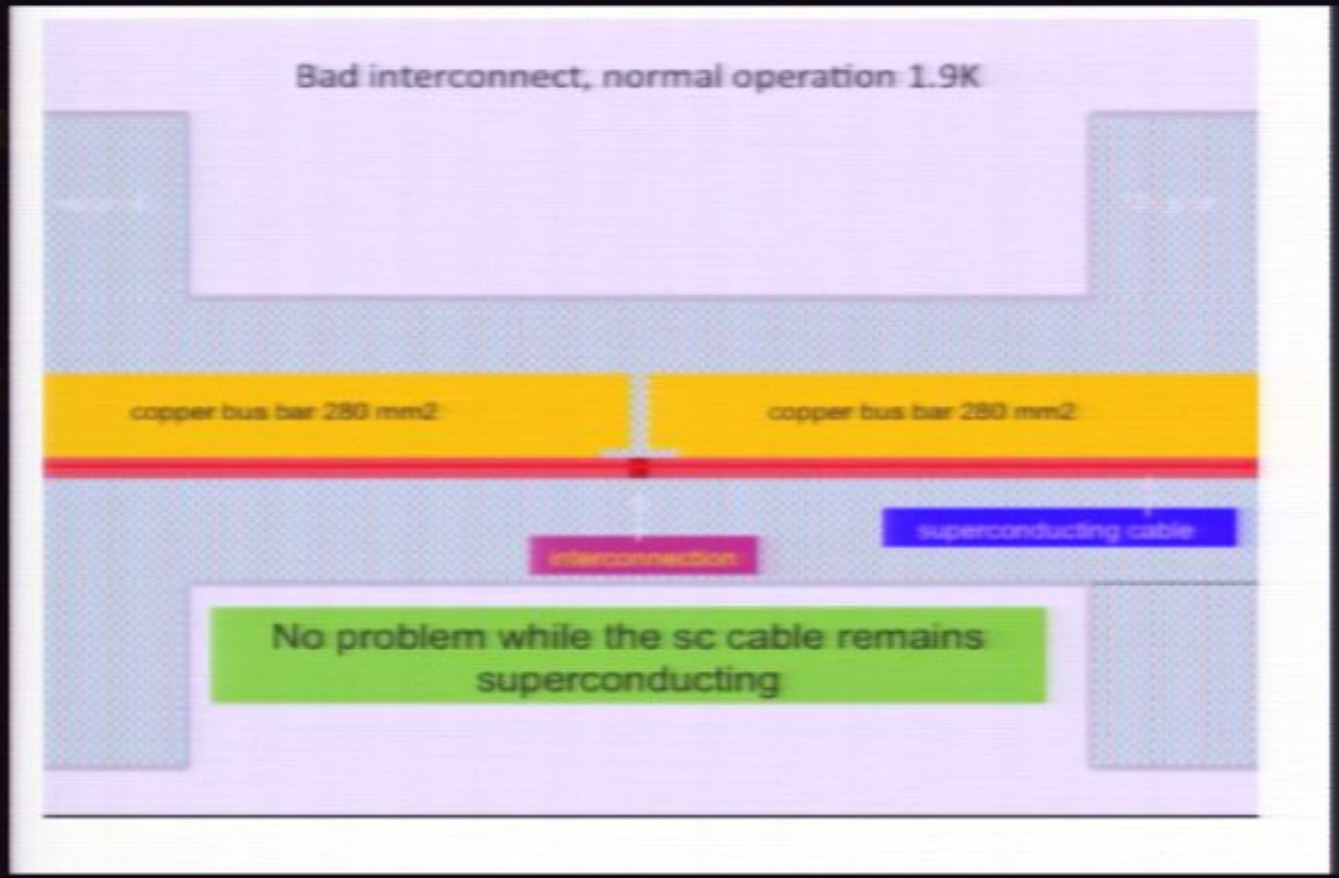

schematic connection

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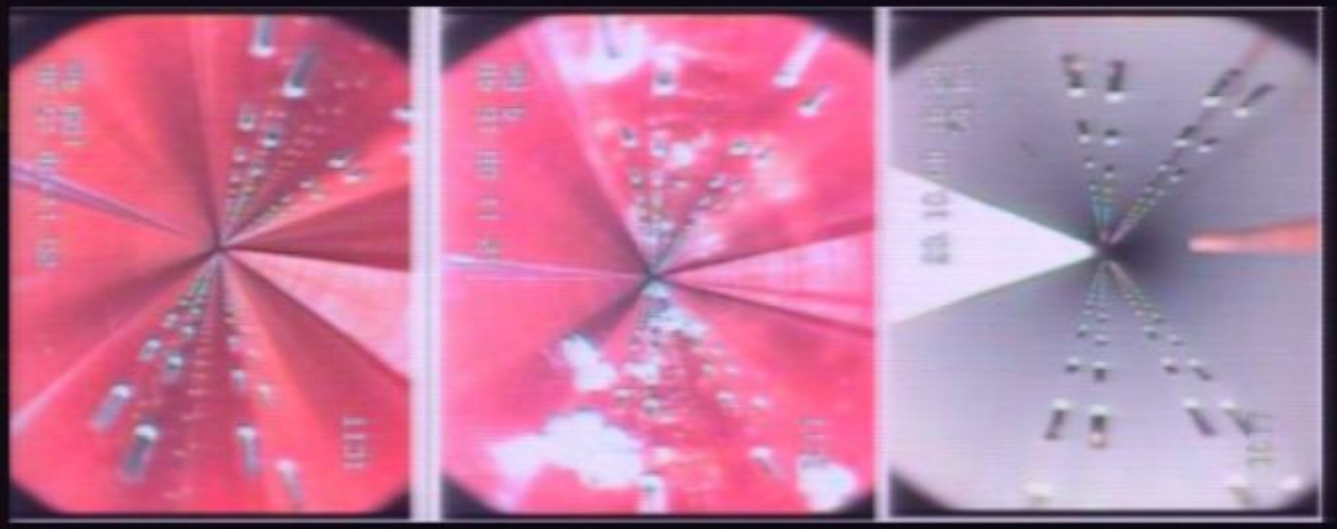

soot in the beam pipe

(normal copper looks red)

The Machine

W. Trischuk

- The Accelera
- The Detector

Replaced 14 quadrupoles and 29 dipoles,
34 interconnections fully repaired

The Machine

W. Trischuk

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- The Detector

Circuit	Sector 12	Sector 23	Sector 34	Sector 45	Sector 56	Sector 67	Sector 78	Sector 81
RB	300		300, 300	300, 300	300	300, 300		
RB		80		80			80	80
RQ	300		300	300	300	300, 300		
RQ		80		80			80	80, 80

- Huge effort of dedicated measurement teams
  - About 35000 manual measurements
  - Over 400 kilometers walked in the tunnel

Some sectors remain cold

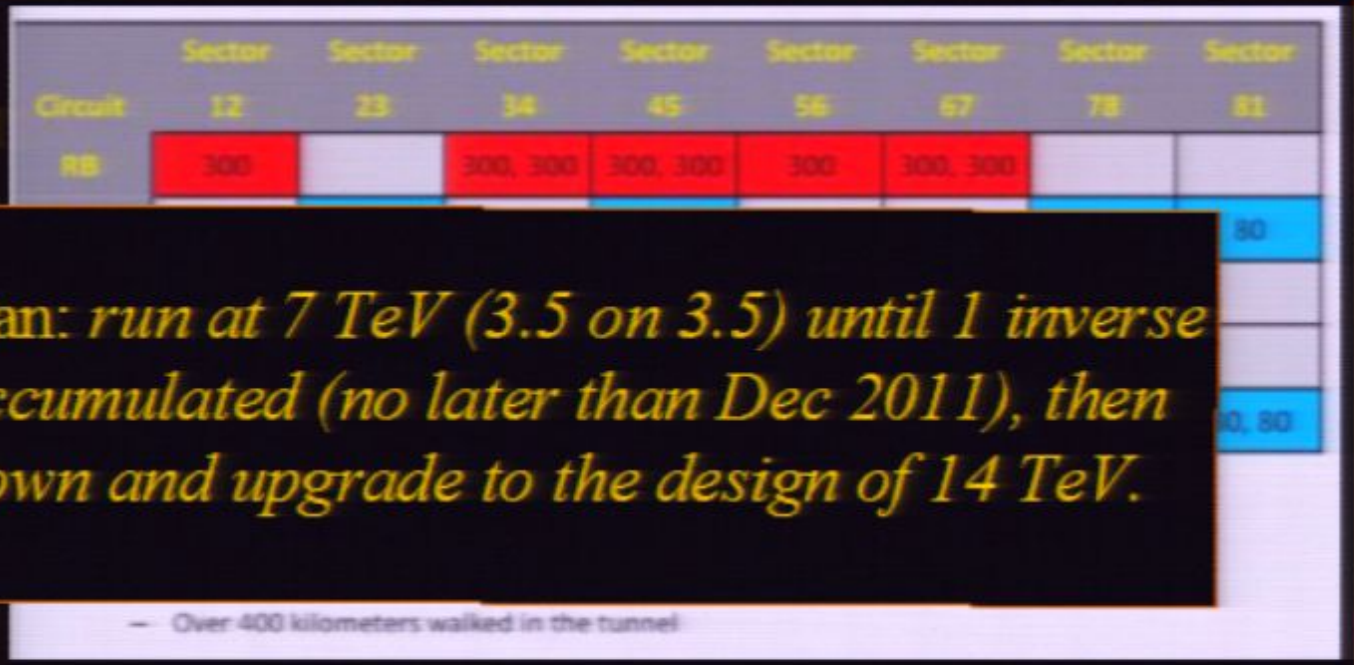
Takes months to heat and recool and there is not enough storage for the He

The Machine

W. Trischuk

- The Accelera
- The D

The Plan: *run at 7 TeV (3.5 on 3.5) until 1 inverse fb is accumulated (no later than Dec 2011), then shut down and upgrade to the design of 14 TeV.*



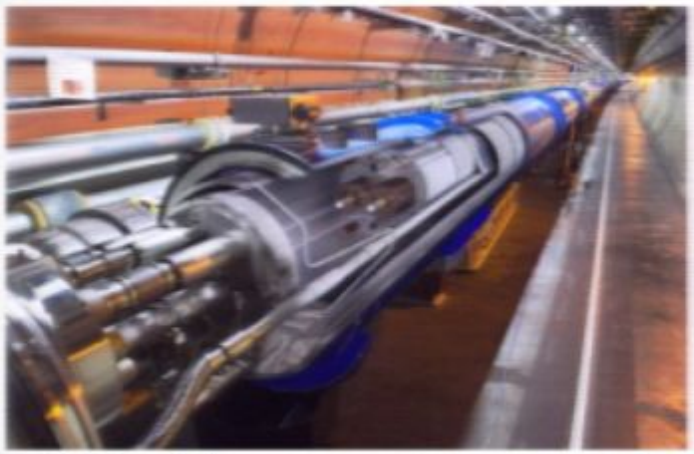
Some sectors remain cold

Takes months to heat and recool and there is not enough storage for the He

The Machine

- The Accelera
- The Detector

20.11.2009: LHC about to restart



The LHC tunnel. Illustration shows the beampipes inside a dipole magnet. [M.Brice, CERN]

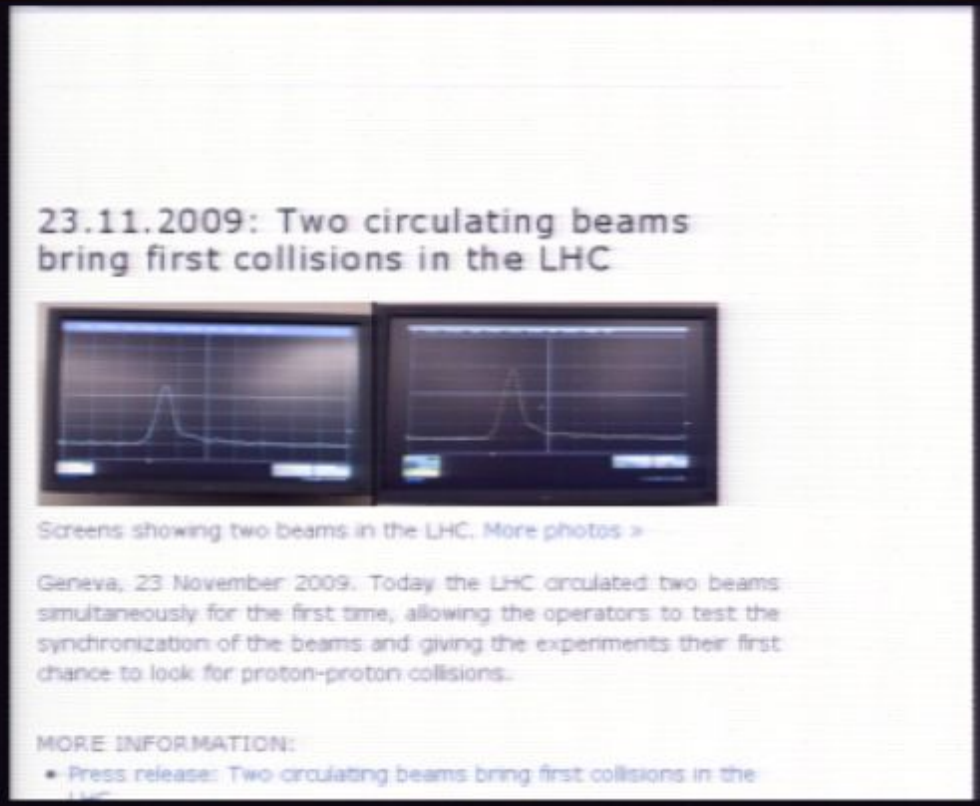
On 18 November, the LHC was handed over for operation. Teams are now preparing for injecting and circulating the first beams of 2009.

For latest updates, follow us on Twitter: twitter.com/cern

The LHC is now back!

The Machine

- The Accelera
- The Detector



23.11.2009: Two circulating beams bring first collisions in the LHC

Screens showing two beams in the LHC. More photos »

Geneva, 23 November 2009. Today the LHC circulated two beams simultaneously for the first time, allowing the operators to test the synchronization of the beams and giving the experiments their first chance to look for proton-proton collisions.

MORE INFORMATION:

- Press release: Two circulating beams bring first collisions in the

The LHC is now back!

The Machine

- The Accelera
- The Detector

30 November 2009

LHC sets new world record

Scenes of joy in the CERN Control Centre more photos »

Geneva, 30 November 2009. CERN's Large Hadron Collider has today become the world's highest energy particle accelerator, having accelerated its twin beams of protons to an energy of 1.18 TeV in the early hours of the morning. This exceeds the previous world record of 0.98 TeV, which had

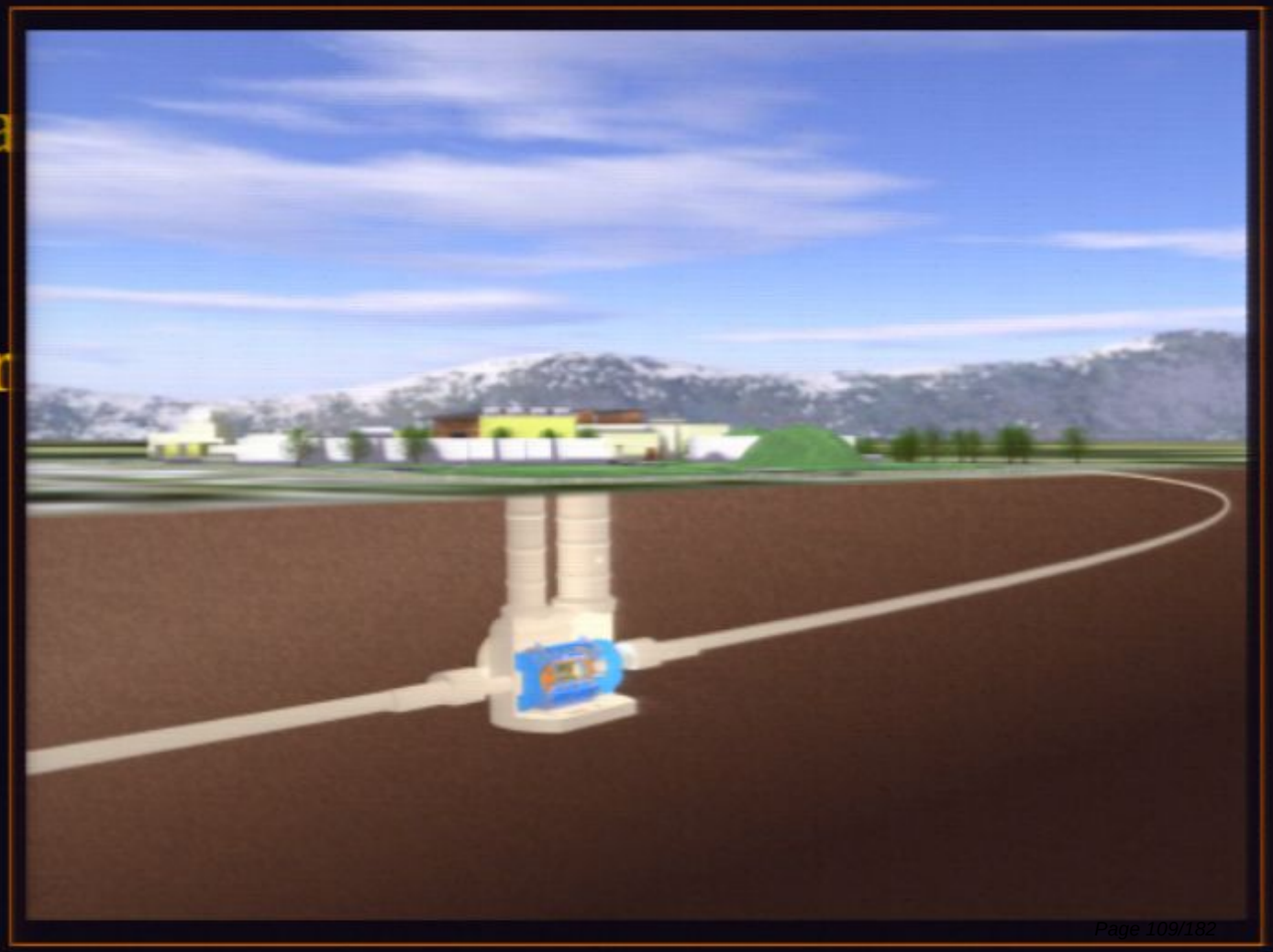
The LHC is now back!

