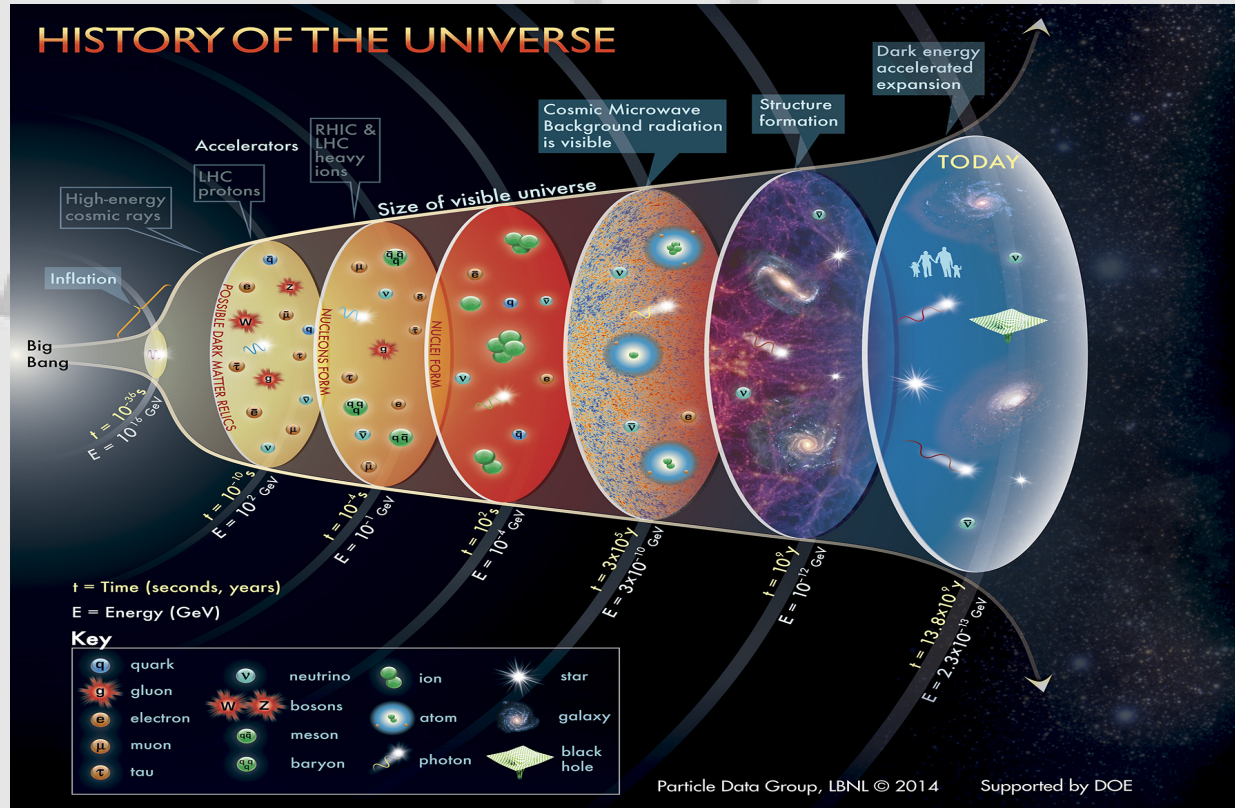




Mörk Materia på labbet

Richard Brenner - Uppsala universitet

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Världen häger ej ihop



$$\begin{aligned} \mathcal{L} = & -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} \\ & + i\bar{\psi}\not{D}\psi + \text{h.c.} \\ & + \chi_i y_{ij} \chi_j \phi + \text{h.c.} \\ & + |D_\mu \phi|^2 - V(\phi) \end{aligned}$$





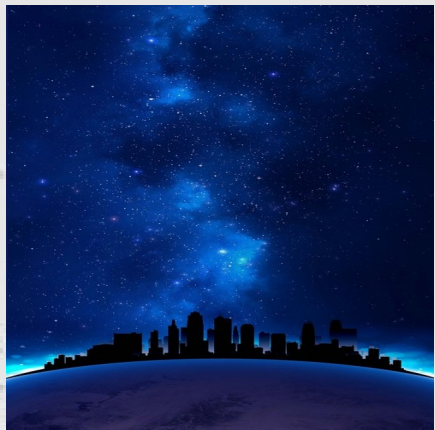
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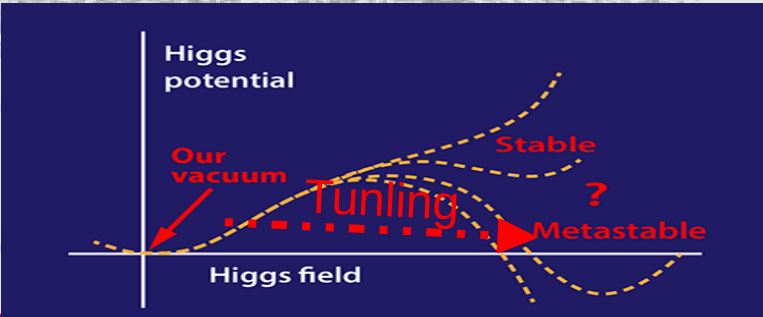
Världen häger ej ihop



$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i\bar{\psi}\not{D}\psi + h.c. + \chi_i y_{ij} \chi_j \phi + h.c. + |D_\mu \phi|^2 - V(\phi)$$



, och är ej stabil.....





Mörk Materia i laboratoriet? (Hemmagjord)

**Kan vi skapa
Mörk Materia?**



**Kanske, med hjälp
av accelerators**

**Kan vi detektera
Mörk Materia?**



**Inte direkt, men indirekt
i experiment**



Principen för att skapa materia



Total energi = Energi i vila + Energi från rörelse



materia



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Materia - inte vad som helst

Energi

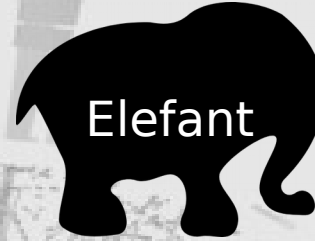


Materia



Kanin

Lätt = lite energi

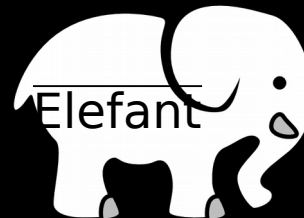


Elefant

Tung = mycket energi



Kanin



Elefant

Antimateria



**Mörk Materia skapas på samma sätt
som Materia**

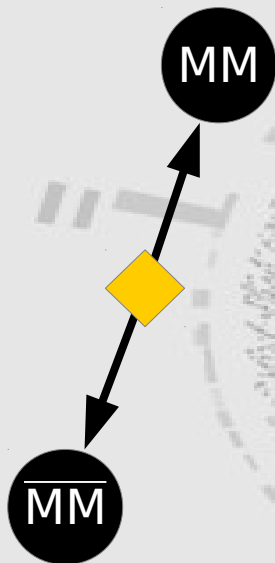
**I processen att omvandla energi till
Materia skapas lika mängder Materia
som Antimateria**



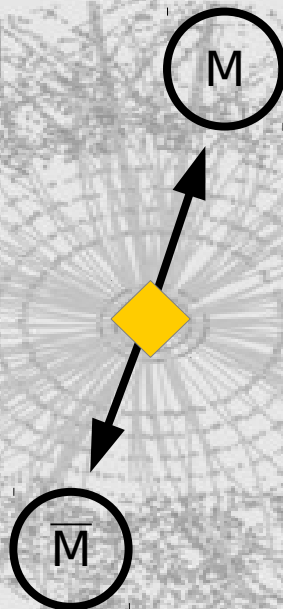
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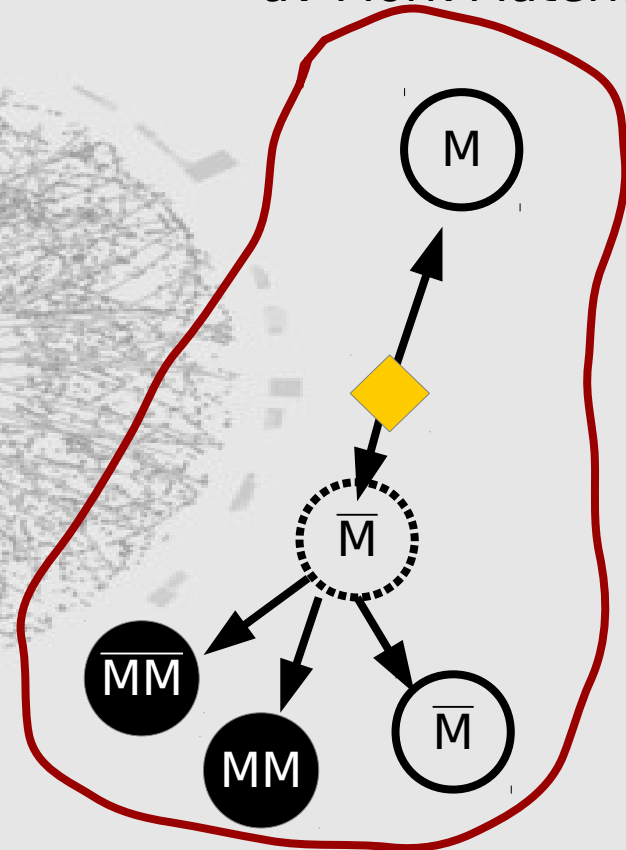
Produktion
av Mörk Materia



