
# Stuff: What is it?

## An Introduction to Particle Physics and Accelerators

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13 September 2013

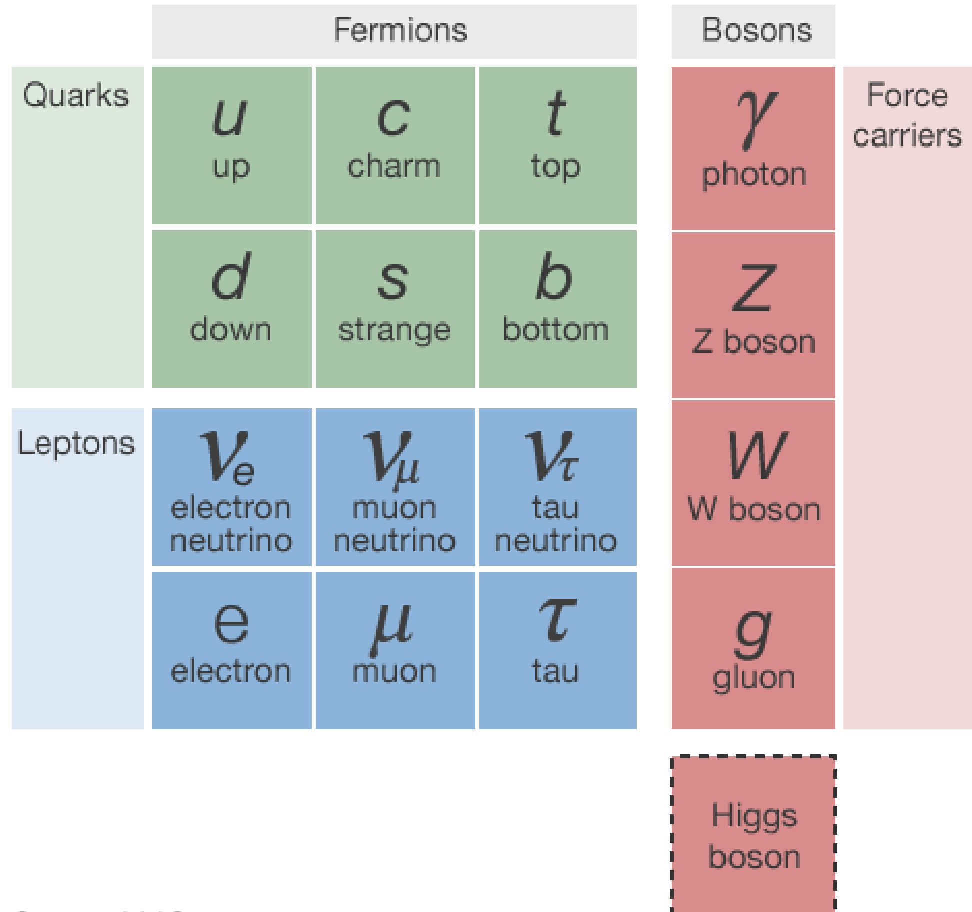
# Contents

Highly selective whirlwind tour: 20 lectures → 1 lecture

In full: http://epweb2.ph.bham.ac.uk/user/newman/appt10/appt.html

Designed to give a feel for what we need to trigger on

- 116 Years of Accelerators
- Electroweak Interactions
- Flavour Physics
- Strong Interaction
- LHC Physics




Source: AAAS

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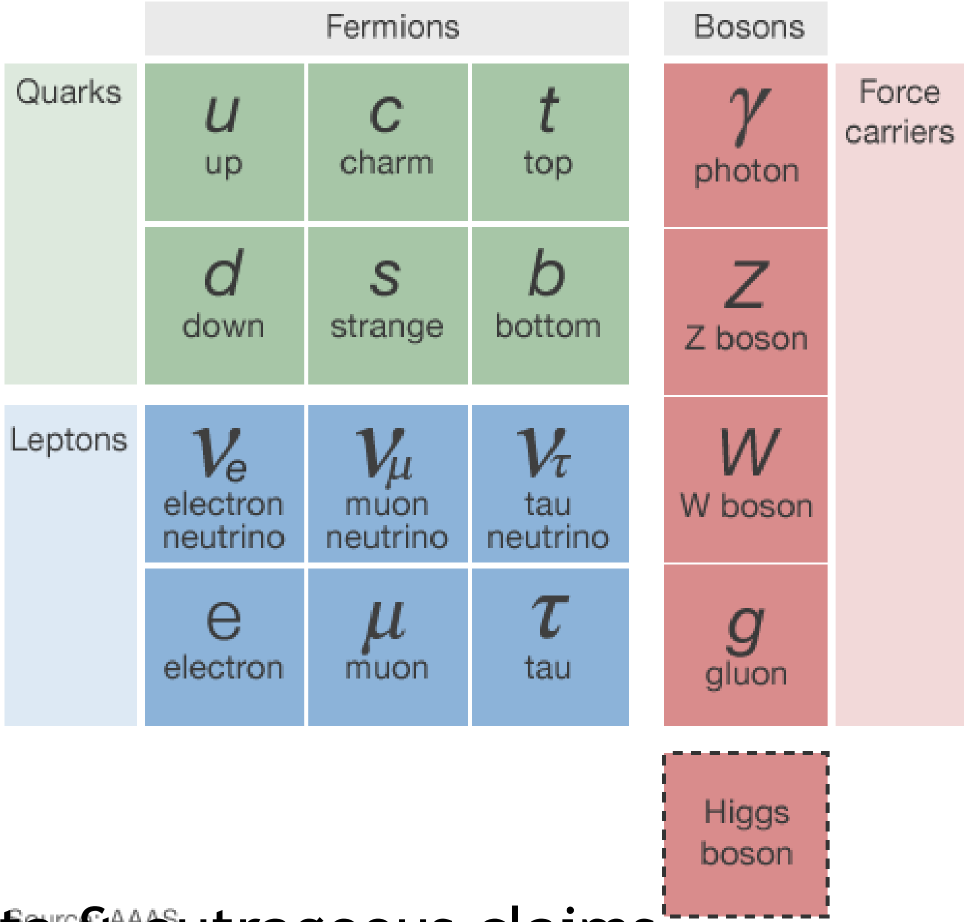


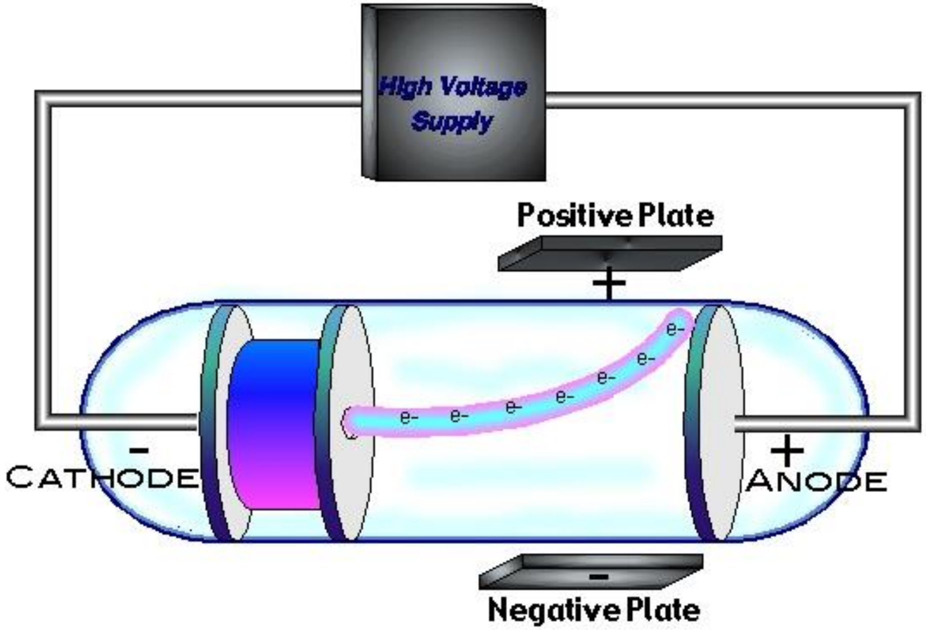

Not covered at all:

- Neutrinos
- Dark Matter
- All Experimental issues
- Proper theory … just some data & outrageous claims

# The first accelerators and the first fundamental particle

Cathode Ray Tubes: High Voltage across low pressure gas

Mysterious charged particles emitted from cathode

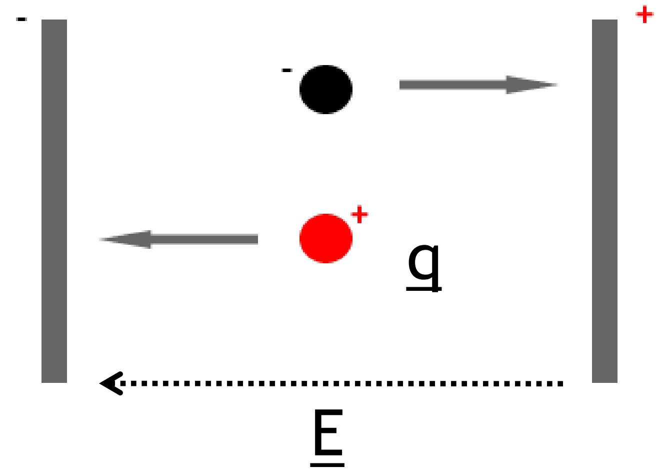



1897: JJ Thompson measured cathode ray mass from bending in electric field

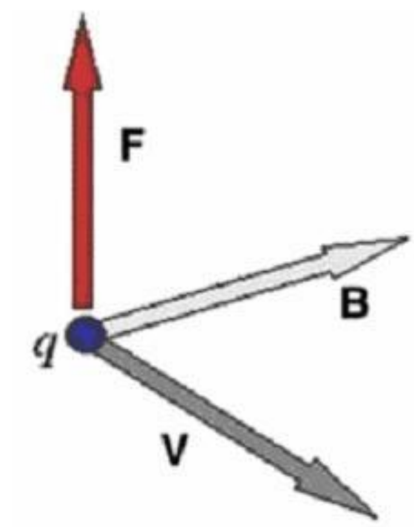
… 1/1000$^{th}$ of mass of Hydrogen
… there are smaller things than atoms!
… we now know them as ‘electrons’

# How does a Cathode Ray Tube work?

We can accelerate charged particles by applying an electric field to them




We can also change the direction of the particle by applying magnetic fields

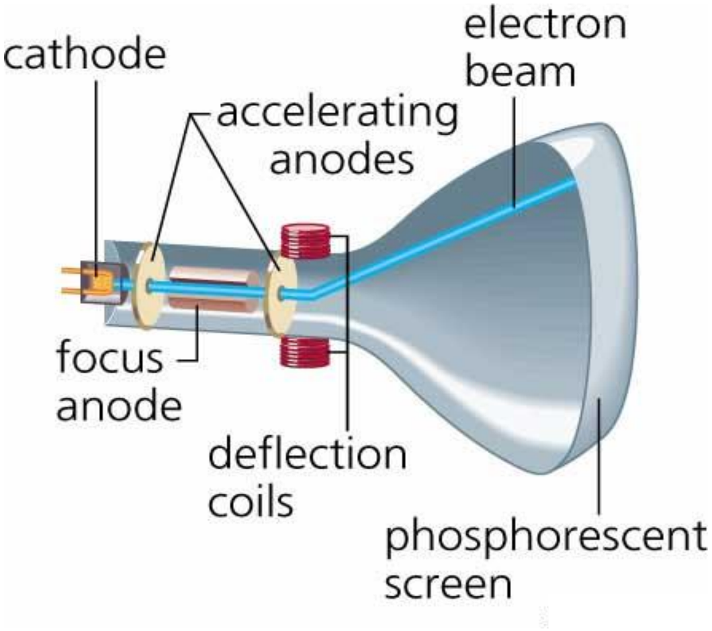



… acting perpendicular to the B field and the particle's motion

Modern particle accelerators work on the same principle …

# More Cathode Ray Tubes

(Old fashioned) TVs accelerate electrons through ~20keV, bend them using magnets and image on light-emitting screen



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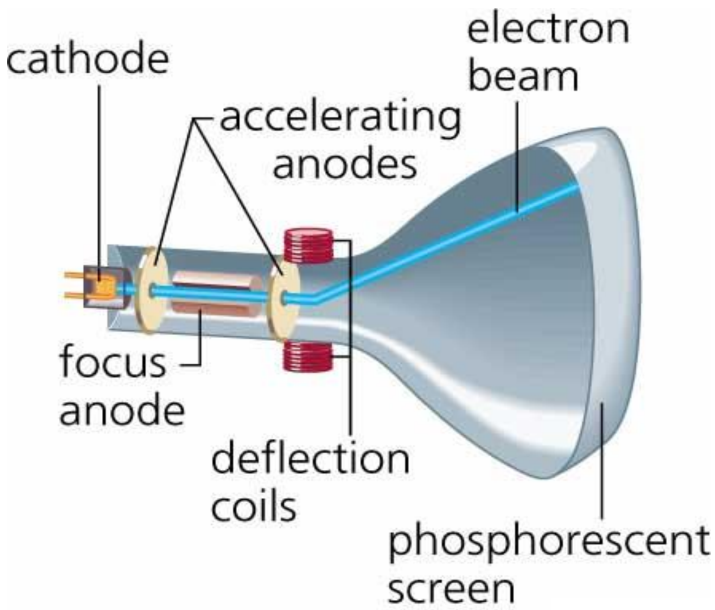
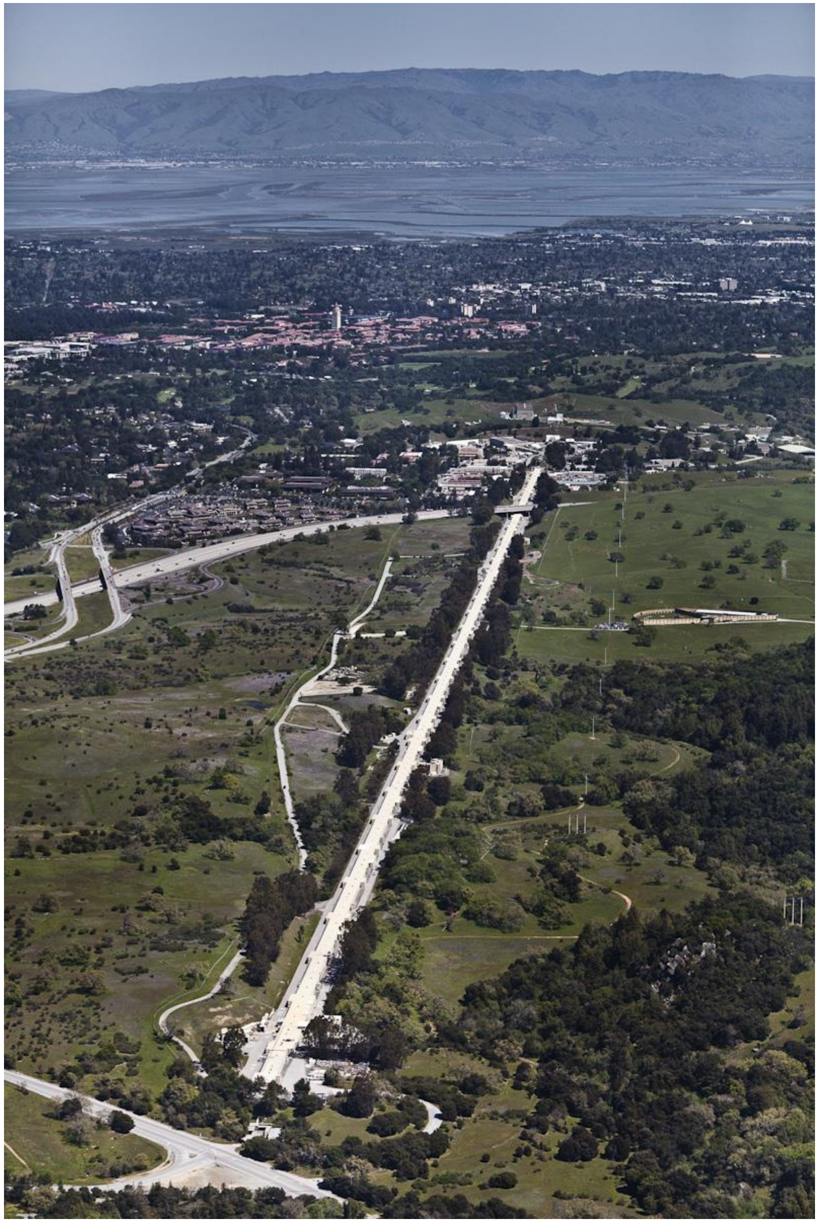
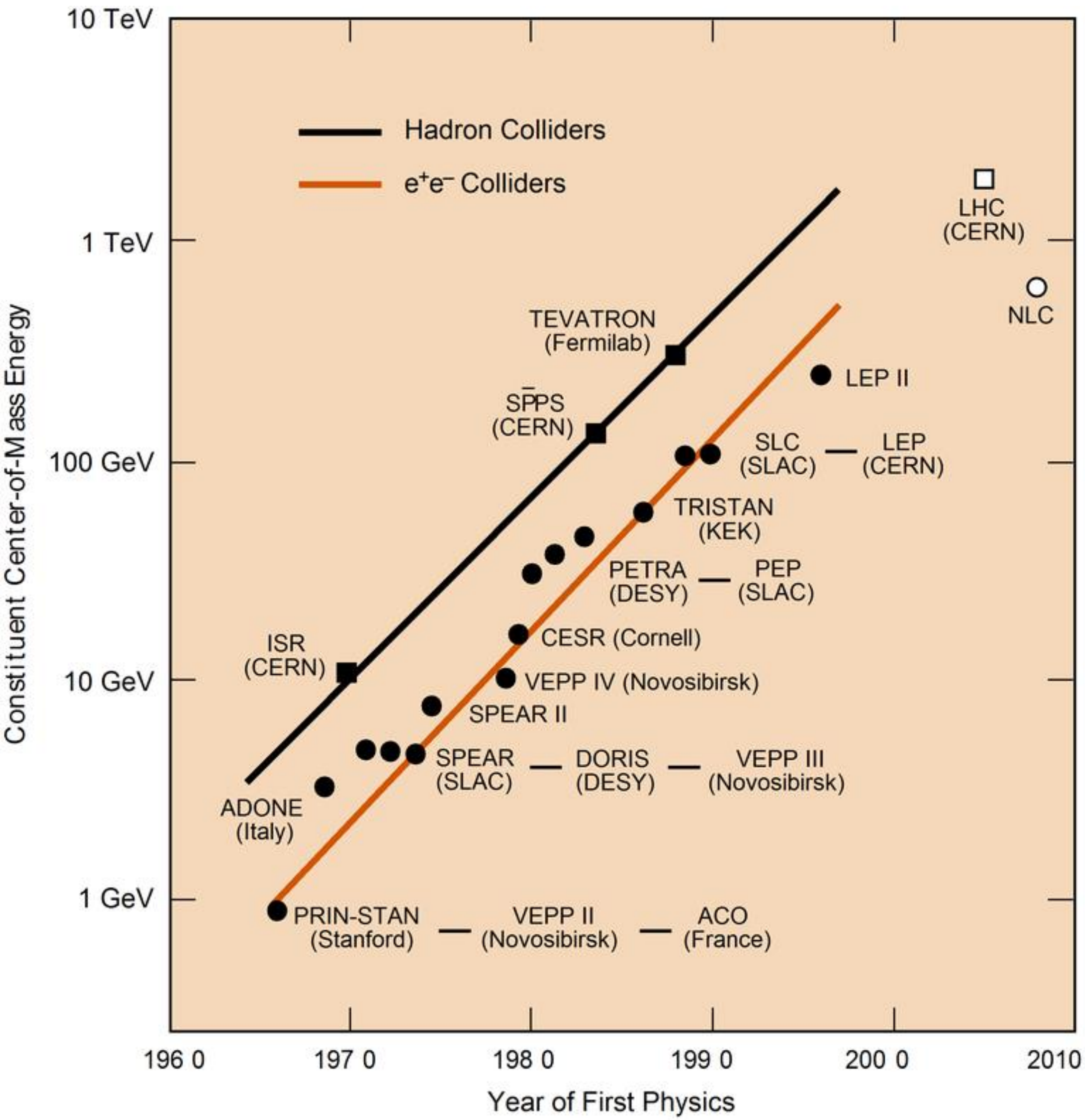


1969: SLAC 2-mile 20 GeV electron accelerator showed that protons have structure → quarks

# The 'Livingstone' Plot

Energy of machines grew exponentially from 1950s to 1990s.