The Machine

- The Accelerator
- The Detectors

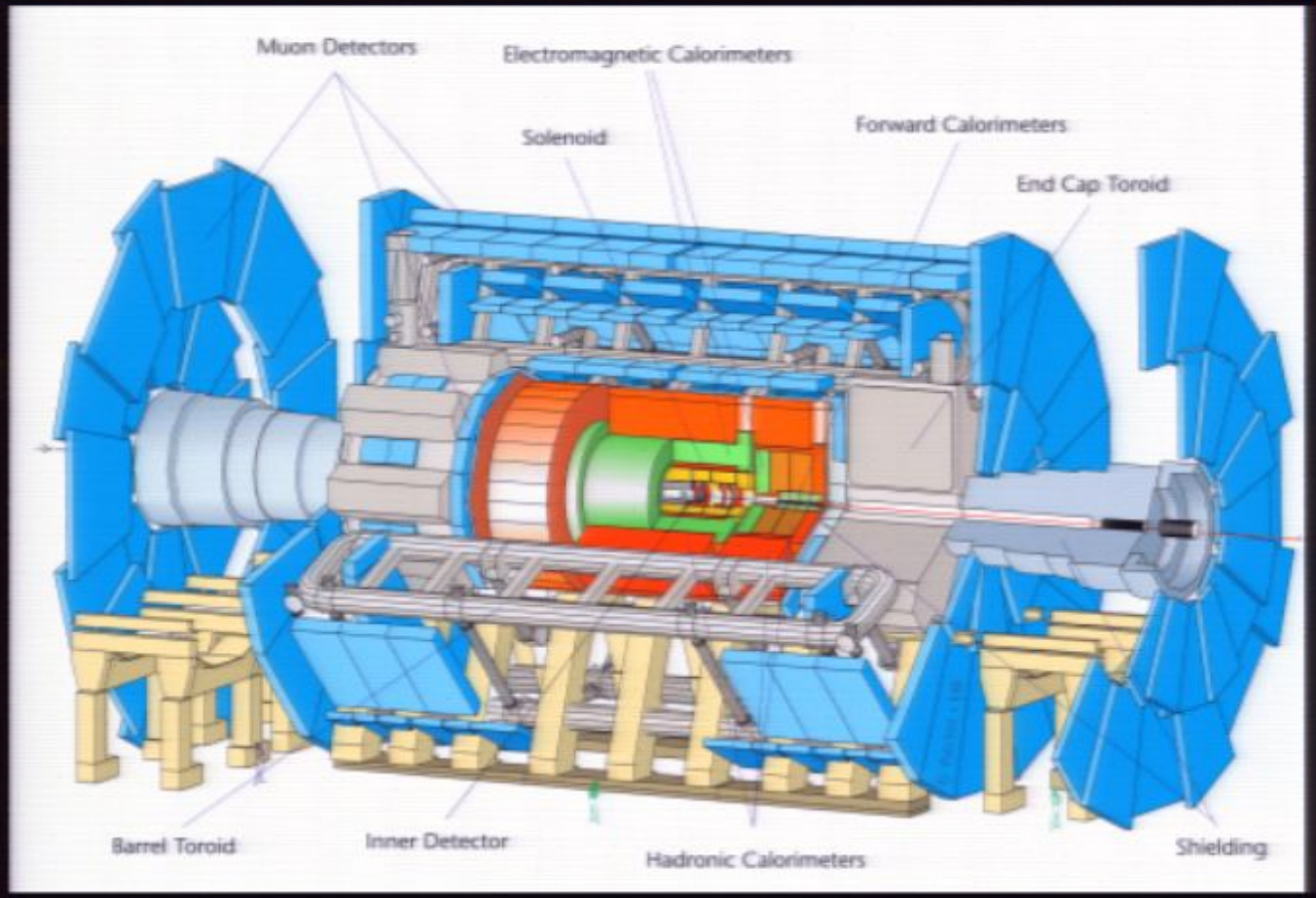
The Machine

- The Accelera
- The Detector



The Machine

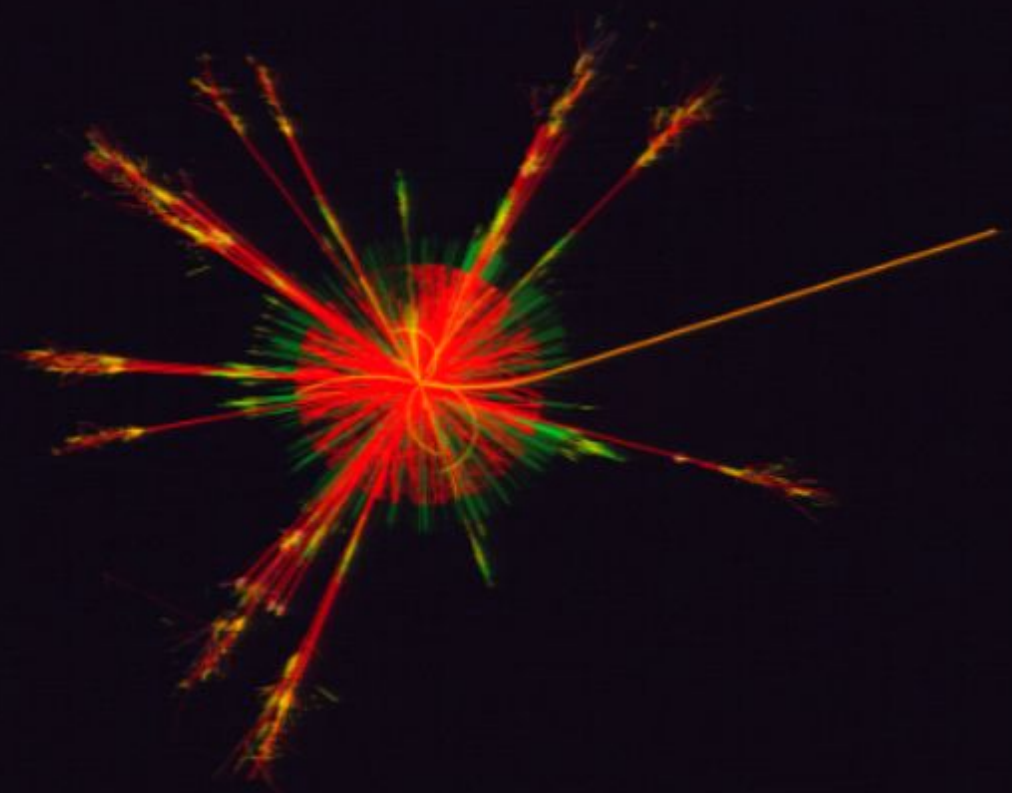
- The Accelera
- The Detector

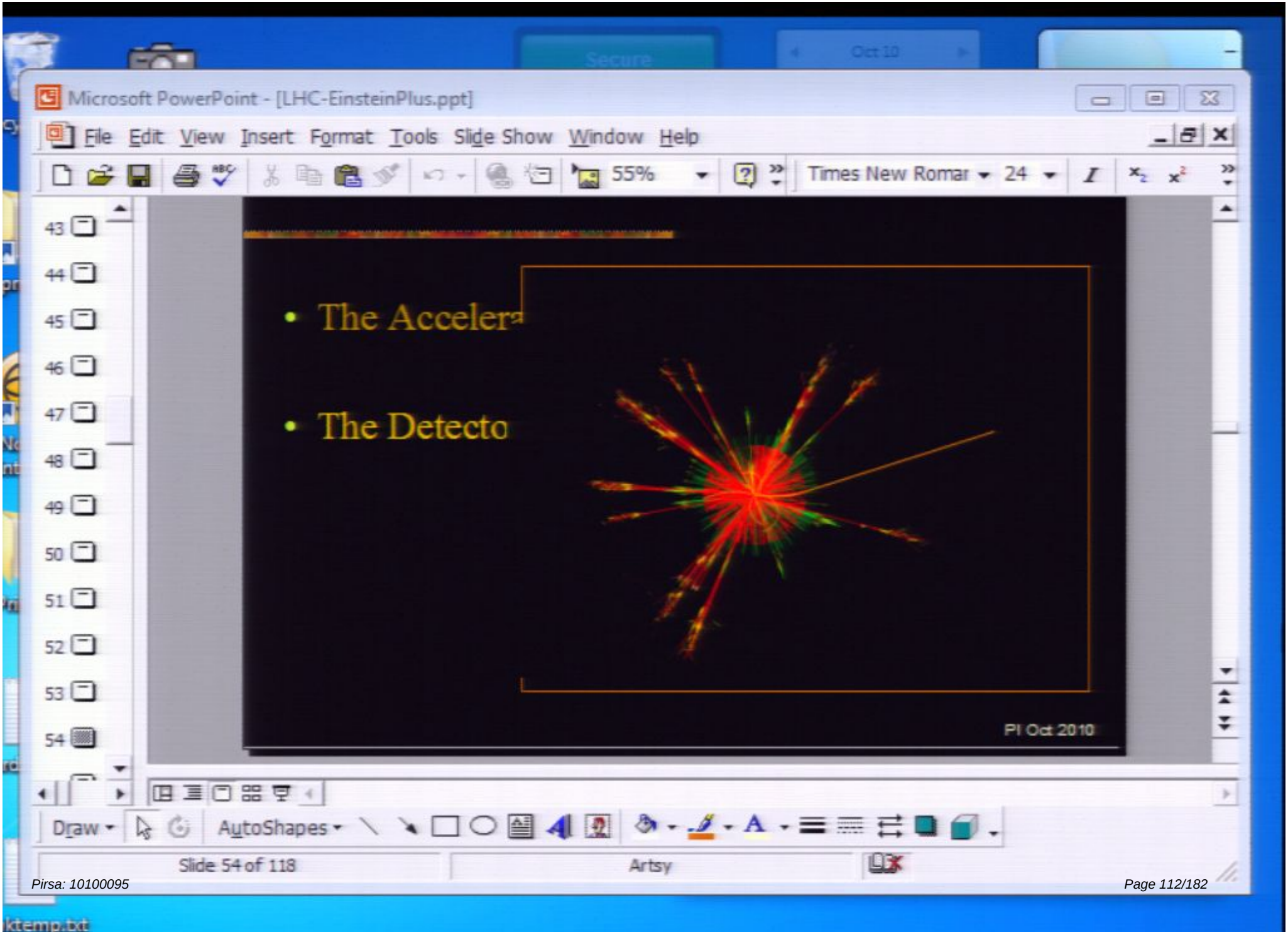


The ATLAS Detector

The Machine

- The Accelera
- The Detecto

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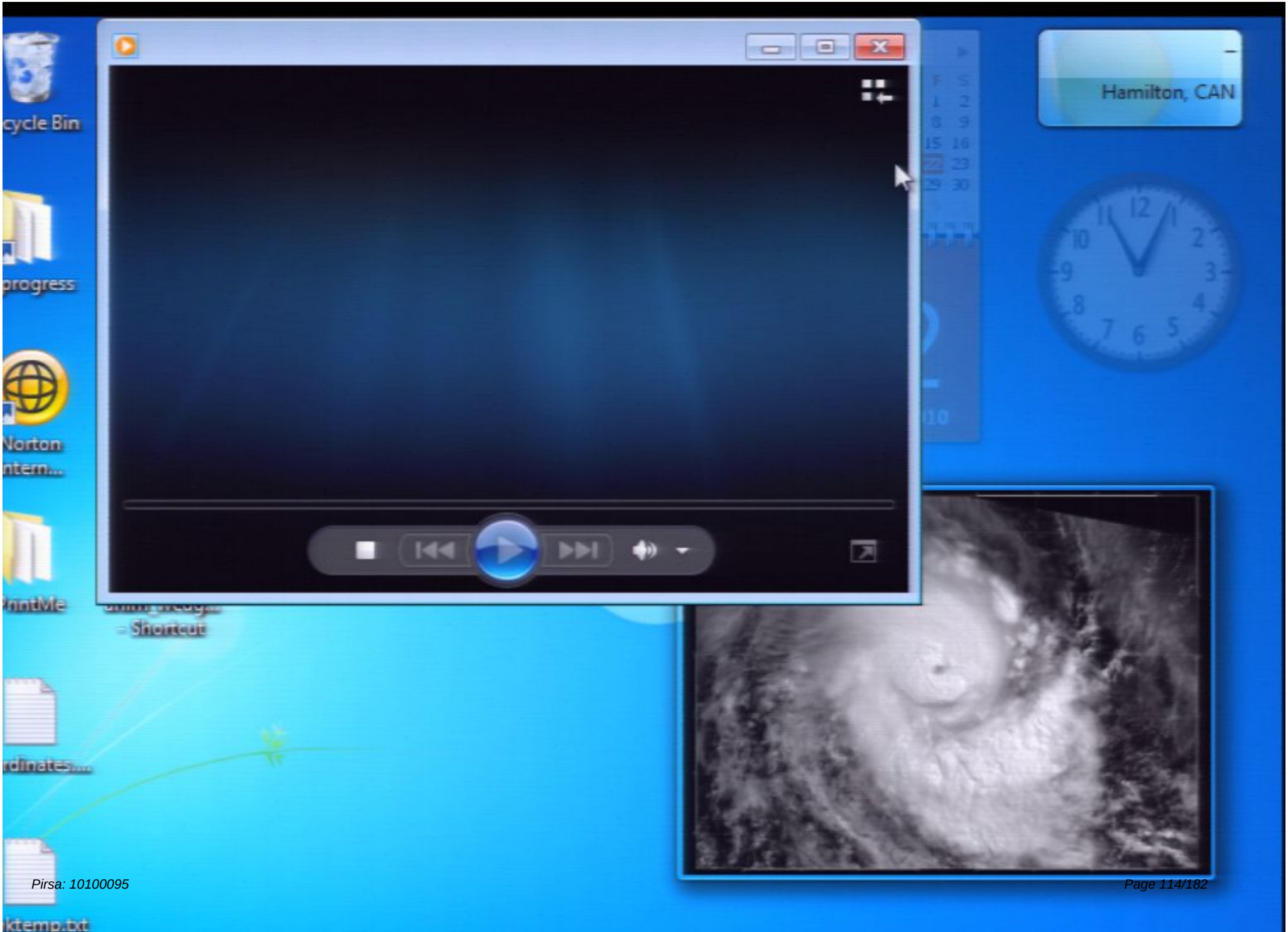
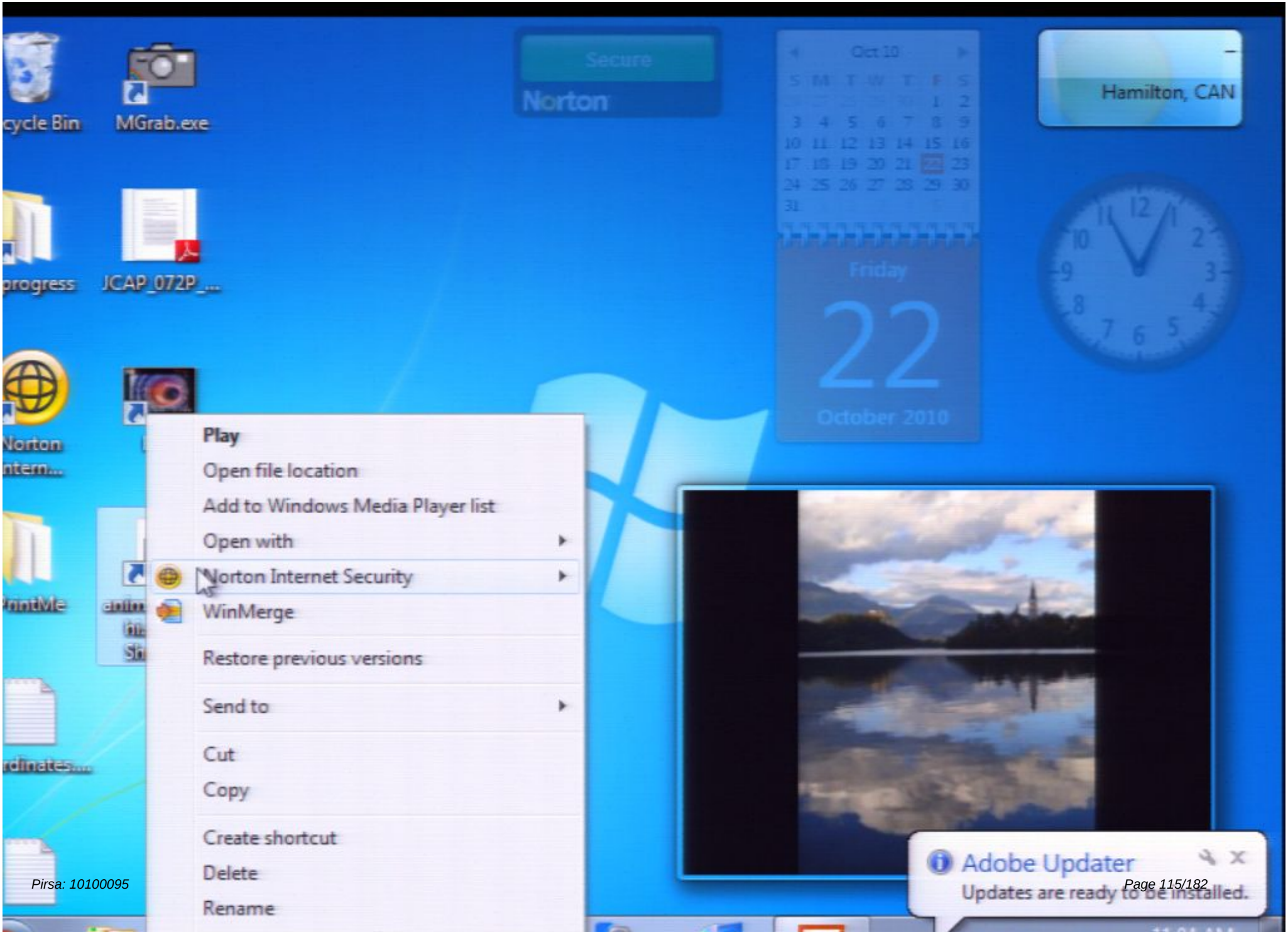
October 2010