Produktion
av Materia



Produktion
av Materia med
indirekt produktion
av Mörk Materia



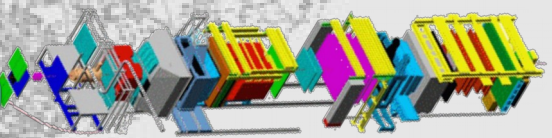
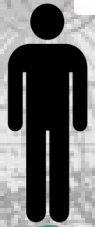
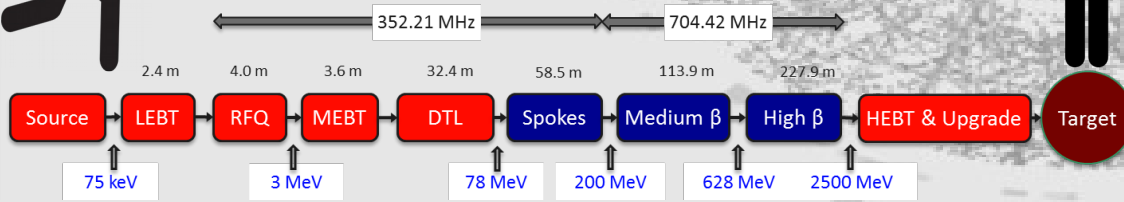
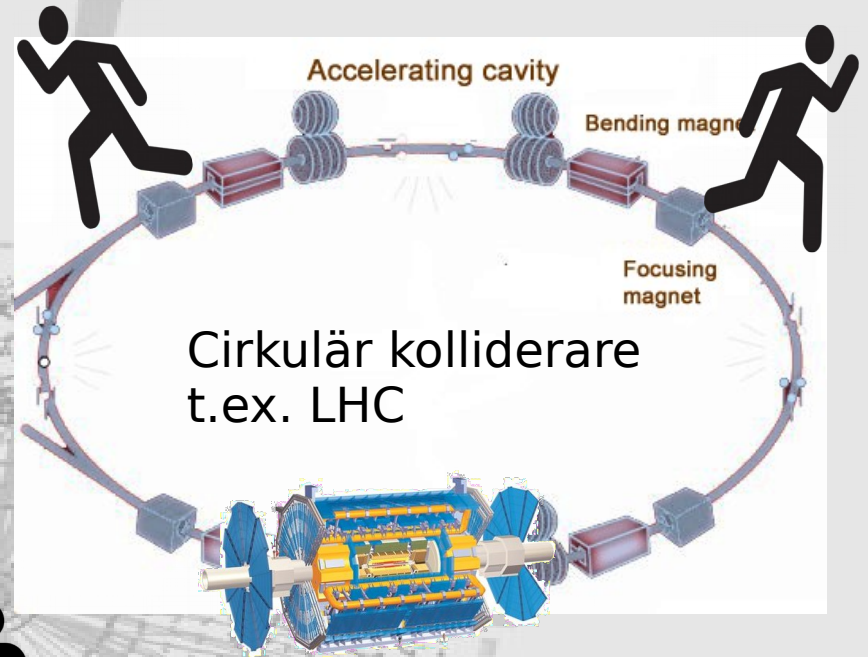


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Acceleratorer

Linjäraccelerator t.ex. ESS
med strålmål ("fixed-target")



Detektorer



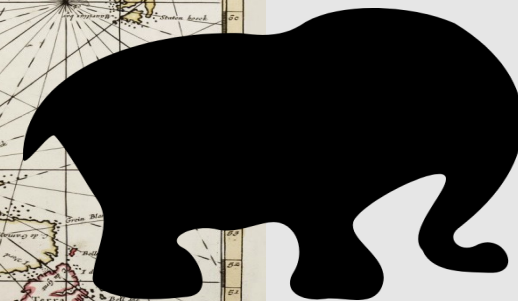
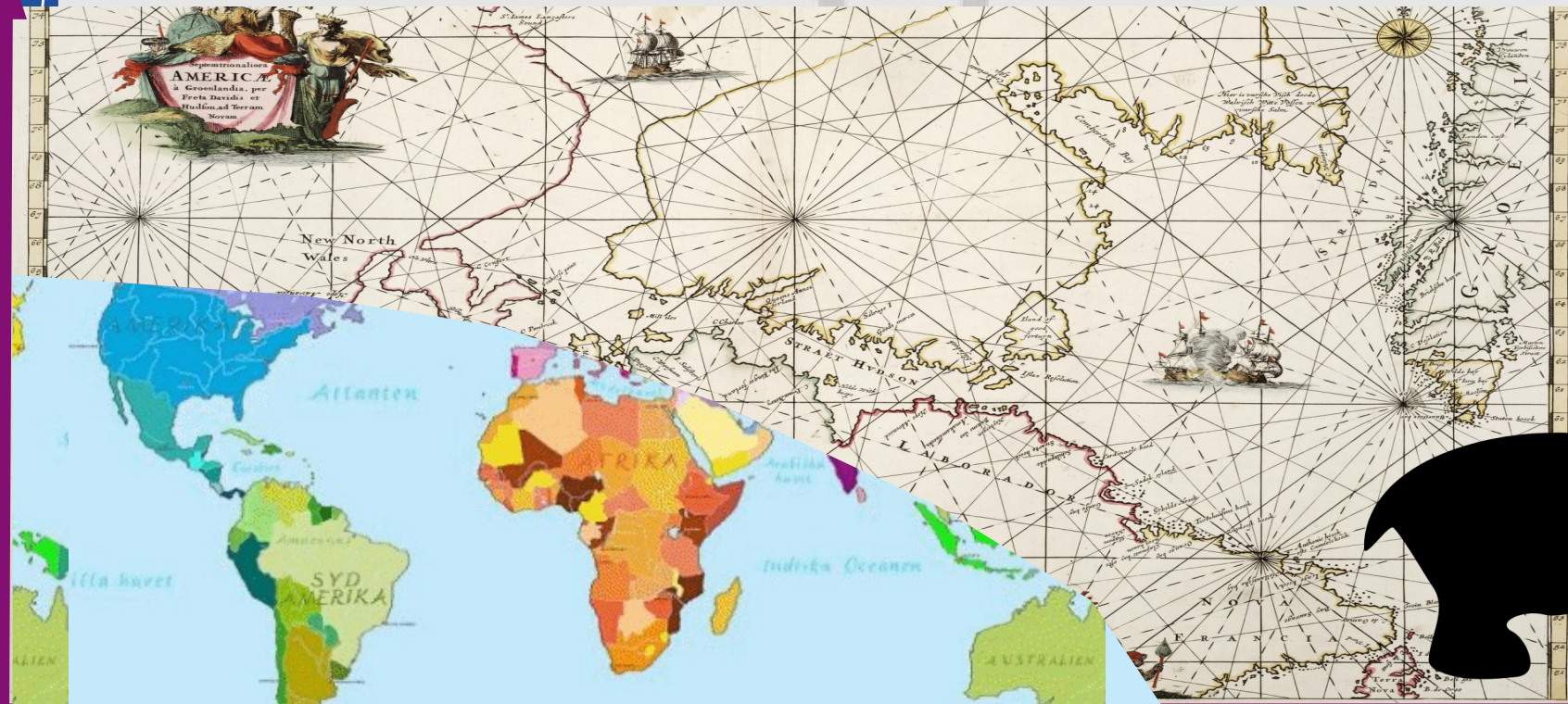
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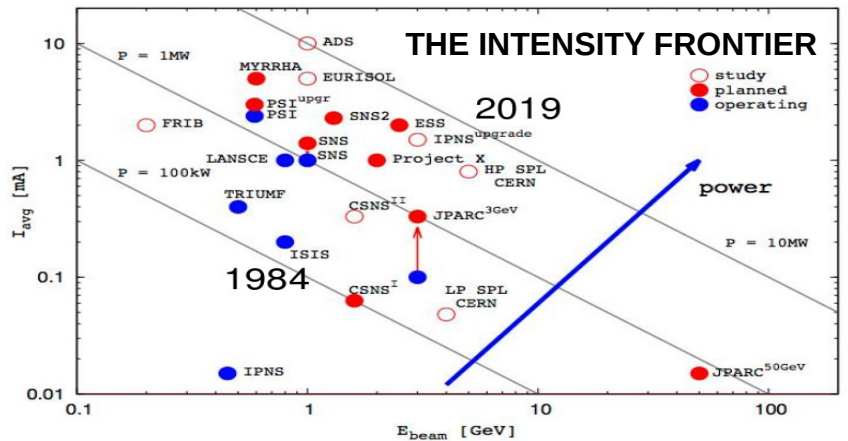
Utforskade territorier