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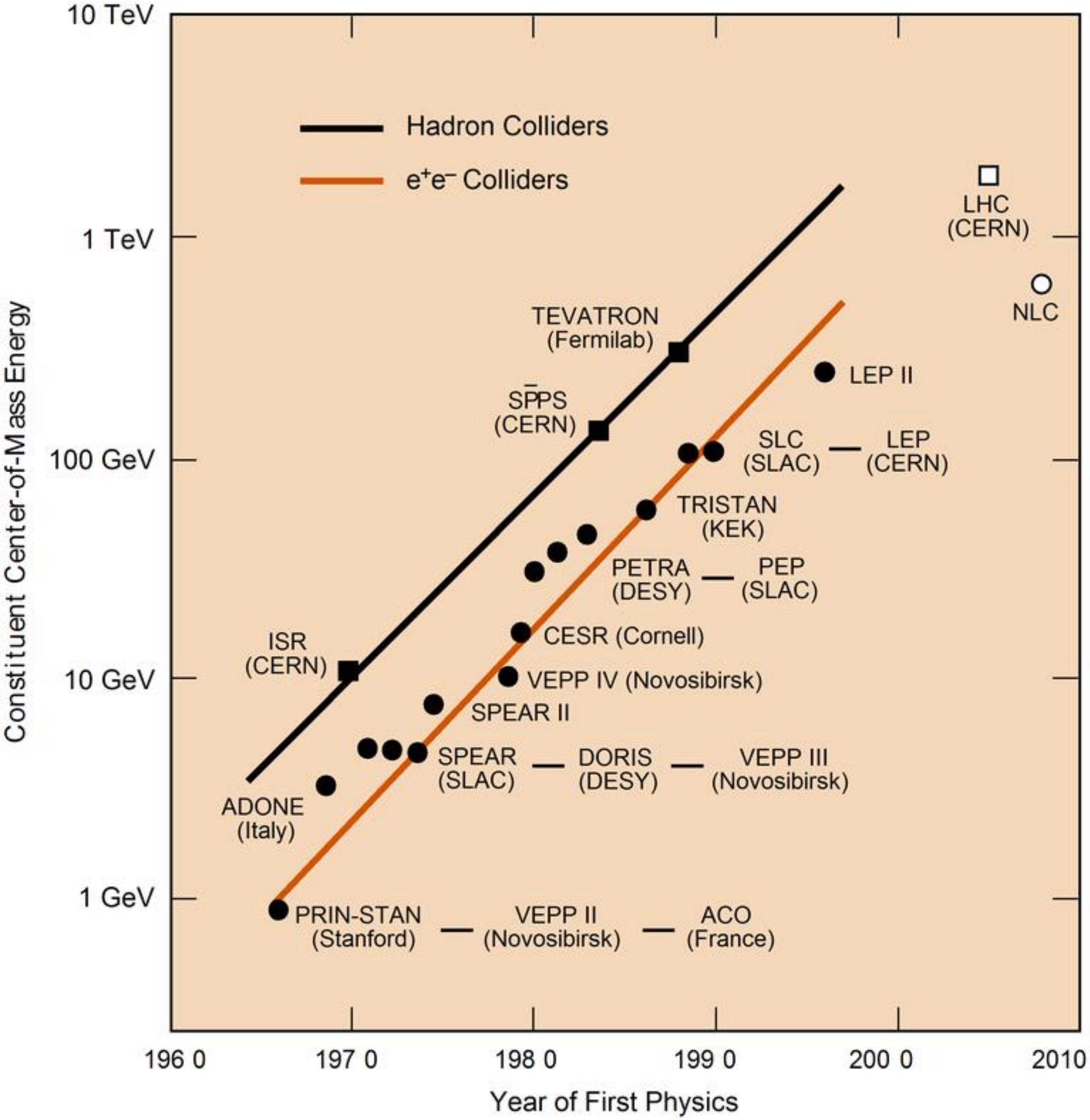



Current state of the art:

$e^+e^-$: $E_{cms}$=209 GeV (LEP, CERN)

pp: $E_{cms}$=7 - 14 TeV (LHC, CERN)

ep: $E_{cms}$=318 GeV (HERA, DESY)

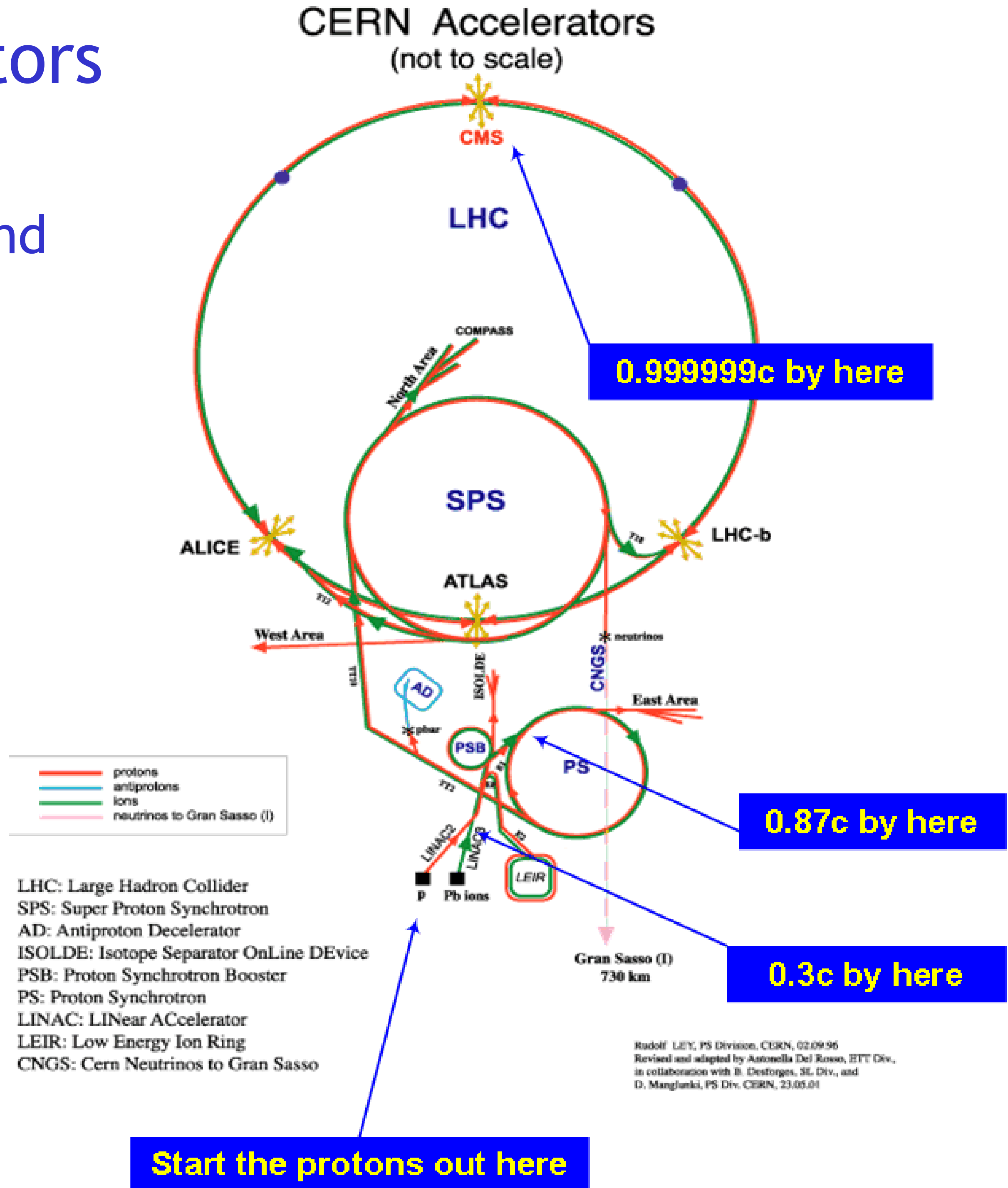
AA: $E_{cms}$=200 GeV for nucleons in Au-Au (RHIC, BNL)

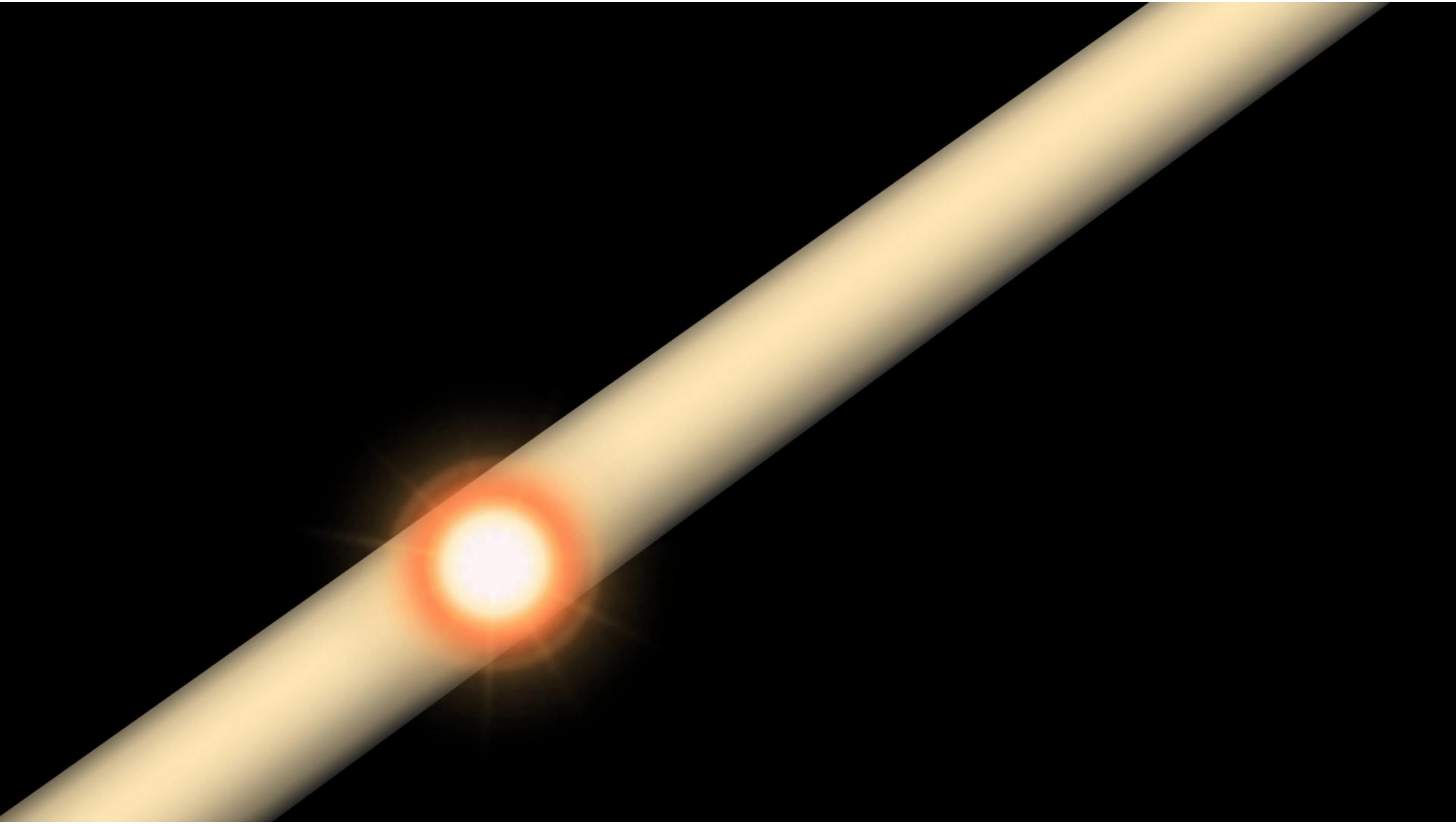
$E_{cms}$=2.7-5.4 TeV per nucleon Pb-Pb (LHC)

# CERN Accelerators

Little wastage!…
Accelerators recycled and re-used often as injectors, but also to run other experiments simultaneously with the big one.

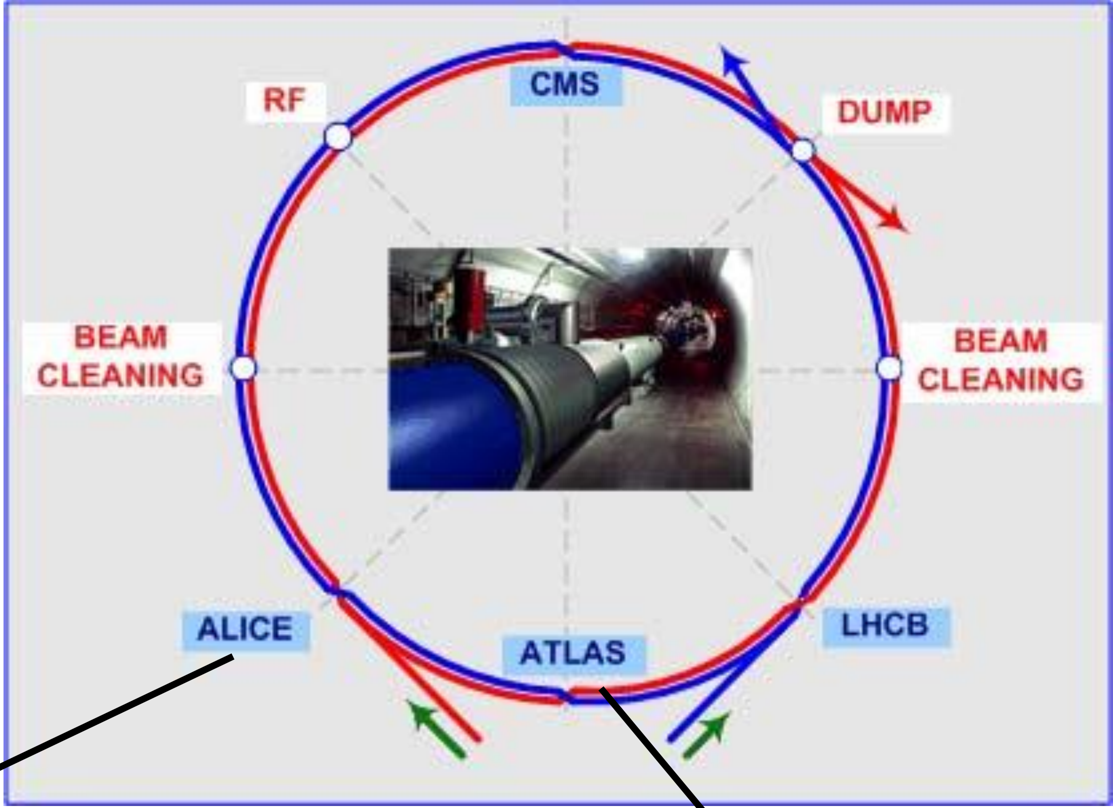
In parallel detection techniques have developed!
… bubble / spark / cloud chambers → complex multi-layer detectors with many sub-components





# Birmingham's Current Work

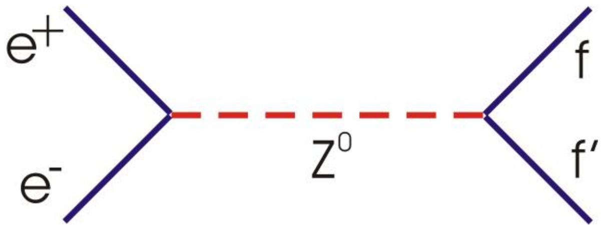
Birmingham has large groups, playing important roles in three of the four LHC experiments [ALICE, ALTAS & LHCb] and one SPS experiment [NA62]




Dave Charlton, ATLAS Spokesperson

David Evans, UK ALICE Spokesman

# e+ e- Scattering at Z Pole: LEP1 (1989-1995)




f = quark (u,d,s,c,b)
lepton (e, $\mu$, $\tau$)
neutrino ($\nu_e$, $\nu_\mu$, $\nu_\tau$)

- CMS energy $\sqrt{s}$=91.2 GeV
  → Many millions of Z bosons

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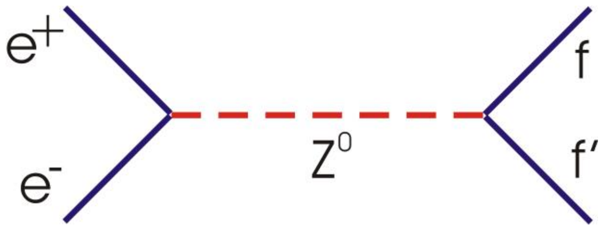


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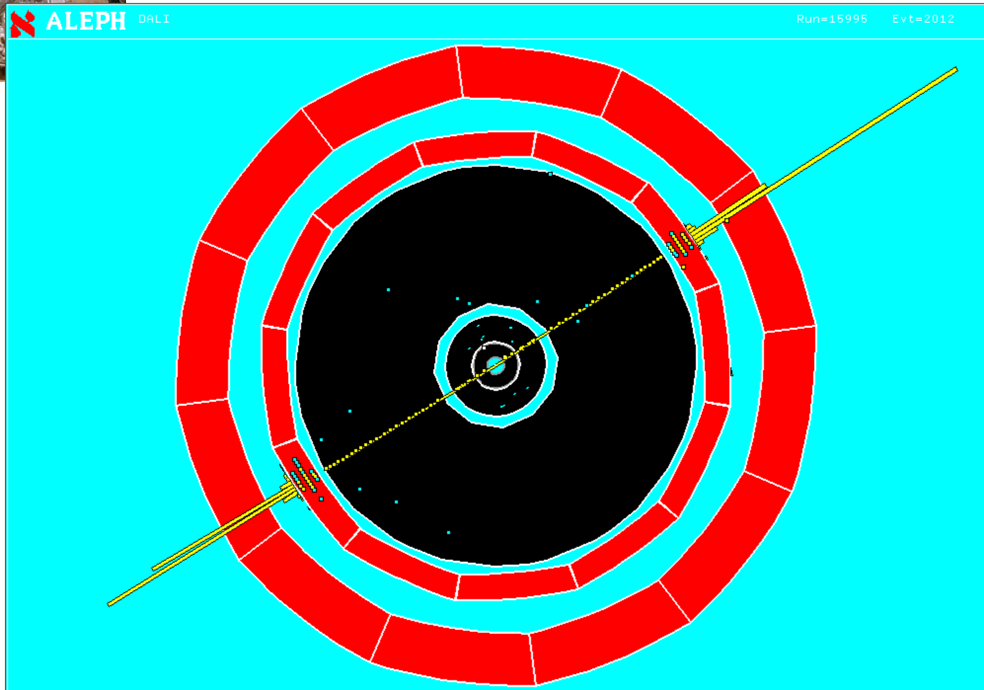
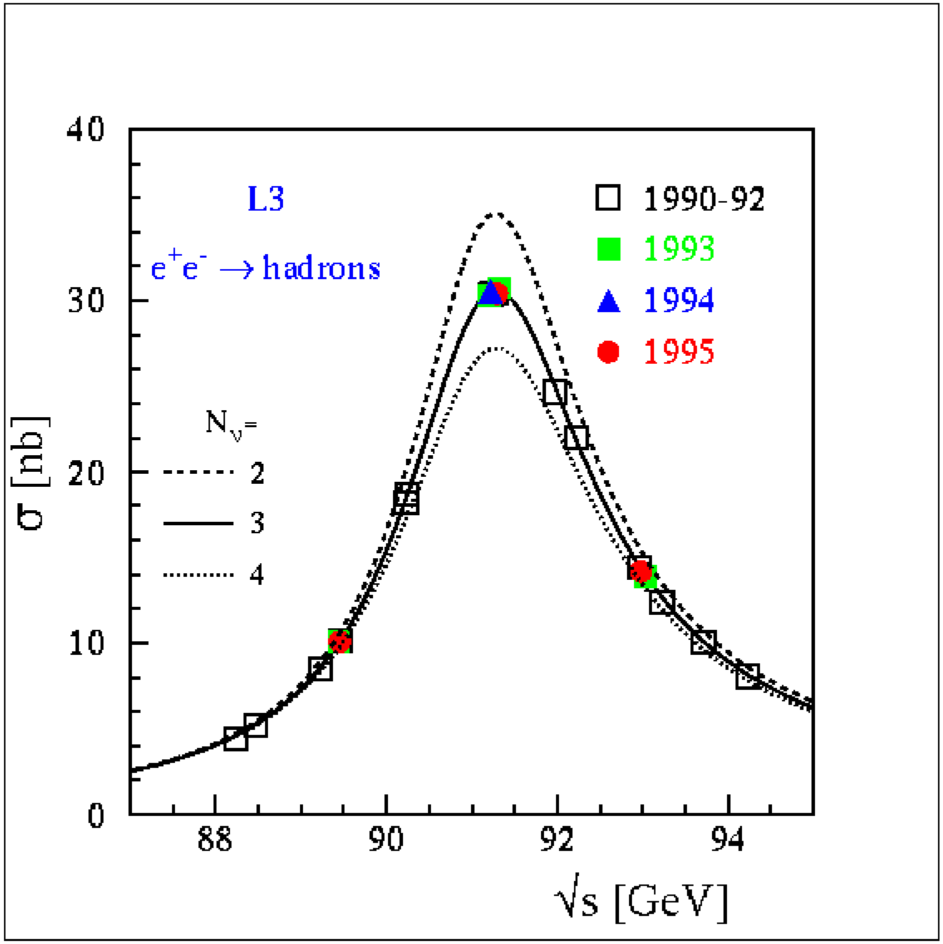
- Unprecedented precision in testing the Standard Model and constraining new physics



# (Very) selected LEP Results

$20M\ Z^0$ decays at LEP-I

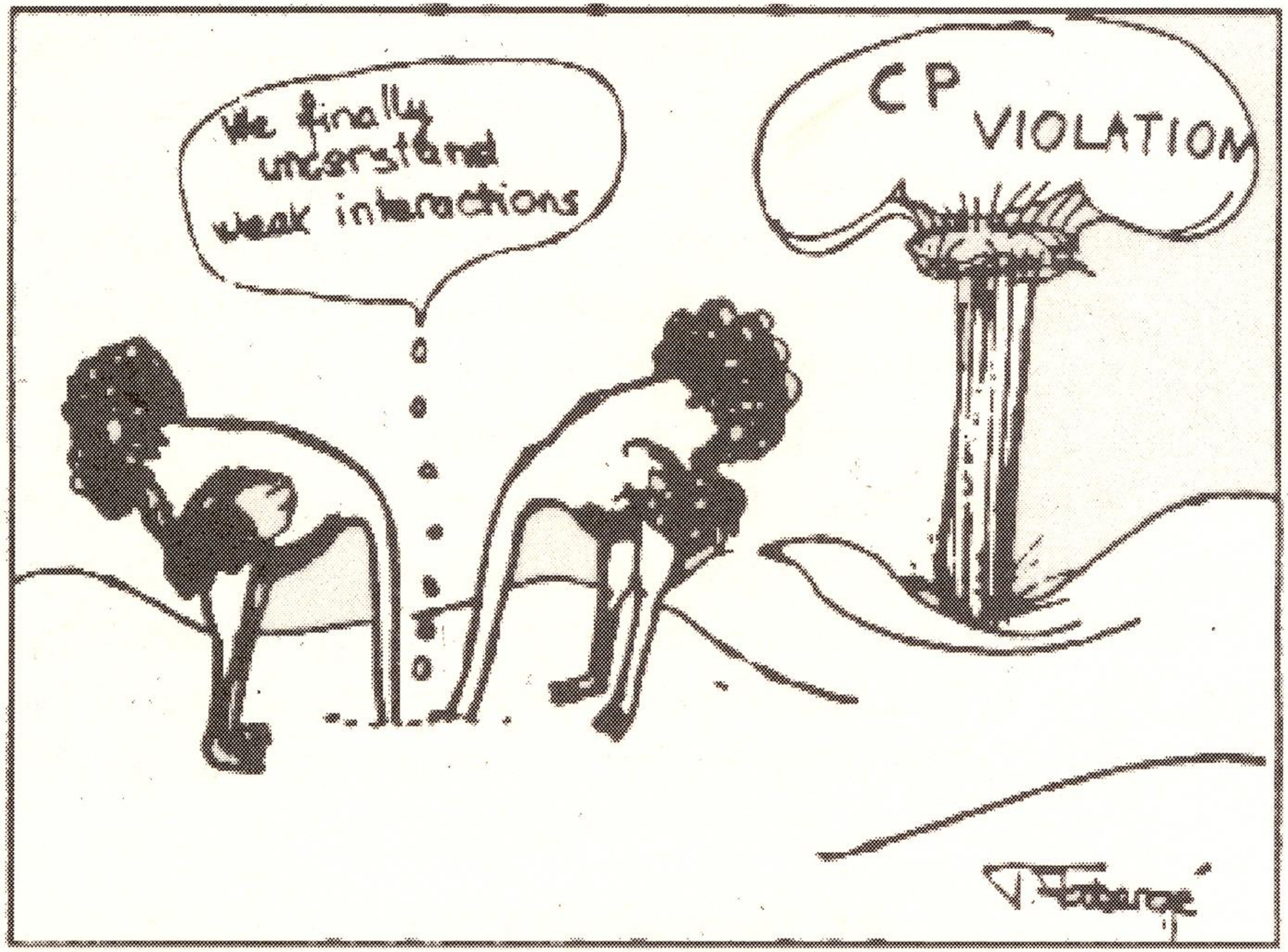
$40k\ W^+W^-$ events at LEP-II.




- There are 3 families of leptons
- They all feel the electroweak force equally (lepton universality)
- Standard Model established in detail and its parameters measured very precisely (e.g. $m_Z$ to 0.002%, $m_W$ to 0.05%)
- Many limits on physics beyond the Standard Model
- Indirect constraints on Higgs and other new physics (loops!)