Hamilton, CAN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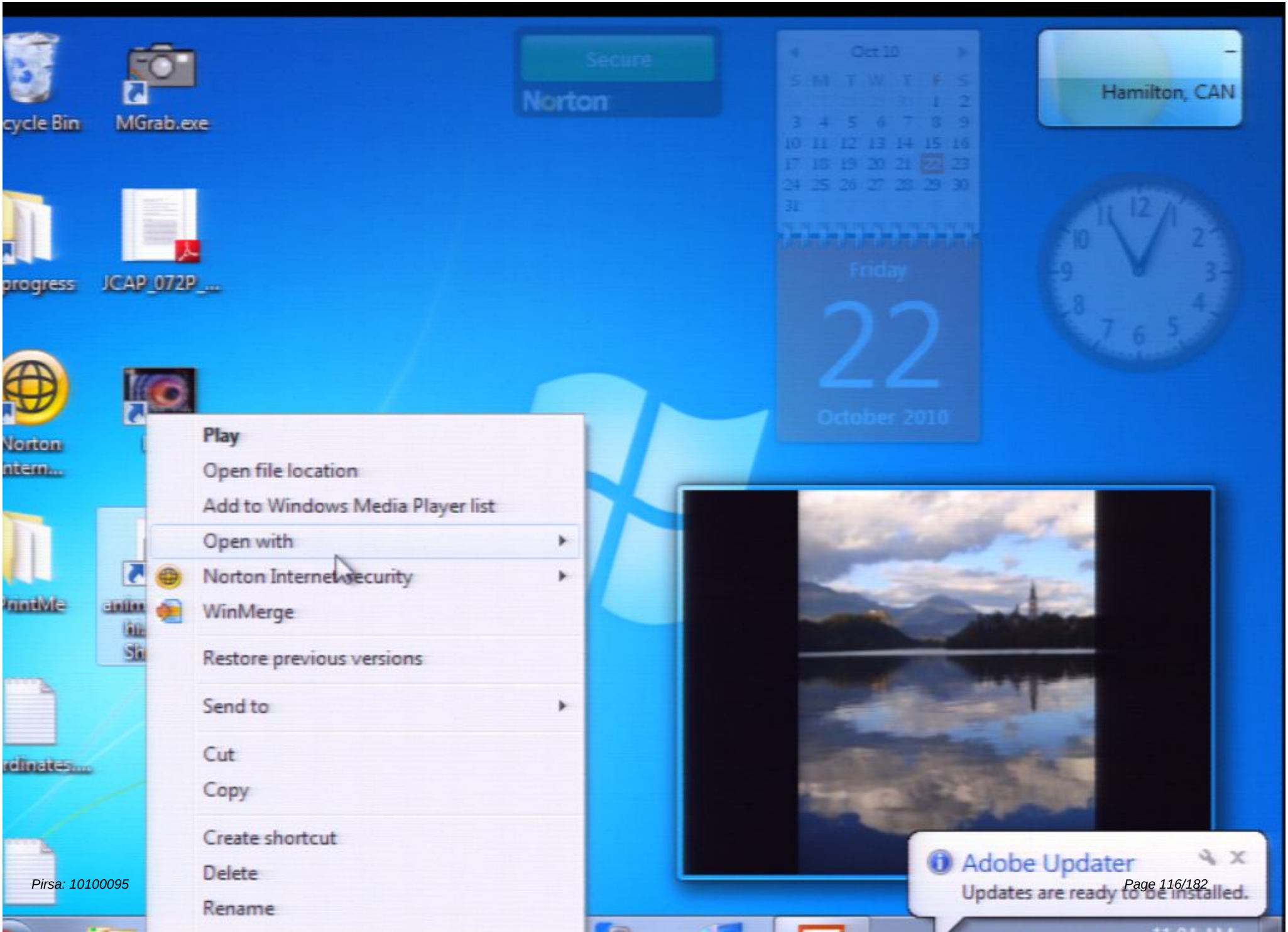
Updates are ready to be installed.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October 2010
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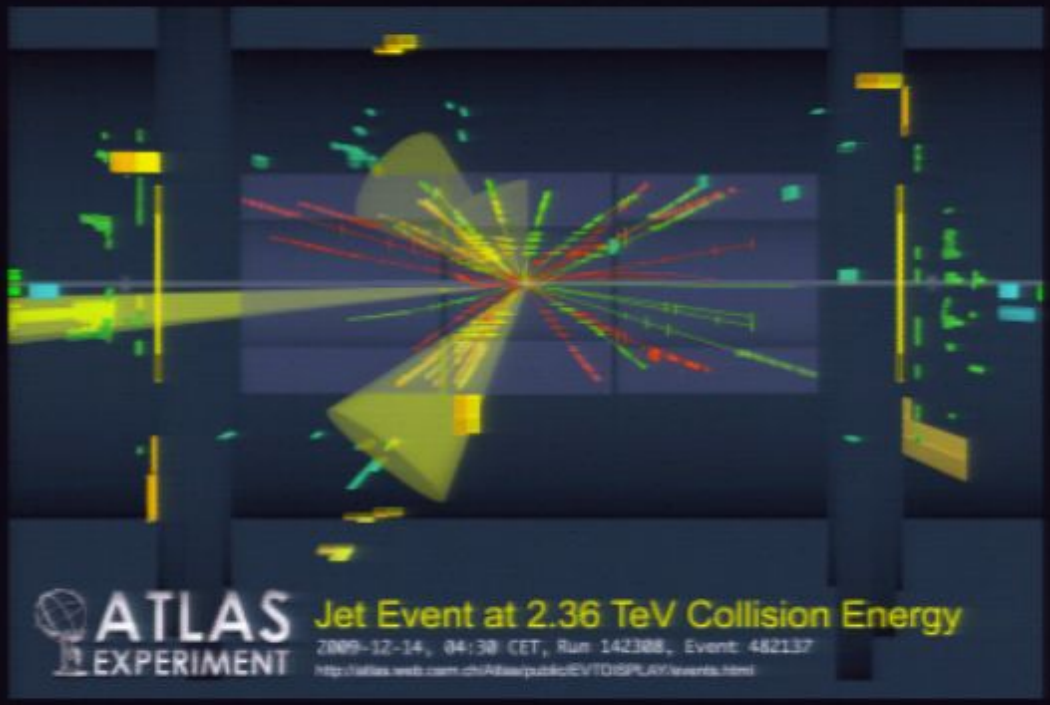
The Machine

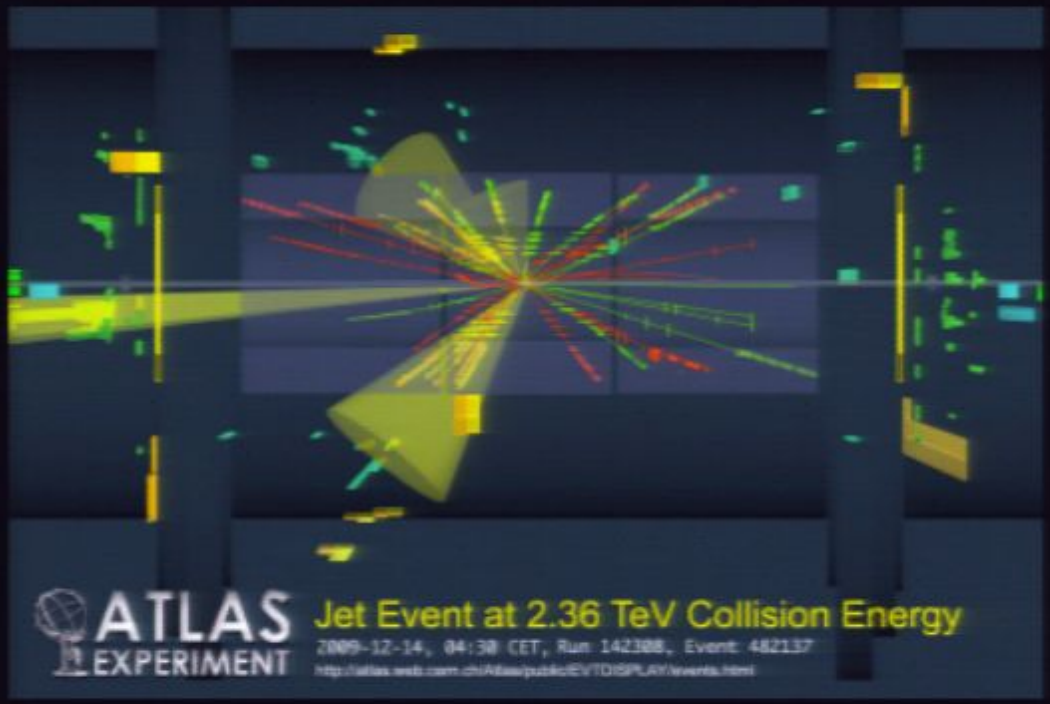
- The Accelera
- The Detector



The detectors have been recording data

The Machine

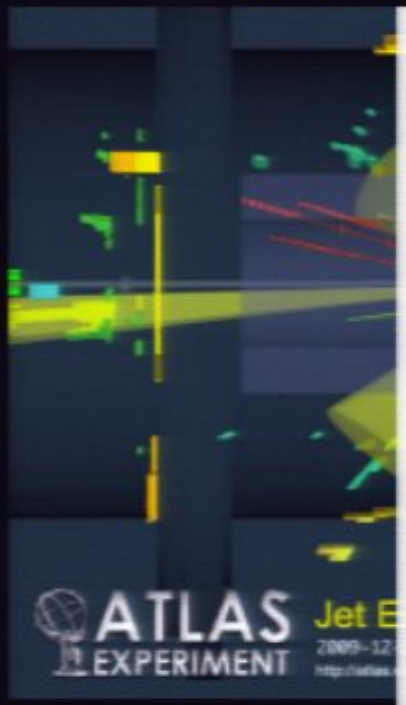
- The Accelera
- The Detector

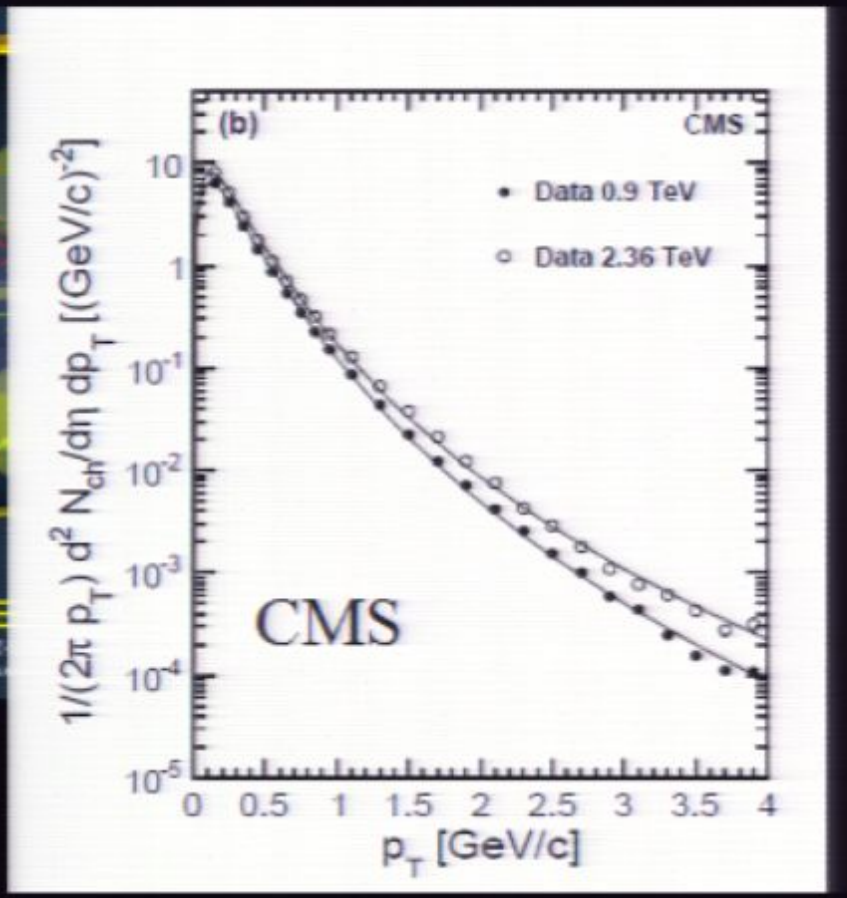


The detectors have been recording data

The Machine

- The Accelera
- The Detector





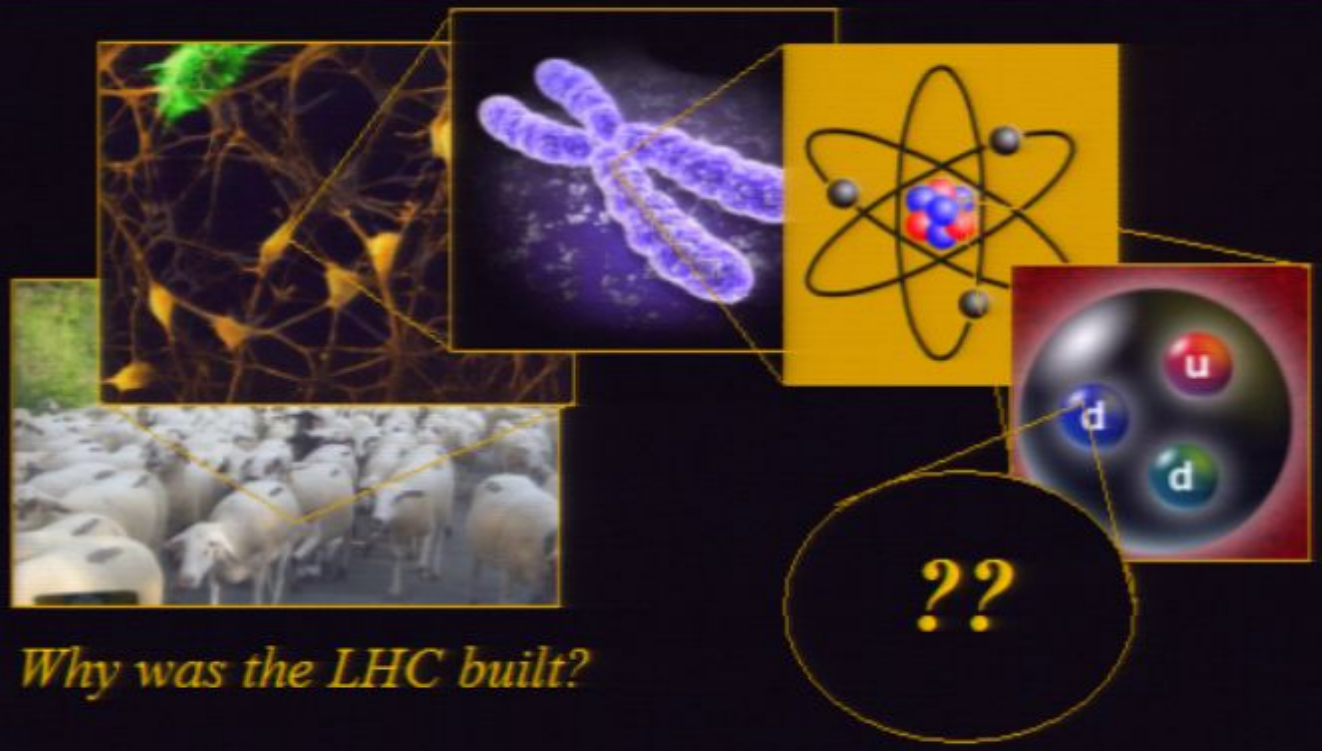
The first papers have come out

Outline

- What is it?
  - *The machine*
- Why was it built?
  - *The Standard Model and its limitations*
- What might it hope to see?
  - *Problems*
- Outlook

Outline

- What is it?
  - *The machi*
- Why was it
  - *The Stand*
- What might
  - *Problems*
- Outlook



Why was the LHC built?

Our presently successful understanding of elementary particles and the four forces through which they interact must break down at distances just out of reach.

The Standard Model

- The particles and interactions
- Successes
- Limitations

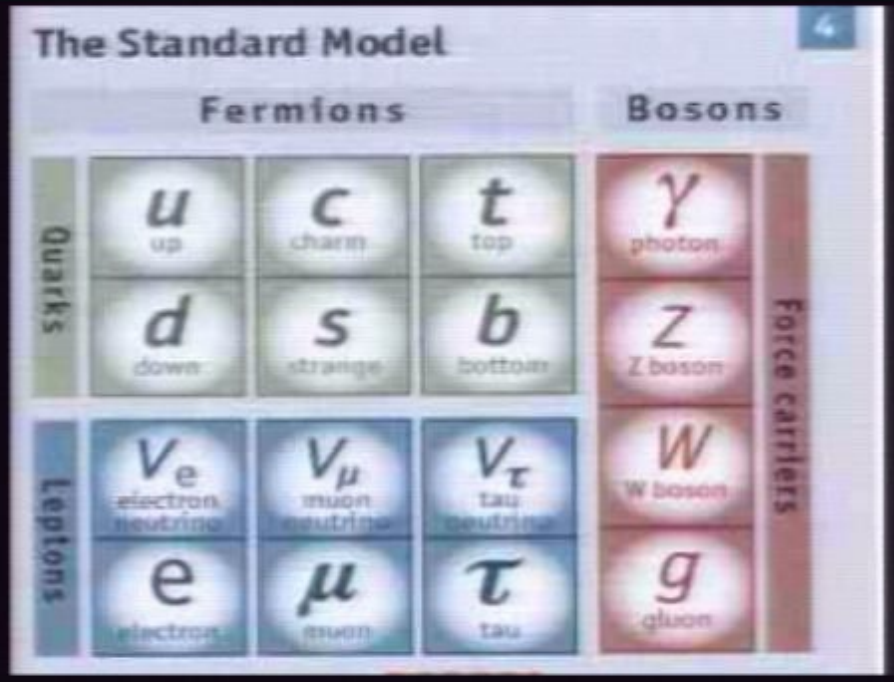
The Standard Model

- The particle interactions
- Successes
- Limitations

The Standard Model is the theory which describes the known elementary particles and their interactions. It describes well all experiments which have been performed to date, with a few recent exceptions.