Intensitet

CERN

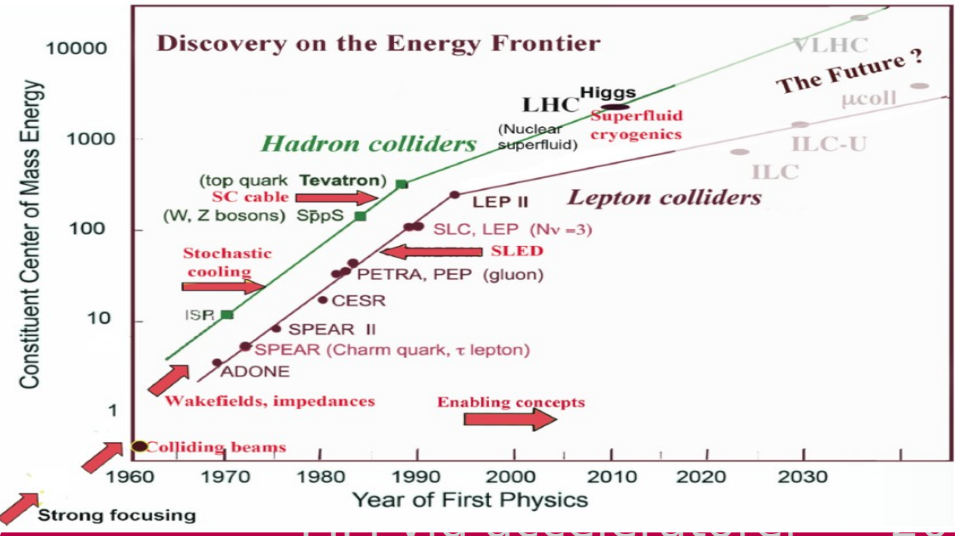
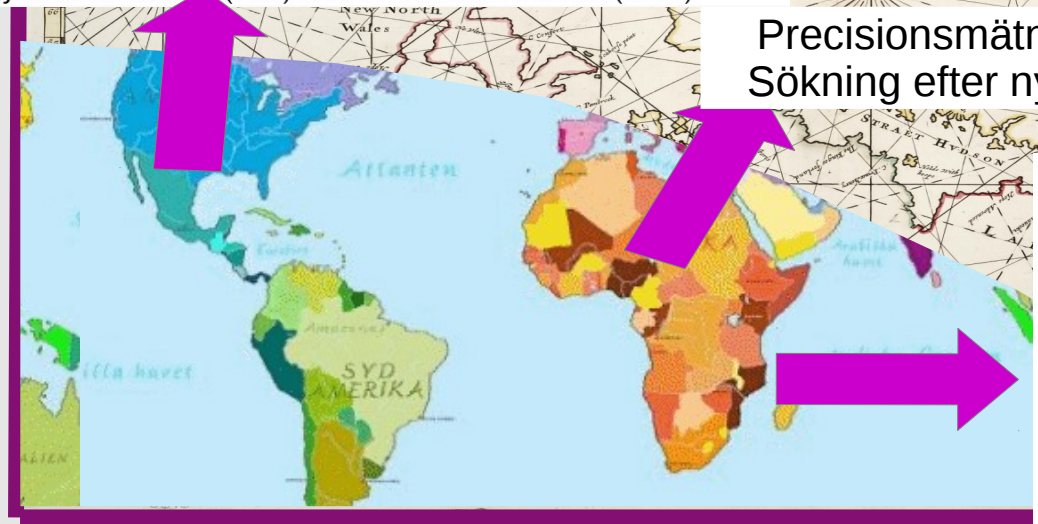


Energi



Courtesy of Mike Seidel (PSI) and Emmanuel Laface (ESS)