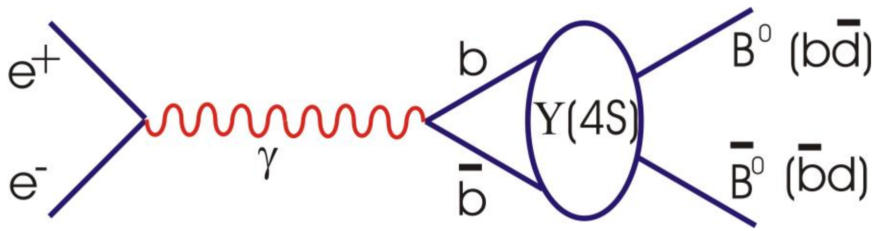
# Flavour Physics & the Weak Interaction

Cartoon shown by N Cabbibo, 1966, after Cronin & Fitch discovered CP violation in $K^0$ (s-dbar / d-sbar) decays, 1964




… implies asymmetry between matter and antimatter …

# CP Violation and $e^+e^-$ B Factories




– Υ(4S) just above B Bbar threshold

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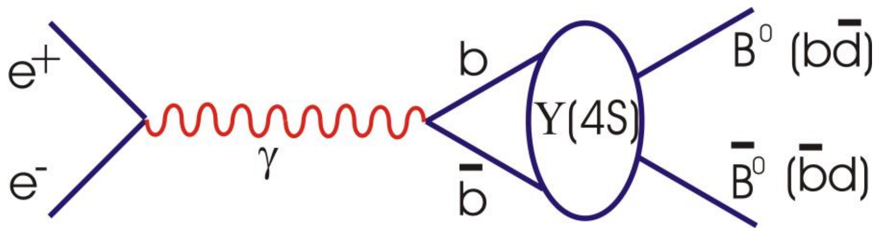
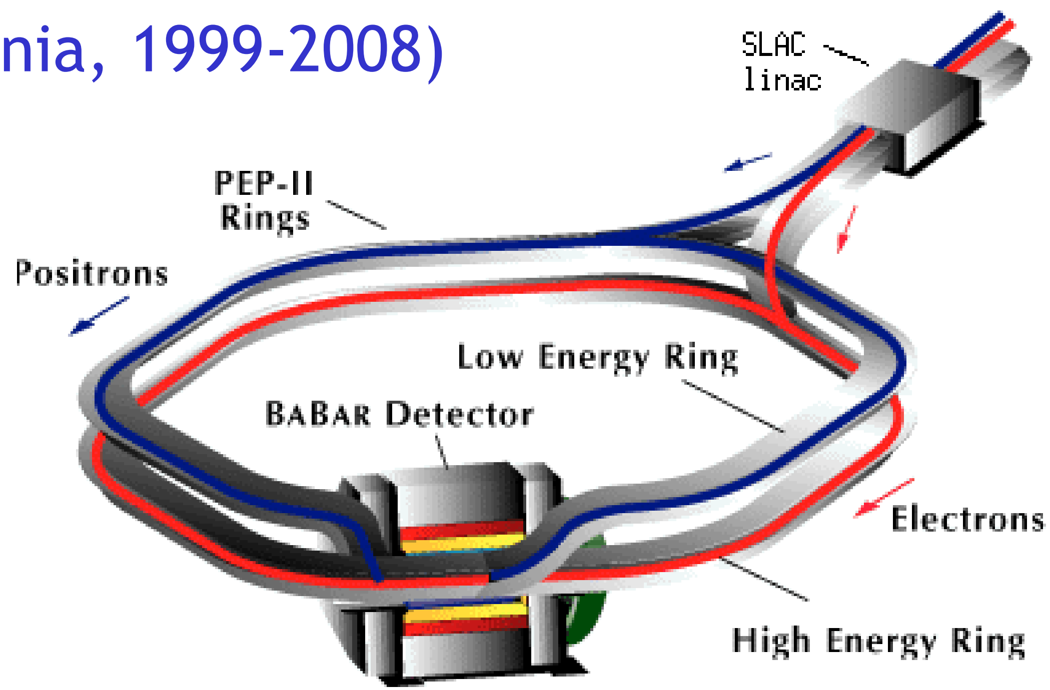



– $\Upsilon$(4S) just above B Bbar threshold
- Asymmetric e+ e- beams

• e.g. **BaBar** (SLAC, California, 1999-2008)

- 9 GeV electrons
- 3.1 GeV positrons
- Lumi > $10^{34}$ $cm^{-2}$ $s^{-1}$



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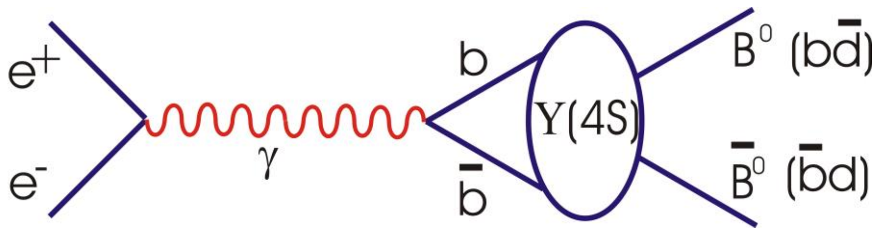


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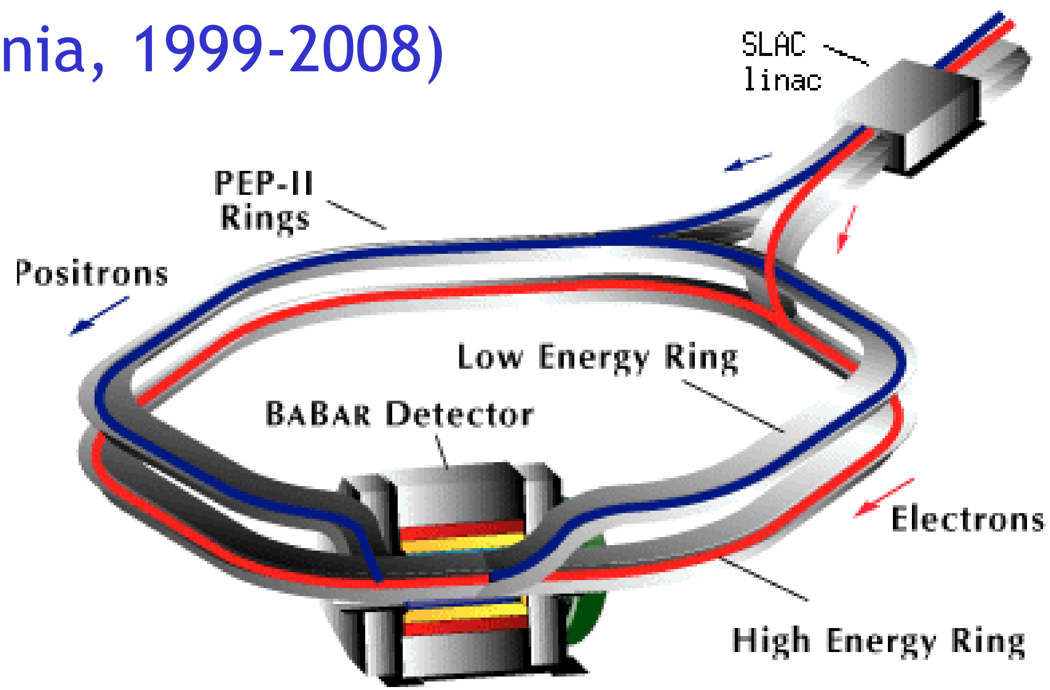
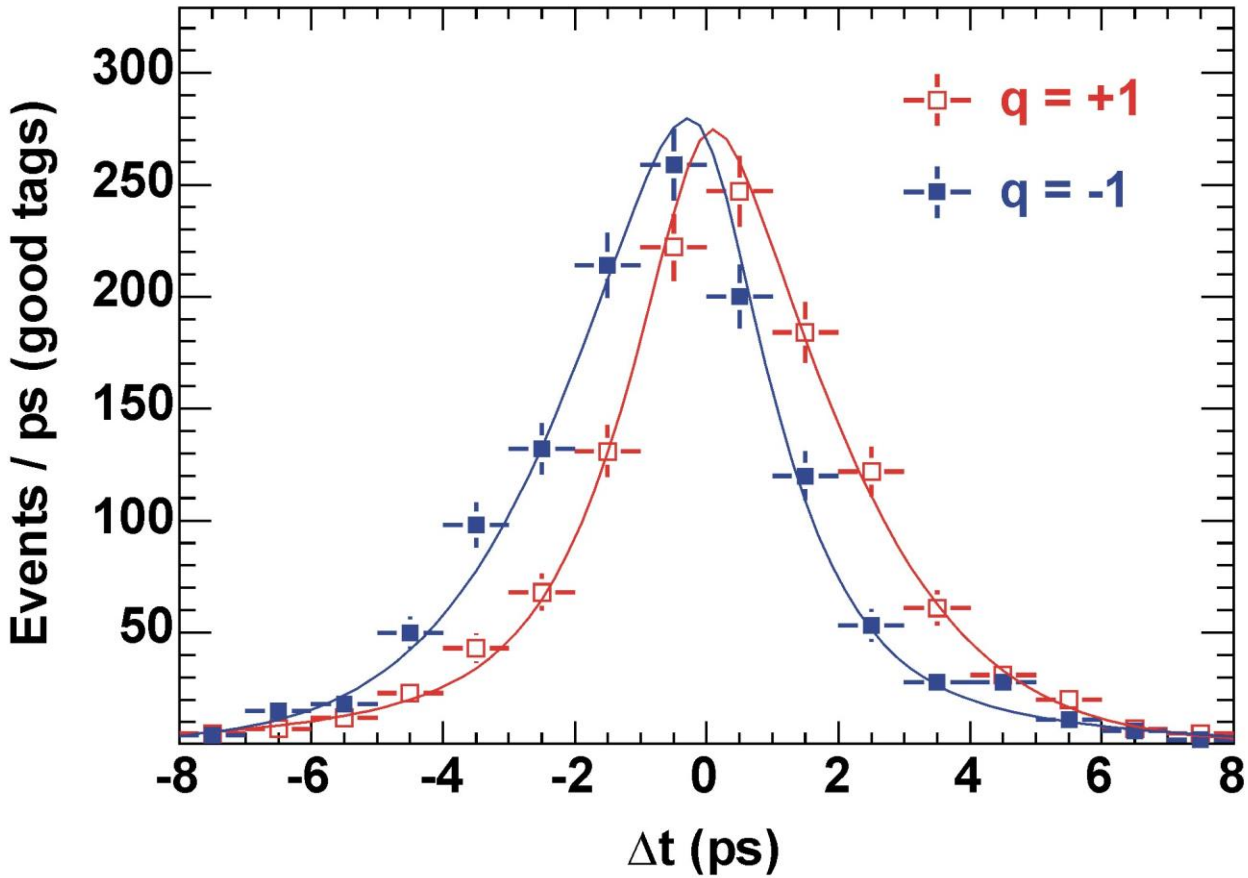



→$10^9$ co-moving $B^0$ (b+dbar)& $B^0$bar (bbar+d) pairs to study differences in well controlled way

# An Important Result from B Factories

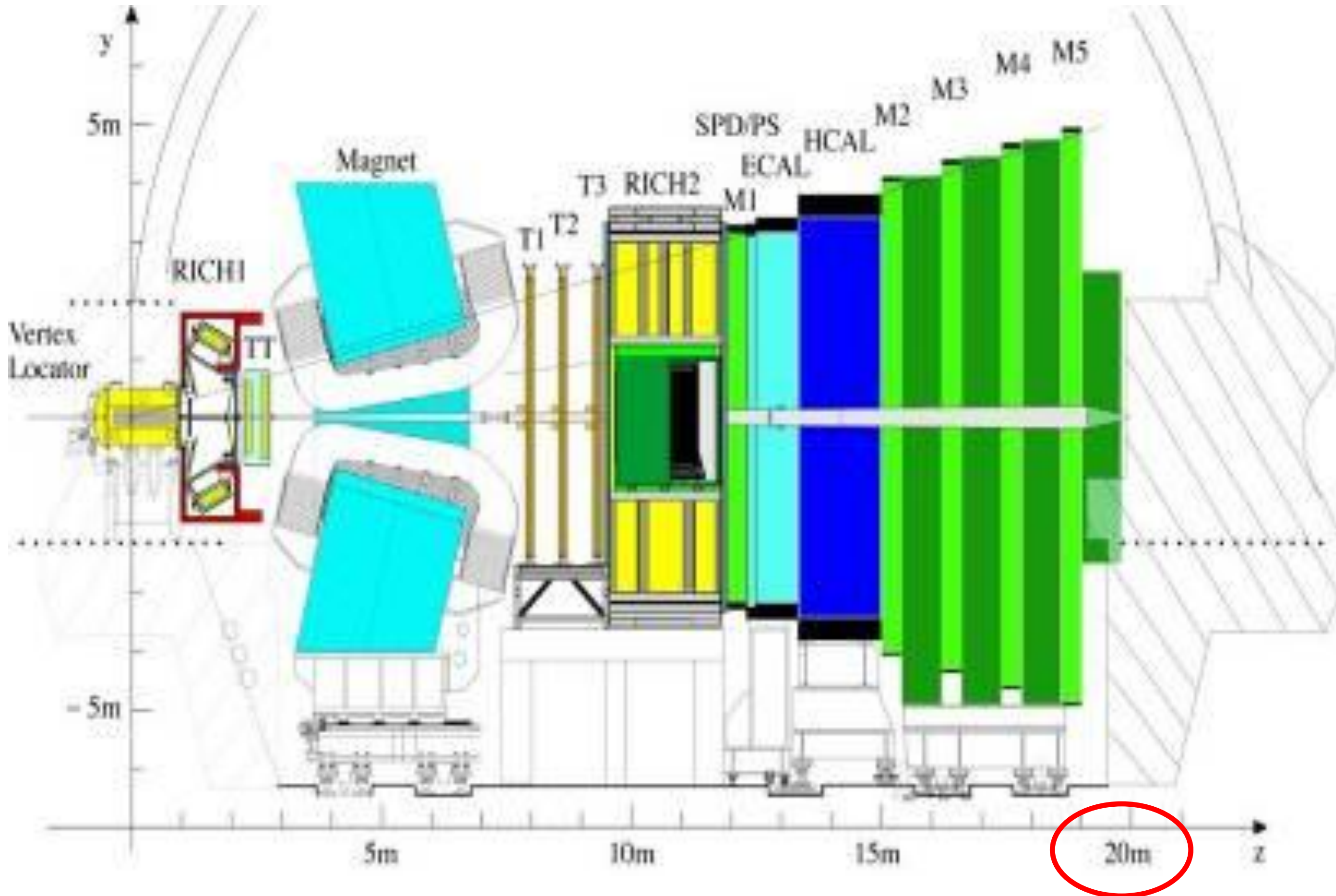
Tiny difference between lifetimes of $B^0$ (q=+1) and $B^0$bar (q=-1):
A `time dependent CP asymmetry' measurement



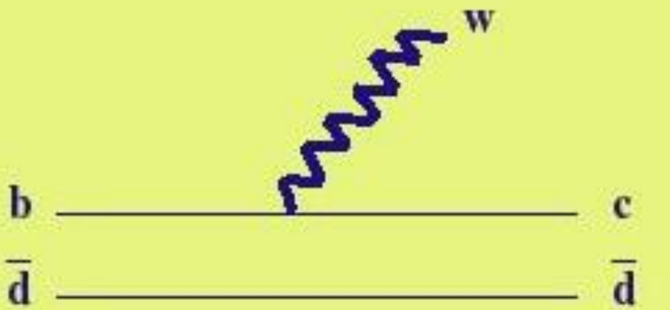
# LHCb: A B Factory at the LHC

Looks more like a fixed target configuration, with detectors stacked transverse to the beam direction

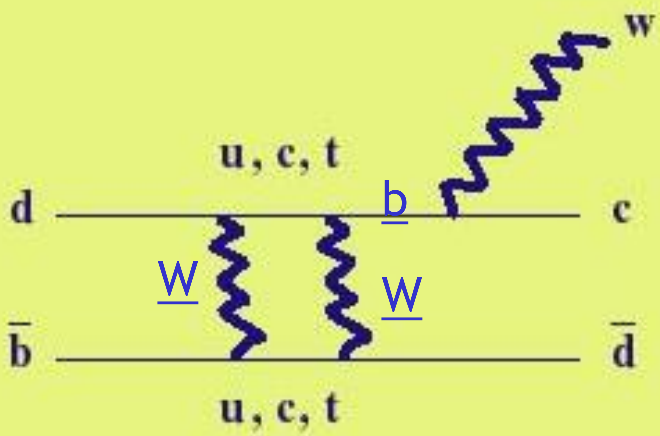
Pairs of B hadrons tend to have similar momentum & emerge close to the beam-pipe ...not so very different from BaBar!...



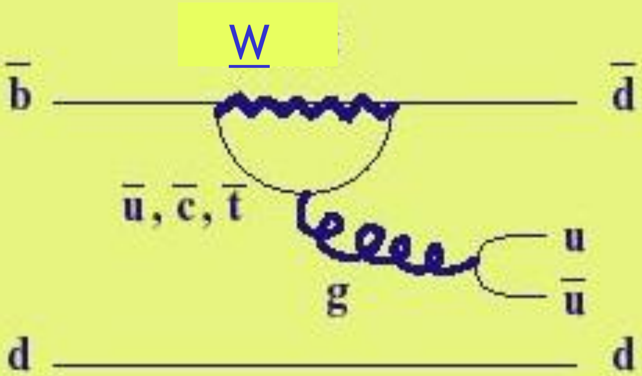
# Types of B Decay




Most common: $B^0 \rightarrow D^0$ W (Tree)

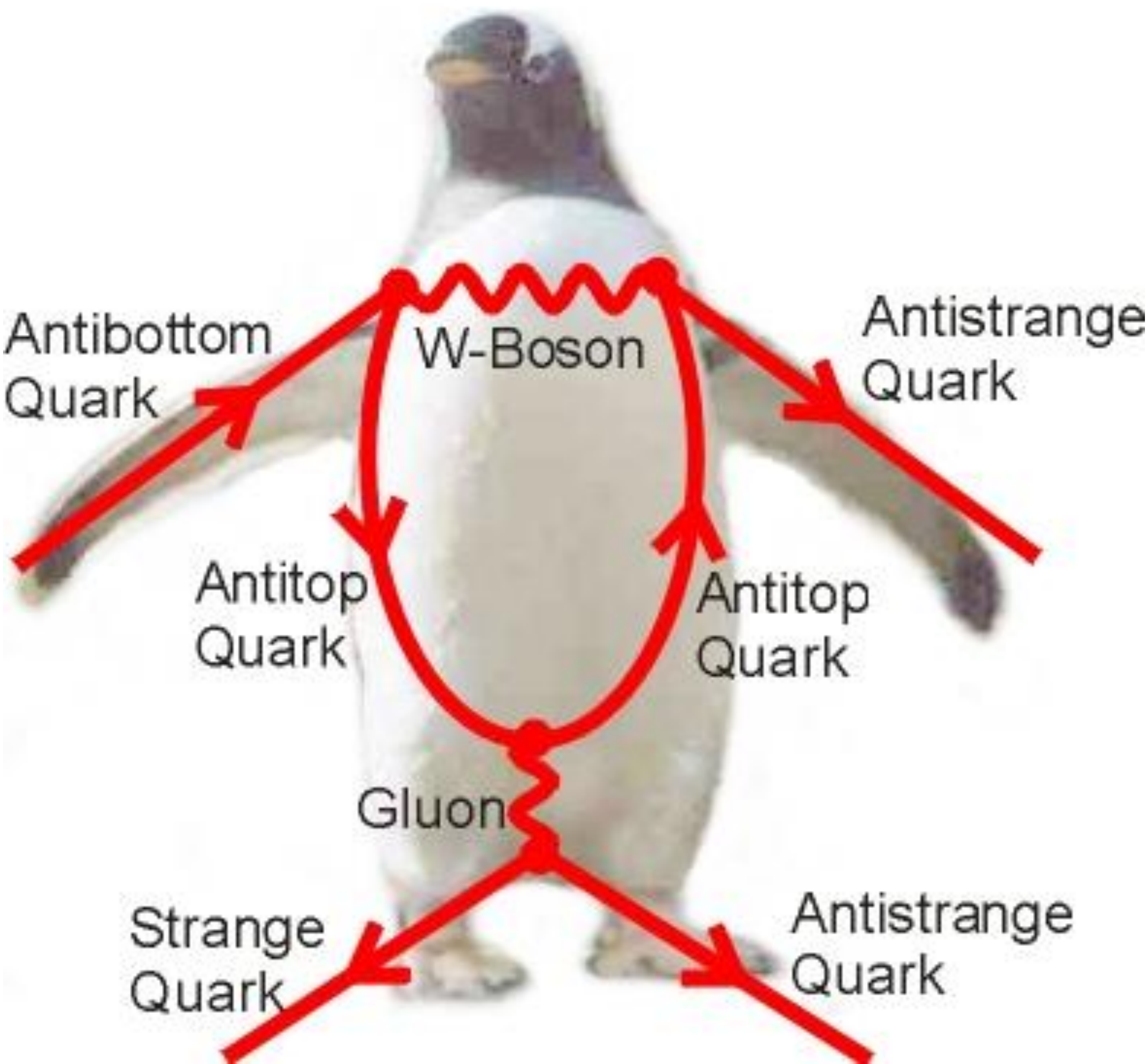



CP violation via mixing:
$B^0$bar → $B^0$ → $D^0$ W (Box)




Flavour Changing Neutral Current:
B0bar → $\pi$+$\pi$- (Penguin)

Virtual Loop processes are very rare and some Penguins are very rare indeed → loops are sensitive to new particles with mass well beyond $\sqrt{s}$


Antibottom
Quark
W-Boson
Antistrange
Quark
Antitop
Quark
Antitop
Quark
Gluon
Strange
Quark
Antistrange
Quark

# Rare Kaon Decays: NA48 and NA62

- **Strangeness** (K mesons) represented most of the history and development of flavour phsics and CP violation ...