The Standard Model

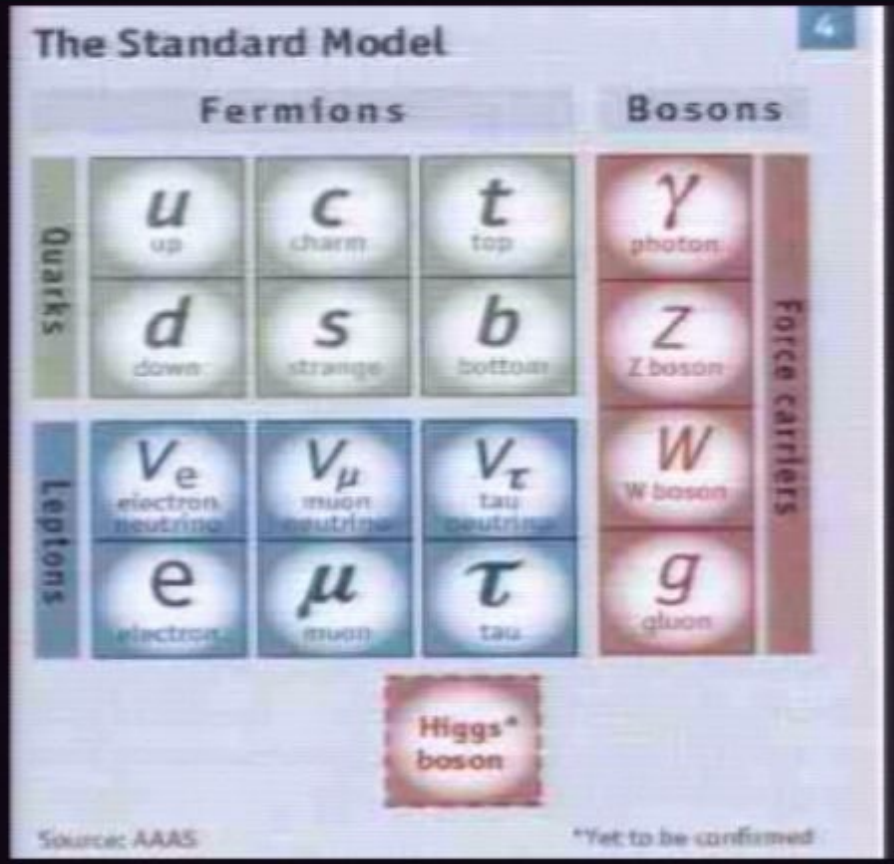
- The particles interactions
- Successes
- Limitations



The 12 known constituents of matter and the 4 fundamental forces

The Standard Model

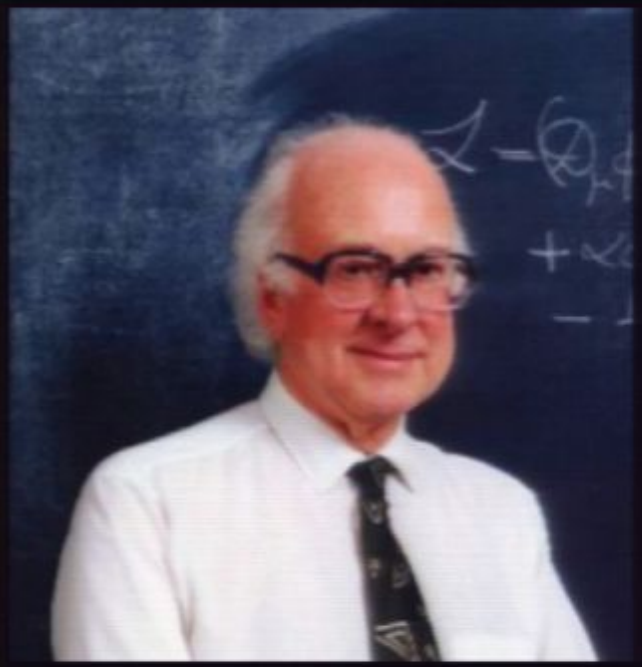
- The particles interactions
- Successes
- Limitations



One SM particle remains AWOL: the Higgs boson

The Standard Model

- The particles interactions
- Successes
- Limitations



The Higgs boson is inferred theoretically, because it is associated with the *Higgs mechanism*: the reason why all of the SM particles have any mass at all.

AAAS

The Standard Model

- The particles interactions
- Successes
- Limitations

The SM has a symmetry which requires all known particles to be massless. BUT, the vacuum has physical properties, which can break this symmetry.

AAAS

The Standard Model

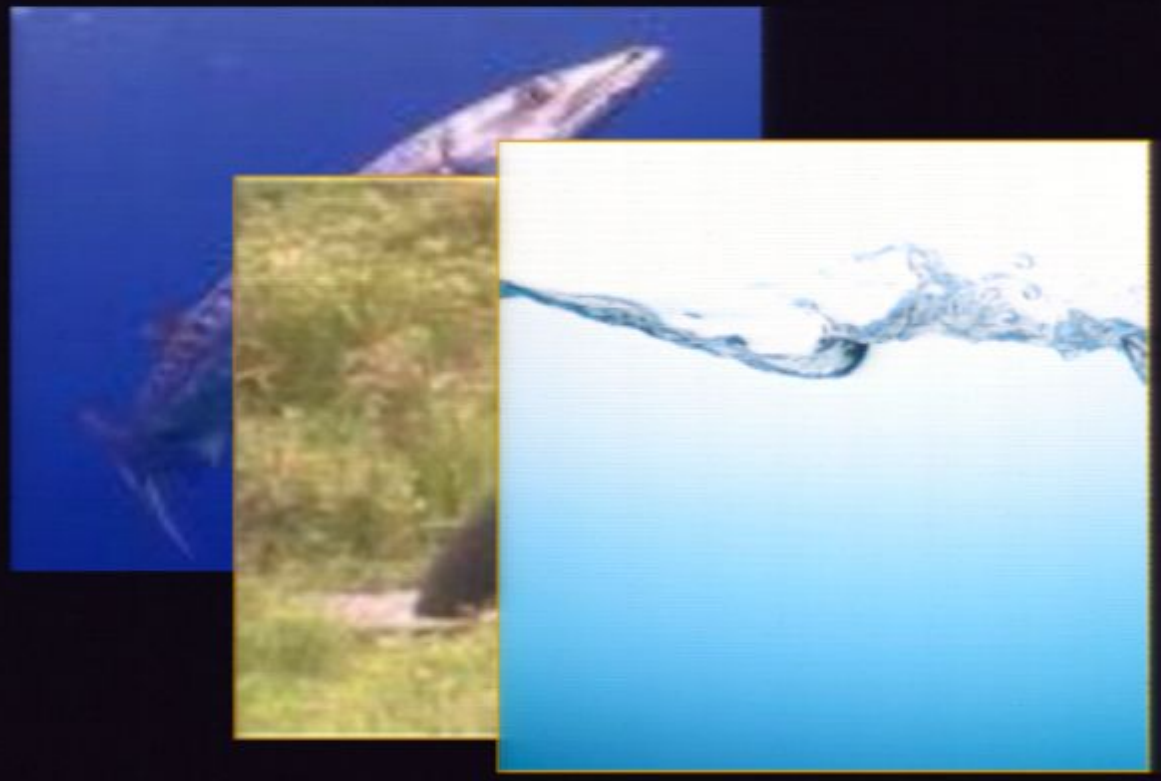
- The particles interactions
- Successes
- Limitations

Particle masses are due to the resistance of moving through the Higgs vacuum.

AAAS

The Standard Model

- The particles interactions
- Successes
- Limitations



The Higgs *particle* is a wave moving through this Higgs vacuum.

AAAS

The Standard Model

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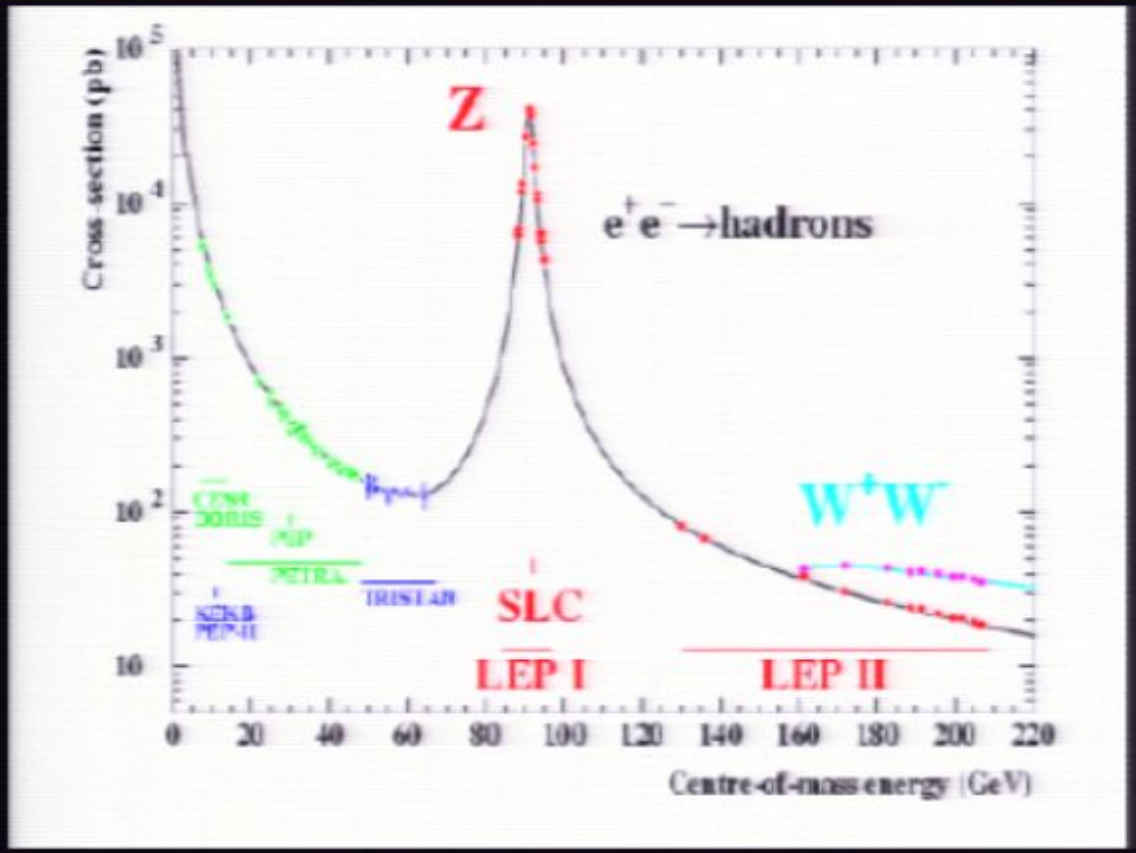
- Successes
- Limitations

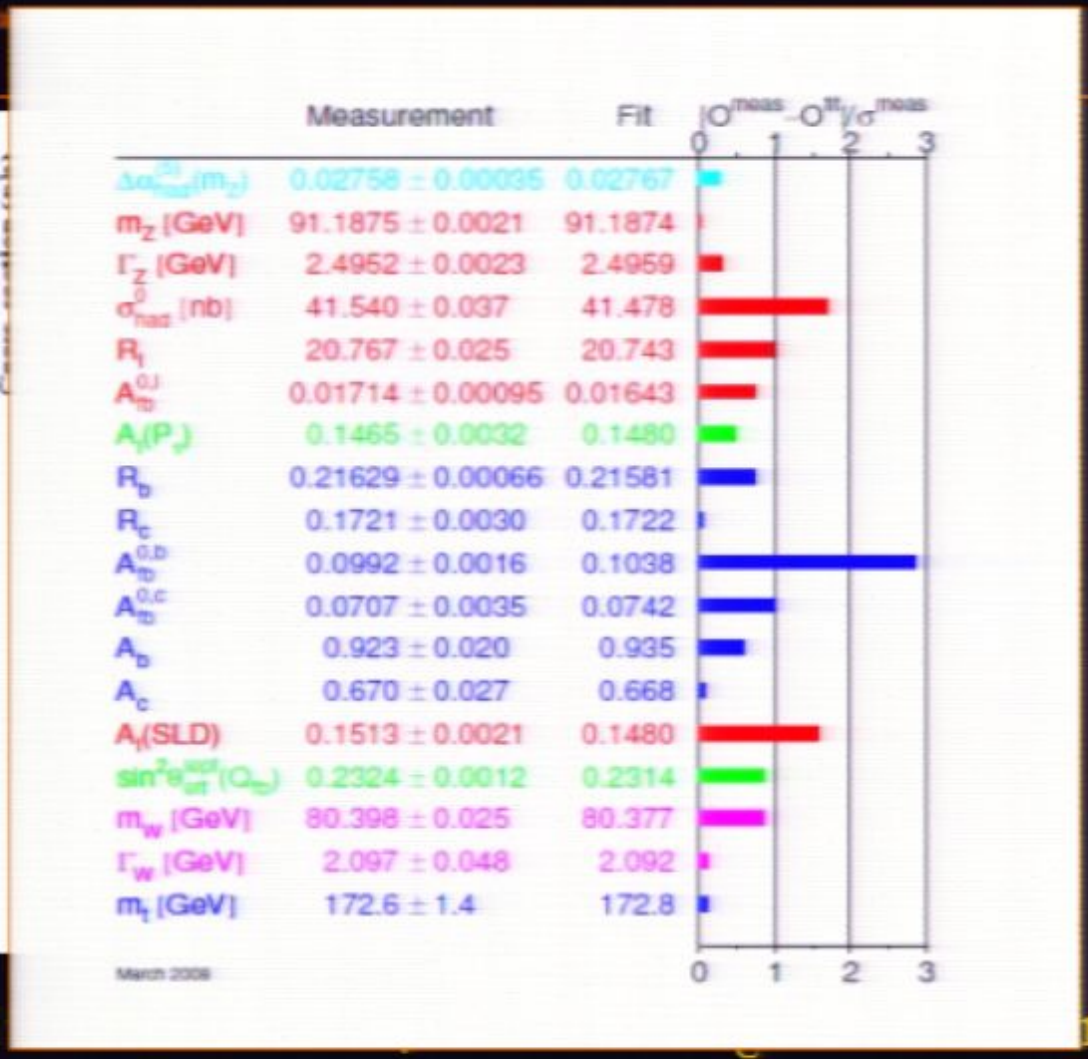


The SM is tested in detail, such as through e^+e^- collisions

A Tonazzo: Moriond 2002

The Standard Model

- The particles interactions
- Successes
- Limitations

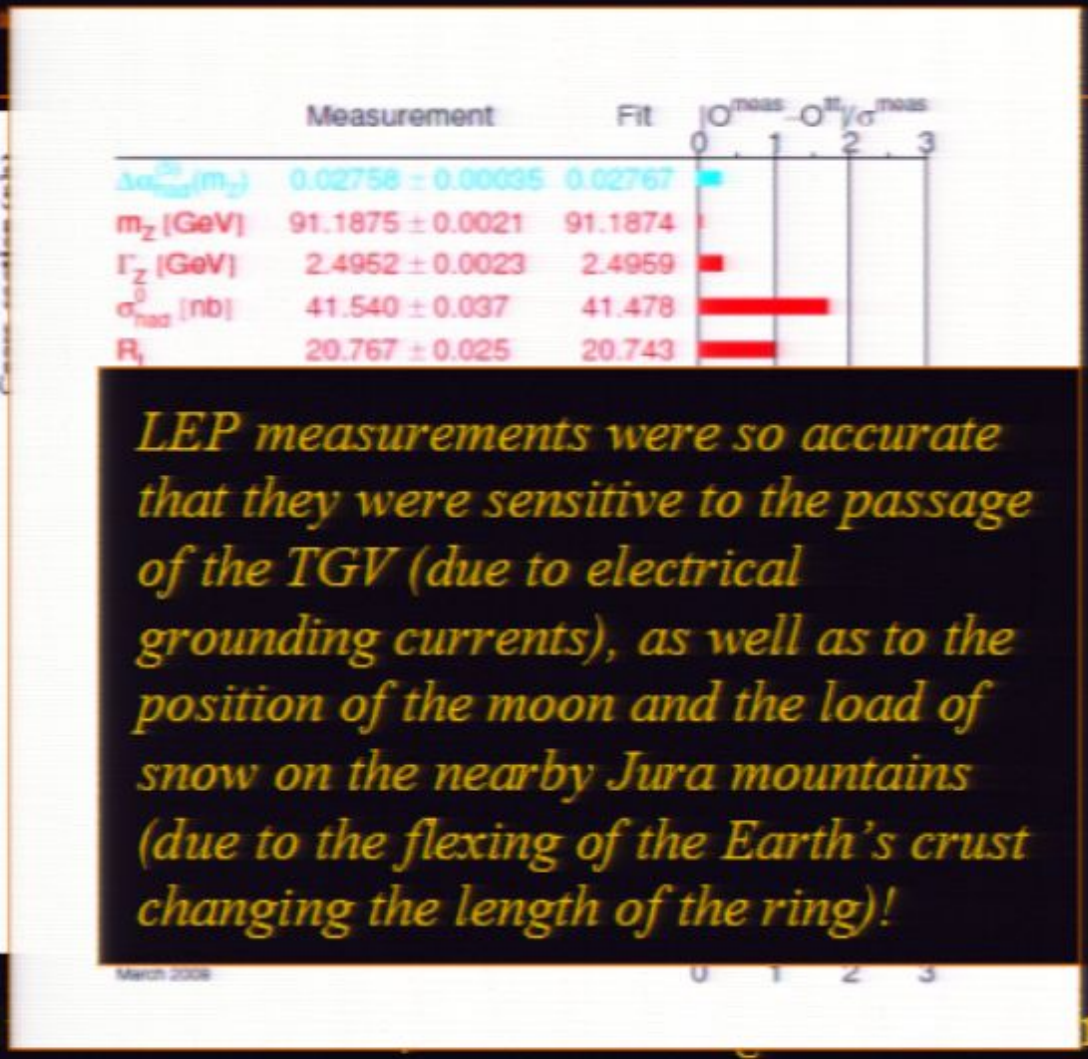


The SM ns

M. Verzocchi: ICHEP 2008

The Standard Model

- The particles interactions
- Successes
- Limitations



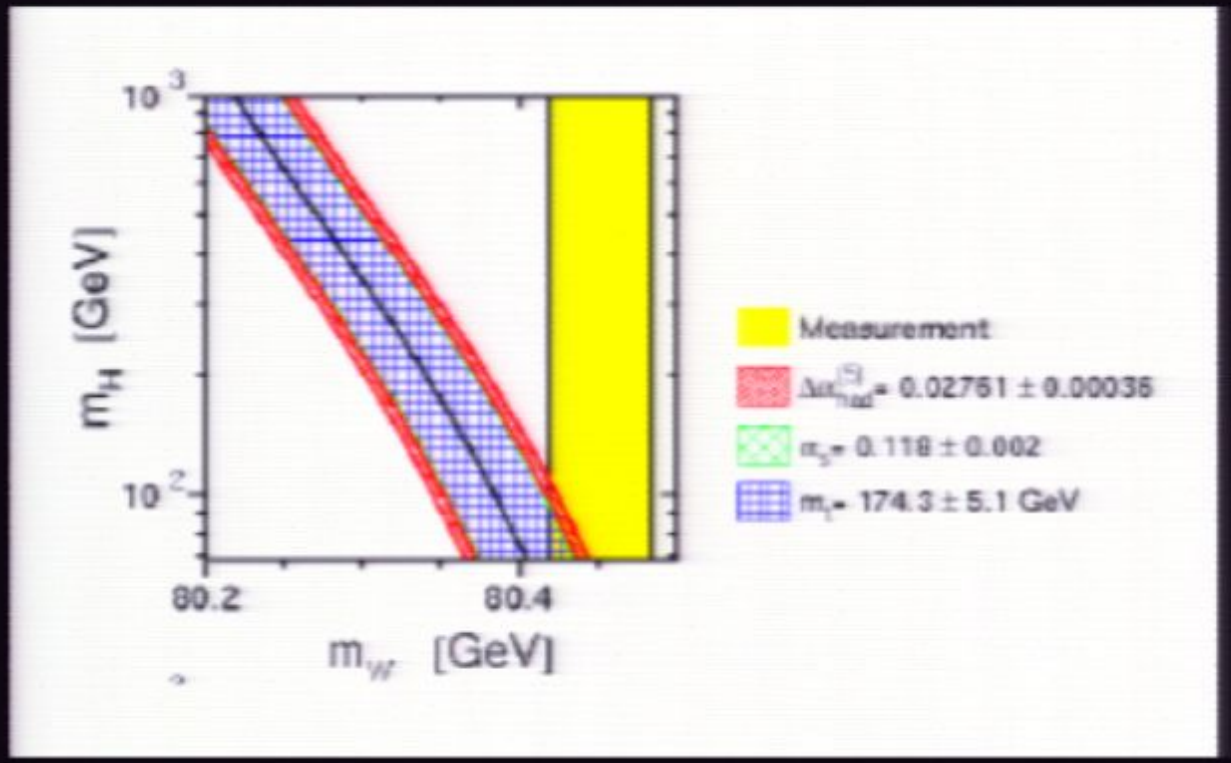
LEP measurements were so accurate that they were sensitive to the passage of the TGV (due to electrical grounding currents), as well as to the position of the moon and the load of snow on the nearby Jura mountains (due to the flexing of the Earth's crust changing the length of the ring)!