Precisionsmätningar
Sökning efter ny fysik

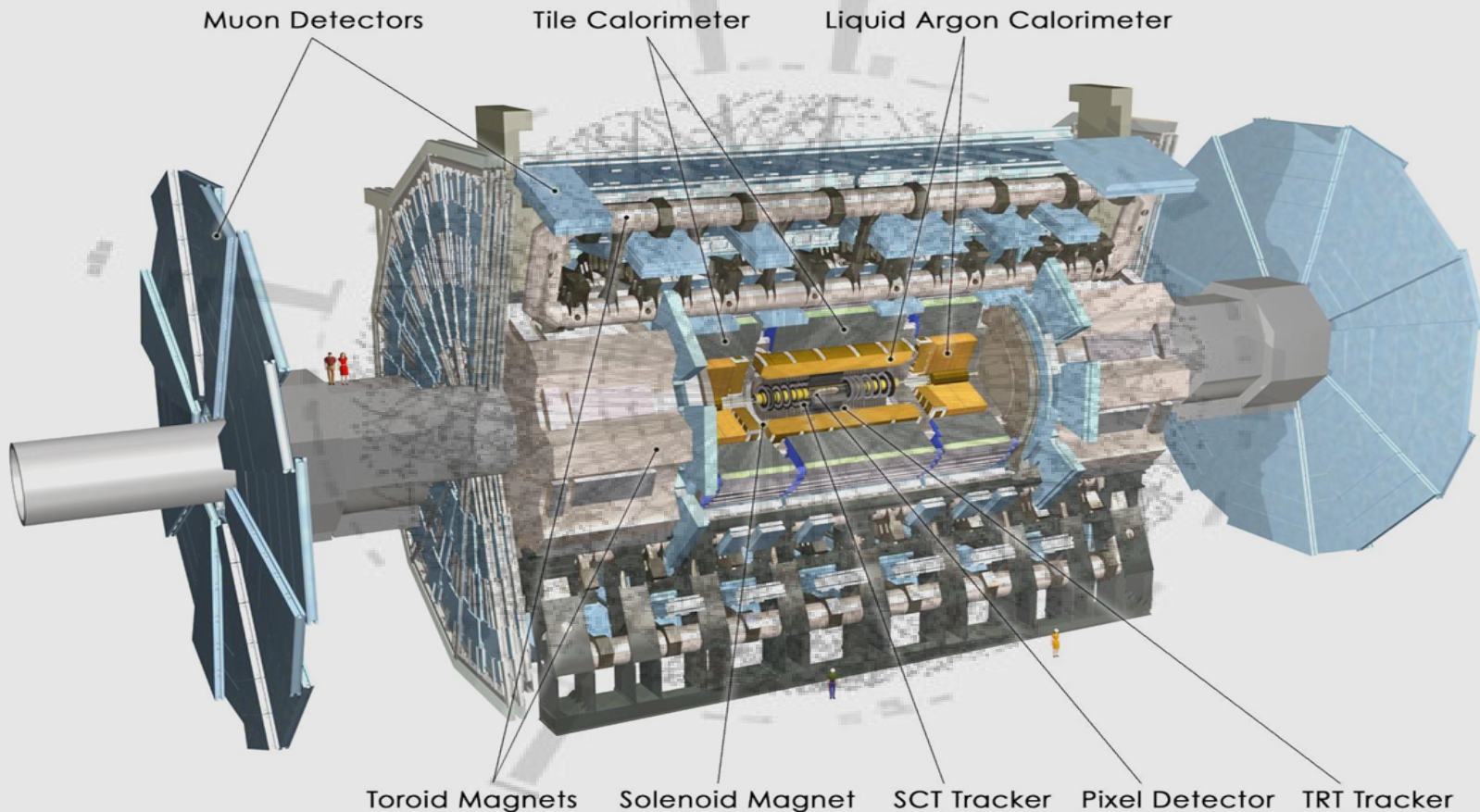




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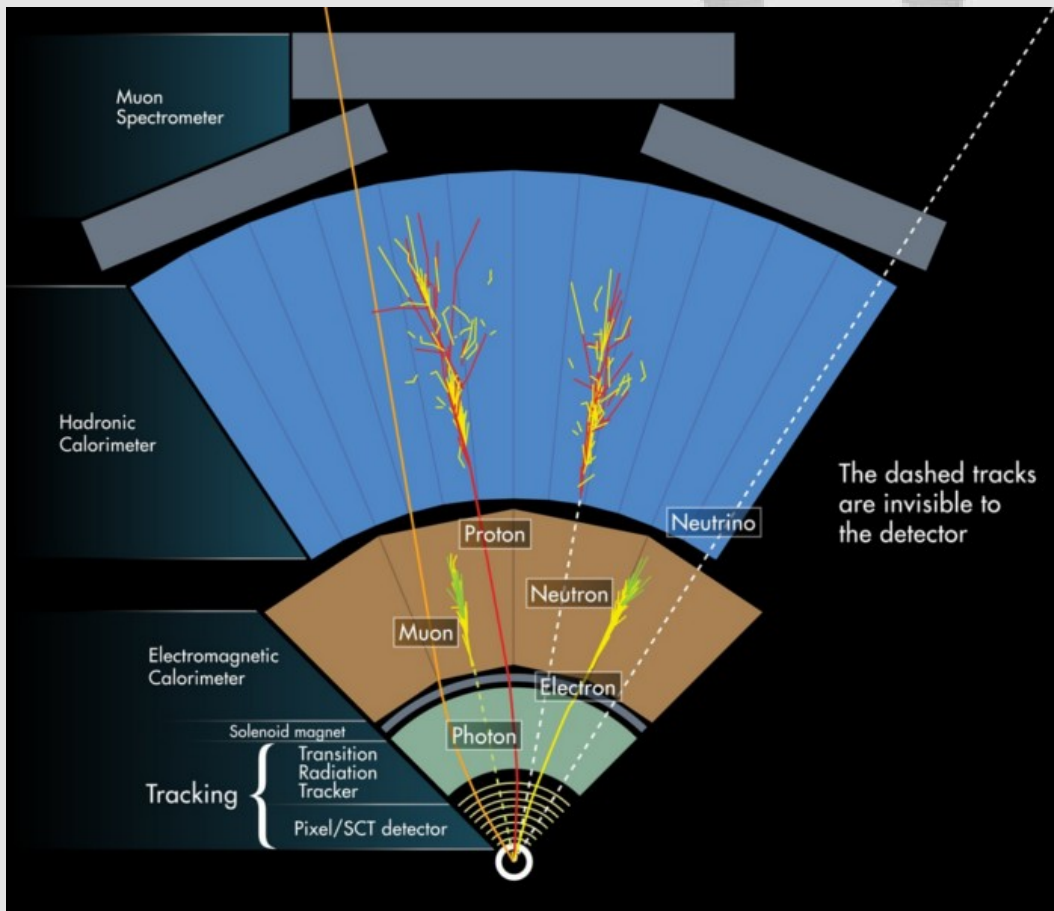


Mörk Materia vid kolliderare med ATLAS experimentet





Att (ej) detektera Mörk Materia



Neutriner
och
Mörk Materia
ger inga direkta spår
i våra experiment

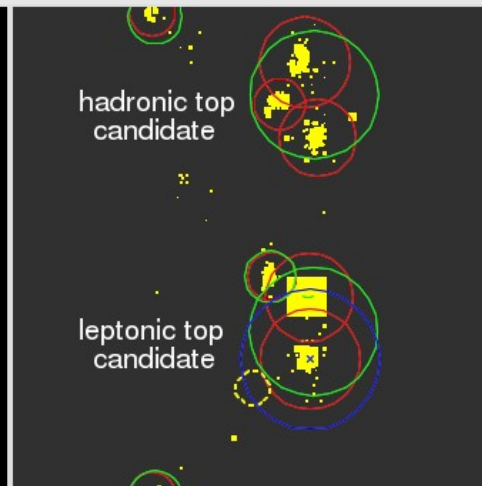
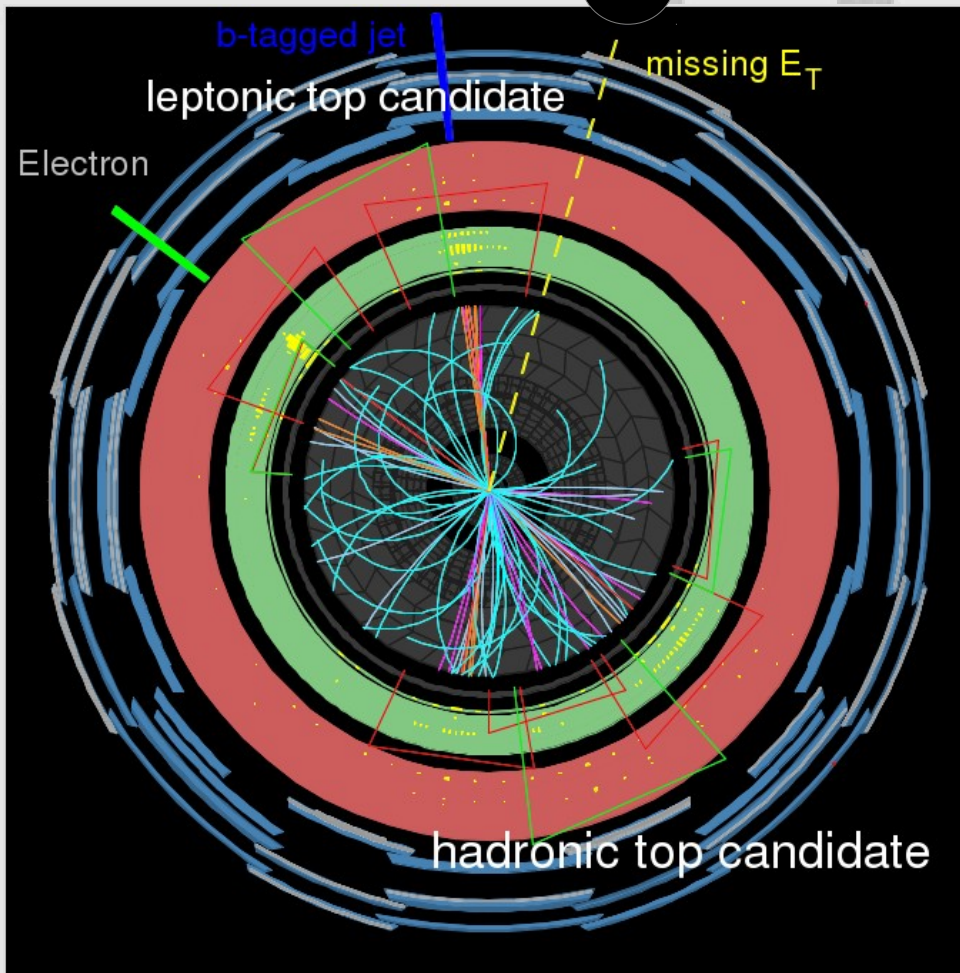