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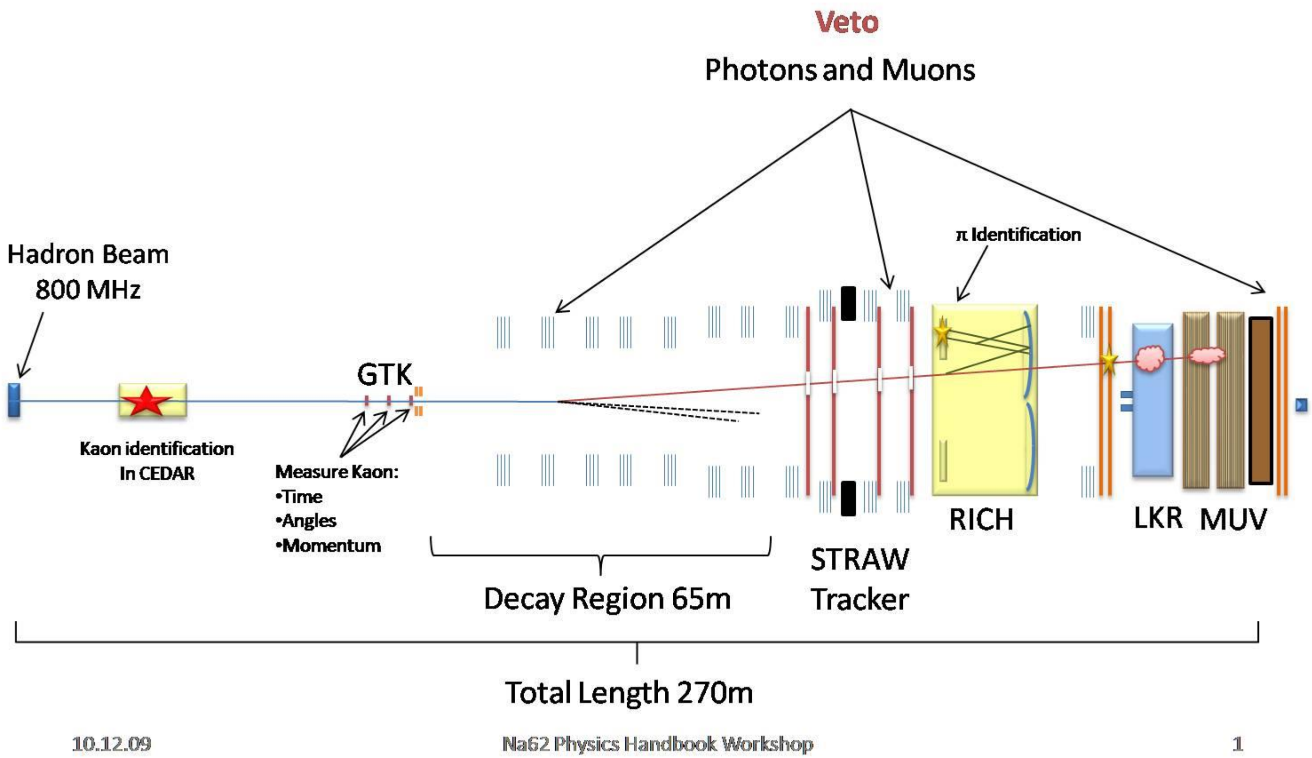


Next plan at CERN: NA62 (2015-)

… to study $K \rightarrow \pi \nu \bar{\nu}$ decays in flight

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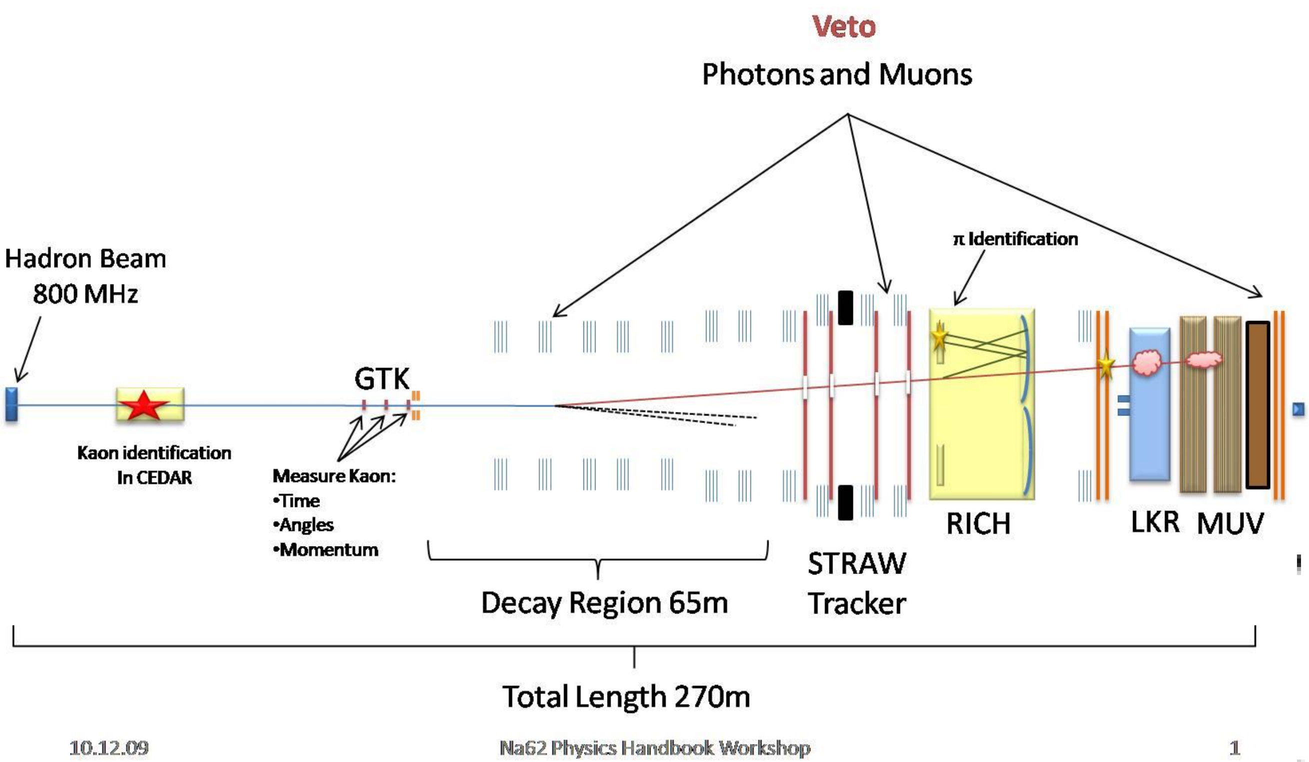


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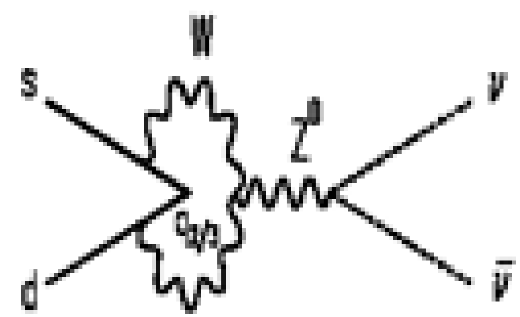


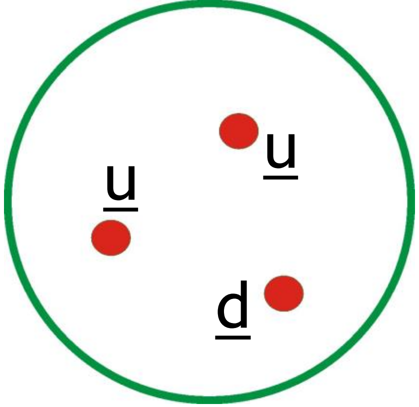

$<10^{-10}$ branching ratio …

~100 events expected with low background after running for 2 years!... Clear exotic signal if there are many more events …

# Proton "Structure"?

Proton constituents …

2 up and 1 down **valence quarks**



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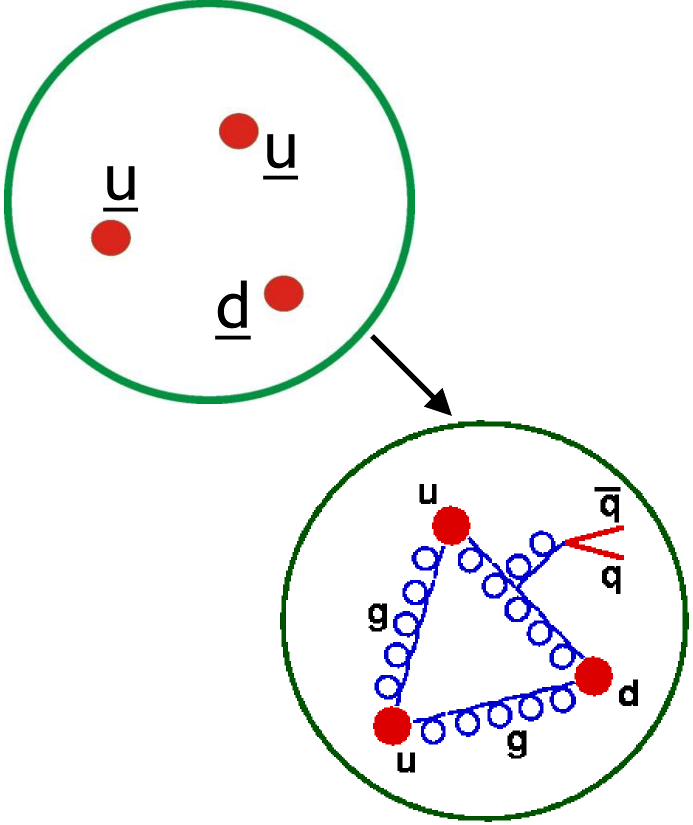
… and some **gluons**

… and some **sea quarks**



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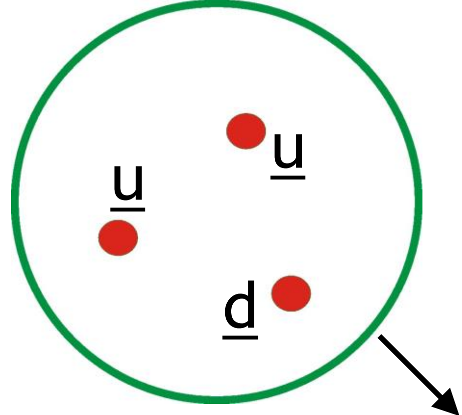
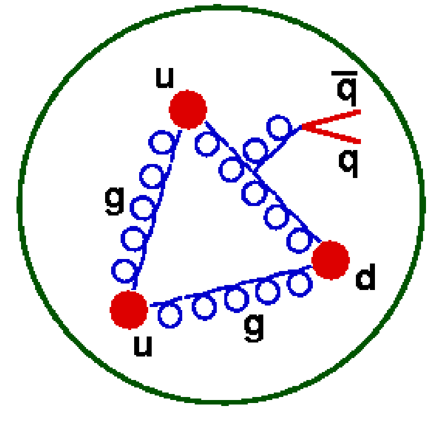
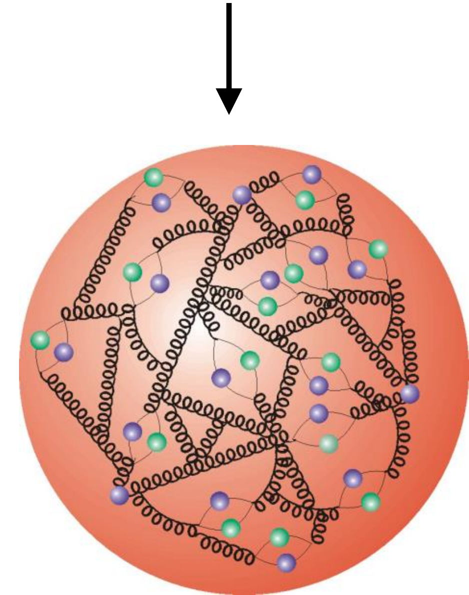
… and lots more gluons and sea quarks …

→ strong interactions induce rich and complex `structure’ of high energy proton interactions!



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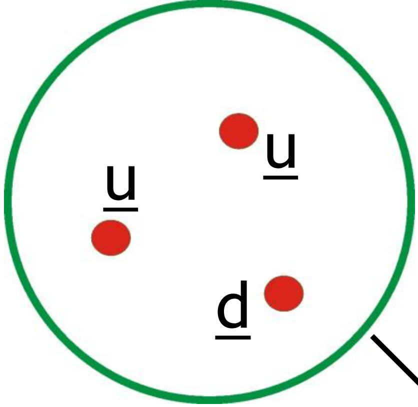


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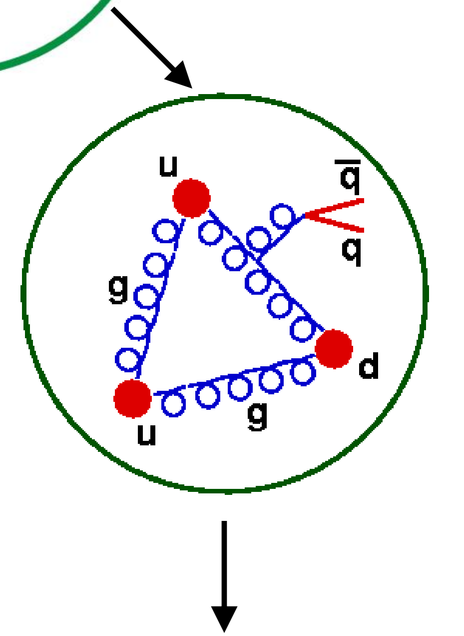
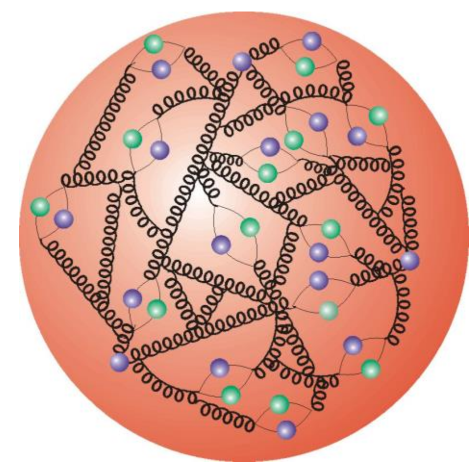
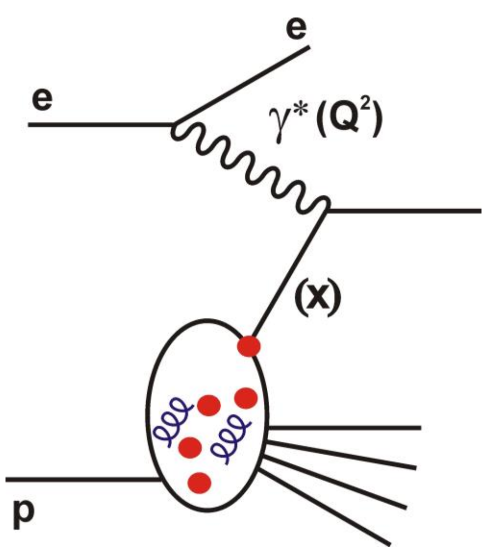




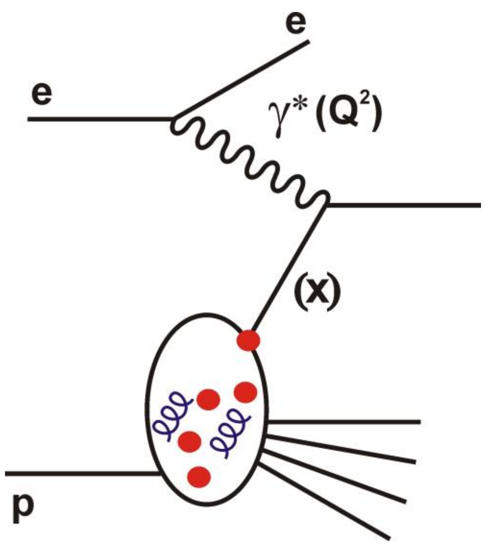

Scattering electrons from protons at $\sqrt{s}$ > 300GeV at HERA established detailed proton structure & provided a testing ground for QCD over a huge kinematic range

… **parton density functions**

# DESY, Hamburg

HERA (1992-2007)

… the only ever collider of electron and proton beams





Equivalent to a 50 TeV beam on a fixed target proton
~2500 times more than SLAC!

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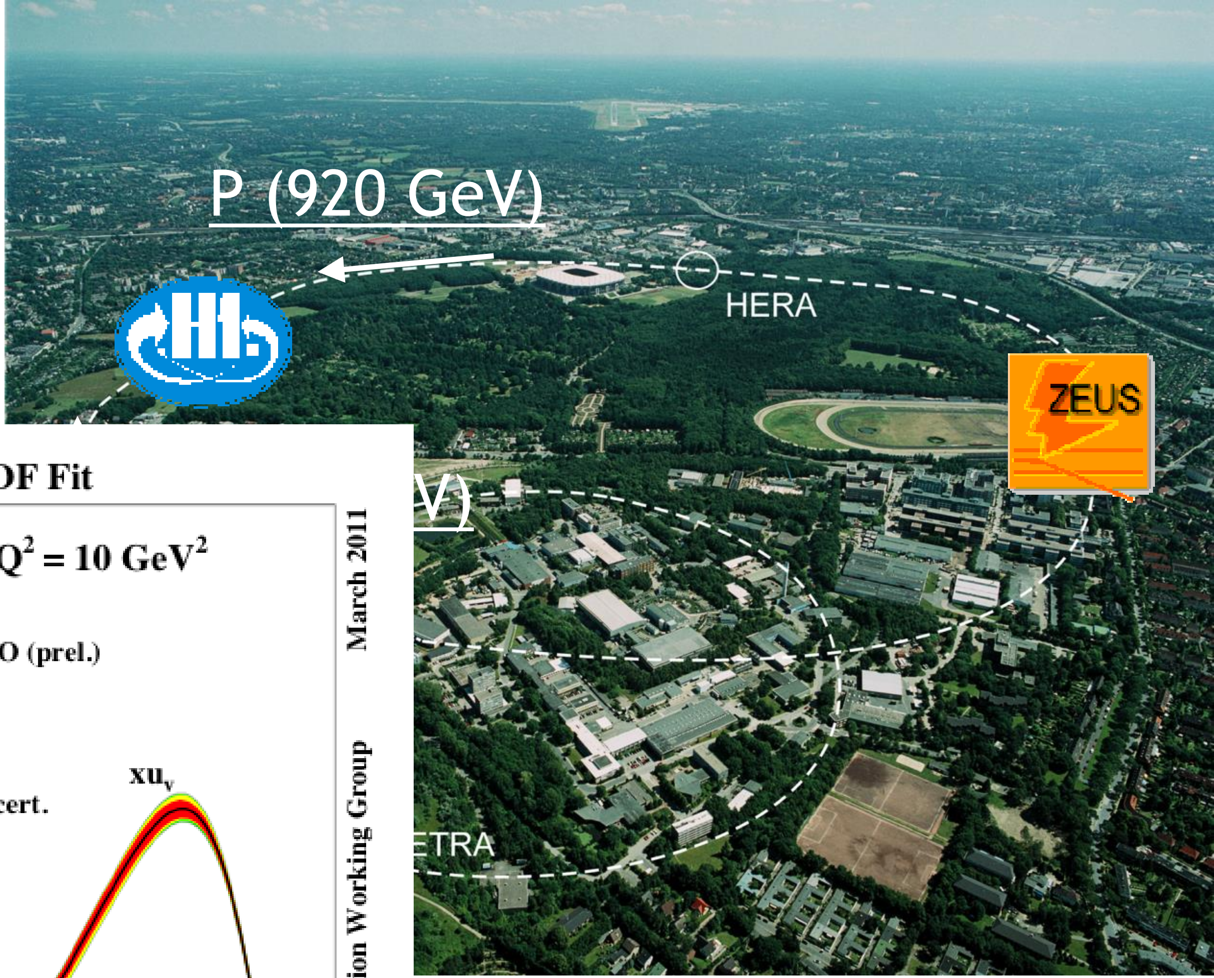
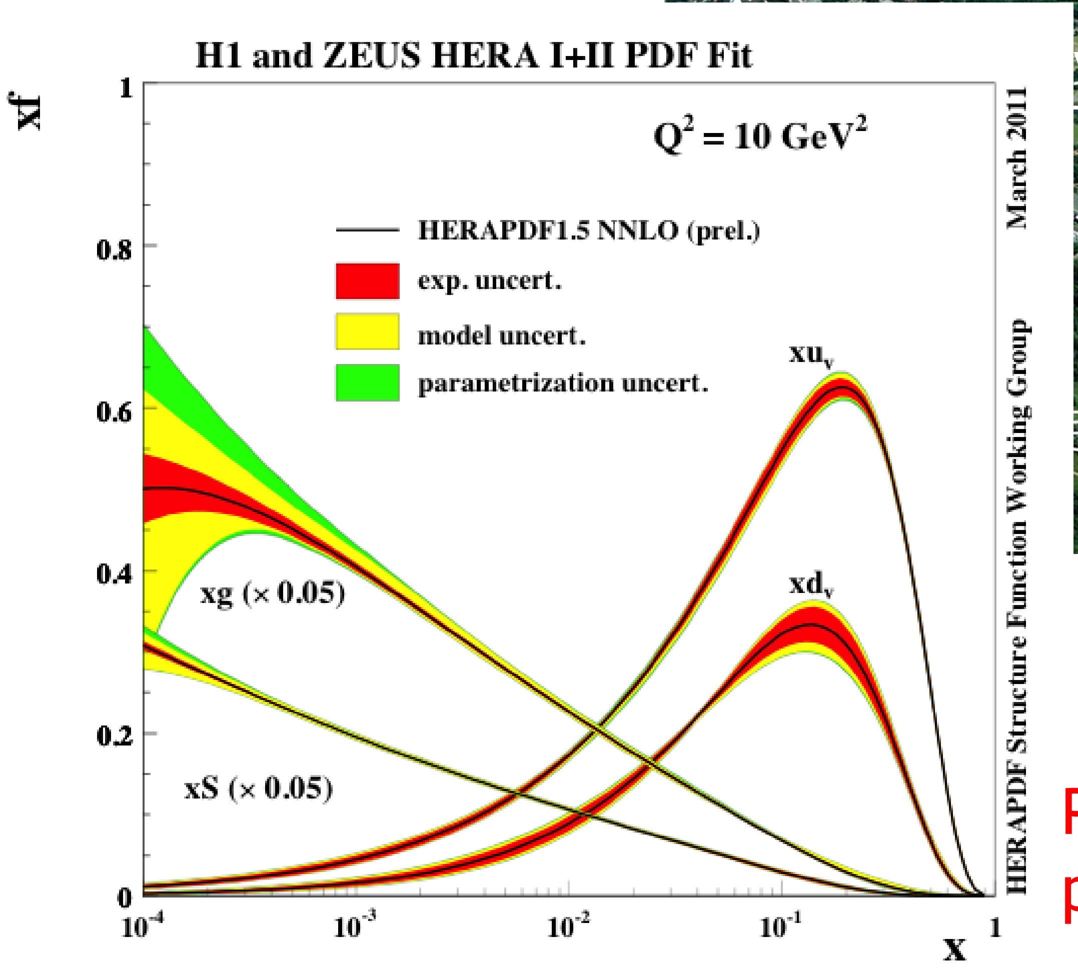
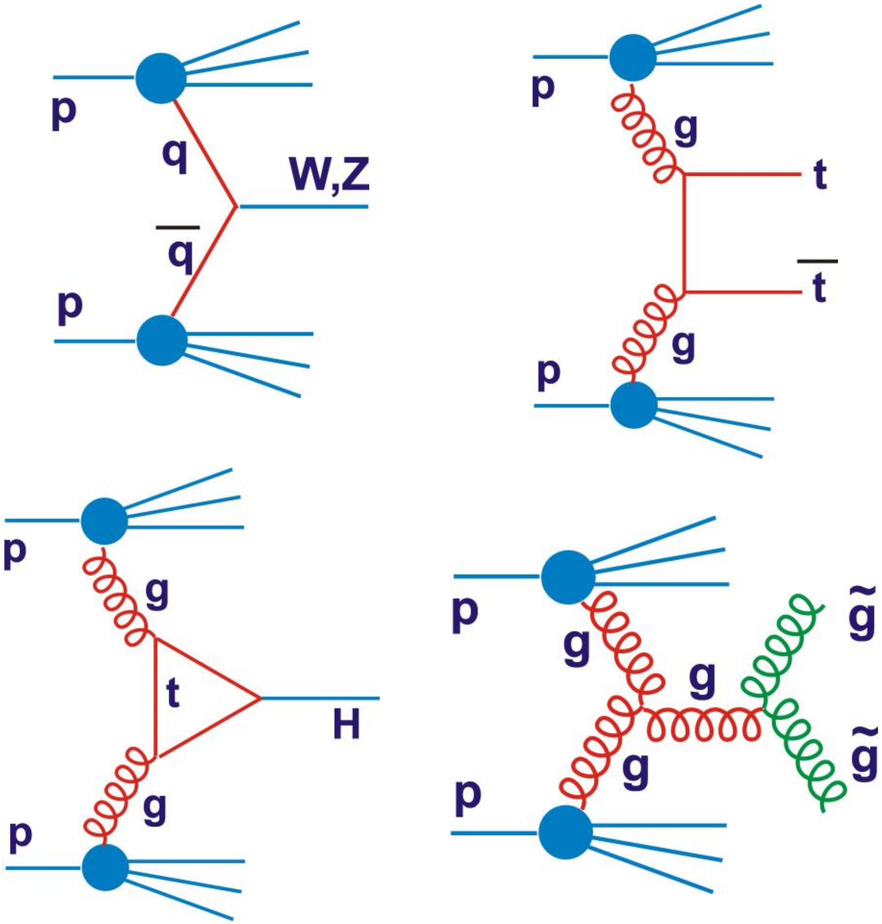



Parton densities of the proton from HERA data

# Partons and the LHC




- All pp physics starts from partons (i.e. quarks and gluons)