The SM ns

M. Vercegchi: ICHEP 2008

The Standard Model

- The particles interactions
- Successes
- Limitations



Unknown quantities, like the Higgs mass, are strongly constrained by the accuracy of these tests

A Tonazzo: Moriond 2002

The Standard Model

- The particles and interactions
- Successes
- Limitations

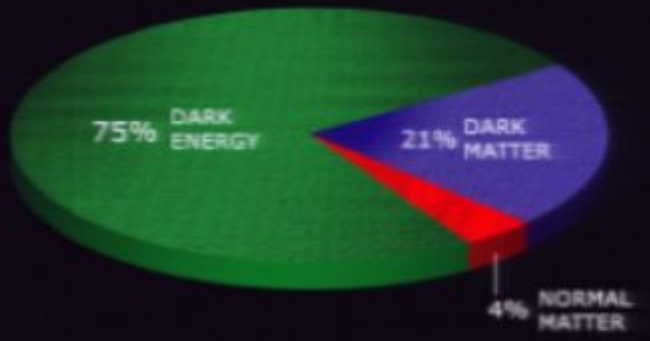
The Standard Model

- The particles interactions

So what's wrong with the Standard Model?

Observational Problems:

Neutrinos appear to have masses…
Dark Matter and Dark Energy unexplained..



The Standard Model

- The particles interactions
- Successes
- Limitations

So what's wrong with the Standard Model?

Observational Problems:

Neutrinos appear to have masses…
Dark Matter and Dark Energy unexplained..

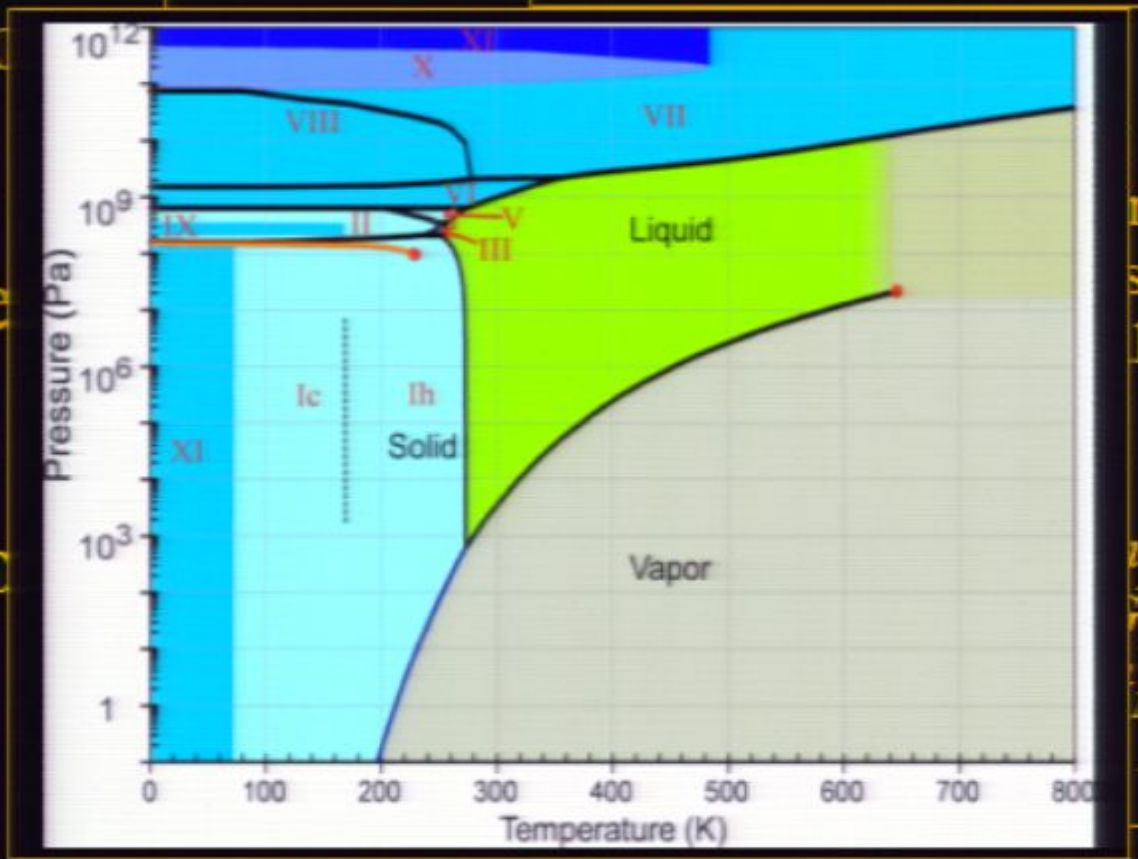
Theoretical Problems:

Hierarchy Problem
Cosmological Constant Problem
Who ordered all this?
What about Gravity?

The Standard Model

- The particles
- Successe
- Limitatic

$$M_{SUN} \approx M_p^3 / m_p^2$$



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l_p = 1 GeV
$l_F^{-1/2} \sim 10^2$ GeV
$l_N^{-1/2} \sim 10^{19}$ GeV
$/m_v \sim 10^{11}$ GeV

The Standard Model

- The particles
- Successe
- Limitatic

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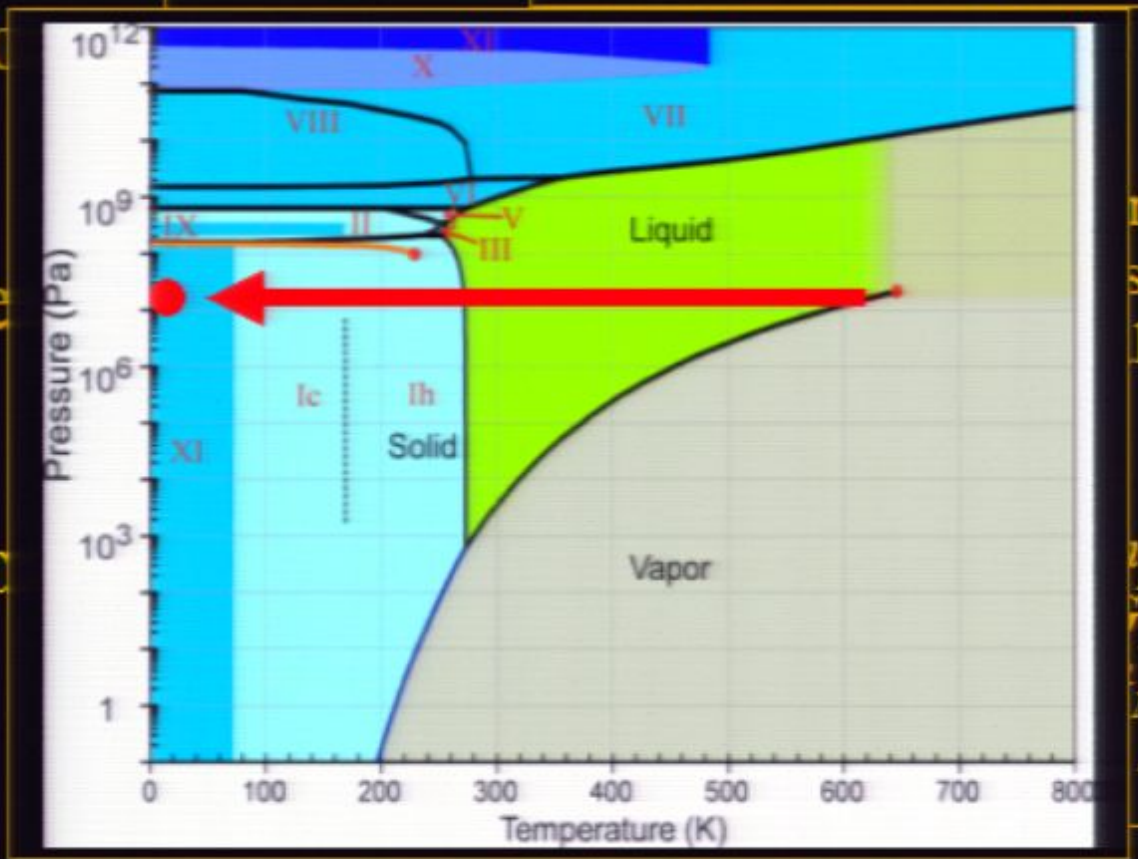

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$l_N^{-1/2} \sim 10^{19}$ GeV
$/m_\nu \sim 10^{11}$ GeV

Outline

- What is it?
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  - *Problems*
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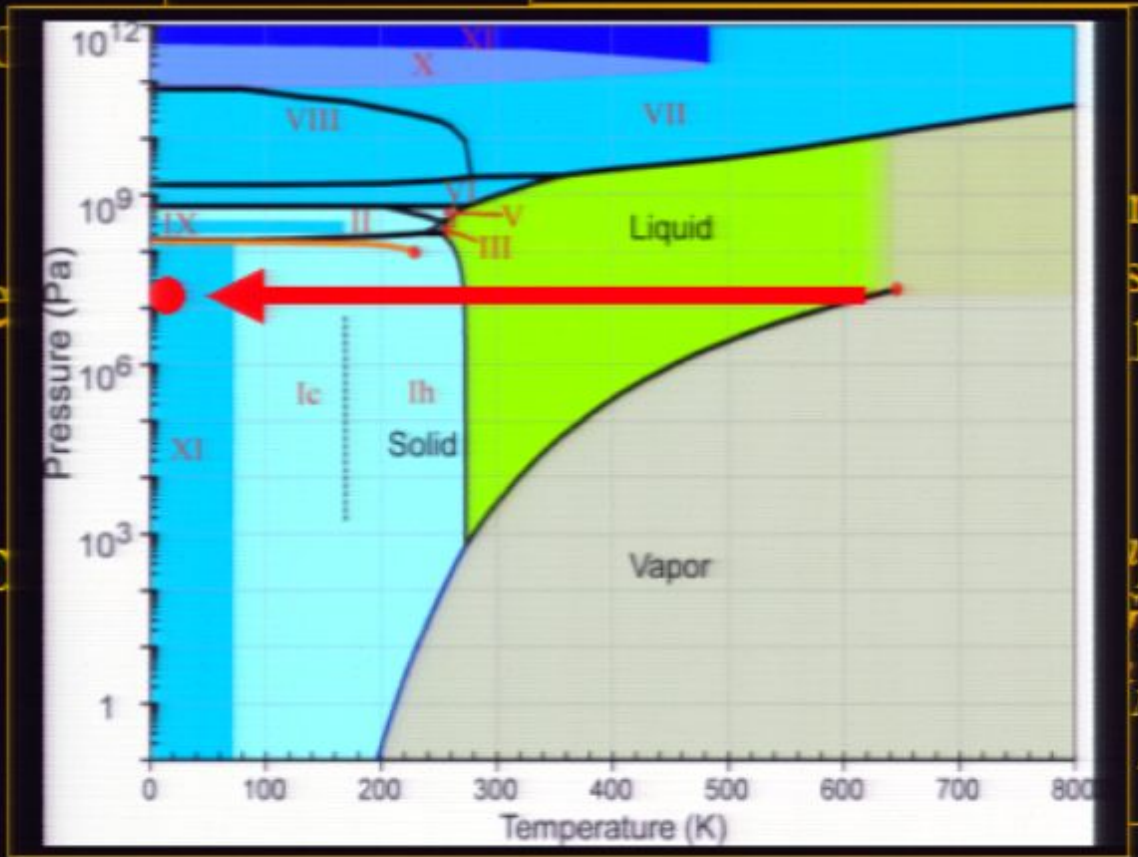
What might be seen

- Nothing?

The Standard Model

- The particles
- Successe
- Limitatio

$$M_{SUN} \approx M_p^3 / m_p^2$$



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What might be seen

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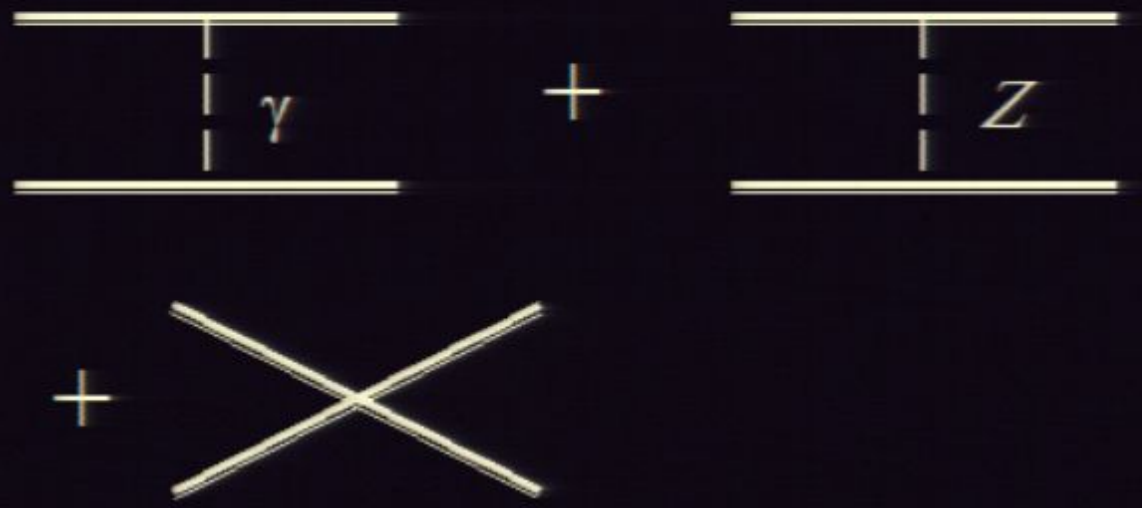
What might be seen

- Nothing?

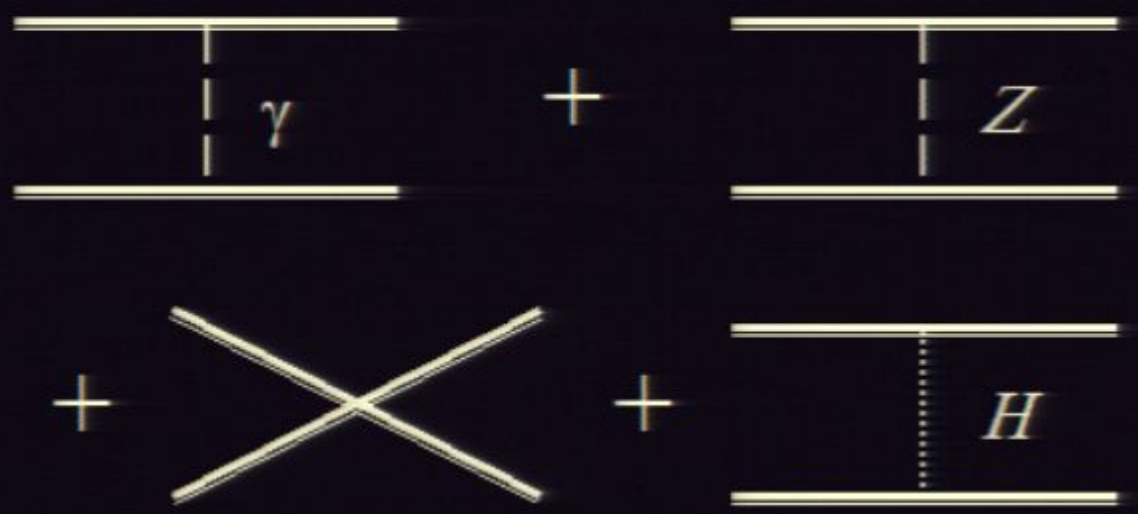


W-W scattering: $\sigma \sim (\alpha^2 \ln E)/M_W^2$

The SM without the Higgs boson must break down at energies of order $M_W/\alpha \sim$ few TeV because $\sigma < 1/E^2$

What might be seen

- Nothing?



W-W scattering: $\sigma \sim \alpha^2/E^2$

The SM with the Higgs boson *can make sense for energies much larger than* $M_W/\alpha \sim$ few TeV

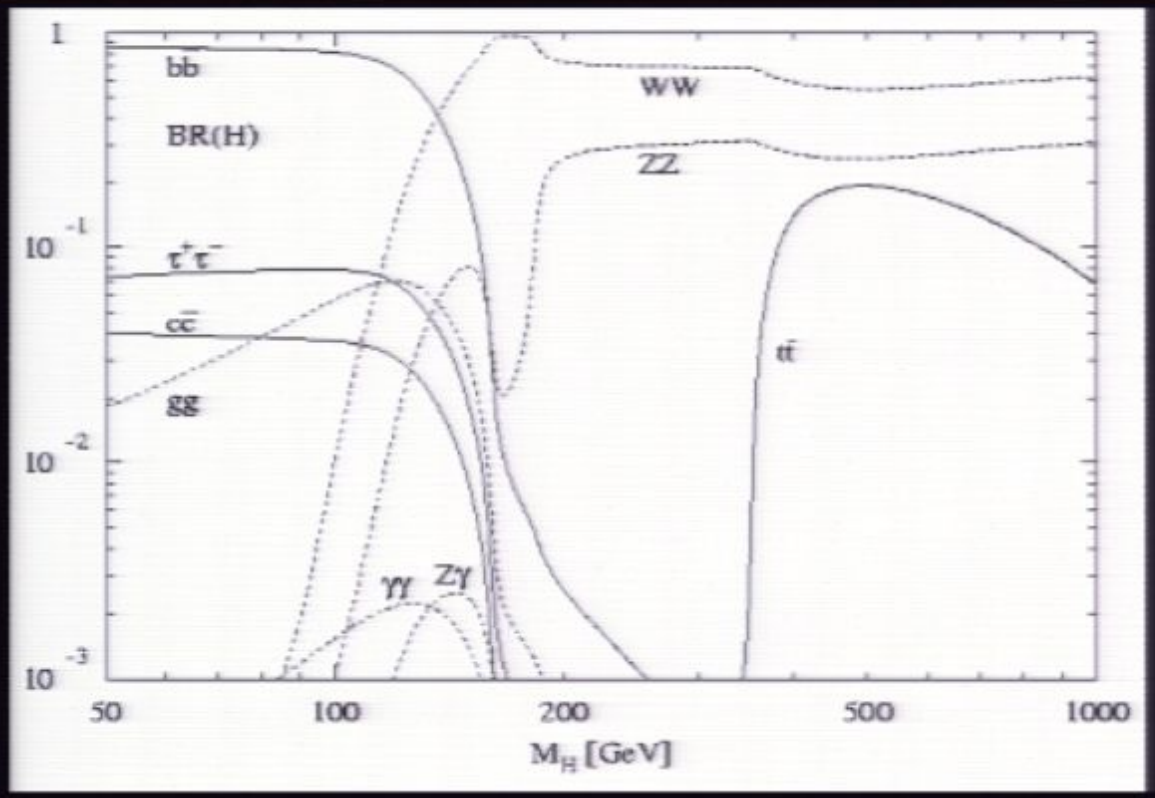
AAAS

What might be seen

- The Higgs Boson?