Letar därför efter
energi som försvunn
ur experimentet



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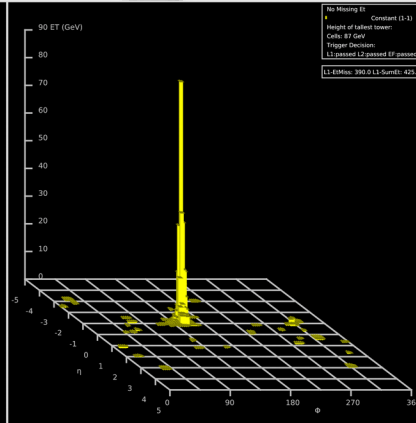
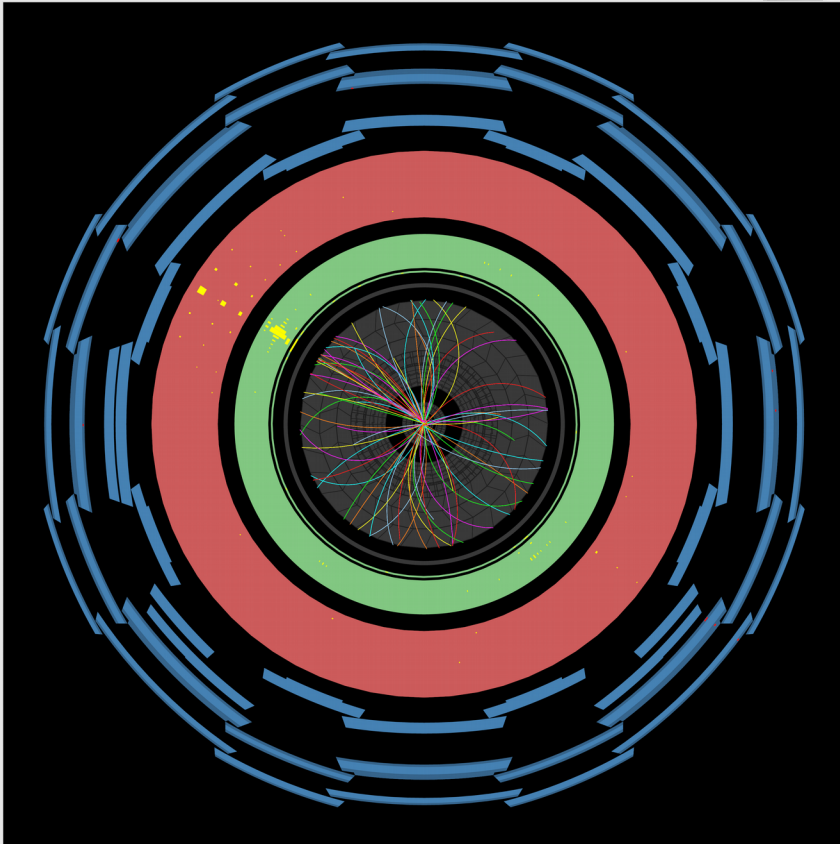
ATLAS
EXPERIMENT

Run Number: 166658, Event Number: 34533931

Date: 2010-10-11 23:57:42 CEST



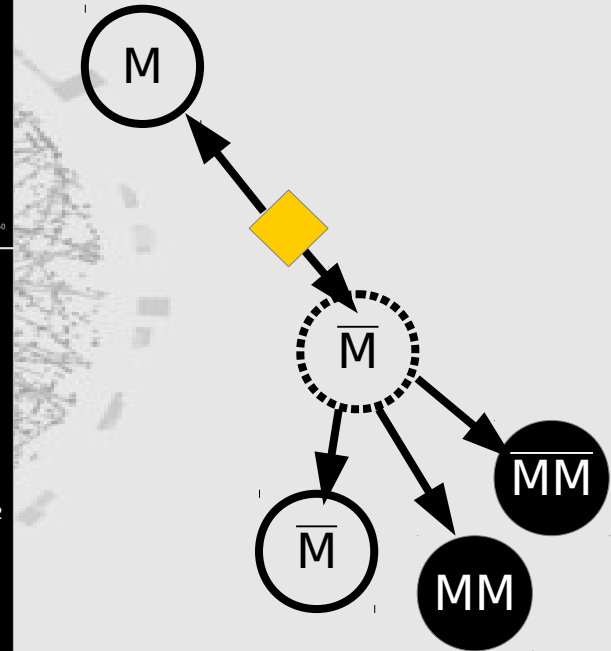
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**ATLAS
EXPERIMENT**

Run Number: 180309, Event Number: 36060682

Date: 2011-04-27 02:33:15 CEST

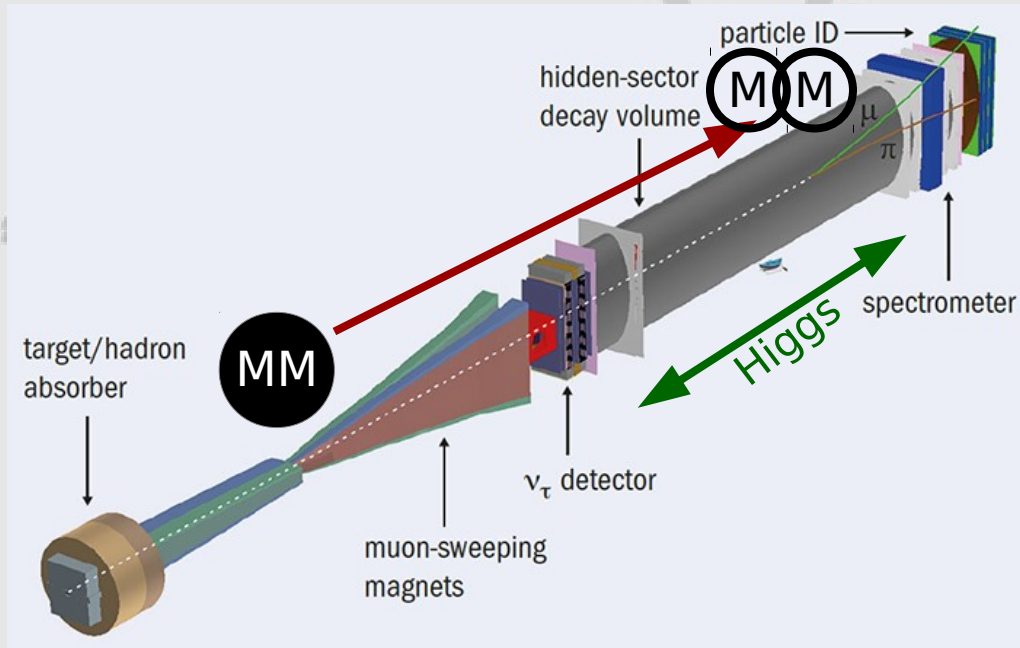




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Mörk materia vid experiment med strålmål med SHiP experimentet



När Mörk Materia partnern till den "vanliga" neutrino rör sig genom Higgs-fältet skapas Materia som ger spår i våra experiment



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Kanske kommer vi att upptäcka att det mörka trots allt inte är så mörkt



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Del II: Vad gör jag?



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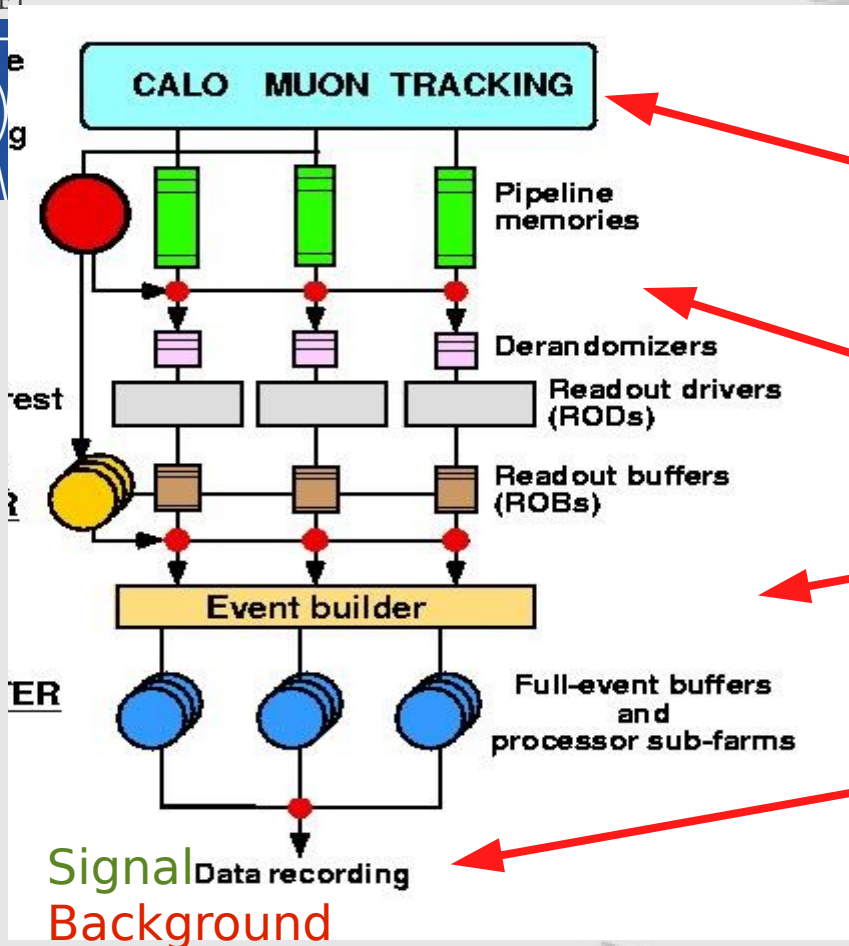
www.jobyan.co.uk

DATA ANALYSIS TODAY



The data challenge

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- 40 million events/s (when bunches of protons collide)
- ~800 million proton collisions/s (~500000 CD's per second)
- 40 million events held for 3 μ s, then reduced by hardware trigger(filter) to 100 000 events/s
- Software algorithms reduces data in 10-100 ms to about 500 events/s that are stored on tape (~10 PB/year)
- Data distributed and analysed on GRID. WLCG with ~170 data centres in 42 countries.