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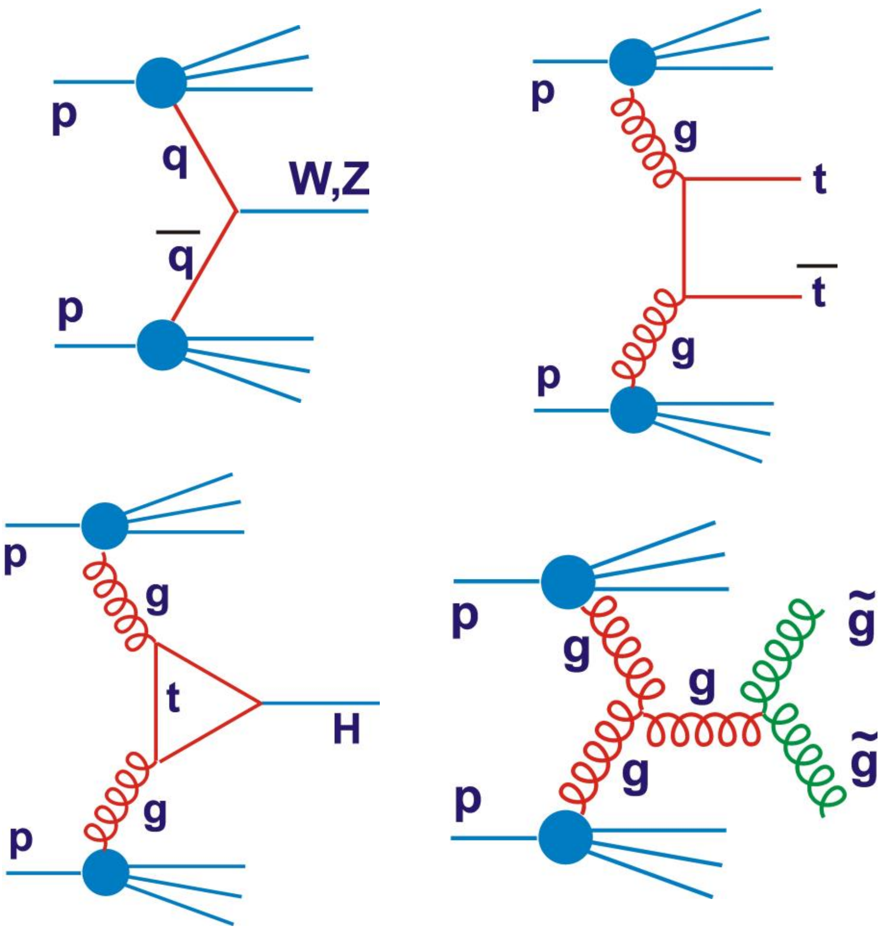
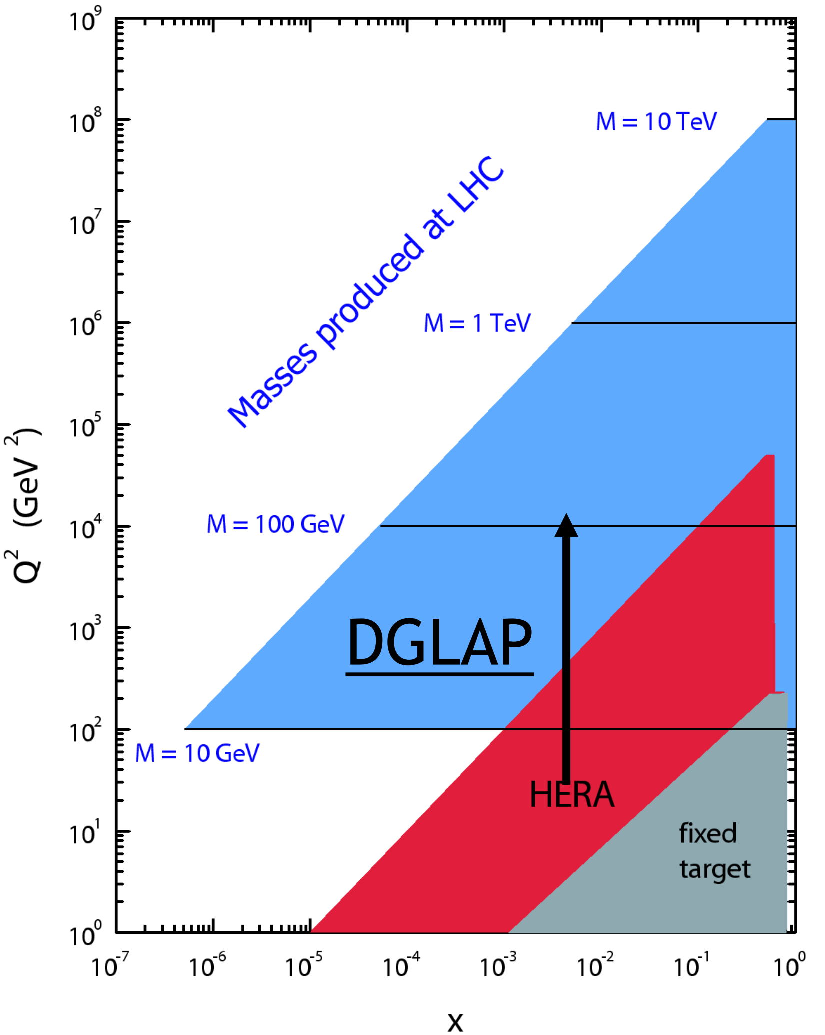
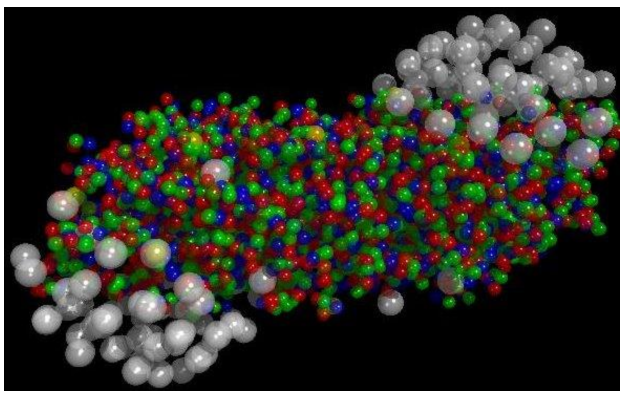



- All pp physics starts from partons (i.e. quarks and gluons)
- LHC uses partons over very similar range in x to HERA!
- QCD (DGLAP equations) tells us the parton densities at all $Q^2$ if we know them at one value of $Q^2$

# Melting Hadrons: High Denstity QCD

Relativistic Heavy Ion Collisions place as much baryonic matter in one place as possible → the QCD phase diagram and the Quark Gluon Plasma



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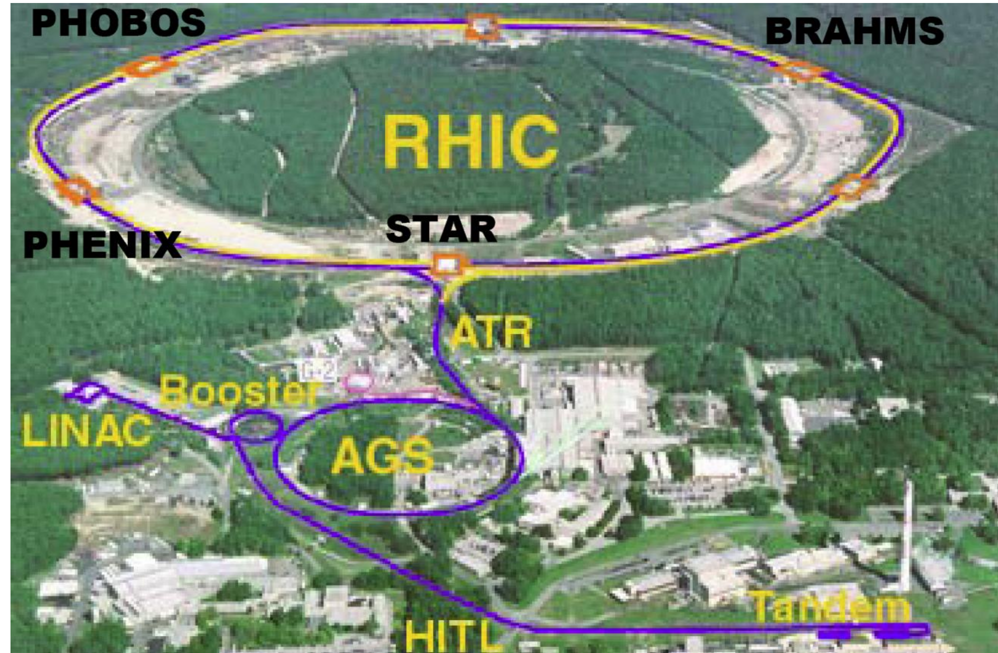
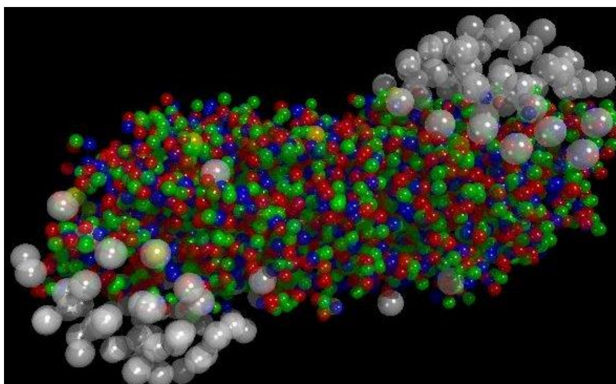
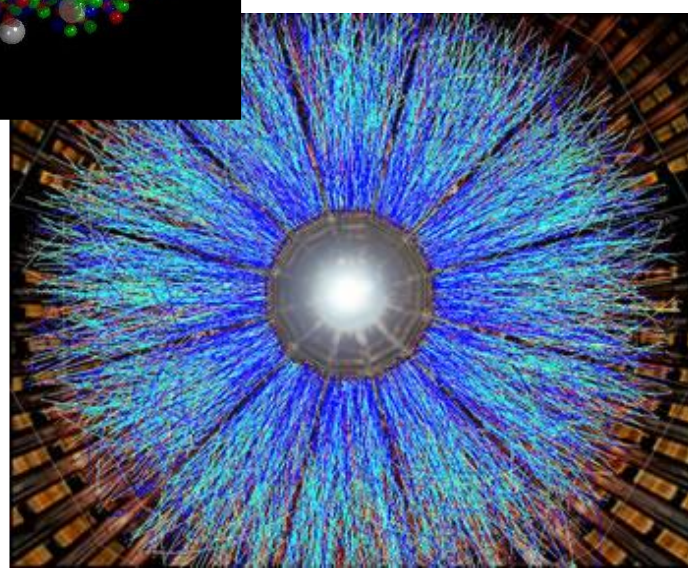
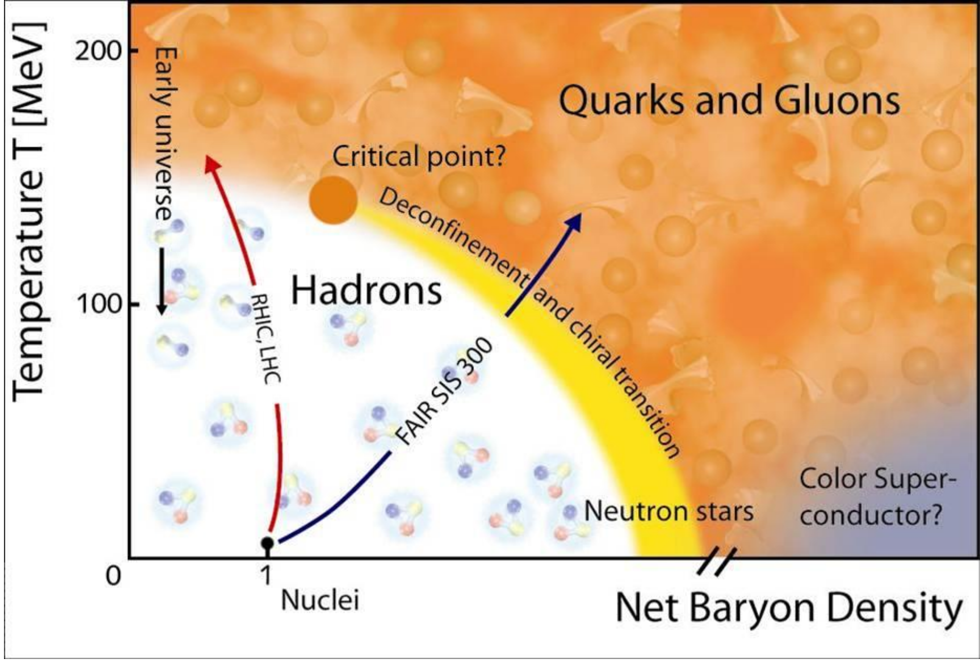




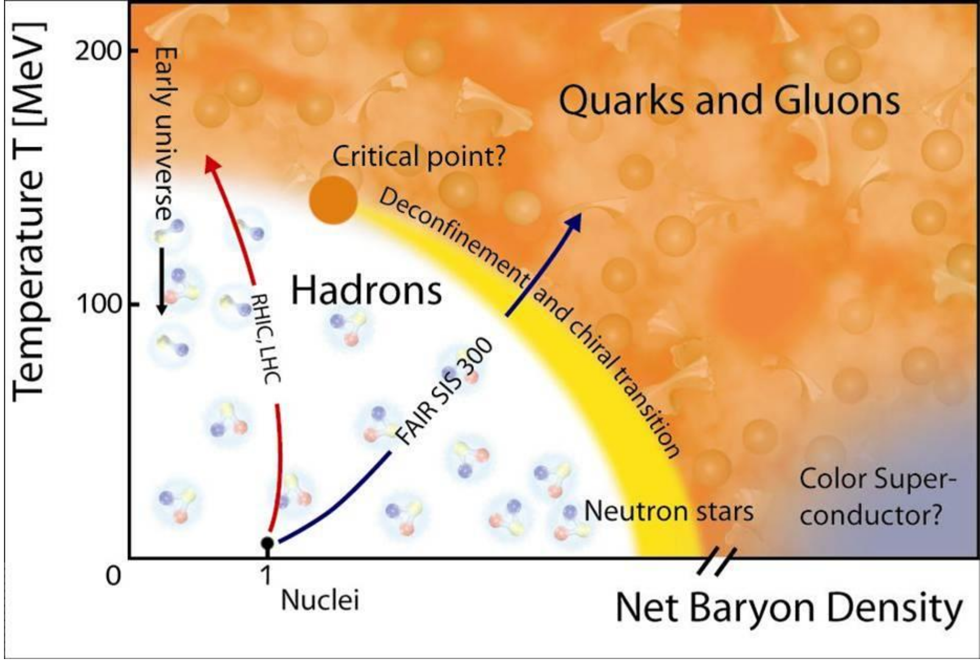
AuAu @ RHIC
PbPb @ LHC

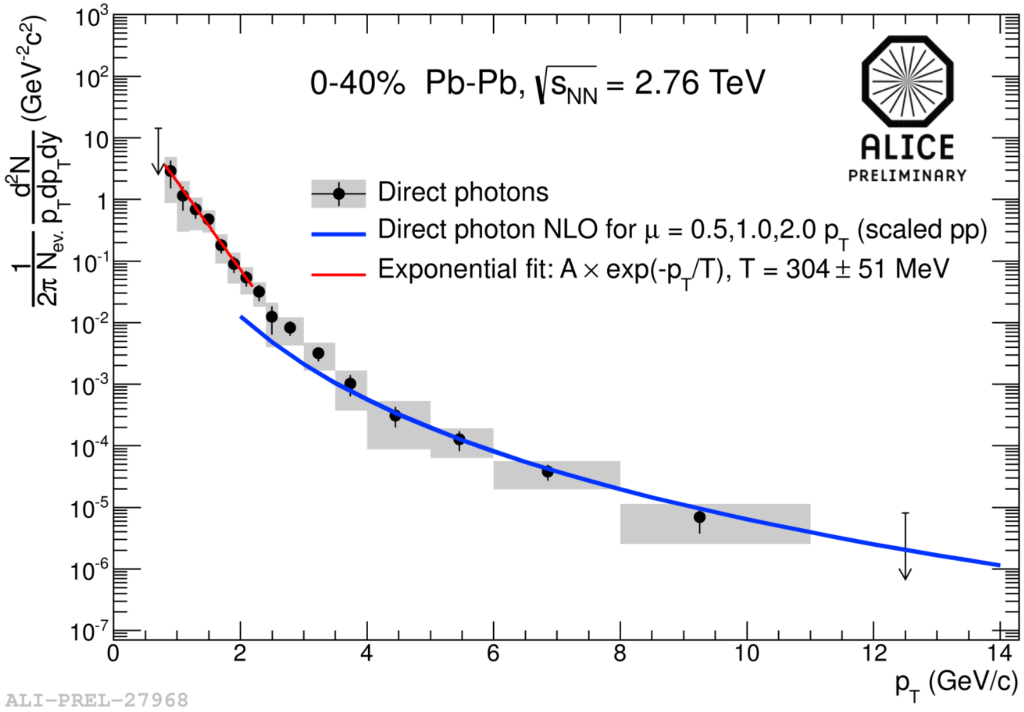
# QCD Phase Diagram & Evidence for QGP



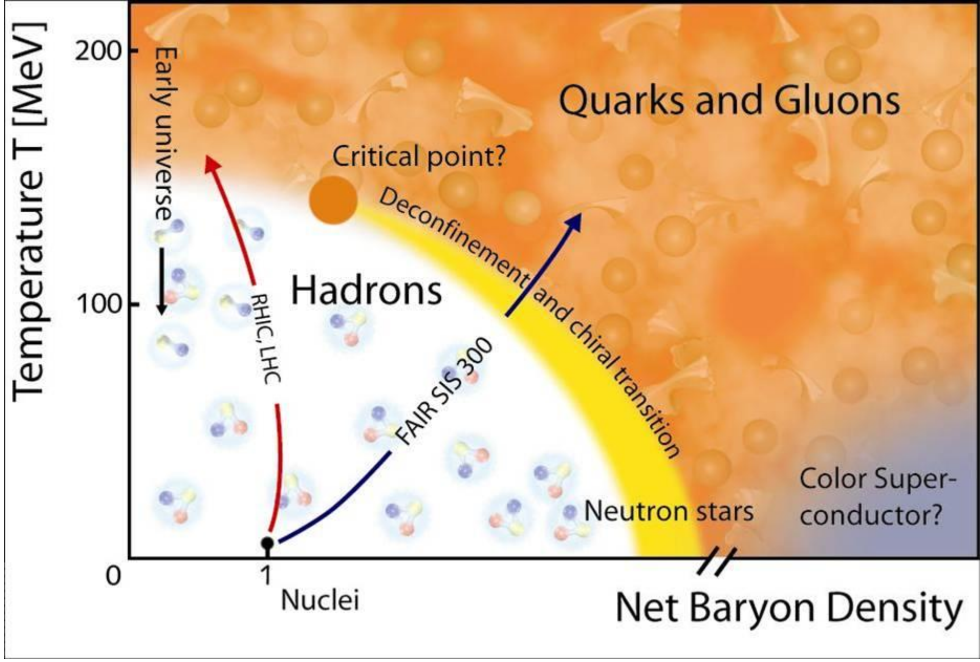
# QCD Phase Diagram & Evidence for QGP

Inverse $p_T$ slopes give
kT ~ 300 MeV at LHC



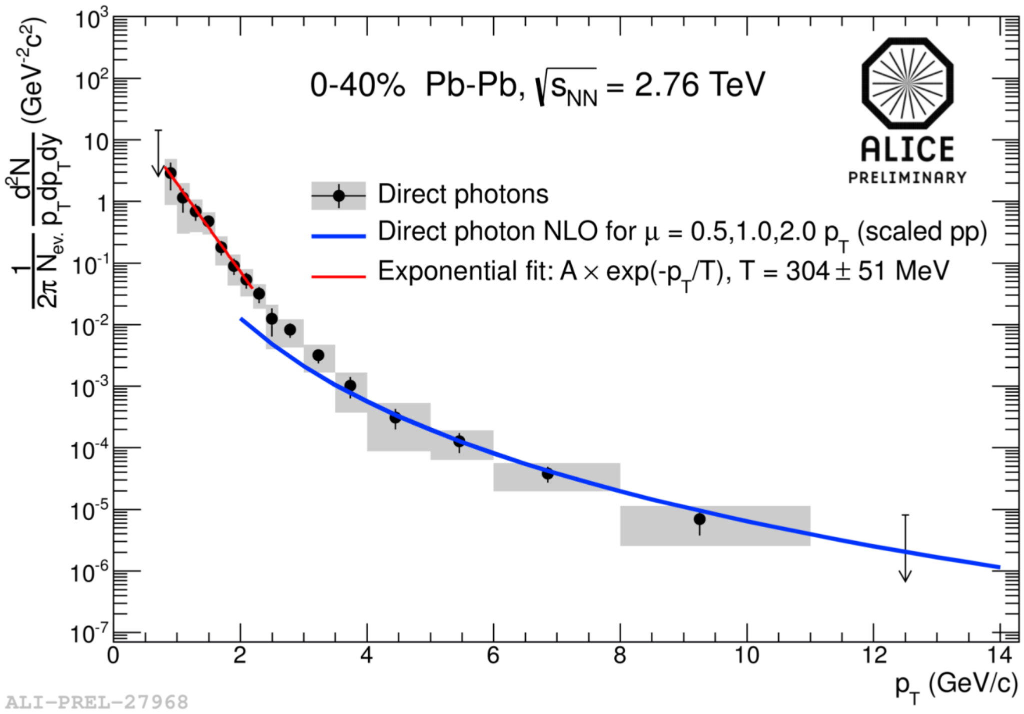



# QCD Phase Diagram & Evidence for QGP

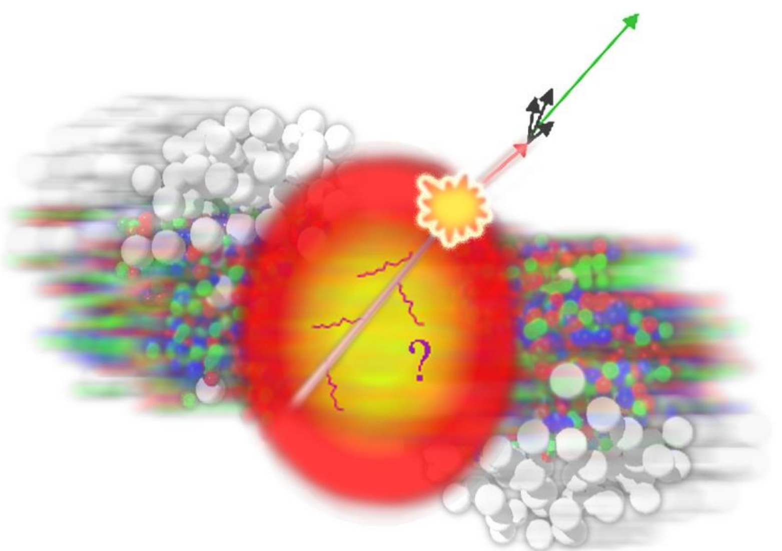



Inverse $p_T$ slopes give kT ~ 300 MeV at LHC

Many QGP signatures:




e.g. jet quenching …



# Why do we need a Higgs Field?

… it generates mass for the particles in the Standard Model …

… Couples to other particles in a way that depends on their mass, giving them inertia relative to massless particles travelling at the speed of light.