What might be seen

- The Higgs B

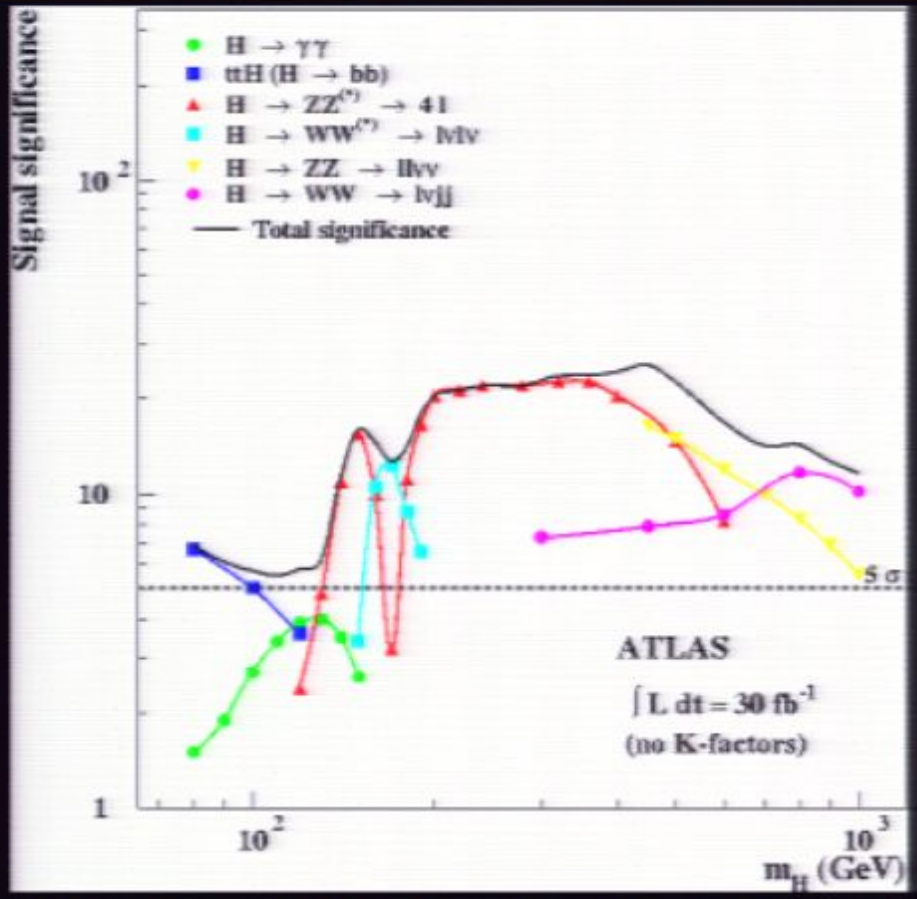


Search strategies depend on what it decays into, and this depends on its mass

M. Lefebvre (Astbury Symposium 2000)

What might be seen

- The Higgs B



Expect it to be visible for the allowed mass range

M. Lefebvre (Asbury Symposium 2000)

What might be seen

- Beyond the Standard Model?

What might be seen

- Beyond the S

- *Beyond the SM*: the Hierarchy problem provides clues as to what else might be found, since any explanation of what allows $M_w \ll M_p$ must change physics at energies *just above* M_w

What might be seen

- Beyond the S
- *Beyond the SM*: basically three options:

What might be seen

- Beyond the S

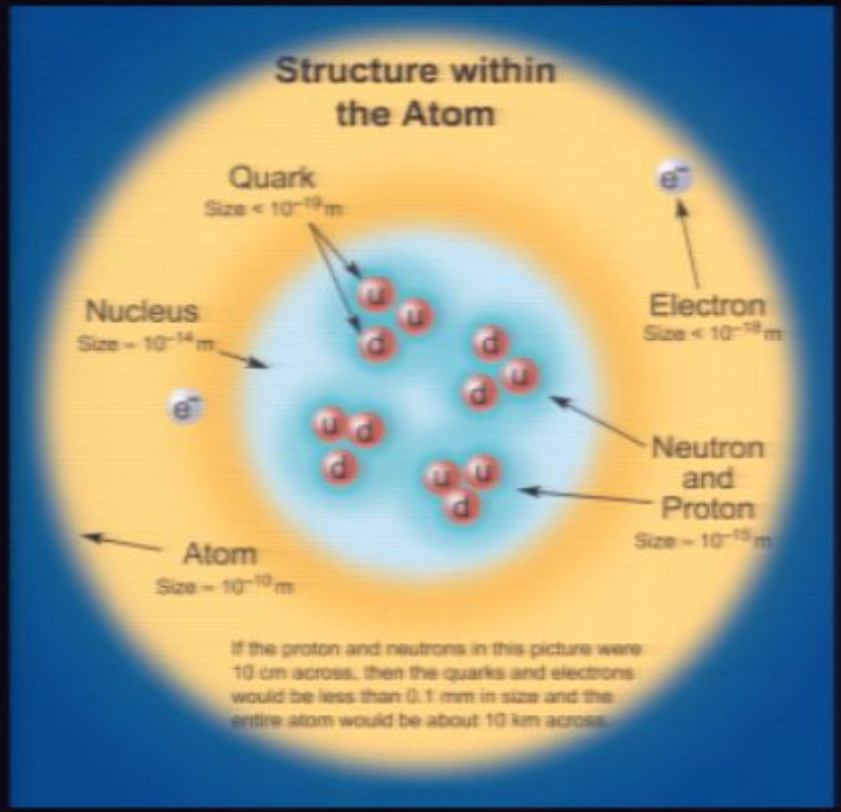
- *Beyond the SM*: basically three options:

  No elementary Higgs:

  - ***Composite models***

What might be seen

- Beyond the S



- Another level of substructure is historically the most conservative guess

What might be seen

- Beyond the S

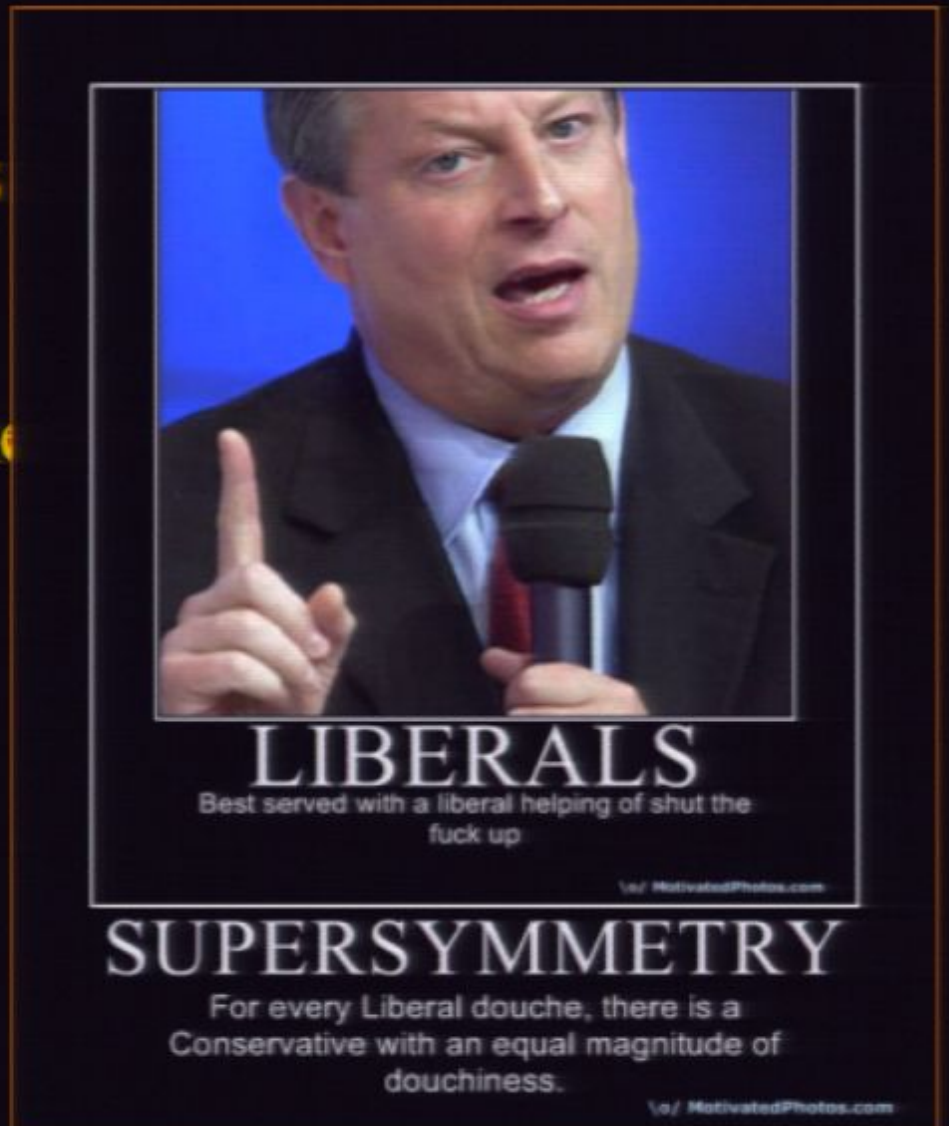
- *Beyond the SM*: basically three options:

  No elementary Higgs:
  - ***Composite models***

  New symmetry alleviating fine tuning:
  - ***Supersymmetry***

What might be seen

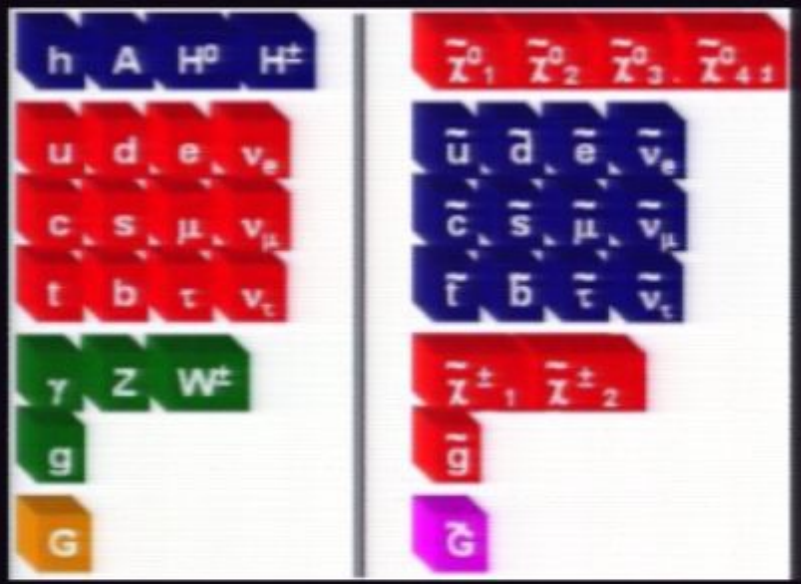
- The Higgs
- Beyond the



What might be seen

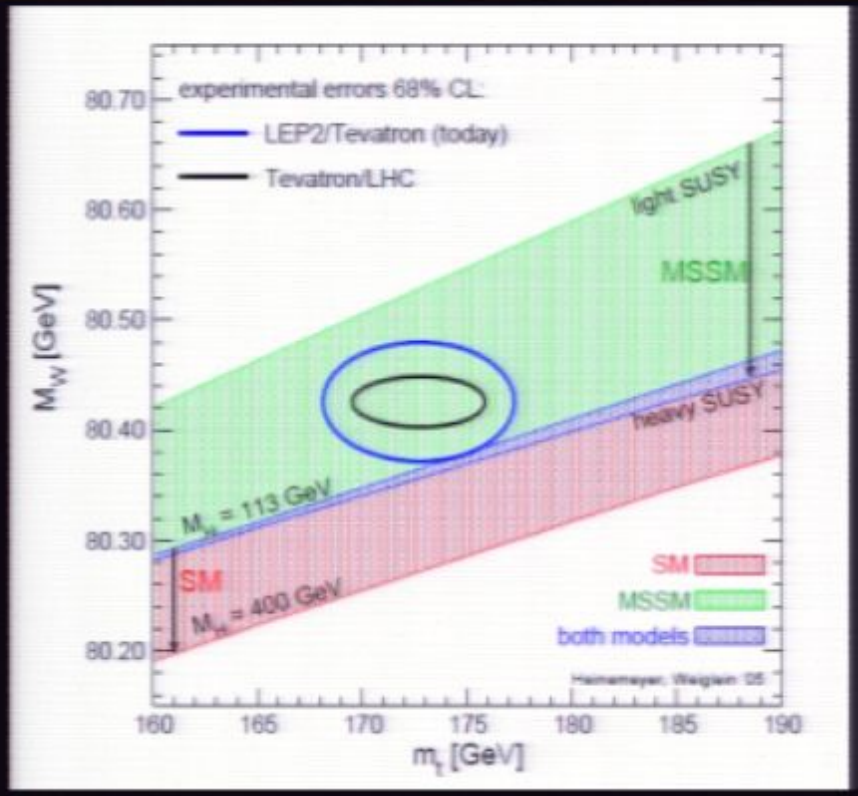
- The Higgs B
- Beyond the S

- Usually implies 'superpartners' for each kind of known particle
- lightest superpartner is usually a good dark matter candidate



What might be seen

- The Higgs B
- Beyond the S

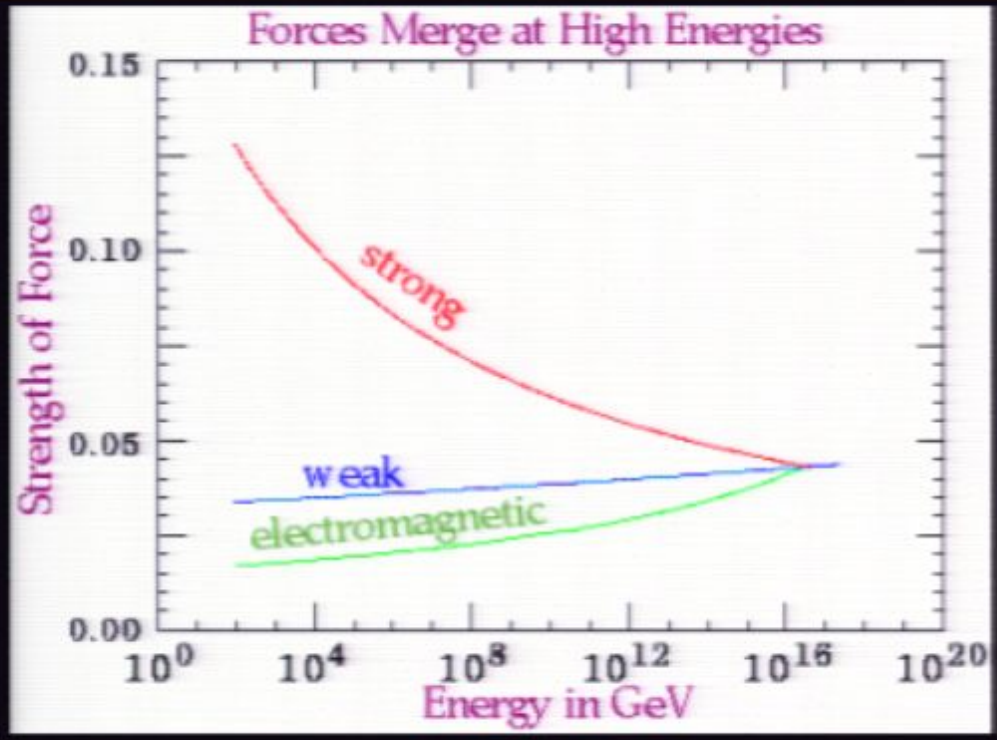


- Hint for supersymmetry: in the preference for light Higgs in precision measurements

A Tonazzo: Moriond 2003

What might be seen

- Beyond the S



- Hints for supersymmetry: apparent unification of SM couplings

What might be seen

- Beyond the S

- *Beyond the SM*: basically three options:

  No elementary Higgs:
  - ***Composite models***

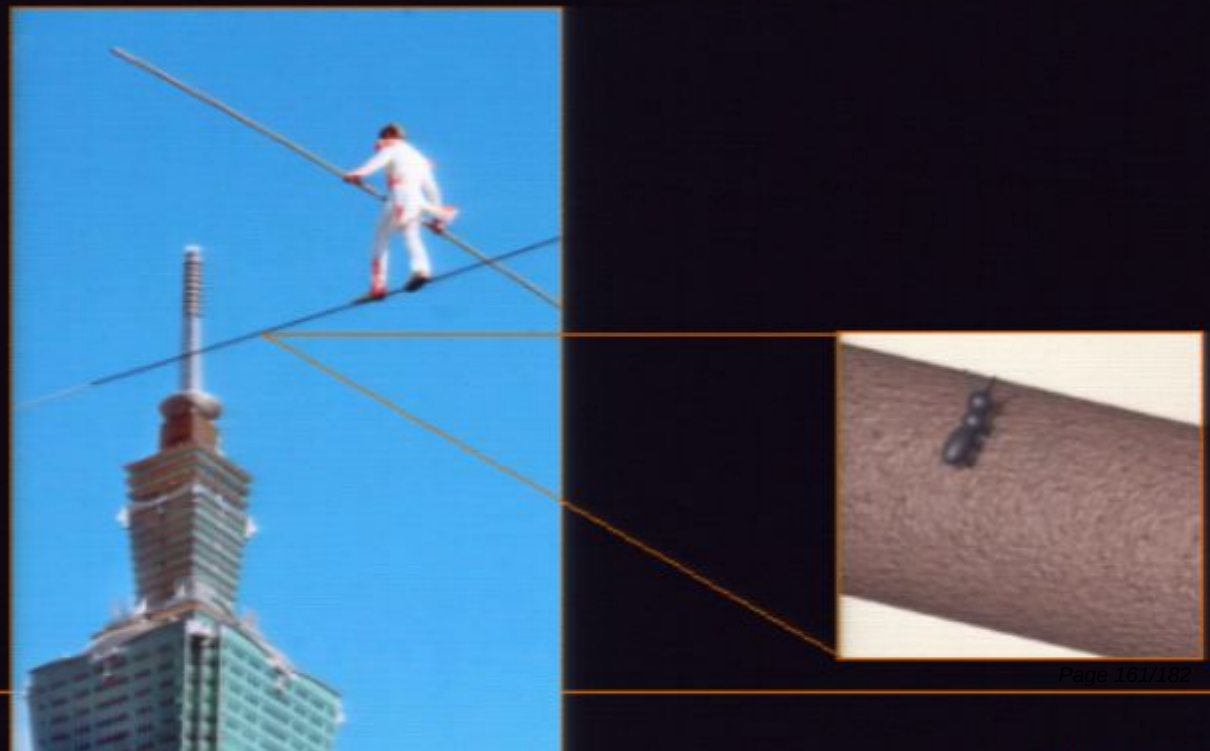
  New symmetry alleviating fine tuning:
  - ***Supersymmetry***

  Gravity scale is not really M_p
  - ***Extra dimensions***

What might be seen

- The Higgs B
- Beyond the S

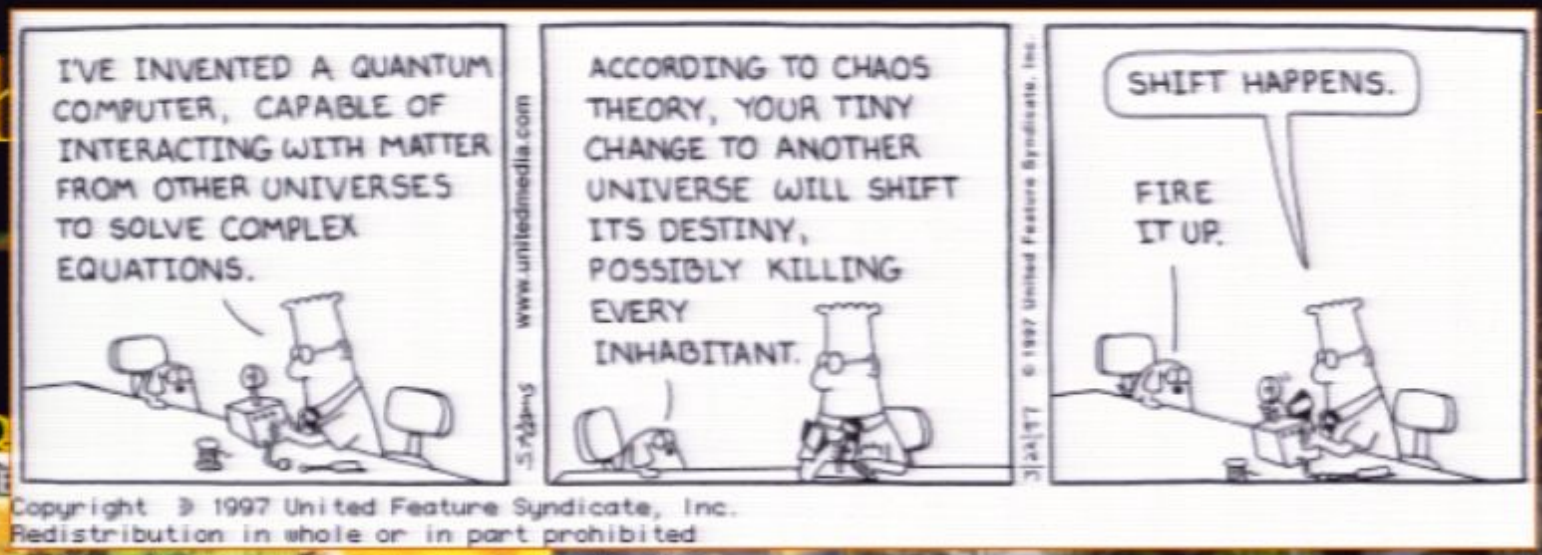
- If there are extra dimensions and they are large, then the gravity scale could be much lower than we think….



What might be seen

- Beyond the S

This is the scenario that potentially leads to black hole production…


I'VE INVENTED A QUANTUM COMPUTER, CAPABLE OF INTERACTING WITH MATTER FROM OTHER UNIVERSES TO SOLVE COMPLEX EQUATIONS.
ACCORDING TO CHAOS THEORY, YOUR TINY CHANGE TO ANOTHER UNIVERSE WILL SHIFT ITS DESTINY, POSSIBLY KILLING EVERY INHABITANT.
SHIFT HAPPENS.
FIRE IT UP.
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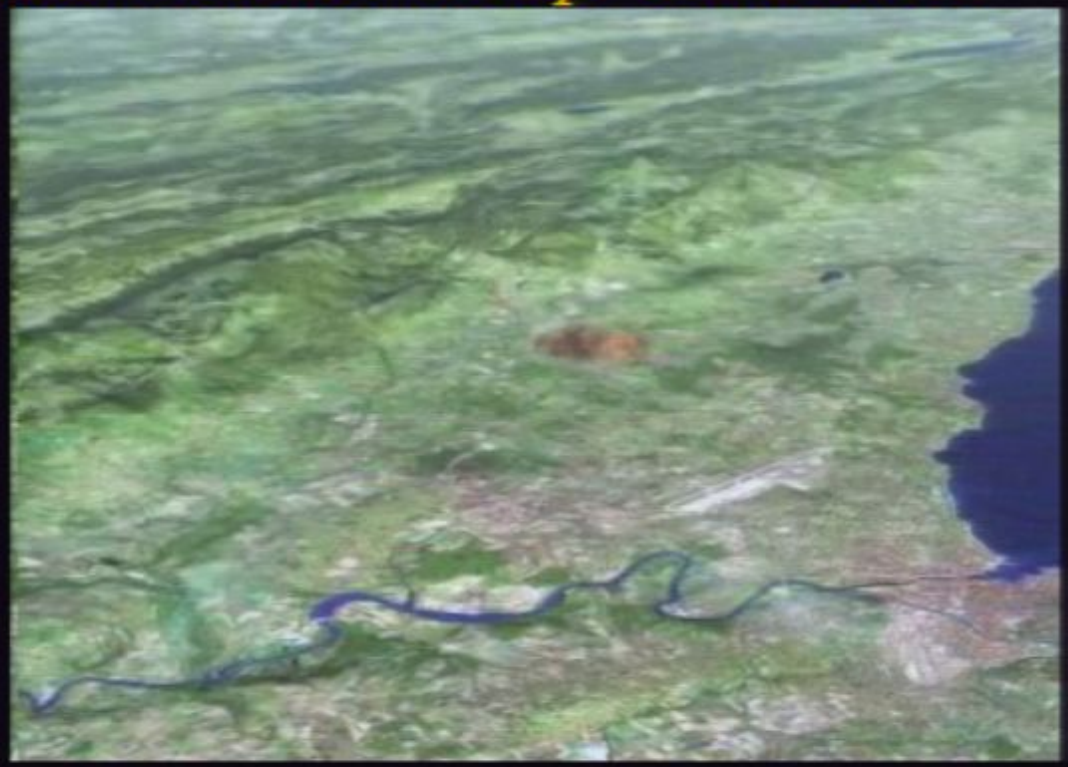
THE FLY
COLLECTION
INCLUDES
The Fly
Return of the Fly
JURASSIC PARK
UNIVERSAL

What might be seen

- Beyond the S

This is the scenario that potentially leads to black hole production…



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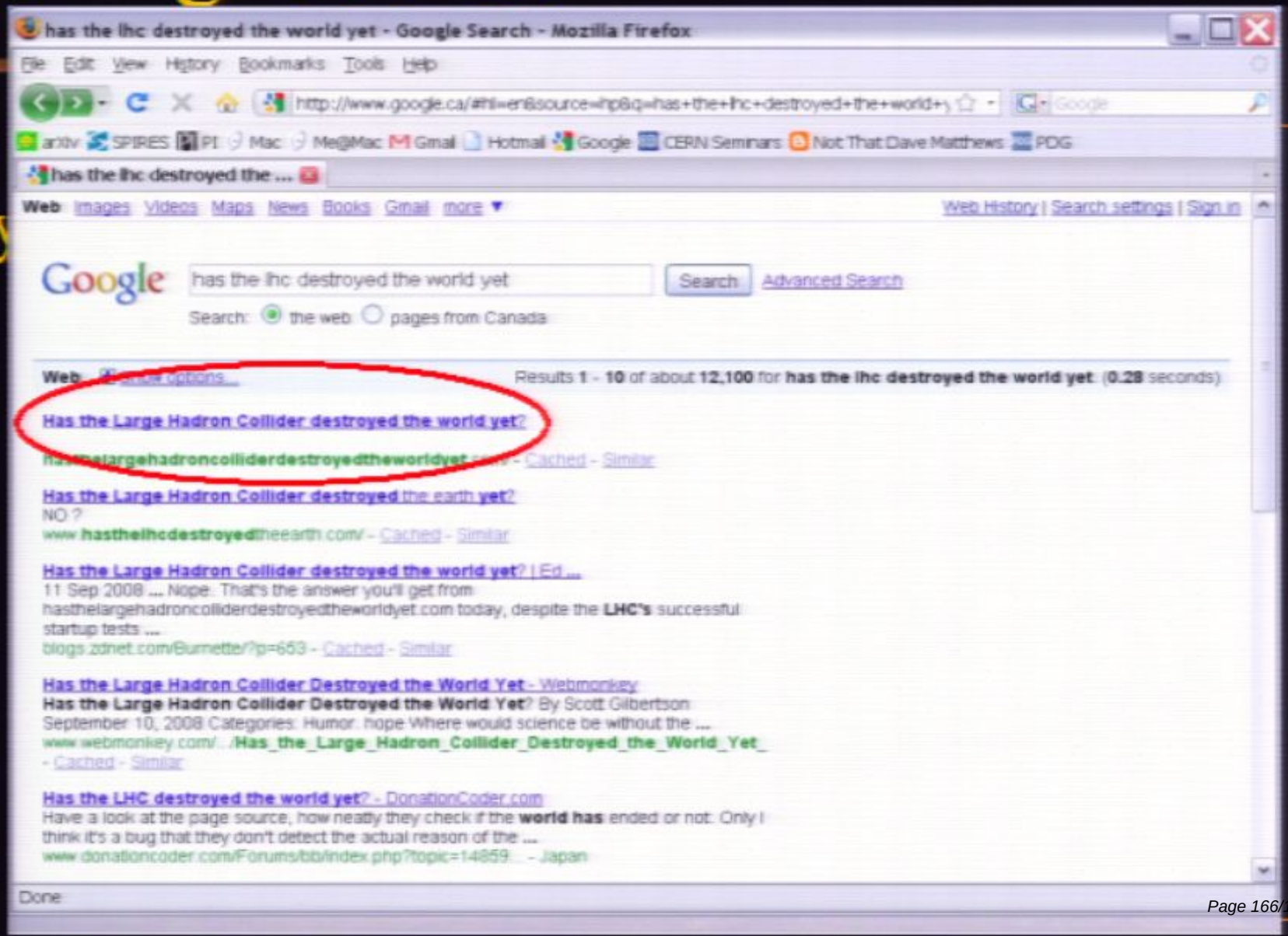

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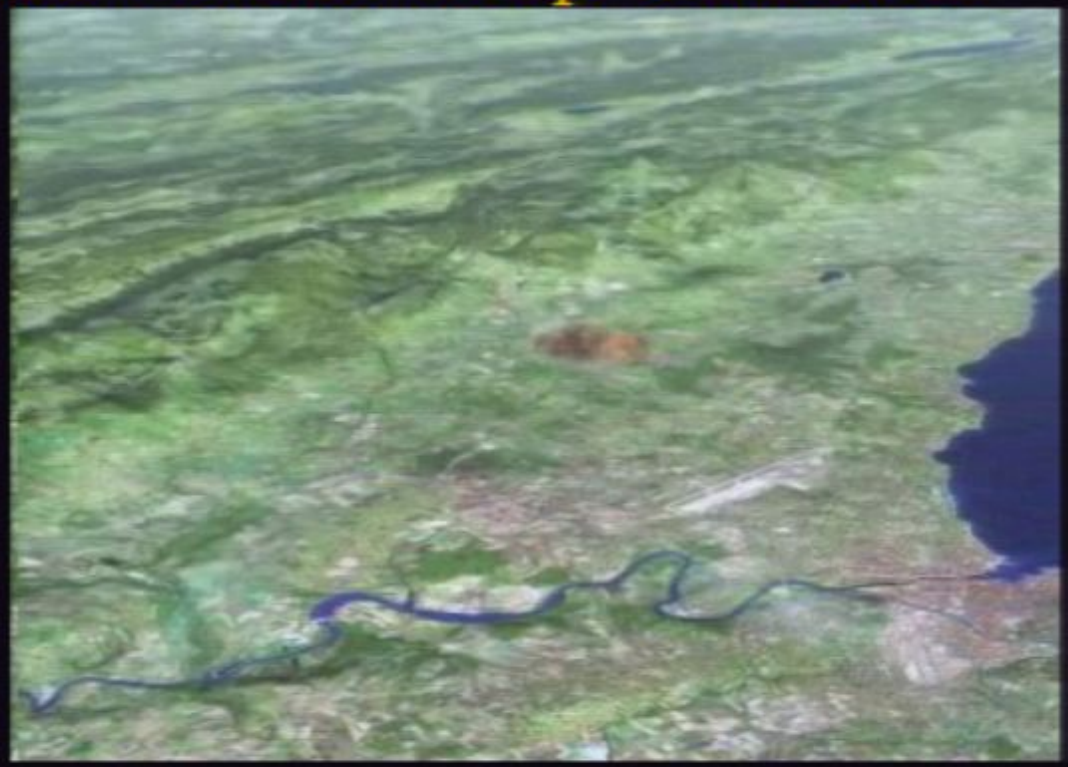

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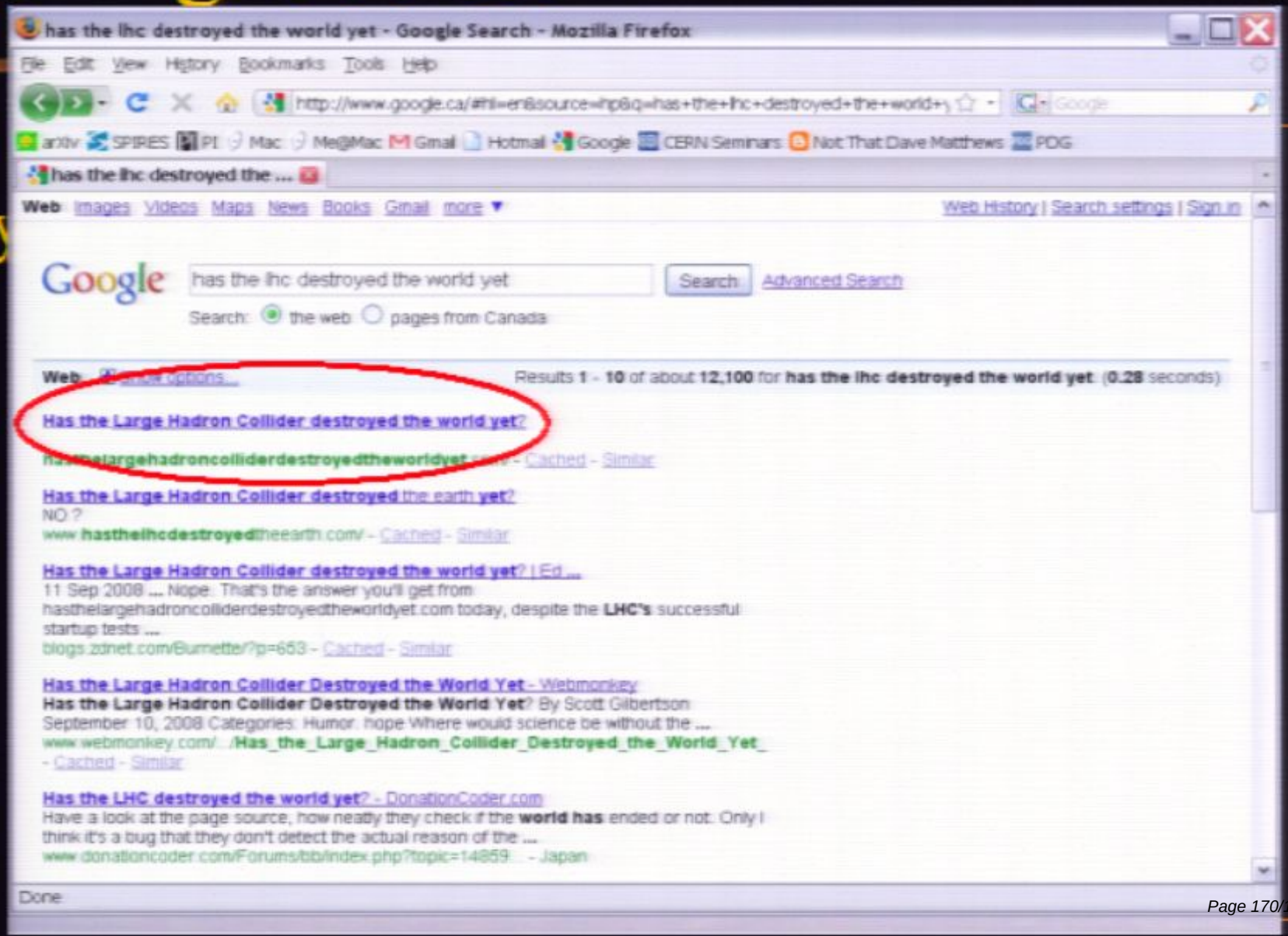