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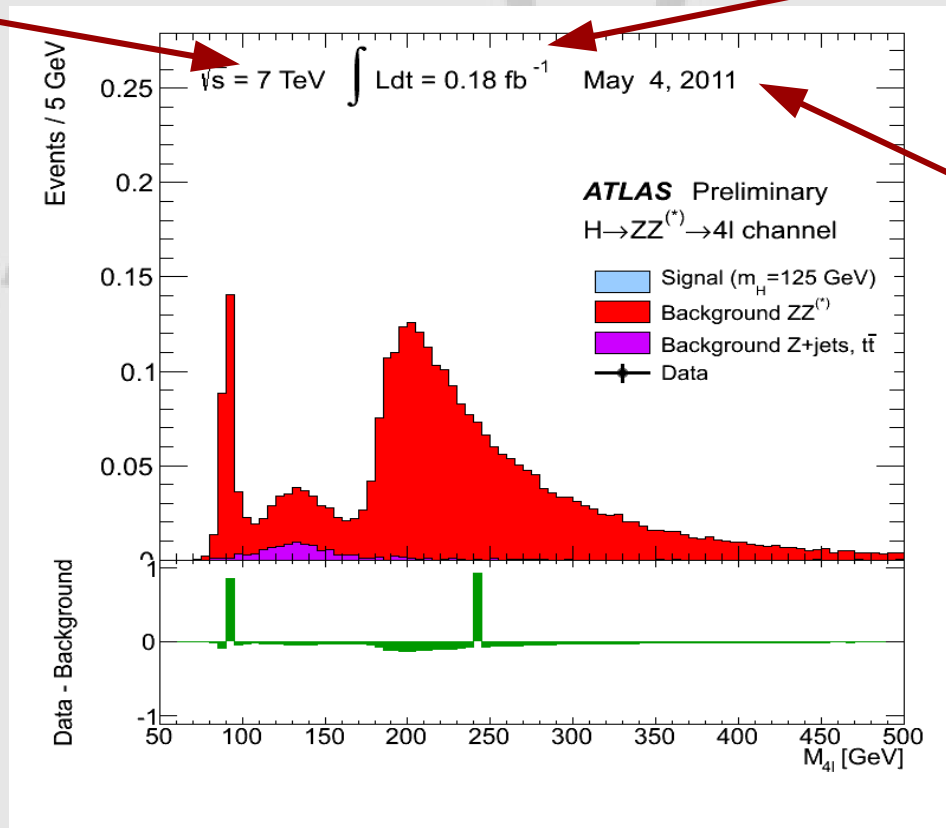


Higgs \rightarrow 4 leptons (electrons/muons)

Kollisionsenergi

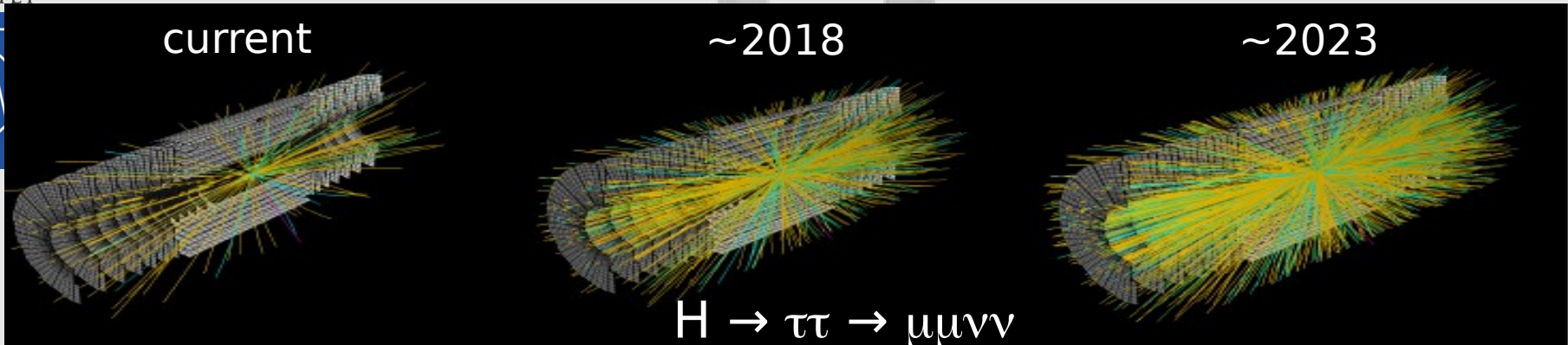
Datamängd

Datum





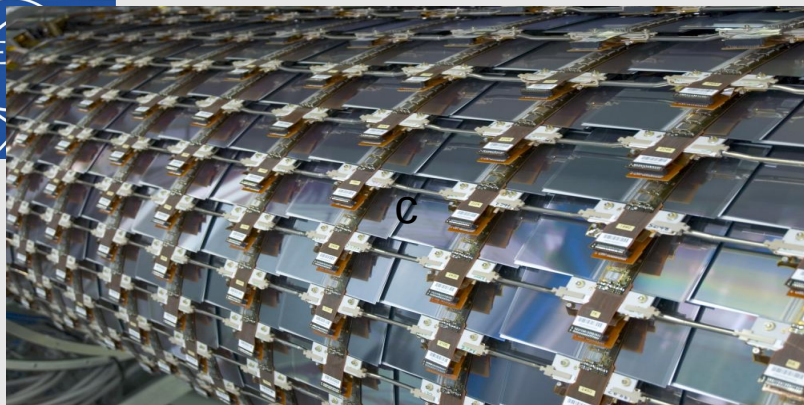
Future challenges → upgrade



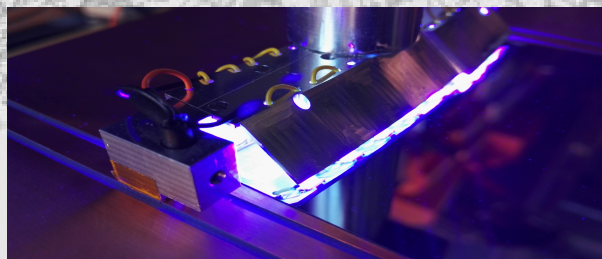
- To gain sensitivity for rare processes the intensity of the LHC beam will be increase $>10X$ → more data/event and much more difficult environment for the trigger to decide
- Currently 20 simultaneous collisions in every event. When LHC is running at full intensity (High Luminosity LHC) 200 simultaneous collisions will be recorded in every event. One of the collision may contain interesting physics....
- The radiation damage to the electronics will also increase by an order of magnitude. Some parts may get $> 10MGy!$