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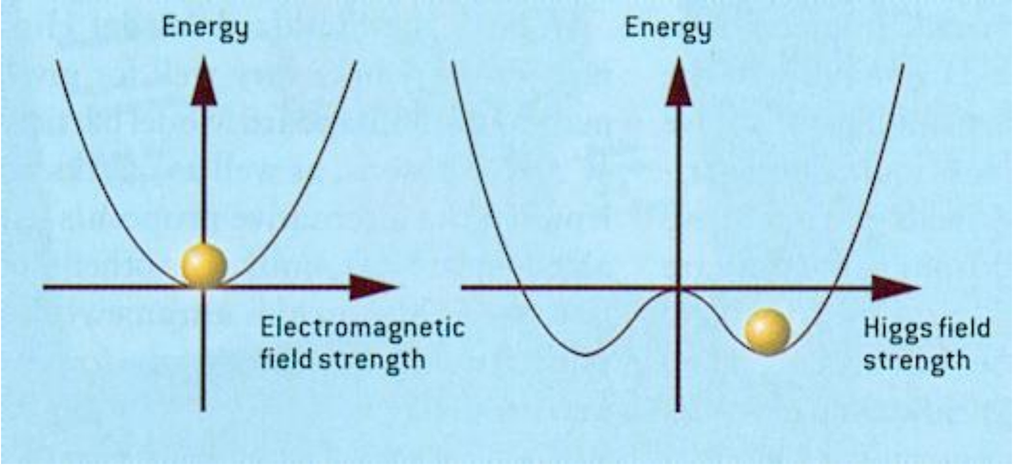


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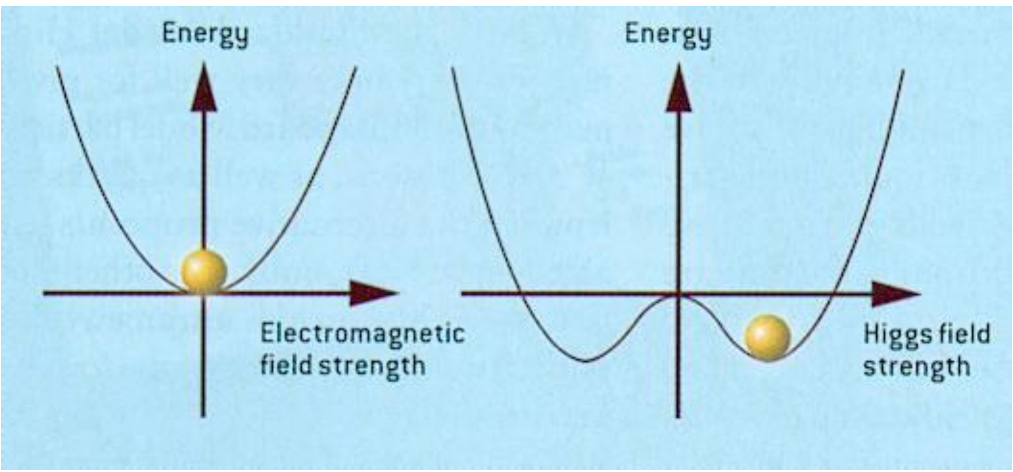


… a field with a non-zero vacuum expectation value

… with no preferred direction

**Consequence:** Unlike force fields such as gravity:

→ No need for a source … equally strong in vacuum of inter-galactic space as it is in this room … **Weird!!!**

# Why do we need a Higgs Field?

**An analogy:**

What happens when a (light) Mr Nobody and a (heavy) Mrs Thatcher try to walk quickly through a room full of Conservative party workers?...

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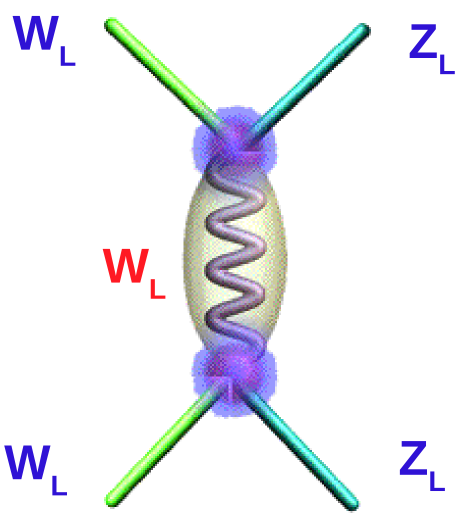

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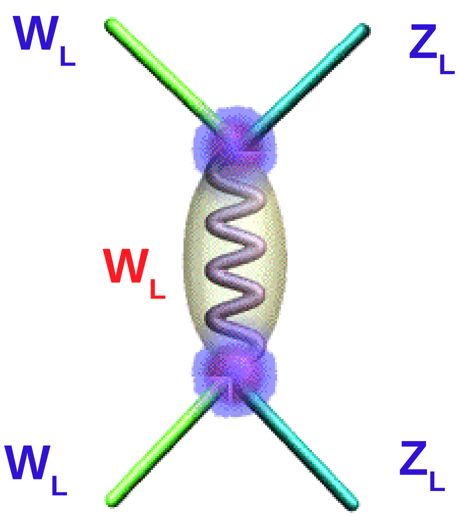
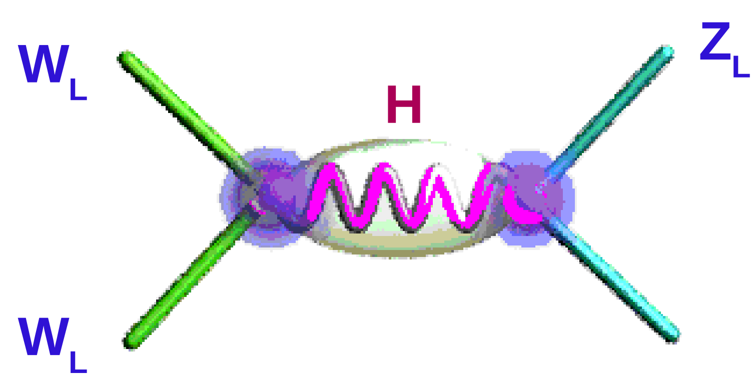
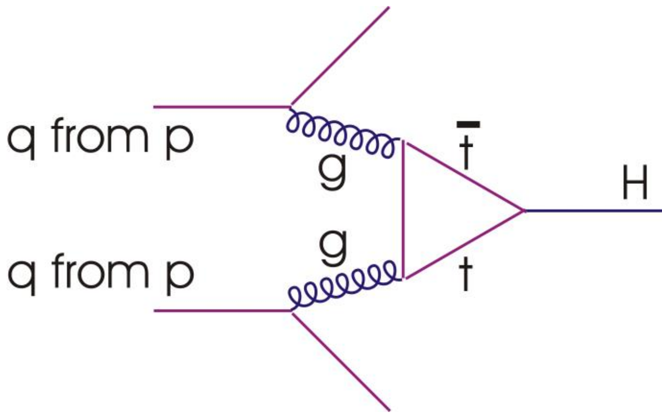


# LHC: Higgs Production & Decay




- Higgs boson couples to mass …

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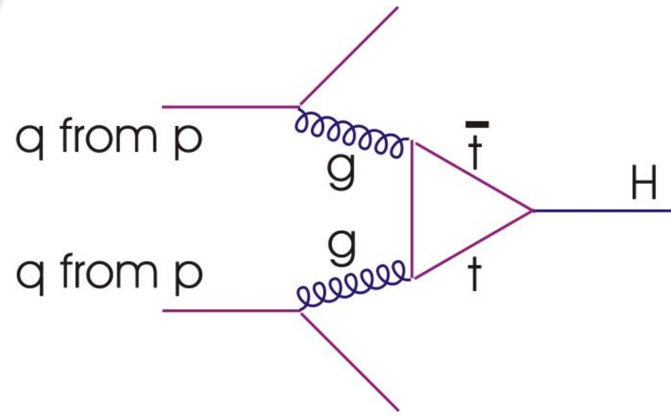
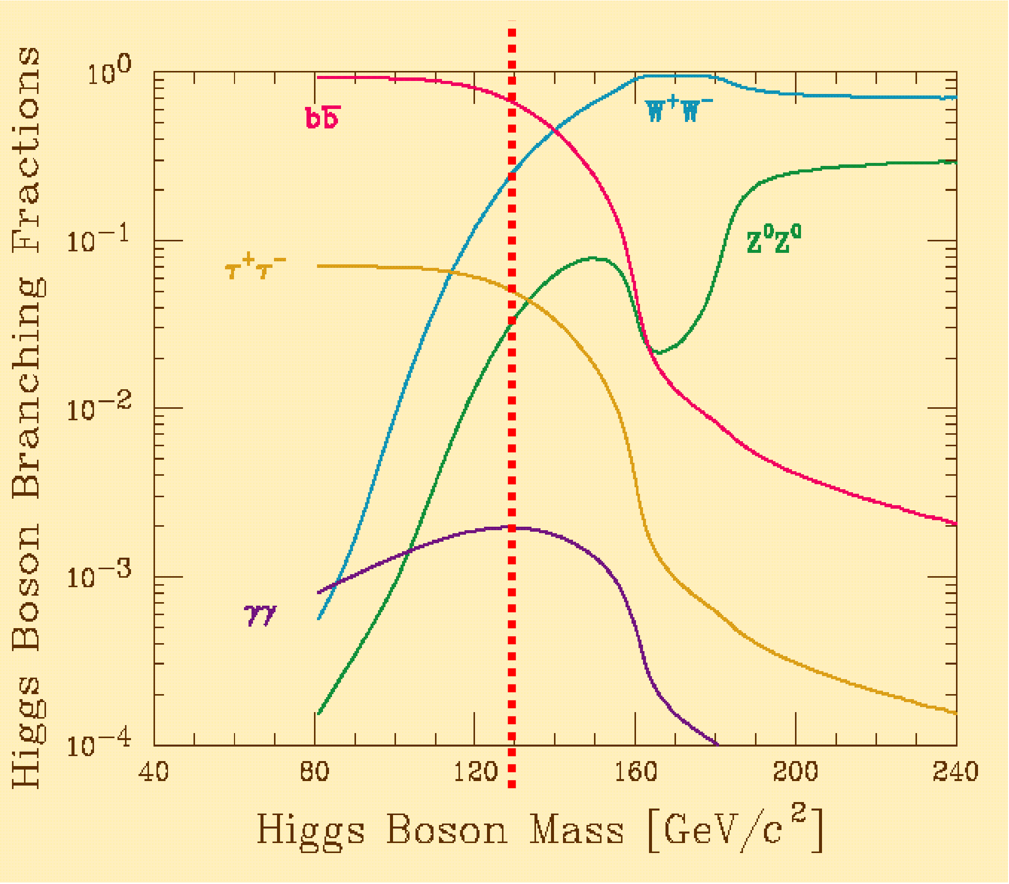
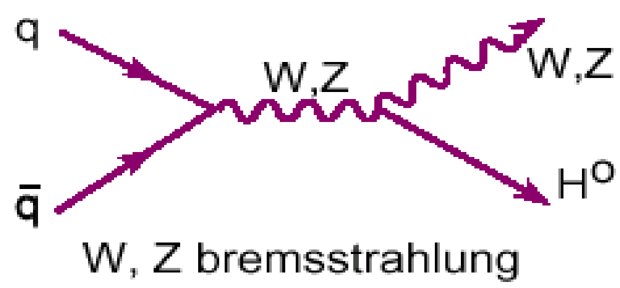



- At $m_H$ ~ 125 GeV, dominant decay is to b bbar … huge background at LHC → tough, but not impossible …



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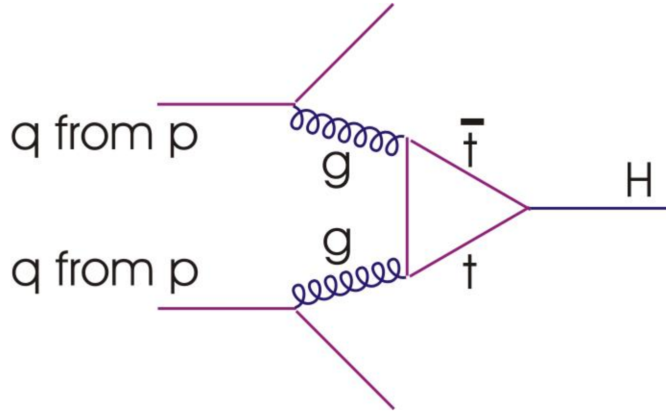


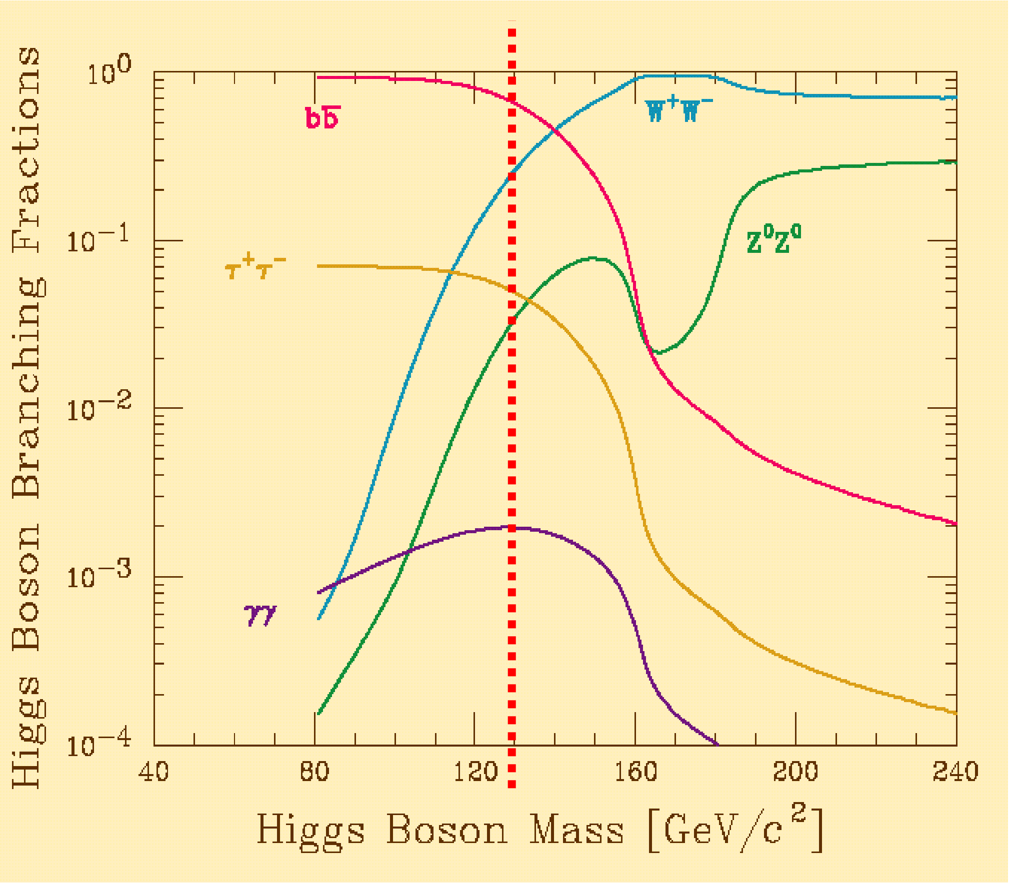


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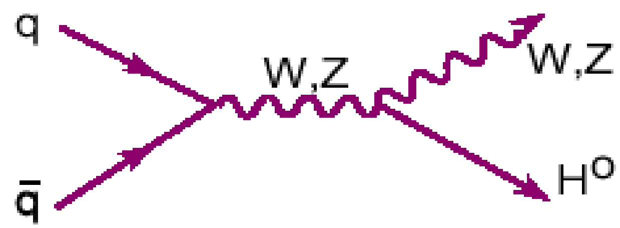
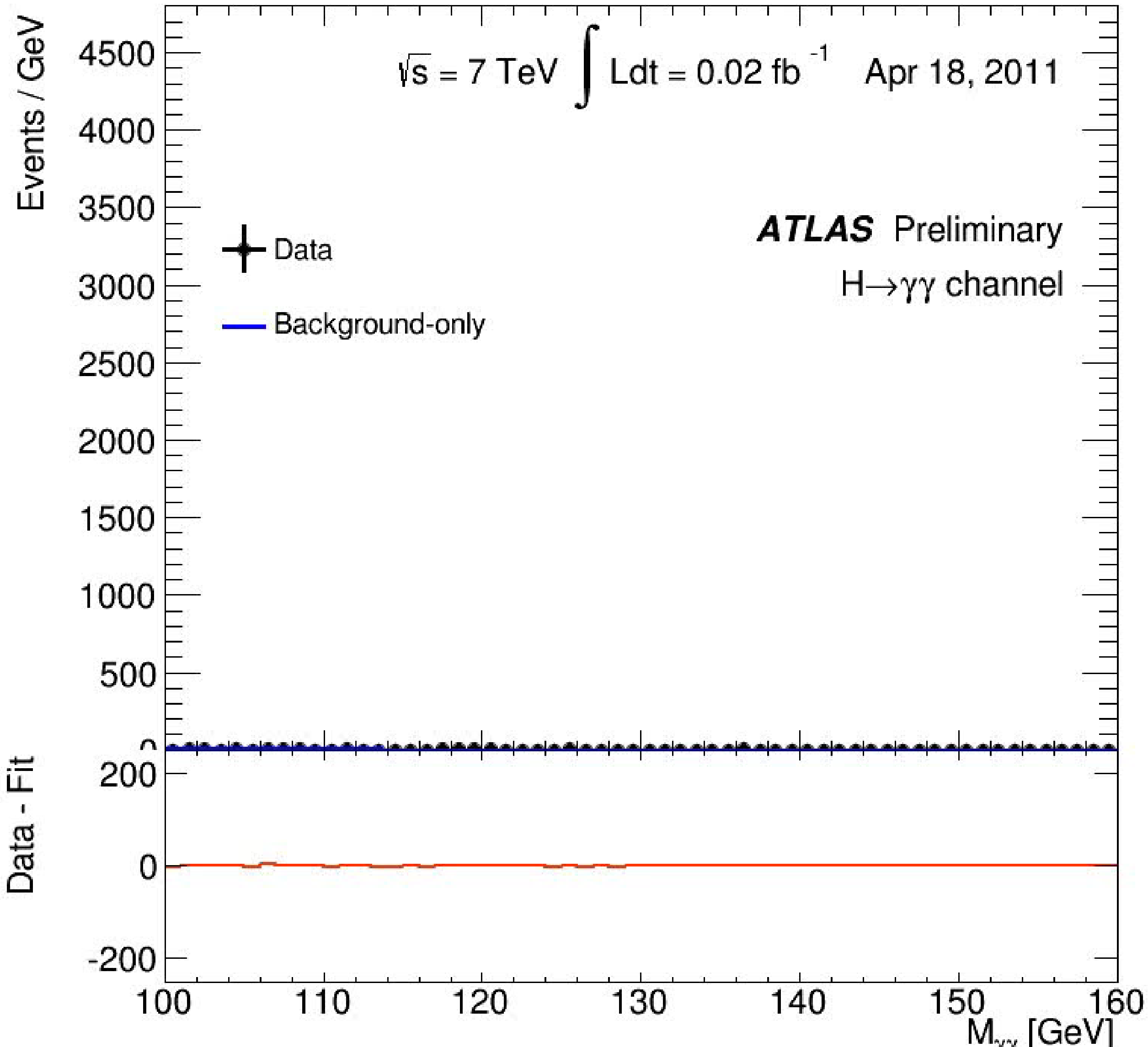


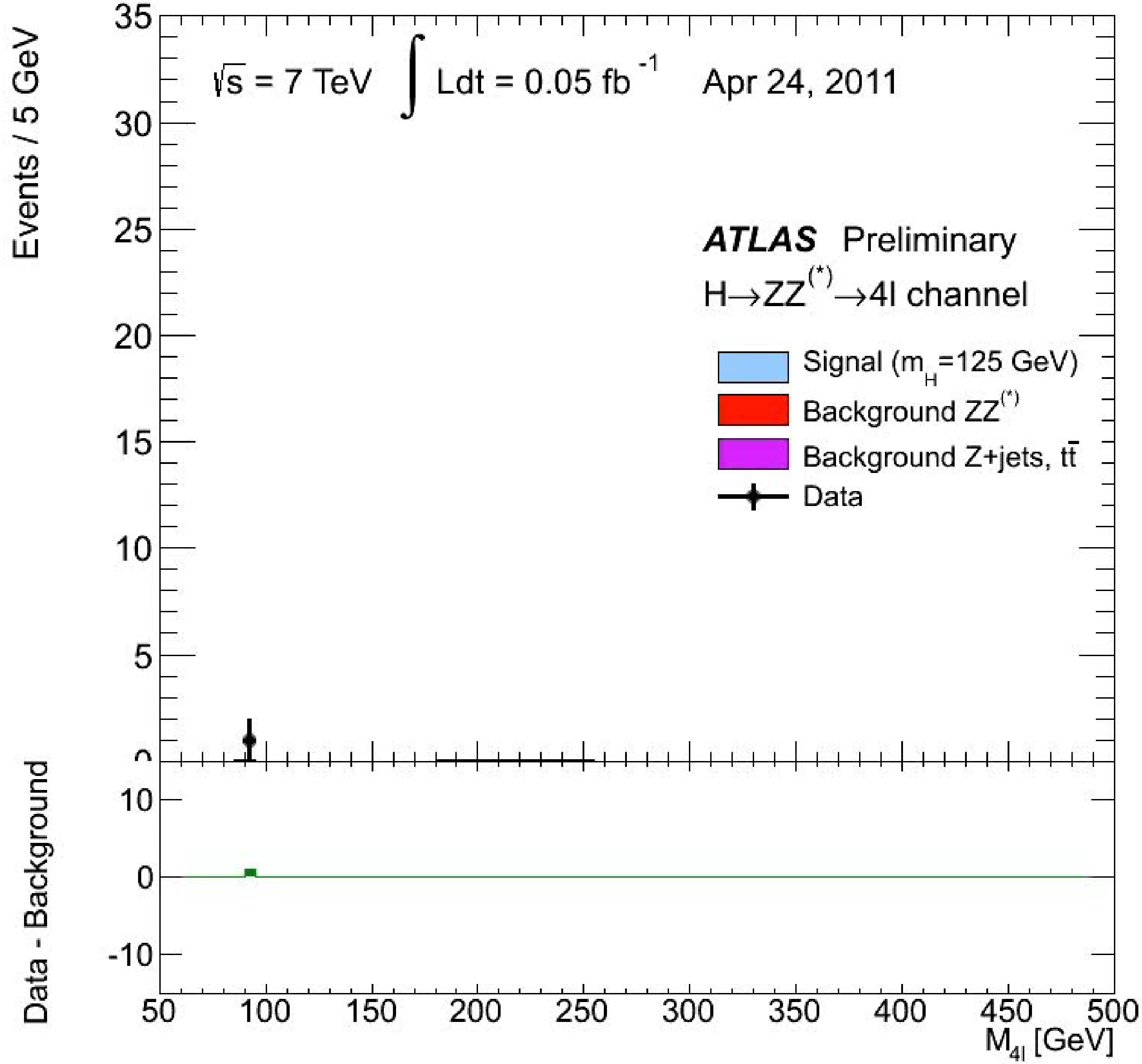

W, Z bremsstrahlung

- $\gamma\gamma$, ZZ, WW and $\tau\tau$ have all shown signals …

# Looking for Higgs decaying to 2 photons



# … and Higgs decaying to two Z bosons …



# July 4 2012: The world went Higgs-crazy

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# July 4 2012: The world

# How Discoveries Change 1: W, Z bosons (1983)

p-pbar collisions at $\sqrt{s}$=540 GeV in CERN SPS [UA1]

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH



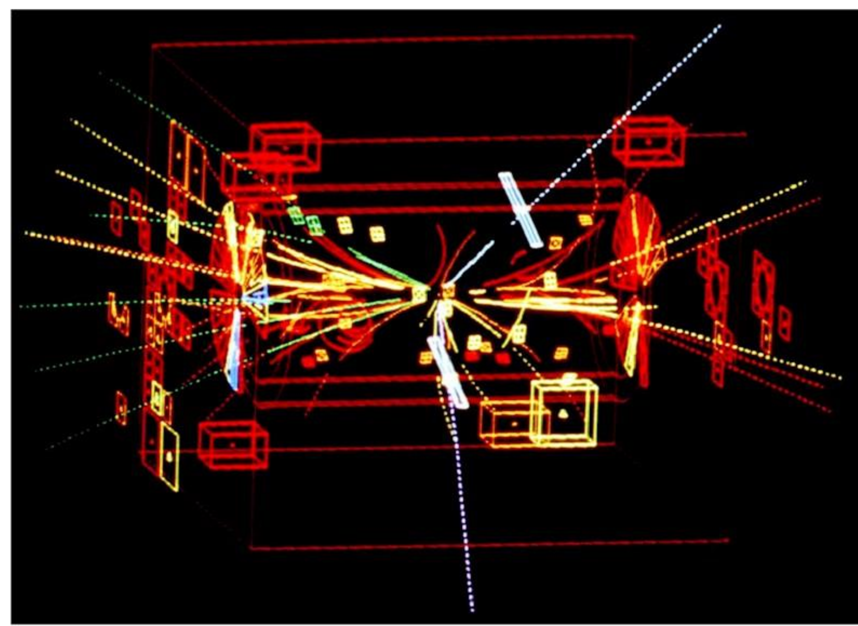
CERN-EP/83-13
21 January 1983

EXPERIMENTAL OBSERVATION OF ISOLATED LARGE TRANSVERSE ENERGY ELECTRONS WITH ASSOCIATED MISSING ENERGY AT $\sqrt{s}$ = 540 GeV