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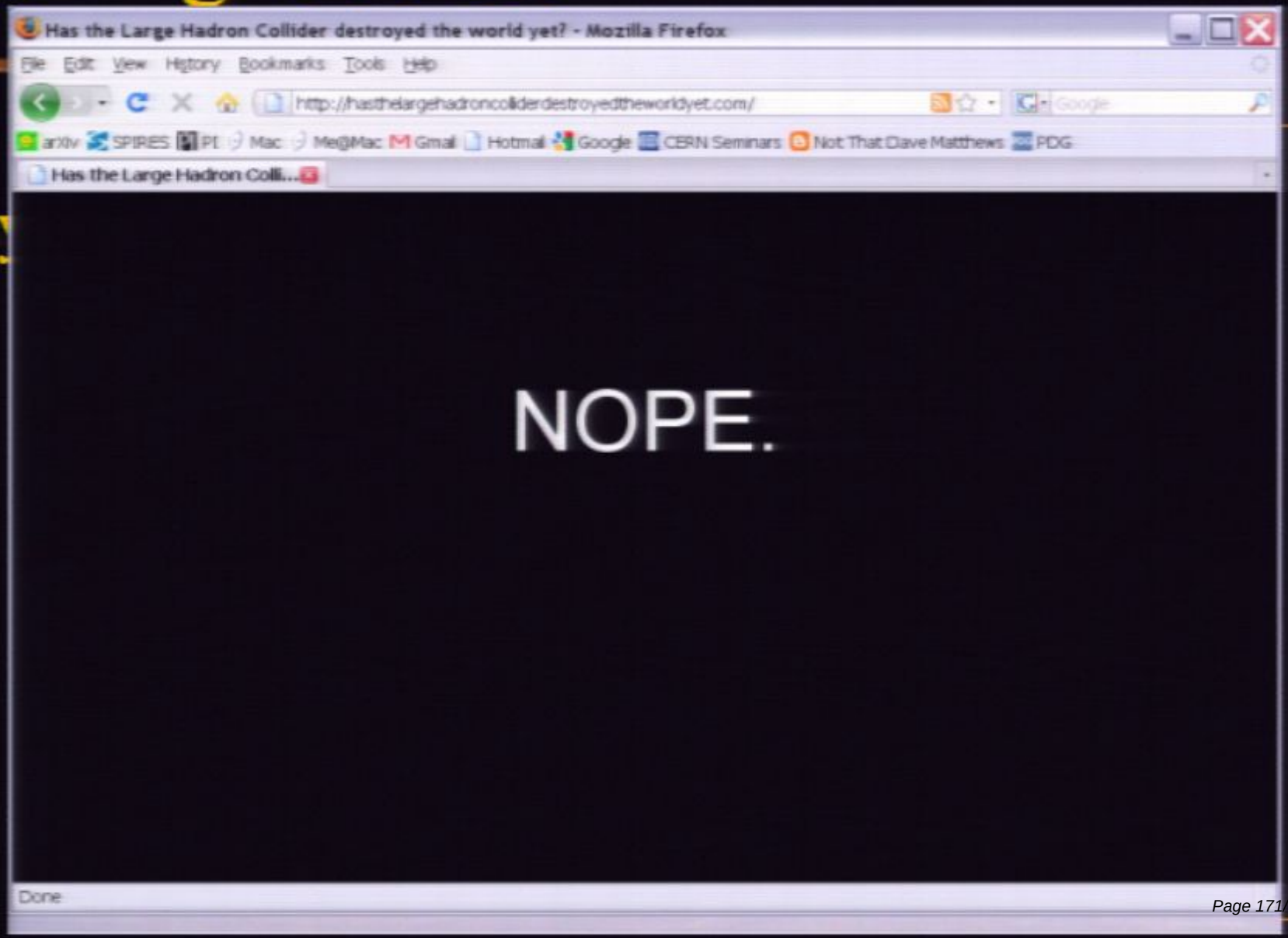

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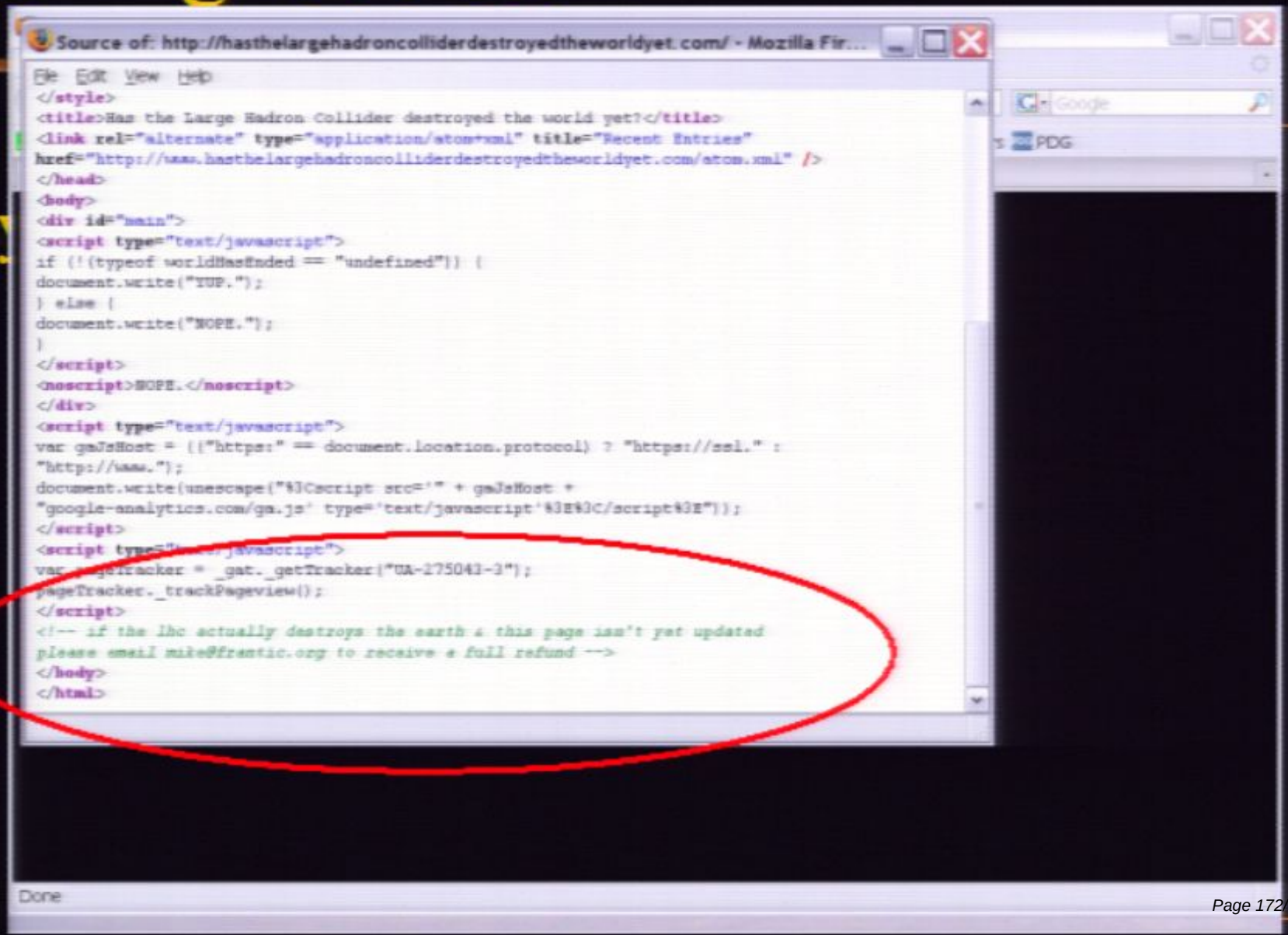

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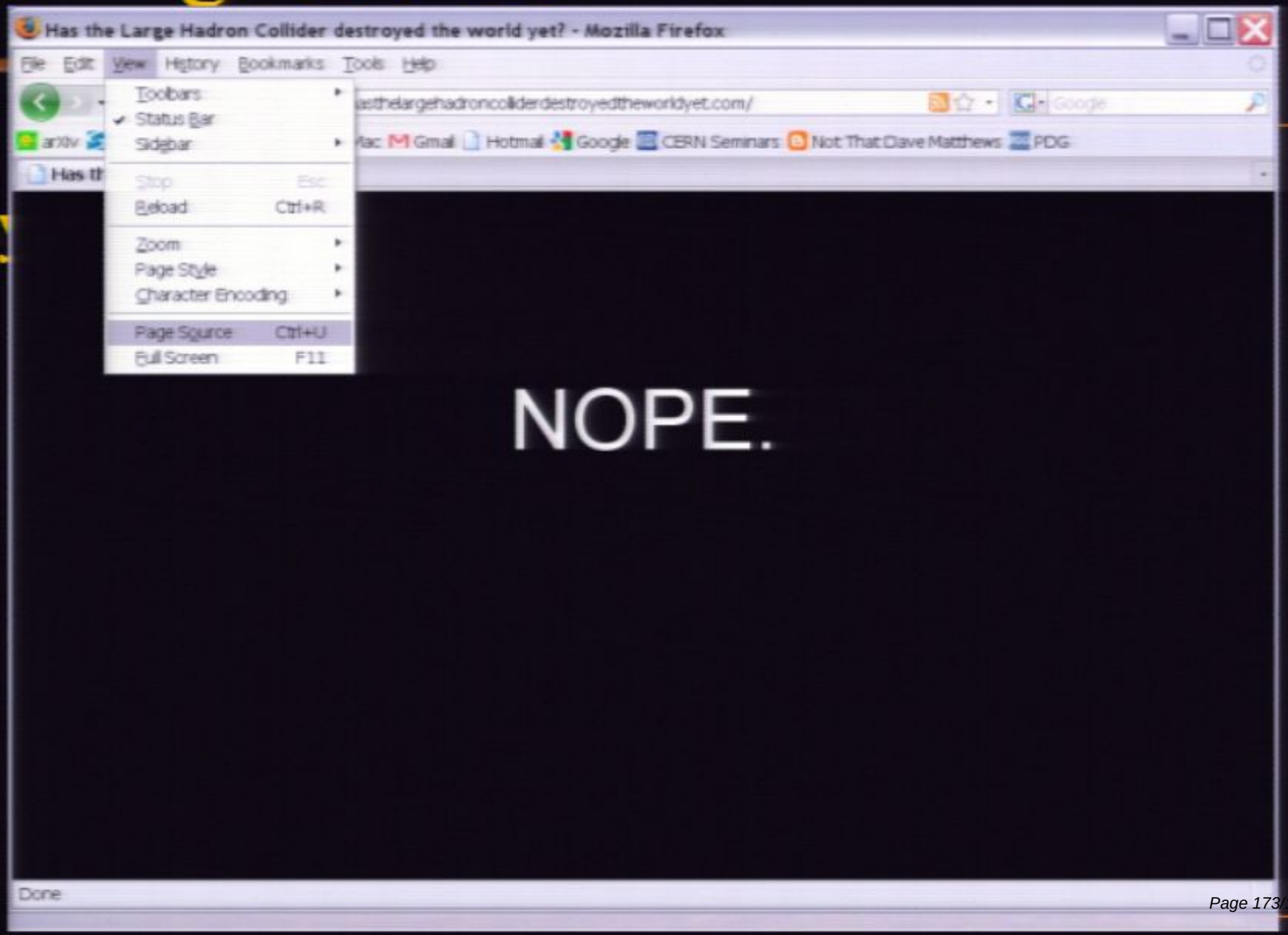

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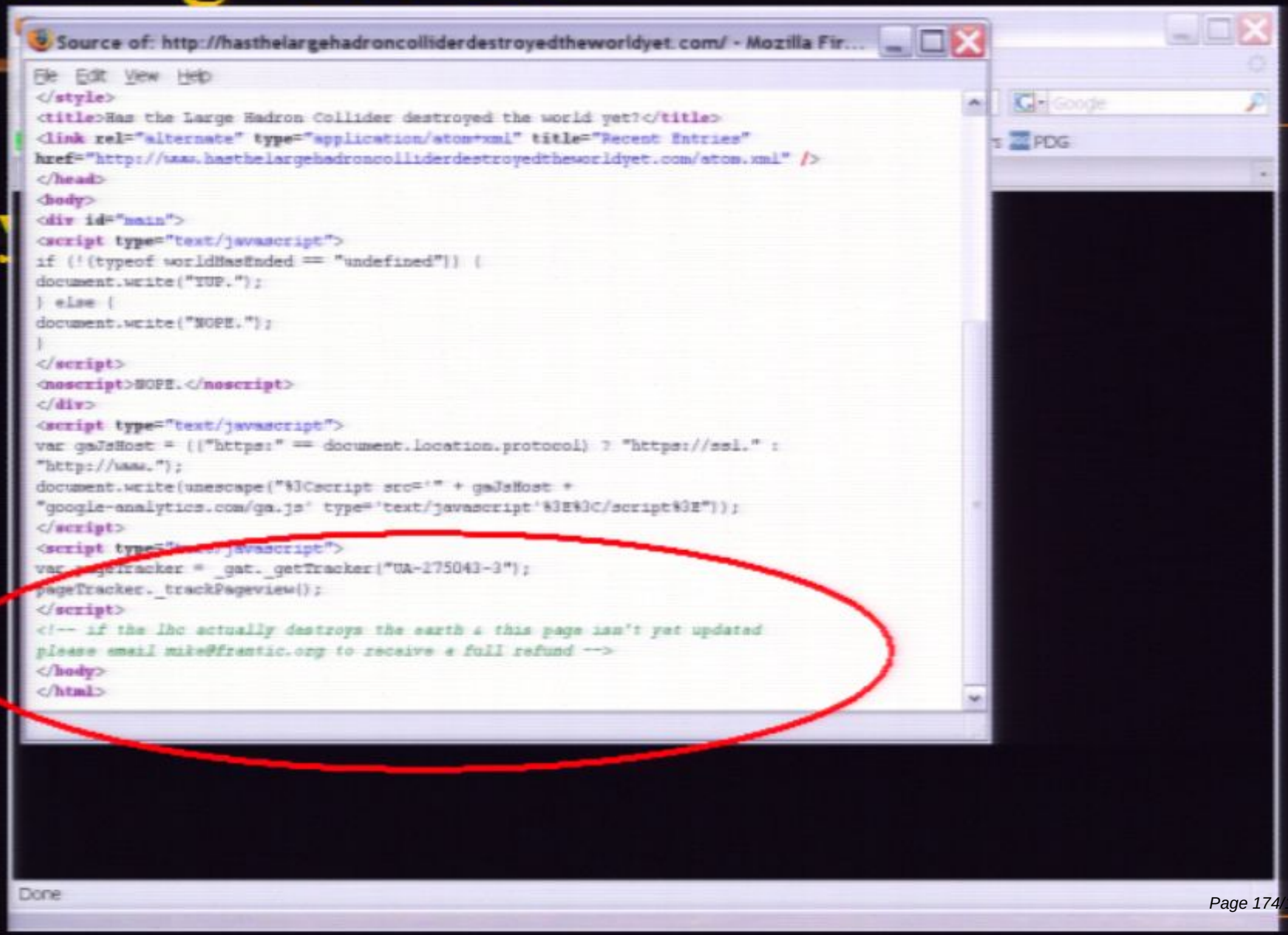

Outline

- What is it?
  - *The machine*
- Why was it built?
  - *The Standard Model and its limitations*
- What might it hope to see?
  - *Problems*
- Outlook

Outlook

- The LHC started a long physics run a few months ago!
  - Runs at full beam energy could begin late next year.

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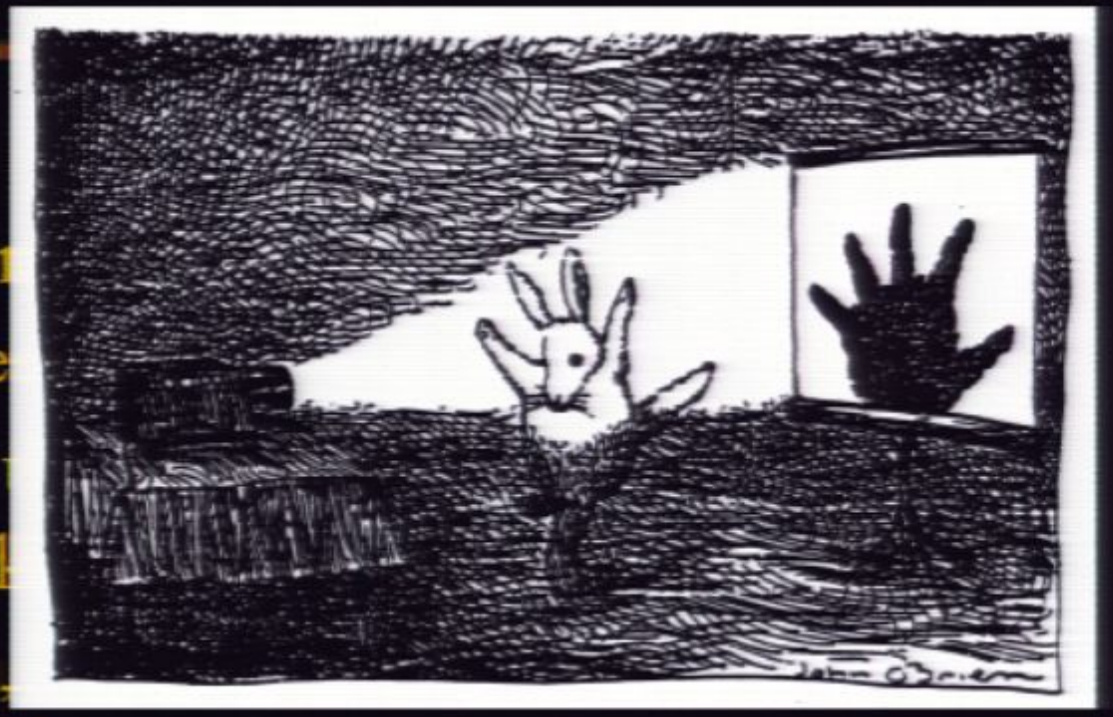
HOLYSHIT!!

Outlook

- The LHC started a long physics run a few months ago!
  - Runs at full beam energy could begin late next year.
- The LHC should tell us if the Higgs mechanism is right, and how it works.
  - The SM Higgs boson, or its alternative, should be found.

Outlook



- The LHC started a lo
  - Runs at full beam ene
- The LHC should tell
  right, and how it work
  - The SM Higgs boson,
- Surprises are inevitable!
  - The LHC is likely to represent a major change to our understanding of Nature at its most elementary level.

Outlook

- The LHC starte
  - Runs at full be
- The LHC shoul
right, and how
  - The SM Higgs
- Surprises are ir
  - The LHC is lil
  understanding

My personal pick: *large extra dimensions and string theory in your face!*

End of slide show, click to exit.

Websites with more information

- The ATLAS and CMS detectors:
  - http://atlas.ch, http://cms.cern.ch
- LHC outreach:
  - http://lhc-machine-outreach.web.cern.ch/lhc-machine-outreach/
- Particle Data Group outreach:
  - http://pdg.lbl.gov/2006/html/outreach.html
- LHC Rap: http://www.youtube.com/watch?v-j50ZssEojtM