Large silicon tracker

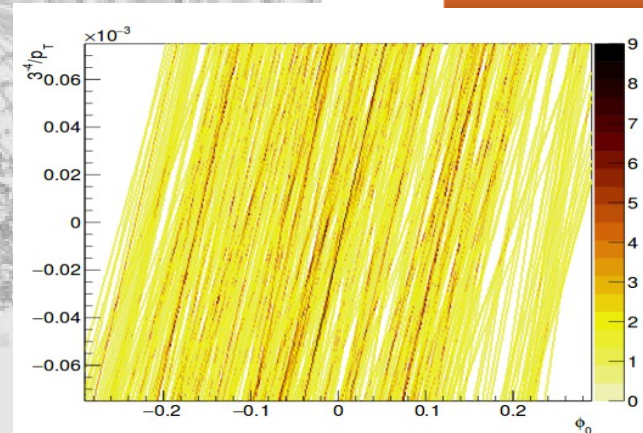
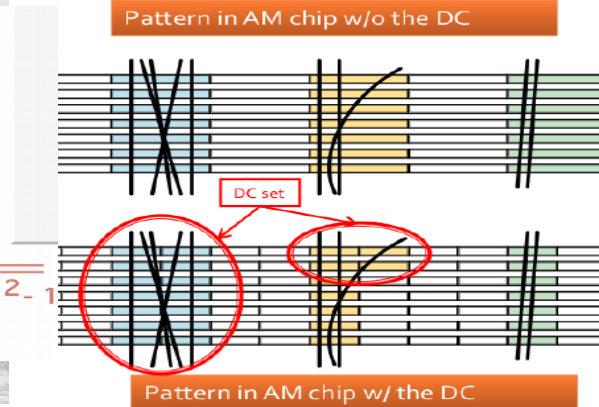
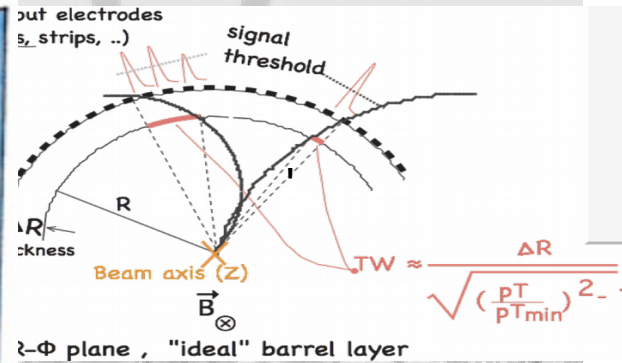
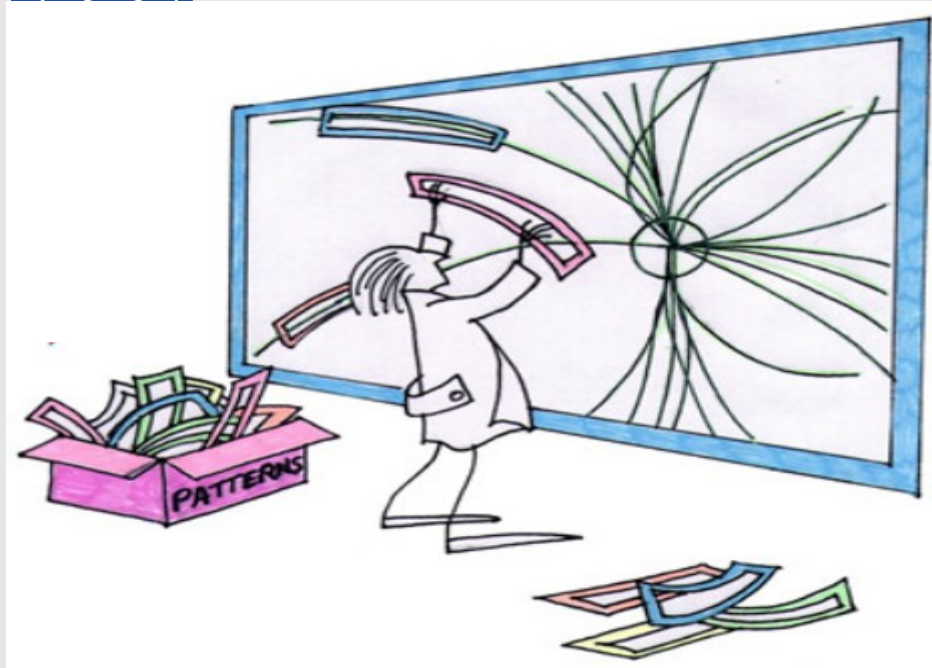


Industrialisation of assembly method to allow for large scale production in industry





Tracking and triggering with deep learning (with hardware accelerators)



Pattern recognition in 3

uS



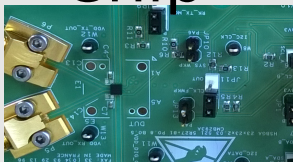
Higher readout bandwidth for future experiments

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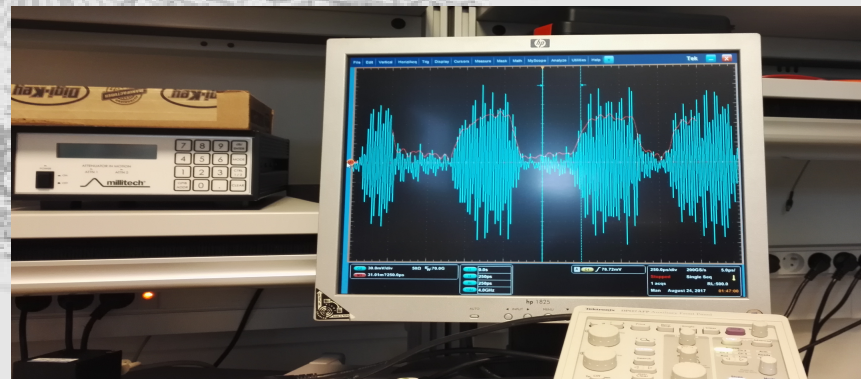
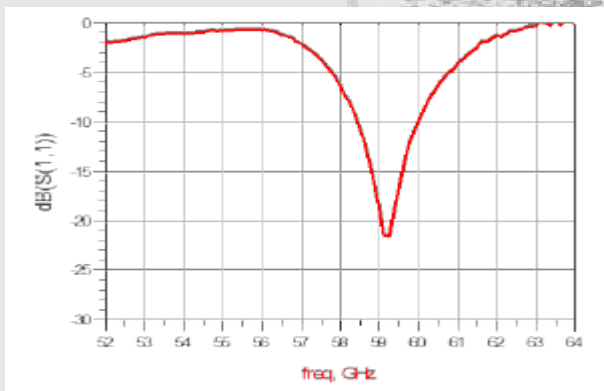
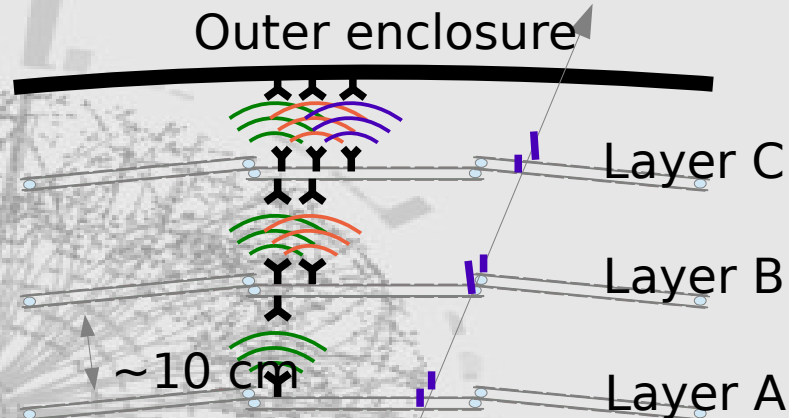
CERN

The future - Wireless data links?