UA1 Collaboration, CERN, Geneva, Switzerland

Aachen[1]-Annecy (LAPP)[2]-Birmingham[3]-CERN[4]-Helsinki[5]-Queen Mary College, London[6]-Paris (Coll. de France)[7]-Riverside[8]-Roma[9]-Rutherford Appleton Lab.[10]-Saclay (CEN)[11]-Vienna[12] Collaboration

G. Arnison[10], A. Astbury[10], B. Aubert[2], C. Bacci[9], G. Bauer**, A. Bézaguet[4],
R. Böck[4], T.J.V. Bowcock[6], M. Calvetti[4], T. Carroll[4], P. Catz[2], P. Cennini[4],
S. Centro[4], F. Ceradini[4], S. Cittolin[4], D. Cline**, C. Cochet[11], J. Colas[2],
M. Corden[3], D. Dallman[4], M. DeBeer[11], M. Della Negra[2], M. Demoulin[4],
D. Denegri[11], A. Di Ciaccio[9], D. DiBitonto[4], L. Dobrzynski[7], J.D. Dowell[3], M. Edwards[3],
K. Eggert[1], E. Eisenhandler[6], N. Ellis[3], P. Erhard[1], H. Faissner[1], G. Fontaine[7],
R. Frey[8], R. Frühwirth[12], J. Garvey[3], S. Geer[7], C. Ghesquière[7],
P. Ghez[2], K.L. Giboni[1], W.R. Gibson[6], Y. Giraud-Héraud[7], A. Givernaud[11],
A. Gonidec[2], G. Grayer[10], P. Gutierrez[8], T. Hansl-Kozanecka[1],
W.J. Haynes[10], L.O. Hertzberger*, C. Hodges[8], D. Hoffmann[1], H. Hoffmann[4],
D.J. Holthuizen*, R.J. Homer[3], A. Honma[6], W. Jank[4], G. Jorat[4], P.I.P. Kalmus[6],
V. Karimäki[5], R. Keeler[6], I. Kenyon[3], A. Kernan[8], R. Kinnunen[5], H. Kowalski[4],
W. Kozanecki[8], D. Kryn[4], F. Lacava[4], J.-P. Laugier[11], J.-P. Lees[2], H. Lehmann[1],
K. Leuchs[1], A. Lévêque[11], D. Linglin[2], E. Locci[11], M. Loret[11], J.-J. Malosse[11],
T. Markiewicz[4], G. Maurin[4], T. McMahon[3], J.-P. Mendiburu[7], M.-N. Minard[2],
M. Moricca[9], H. Muirhead[4], F. Muller[4], A.K. Nandi[10], L. Naumann[4], A. Norton[4],
A. Orkin-Lecourtois[7], L. Paoluzi[9], G. Petrucci[4], G. Piano Mortari[9], M. Pimiä[5],
A. Placci[4], E. Radermacher[1], J. Ransdell[8], H. Reithler[1], J.-P. Revol[4], J. Rich[11],
M. Rijssenbeek[4], C. Roberts[10], J. Rohlf[4], P. Rossi[4], C. Rubbia[4], B. Sadoulet[4],
G. Sajot[6], G. Salvi[6], G. Salvini[9], J. Sass[11], J. Saudraix[11], A. Savoy-Navarro[11],
D. Schinzel[4], W. Scott[10], T.P. Shah[10], M. Spiro[11], J. Strauss[12], K. Sumorok[3],
F. Szoncso[12], D. Smith[8], C. Tao[4], G. Thompson[6], J. Timmer[4], E. Tscheslog[1],
J. Tuominiemi[5], S. Van der Meer[4], J.-P. Vialle[4], J. Vrana[7], V. Vuillemin[4],
H.D. Wahl[12], P. Watkins[3], J. Wilson[3], G.Y. Xie[4], M. Yvert[2], E. Zurfluh[4]



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ELSEVIER

# Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC ☆

**ATLAS Collaboration**

G. Aad [48], T. Abajyan [21], B. Abbott [111], J. Abdallah [12], S. Abdel Khalek [115], A.A. Abdelalim [49], O. Abdinov [11], R. Aben [105], B. Abi [112], M. Abolins [88], O.S. AbouZeid [158], H. Abramowicz [153], H. Abreu [136], B.S. Acharya [164a,164b], L. Adamczyk [38], D.L. Adams [25], T.N. Addy [56], J. Adelman [176], S. Adomeit [98], P. Adragna [75], T. Adye [129], S. Aefsky [23], J.A. Aguilar-Saavedra [124b,a], M. Agustoni [17], M. Aharrouche [81], S.P. Ahlen [22], F. Ahles [48], A. Ahmad [148], M. Ahsan [41], G. Aielli [133a,133b], T. Akdogan [19a], T.P.A. Åkesson [79], G. Akimoto [155], A.V. Akimov [94], M.S. Alam [2], M.A. Alam [76], J. Albert [169], S. Albrand [55], M. Aleksa [30], I.N. Aleksandrov [64], F. Alessandria [89a], C. Alexa [26a], G. Alexander [153], G. Alexandre [49], T. Alexopoulos [10], M. Alhroob [164a,164c], M. Aliev [16], G. Alimonti [89a], J. Alison [120], B.M.M. Allbrooke [18], P.P. Allport [73], S.E. Allwood-Spiers [53], J. Almond [82], A. Aloisio [102a,102b], R. Alon [172], A. Alonso [79], F. Alonso [70], A. Altheimer [35], B. Alvarez Gonzalez [88], M.G. Alviggi [102a,102b], K. Amako [65], C. Amelung [23], V.V. Ammosov [128,*], S.P. Amor Dos Santos [124a], A. Amorim [124a,b], N. Amram [153], C. Anastopoulos [30], L.S. Ancu [17], N. Andari [115], T. Andeen [35], C.F. Anders [58b], G. Anders [58a], K.J. Anderson [31], A. Andreazza [89a,89b], V. Andrei [58a], M.-L. Andrieux [55], X.S. Anduaga [70], S. Angelidakis [9], P. Anger [44], A. Angerami [35], F. Anghinolfi [30], A. Anisenkov [107], N. Anjos [124a], A. Annovi [47], A. Antonaki [9], M. Antonelli [47], A. Antonov [96], J. Antos [144b], F. Anulli [132a], M. Aoki [101], S. Aoun [83], L. Aperio Bella [5], R. Apolle [118,c], G. Arabidze [88], I. Aracena [143], Y. Arai [65], A.T.H. Arce [45], S. Arfaoui [148], J.-F. Arguin [93], E. Arik [19a,*], M. Arik [19a], A.J. Armbruster [87], O. Arnaez [81], V. Arnal [80], C. Arnault [115], A. Artamonov [95], G. Artoni [132a,132b], D. Arutinov [21], S. Asai [155], S. Ask [28], B. Åsman [146a,146b], L. Asquith [6], K. Assamagan [25], A. Astbury [169], M. Atkinson [165], B. Aubert [5], E. Auge [115], K. Augsten [127], M. Aurousseau [145a], G. Avolio [163], R. Avramidou [10], D. Axen [168], G. Azuelos [93,d], Y. Azuma [155], M.A. Baak [30], G. Baccaglioni [89a], C. Bacci [134a,134b], A.M. Bach [15], H. Bachacou [136], K. Bachas [30], M. Backes [49], M. Backhaus [21], J. Backus Mayes [143], E. Badescu [26a], P. Bagnaia [132a,132b], S. Bahinipati [3], Y. Bai [33a], D.C. Bailey [158], T. Bain [158], J.T. Baines [129], O.K. Baker [176], M.D. Baker [25], S. Baker [77], P. Balek [126], E. Banas [39], P. Banerjee [93], Sw. Banerjee [173], D. Banfi [30], A. Bangert [150], V. Bansal [169], H.S. Bansil [18], L. Barak [172], S.P. Baranov [94], A. Barbaro Galtieri [15], T. Barber [48], E.L. Barberio [86], D. Barberis [50a,50b], M. Barbero [21], D.Y. Bardin [64], T. Barillari [99], M. Barisonzi [175], T. Barklow [143], N. Barlow [28], B.M. Barnett [129], R.M. Barnett [15], A. Baroncelli [134a], G. Barone [49], A.J. Barr [118], F. Barreiro [80], J. Barreiro Guimarães da Costa [57], P. Barrillon [115], R. Bartoldus [143], A.E. Barton [71], V. Bartsch [149], A. Basye [165], R.L. Bates [53], L. Batkova [144a], J.R. Batley [28], A. Battaglia [17], M. Battistin [30], F. Bauer [136], H.S. Bawa [143,e], S. Beale [98], T. Beau [78], P.H. Beauchemin [161], R. Beccherle [50a], P. Bechtle [21], H.P. Beck [17], A.K. Becker [175], S. Becker [98], M. Beckingham [138], K.H. Becks [175], A.J. Beddall [19c], A. Beddall [19c], S. Bedikian [176], V.A. Bednyakov [64], C.P. Bee [83], L.J. Beemster [105], M. Begel [25], S. Behar Harpaz [152], P.K. Behera [62], M. Beimforde [99],

# How Discoveries Change 2: Higgs bosons, (2012)

# pp Collisions at $\sqrt{s}$ = 8 TeV in CERN LHC [ATLAS, CMS]

C. Belanger-Champagne[85], P.J. Bell[49], W.H. Bell[49], G. Bella[153], L. Bellagamba[20a], M. Bellomo[30], A. Belloni[57], O. Beloborodova[107,f], K. Belotskiy[96], O. Beltramello[30], O. Benary[153], D. Benchekroun[135a], K. Bendtz[146a,146b], N. Benekos[165], Y. Benhammou[153], E. Benhar Noccioli[49], J.A. Benitez Garcia[159b], D.P. Benjamin[45], M. Benoit[115], J.R. Bensinger[23], K. Benslama[130], S. Bentvelsen[105], D. Berge[30], E. Bergeaas Kuutmann[42], N. Berger[5], F. Berghaus[169], E. Berglund[105], J. Beringer[15], P. Bernat[77], R. Bernhard[48], C. Bernius[25], F.U. Bernlochner[169], T. Berry[76], C. Bertella[83], A. Bertin[20a,20b], F. Bertolucci[122a,122b], M.I. Besana[89a,89b], G.J. Besjes[104], N. Besson[136], S. Bethke[99], W. Bhimji[46], R.M. Bianchi[30], M. Bianco[72a,72b], O. Biebel[98], S.P. Bieniek[77], K. Bierwagen[54], J. Biesiada[15], M. Biglietti[134a], H. Bilokon[47], M. Bindi[20a,20b], S. Binet[115], A. Bingul[19c], C. Bini[132a,132b], C. Biscarat[178], B. 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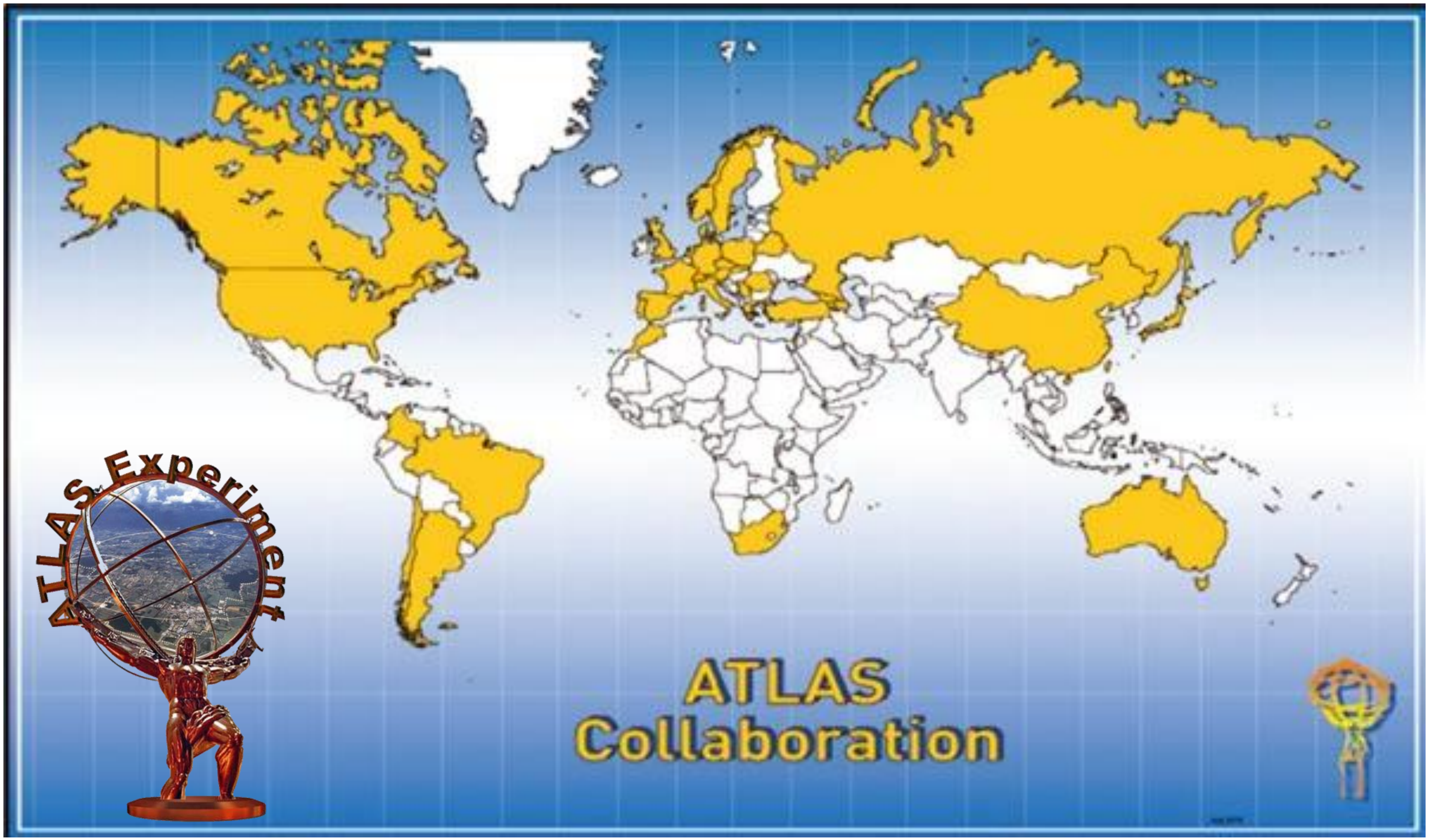
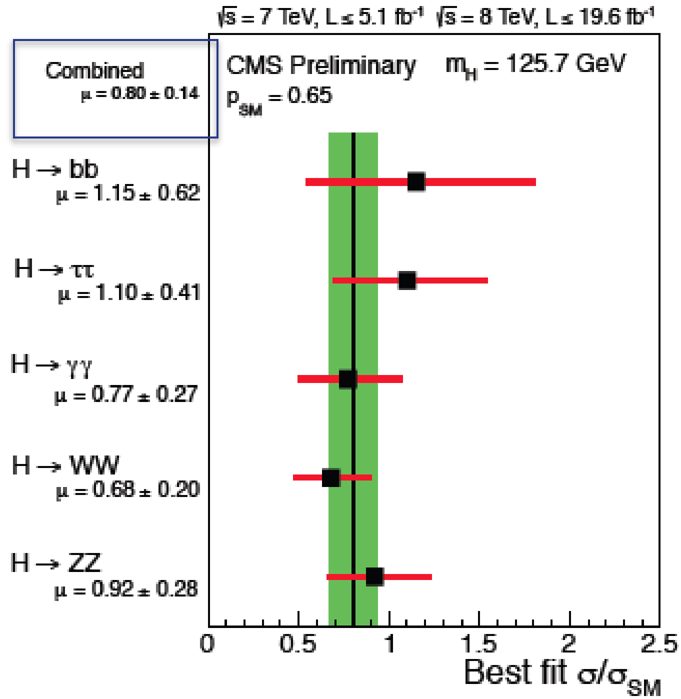
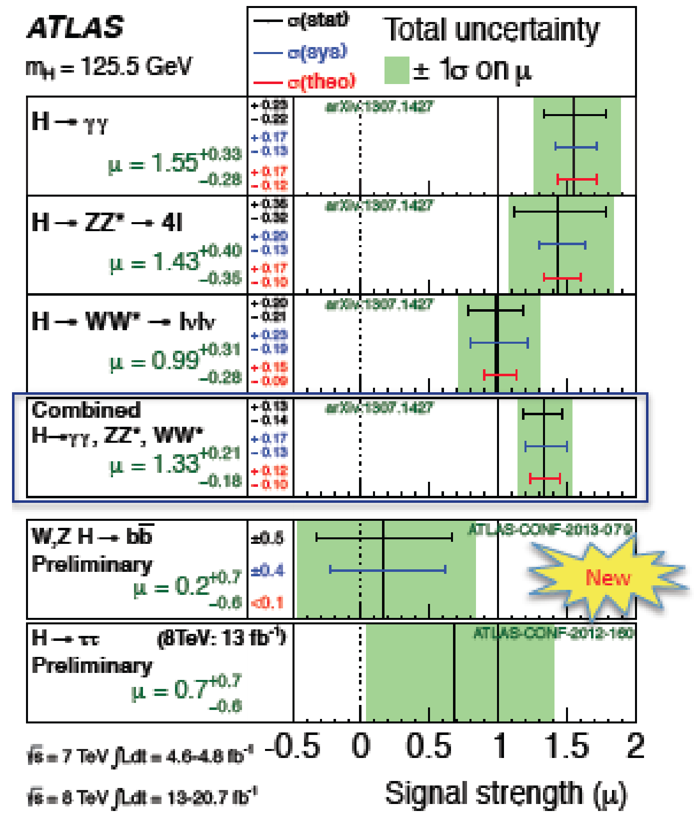
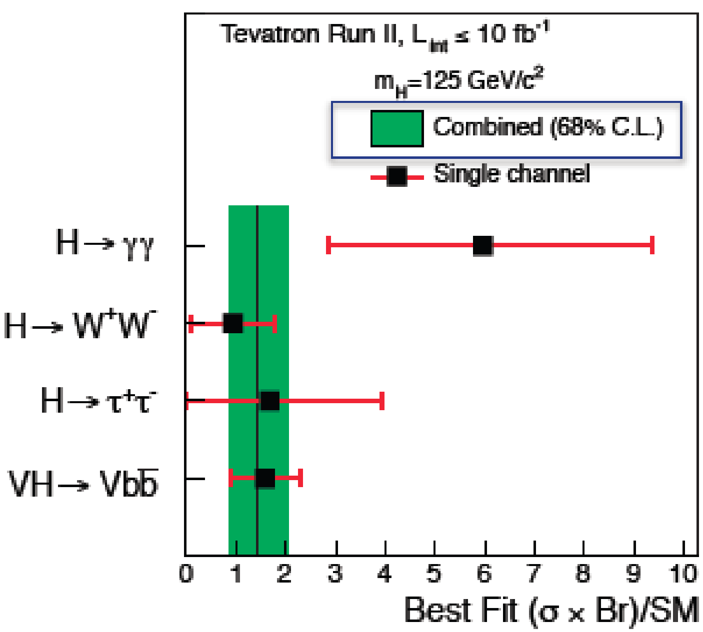


# Higgs Coupling Strength



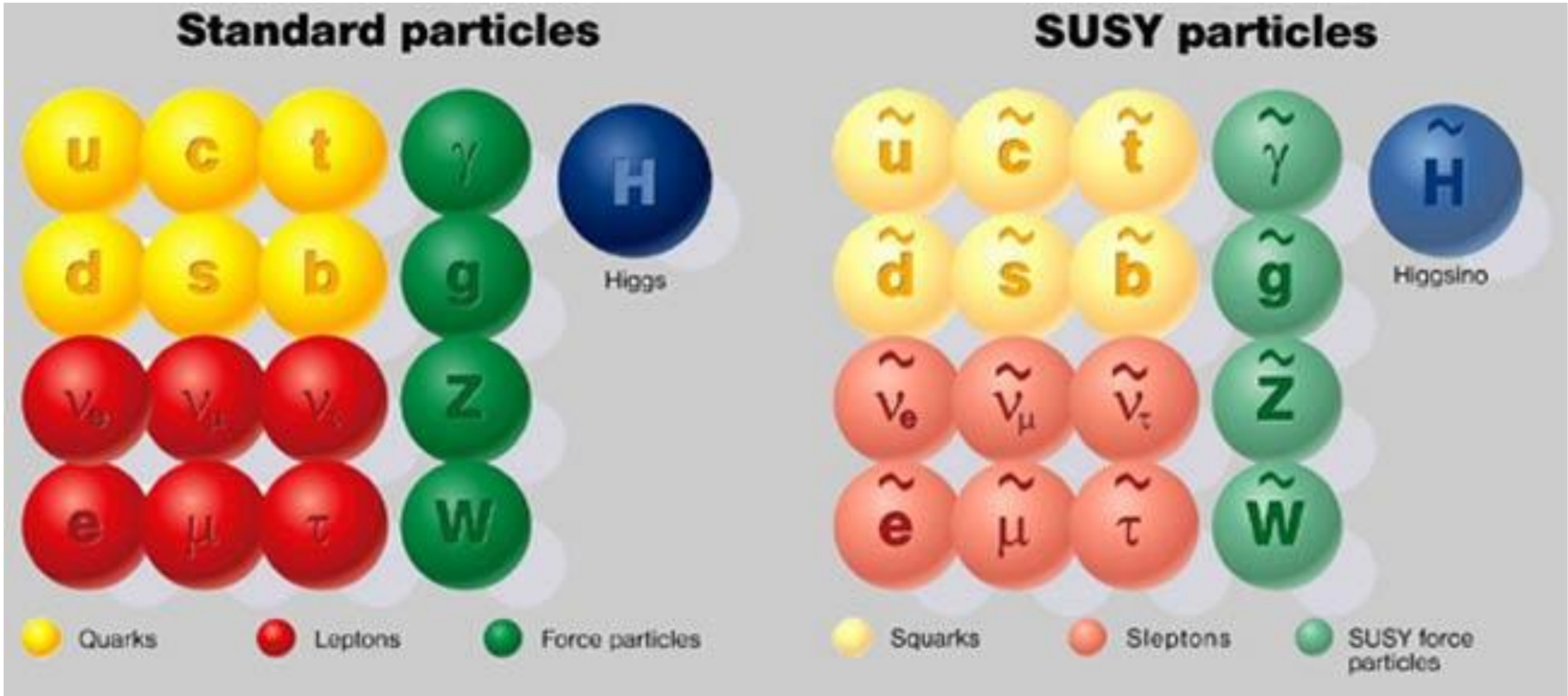



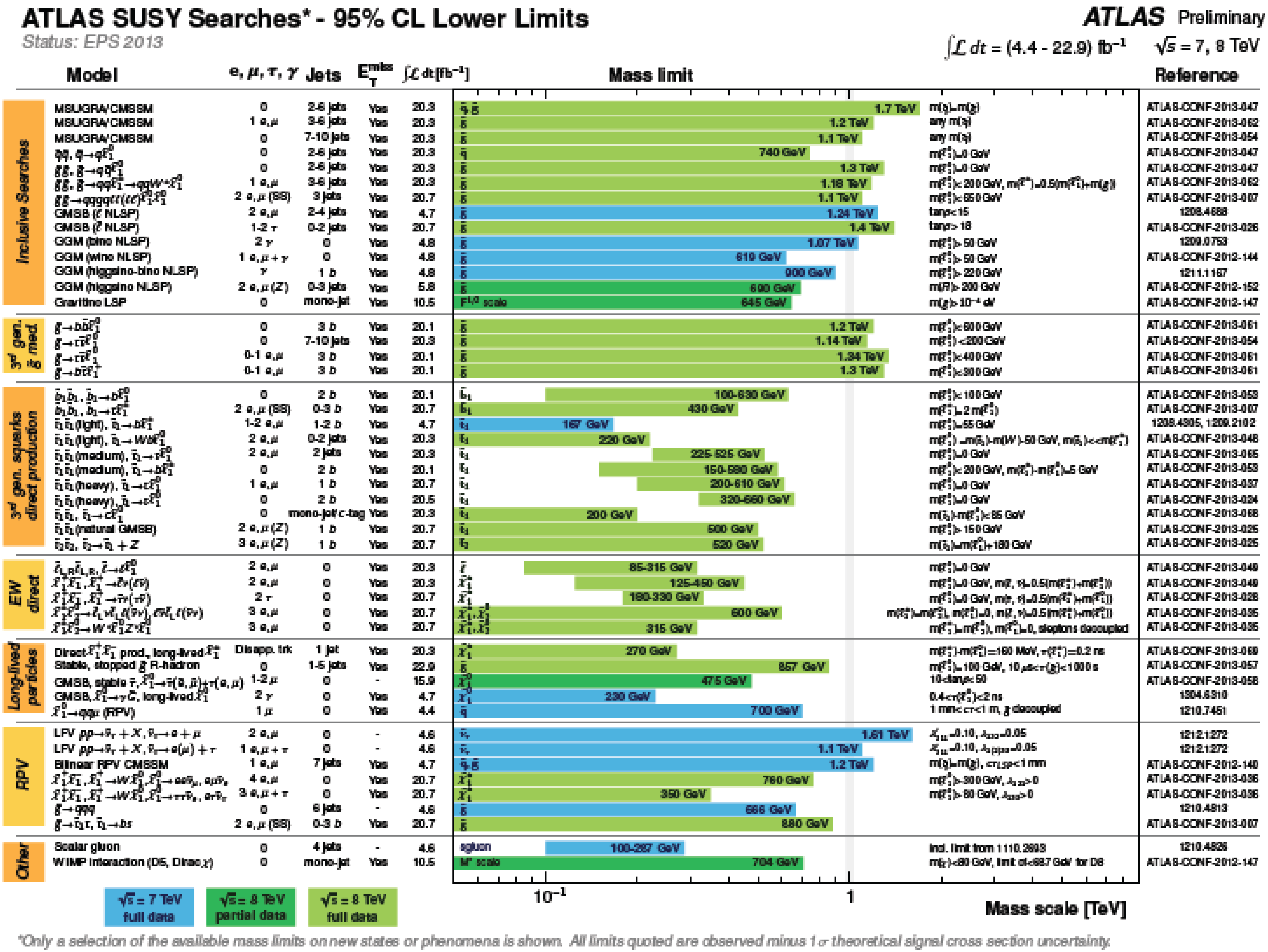

In all measurements of Higgs properies
To date, it is compatible with the
Standard Model version