Chip



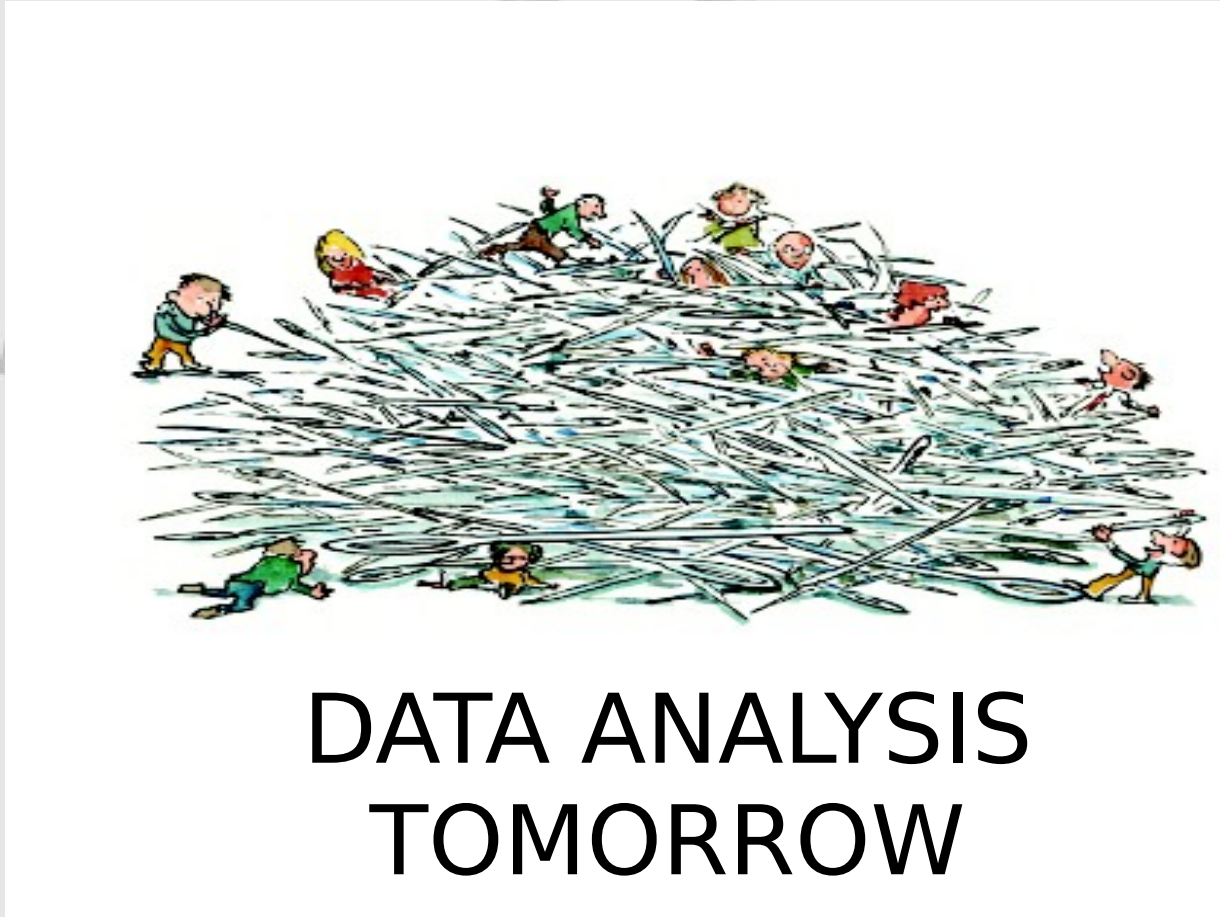
Antenna





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Real time data analysis



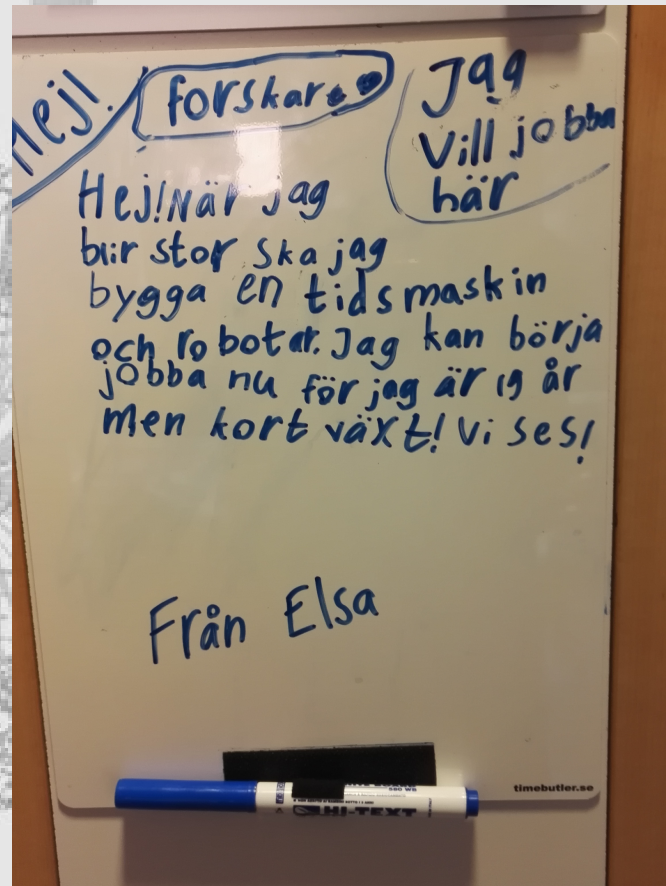
DATA ANALYSIS
TOMORROW



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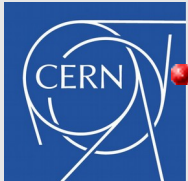


Extra material





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CERN-Conseil européen pour la Recherche nucléaire

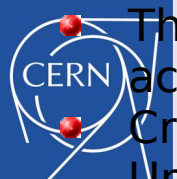
Founded 1952 (1954 ratified) by 12 countries: Belgium, Denmark, France, Germany(West), Greece, Italy, Netherlands, Norway, Sweden, Switzerland, Great Britain and Yugoslavia

- Name today: European Organization for Nuclear Research/Organisation européenne pour la Recherche nucléaire with two official languages (Eng/Fr). Today 22 member states (and 5 associative member states) + 40 more user countries
- ~2400 employee and ~10000 users (Uppsala University has ~6200 employee)
- Budget ~1.2 GCHF/year (~9GSEK, comparable with a large university in Sweden). Sweden pay 2.73% (~30MCHF)/year (2017)





The Large Hadron Collider



The worlds largest and most powerful accelerator, started in 2008
Creates currently the hottest temperature in Universe (~ 5 trillion $^{\circ}\text{C}$)

- 27km circumference with 1237 superconducting magnets (-271°C , colder than outer space)
- Consumes 120MW



	Injection	Collision
Proton energy [GeV]	450	7000
Number of particles per bunch	1.15E+011	
Number of bunches	2808	
Circulating beam current [A]	0.58	
Stored energy per beam [MJ]	23.3	362
RMS bunch length [cm]	11.24	7.55
RMS beam size [μm]	375.2	16.7



High energy-what??

The LHC ring will store a beam energy of 360 Megajoules.

$2\,808 \text{ bunches} \times 1.15 \cdot 10^{11} \text{ protons @ } 7 \text{ TeV each} =$

$2\,808 \times 1.15 \times 10^{11} \times 7 \times 10^{12} \times 1.602 \times 10^{-19} \text{ Joules} = 362 \text{ MJ per beam}$

This can be compared to:

Kinetic energy

- 1 small cruise ship of 10 000 tons moving at 30 km/hour
- 450 automobiles of 2 tons moving at 100 km/hour

Chemical energy

- 80 kg of TNT
- 70 kg of chocolate (counting the calories)

Thermal energy

- melt 500 kg of copper
- raise 1 cubic meter of water 85° C: "a tonne of tea"

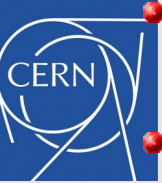
Milk chocolate is 520 calories per 100 g , which gives 350 MJ = 69 kg of chocolate.

The energy in chocolate is released a bit more slowly than in TNT!



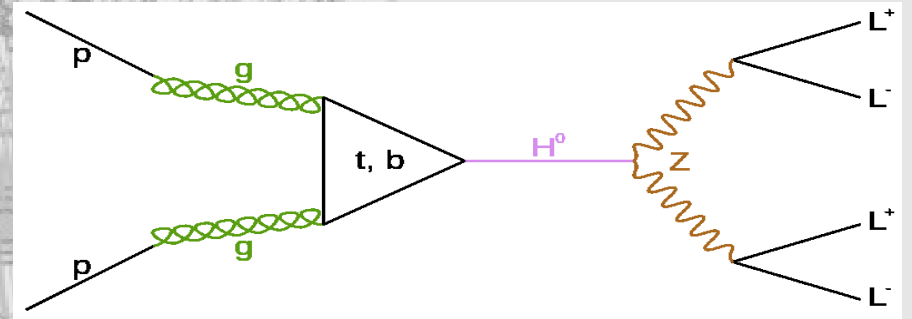
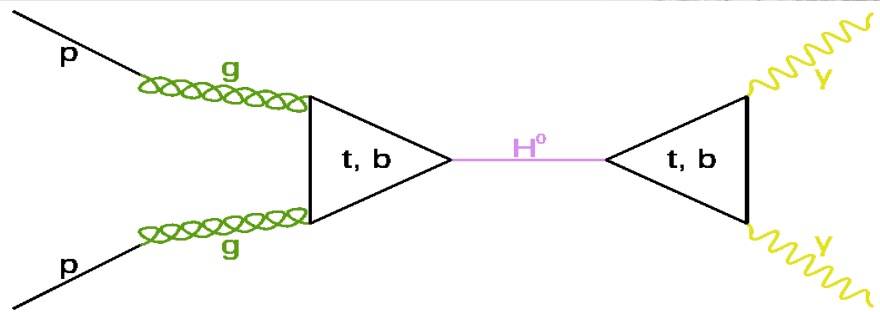
Higgs boson discovery

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The two large experiments ATLAS and CMS at LHC announced on 4 July 2012 that both had independently made the same discovery: the Higgs boson.

The Higgs boson was discovered in two different decay channels.



- More precise studies have confirmed that the discovered particle is the Higgs boson.
- The Nobel prize in Physics was awarded François Englert and Peter Higgs for the theoretical discovery of the Higgs boson.