# Physics Beyond Standard Model

Intense work by ATLAS, CMS, LHCb and many other experiments searching for Supersymmetry




Many other scenarios for physics beyond our current knowledge also investigated



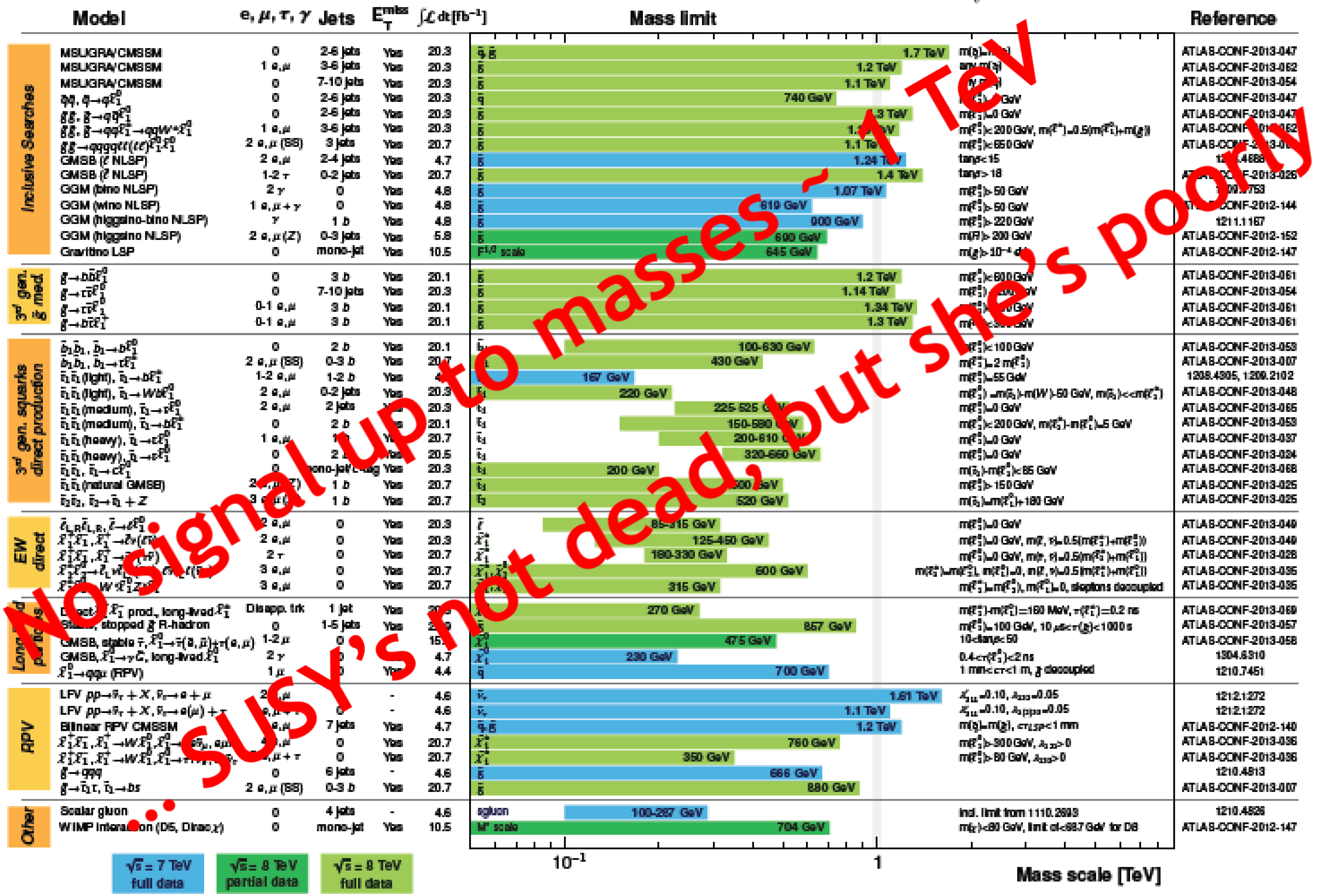
ATLAS SUSY Searches* - 95% CL Lower Limits
Status: EPS 2013
ATLAS Preliminary
∫L dt = (4.4 - 22.9) fb⁻¹
√s = 7, 8 TeV
Model
e, μ, τ, γ
Jets
E_T^miss
∫L dt[fb⁻¹]
Mass limit
Reference
Inclusive Searches
MSUGRA/CMSSM 0 2-6 jets Yes 20.3 1.7 TeV m(q̃)=m(g̃) ATLAS-CONF-2013-047
MSUGRA/CMSSM 1 e,μ 3-6 jets Yes 20.3 1.2 TeV any m(q̃) ATLAS-CONF-2013-062
MSUGRA/CMSSM 0 7-10 jets Yes 20.3 1.1 TeV any m(q̃) ATLAS-CONF-2013-054
740 GeV ATLAS-CONF-2013-047
1.3 TeV ATLAS-CONF-2013-047
1.18 TeV ATLAS-CONF-2013-062
1.1 TeV ATLAS-CONF-2013-007
GMSB 2 e,μ 2-4 jets Yes 4.7 1.24 TeV 1208.4688
GMSB 1-2 τ 0-2 jets Yes 20.7 1.4 TeV ATLAS-CONF-2013-026
GGM (bino NLSP) 2 γ 0 Yes 4.8 1.07 TeV 1209.0753
GGM (wino NLSP) 0 Yes 4.8 619 GeV ATLAS-CONF-2012-144
GGM (higgsino-bino NLSP) γ 1 b Yes 4.8 900 GeV 1211.1167
GGM (higgsino NLSP) 0-3 jets Yes 5.8 690 GeV ATLAS-CONF-2012-152
Gravitino LSP 0 mono-jet Yes 10.5 645 GeV ATLAS-CONF-2012-147
3rd gen. g̃ med.
0 3 b Yes 20.1 1.2 TeV ATLAS-CONF-2013-061
0 7-10 jets Yes 20.3 1.14 TeV ATLAS-CONF-2013-054
0-1 e,μ 3 b Yes 20.1 1.34 TeV ATLAS-CONF-2013-061
0-1 e,μ 3 b Yes 20.1 1.3 TeV ATLAS-CONF-2013-061
3rd gen. squarks direct production
0 2 b Yes 20.1 100-630 GeV ATLAS-CONF-2013-053
2 e,μ (SS) 0-3 b Yes 20.7 430 GeV ATLAS-CONF-2013-007
1-2 e,μ 1-2 b Yes 4.7 167 GeV 1208.4305, 1209.2102
2 e,μ 0-2 jets Yes 20.3 220 GeV ATLAS-CONF-2013-048
2 e,μ 2 jets Yes 20.3 225-525 GeV ATLAS-CONF-2013-065
0 2 b Yes 20.1 150-580 GeV ATLAS-CONF-2013-053
1 e,μ 1 b Yes 20.7 200-610 GeV ATLAS-CONF-2013-037
0 2 b Yes 20.5 320-660 GeV ATLAS-CONF-2013-024
0 mono-jet/c-tag Yes 20.3 200 GeV ATLAS-CONF-2013-068
1 b Yes 20.7 500 GeV ATLAS-CONF-2013-025
1 b Yes 20.7 520 GeV ATLAS-CONF-2013-025
EW direct
2 e,μ 0 Yes 20.3 85-315 GeV ATLAS-CONF-2013-049
2 e,μ 0 Yes 20.3 125-450 GeV ATLAS-CONF-2013-049
2 τ 0 Yes 20.7 180-330 GeV ATLAS-CONF-2013-028
3 e,μ 0 Yes 20.7 600 GeV ATLAS-CONF-2013-035
3 e,μ 0 Yes 20.7 315 GeV ATLAS-CONF-2013-035
Long-lived particles
Disapp. trk 1 jet Yes 20.3 270 GeV ATLAS-CONF-2013-069
Stable, stopped g̃ R-hadron 0 1-5 jets Yes 22.9 857 GeV ATLAS-CONF-2013-057
1-2 μ 0 - 15.9 475 GeV ATLAS-CONF-2013-058
2 γ 0 Yes 4.7 230 GeV 1304.6310
1 μ 0 Yes 4.4 700 GeV 1210.7451
RPV
2 e,μ 0 - 4.6 1.61 TeV 1212.1272
1 e,μ+τ 0 - 4.6 1.1 TeV 1212.1272
Bilinear RPV CMSSM 1 e,μ 7 jets Yes 4.7 1.2 TeV ATLAS-CONF-2012-140
4 e,μ 0 Yes 20.7 760 GeV ATLAS-CONF-2013-036
3 e,μ+τ 0 Yes 20.7 350 GeV ATLAS-CONF-2013-036
0 6 jets - 4.6 666 GeV 1210.4813
2 e,μ (SS) 0-3 b Yes 20.7 880 GeV ATLAS-CONF-2013-007
Other
Scalar gluon 0 4 jets - 4.6 100-287 GeV incl. limit from 1110.2693 1210.4826
WIMP interaction (D5, Dirac χ) 0 mono-jet Yes 10.5 704 GeV ATLAS-CONF-2012-147
10⁻¹
1
Mass scale [TeV]
√s = 7 TeV full data
√s = 8 TeV partial data
√s = 8 TeV full data
*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

# ATLAS SUSY Searches* - 95% CL Lower Limits

Status: EPS 2013

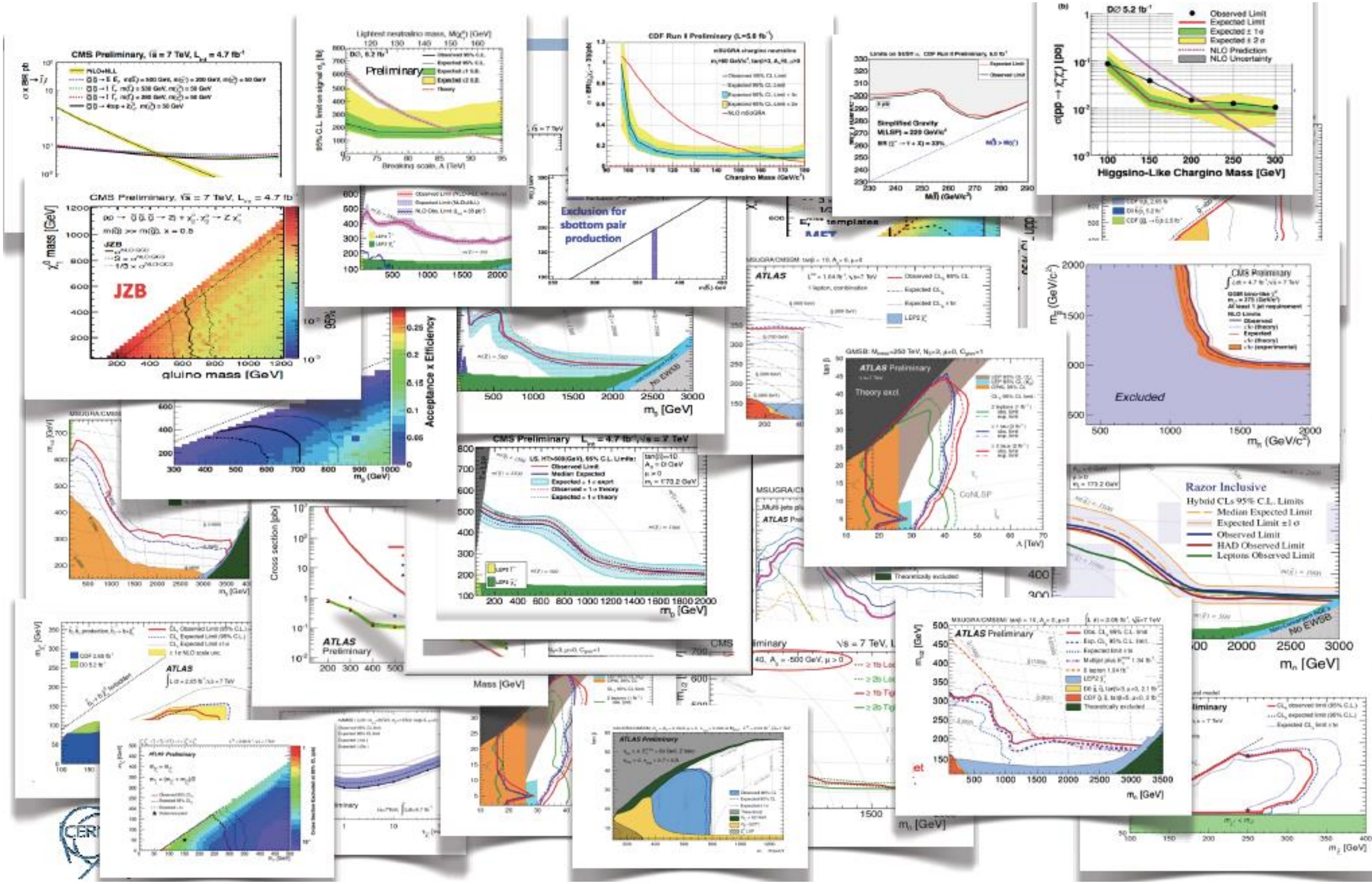
**ATLAS** Preliminary

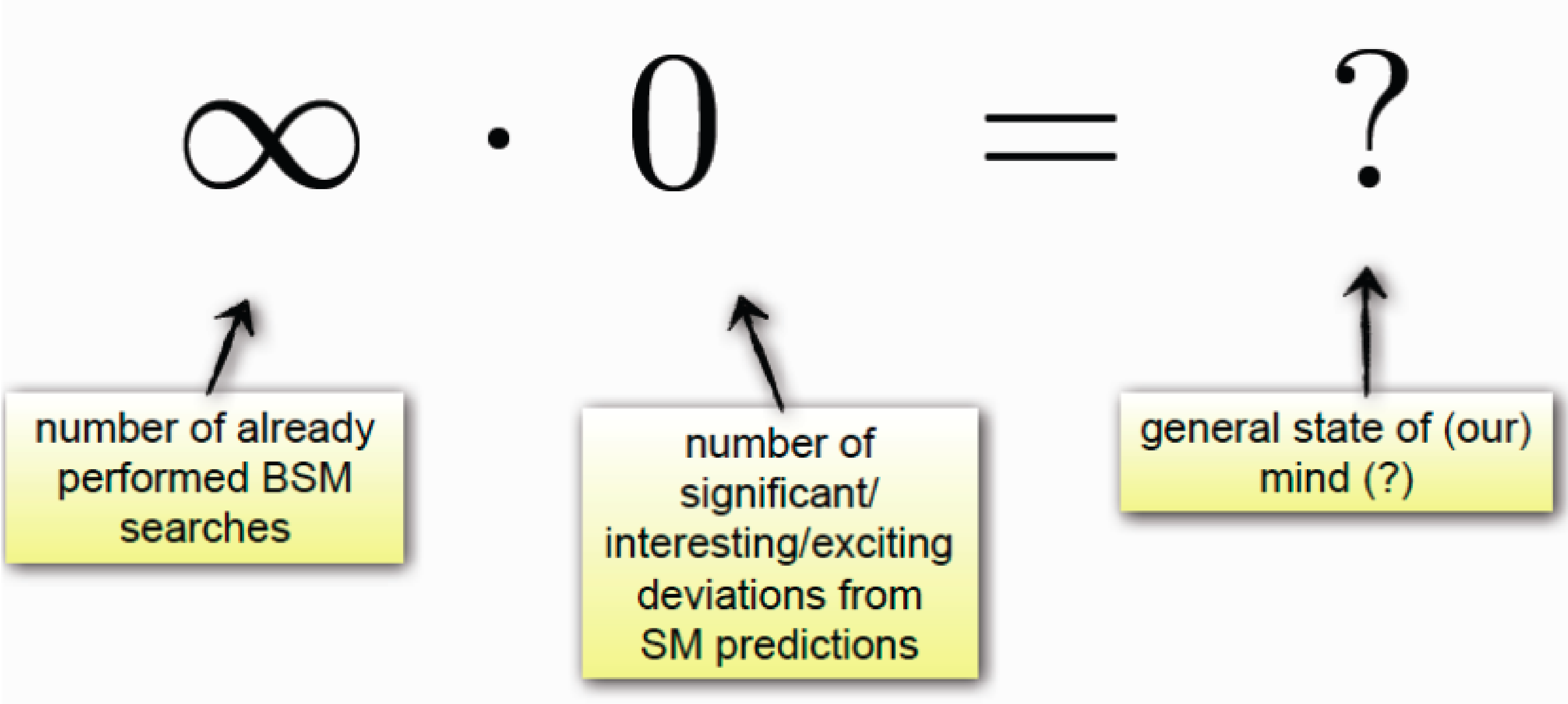
$\int \mathcal{L}\,dt = (4.4 - 22.9)\ \mathrm{fb}^{-1}$ $\sqrt{s} = 7, 8$ TeV

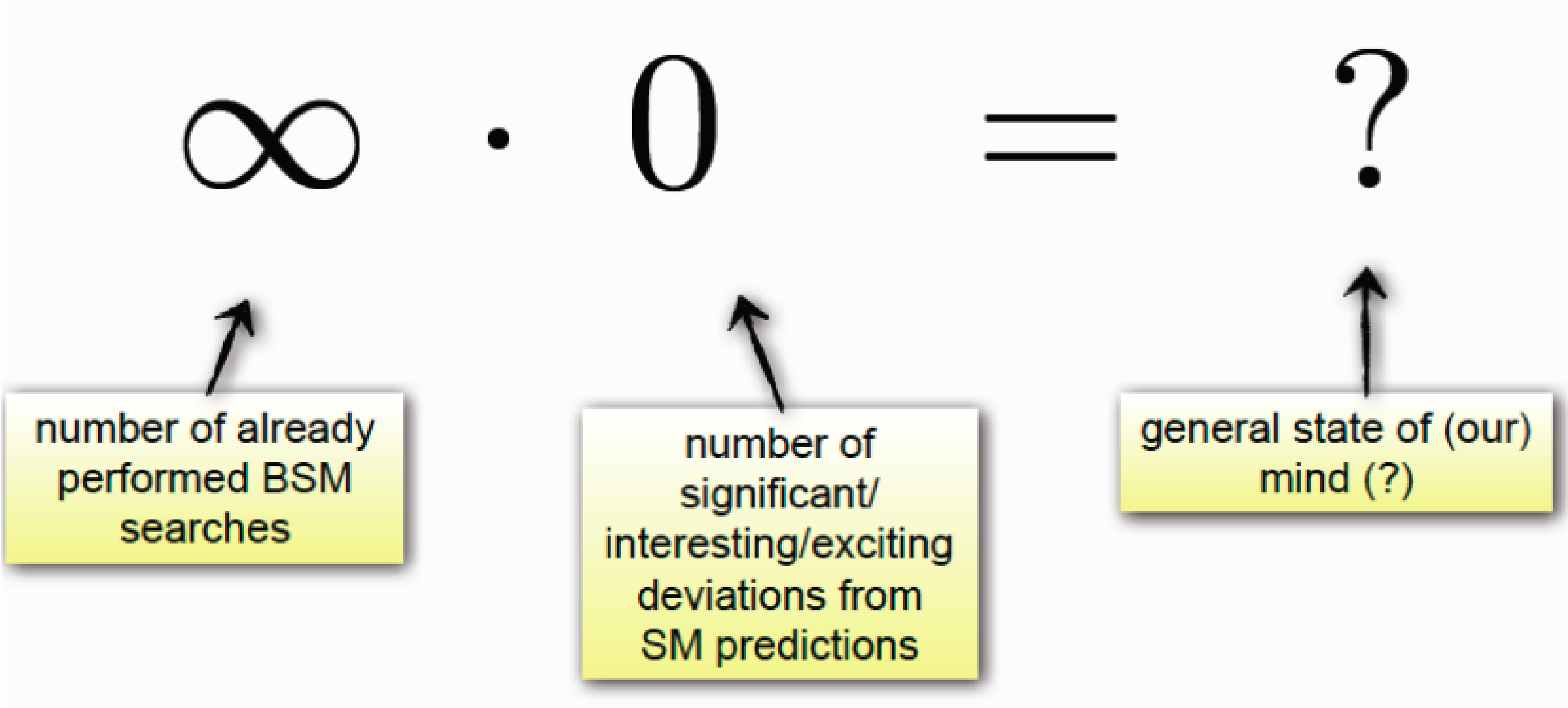



*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

# Many More Searches … without success




∞ · 0 = ?
number of already performed BSM searches
number of significant/ interesting/exciting deviations from SM predictions
general state of (our) mind (?)




It's way too early to give up hope! So far at LHC:

→ Half design beam energy

→ 1% of planned collisions

- The LHC will run for another 15-20 years …

  … and it's certainly not the only show in town ☺

# Thank you for your Attention!