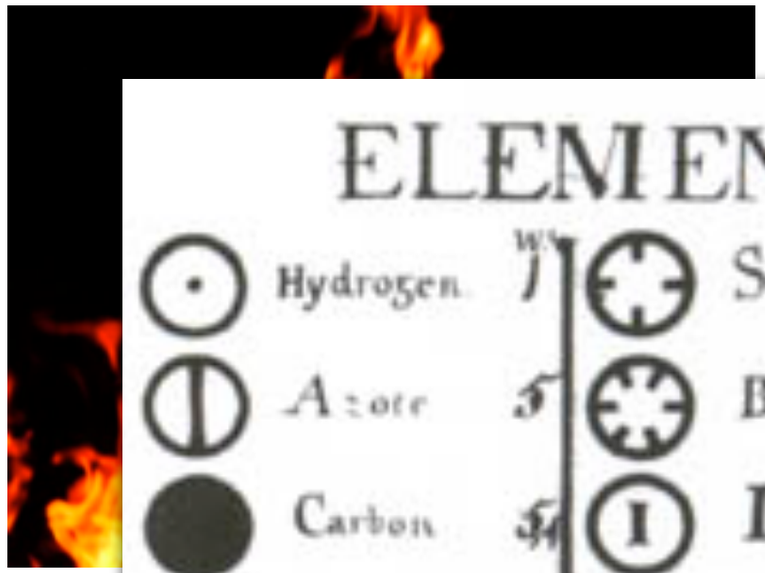
Simulation

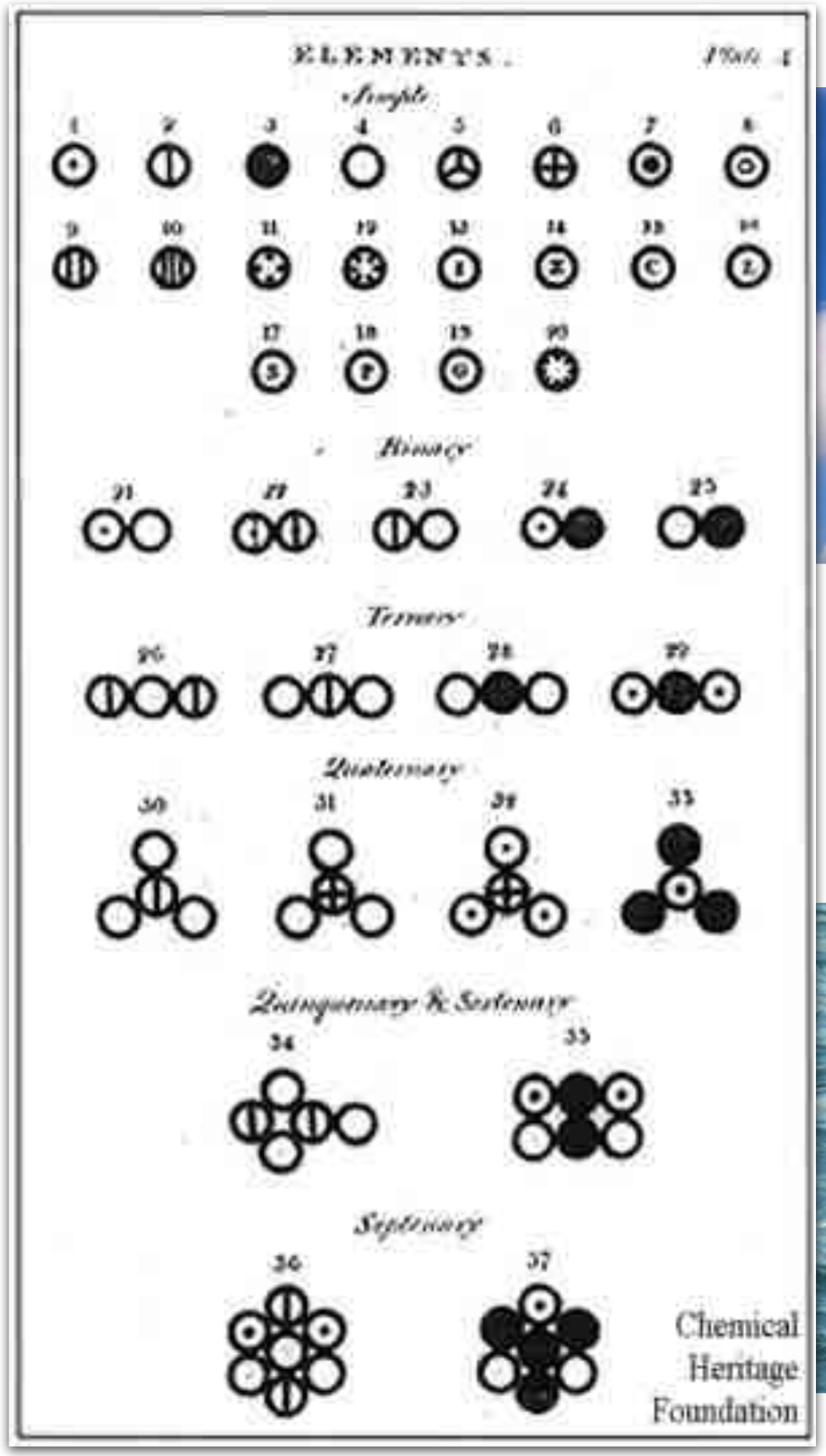
David Grellscheid

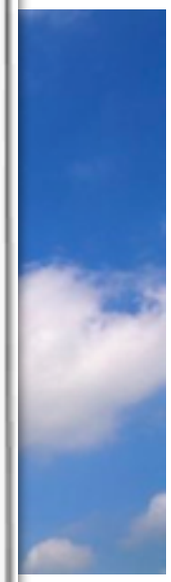
2015-04-2

What are the fundamental building blocks of Nature?



ELEMENTS
Hydrogen 1
Azote 5
Carbon 54
Oxygen 7
Phosphorus 9
Sulphur 13
Magnesia 20
Lime 24
Soda 28
Potash 42
Strontian 46
Barytes 68
Iron I
Zinc Z
Copper C
Lead L
Silver S
Gold G
Platina P
Mercury 167


ELEMENTS.
Simple
Binary
Ternary
Quaternary
Quinquenary & Senenary
Septenary
Chemical Heritage Foundation



ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

		Ti = 50	Zr = 90	? = 180.
		V = 51	Nb = 94	Ta = 182.
		Cr = 52	Mo = 96	W = 186.
		Mn = 55	Rh = 104,4	Pt = 197,1.
		Fe = 56	Ru = 104,4	Ir = 198.
		Ni = Co = 59	Pl = 106,6	Os = 199.
H = 1		Cu = 63,4	Ag = 108	Hg = 200.
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112	
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Sn = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
	O = 16	S = 32	Se = 79,4	Te = 128?	
	F = 19	Cl = 35,5	Br = 80	I = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204.
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207.
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75,6	Th = 118?		

Д. Менделѣевъ

1 IA	2 IIA				13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H Hydrogen 1.00794										2 He Helium 4.002602
3 Li Lithium 6.941	4 Be Beryllium 9.012182				5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
11 Na Sodium 22.989770	12 Mg Magnesium 24.3050				13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.973761	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	Übergangs-metalle	21 Sc	30 Zn	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	Übergangs-metalle	39 Y	48 Cd	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
55 Cs Cesium 132.90545	56 Ba Barium 137.327	Übergangs-metalle Lanthaniden	57 La .... 58 Ce	80 Hg 71 Lu	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	Übergangs-metalle Actiniden	89 Ac .... 90 Th	112 Uub 103 Lr						

Alkalimetalle — Metalle — Nichtmetalle

Erdalkalimetalle — Übergangsmetalle — Edelgase

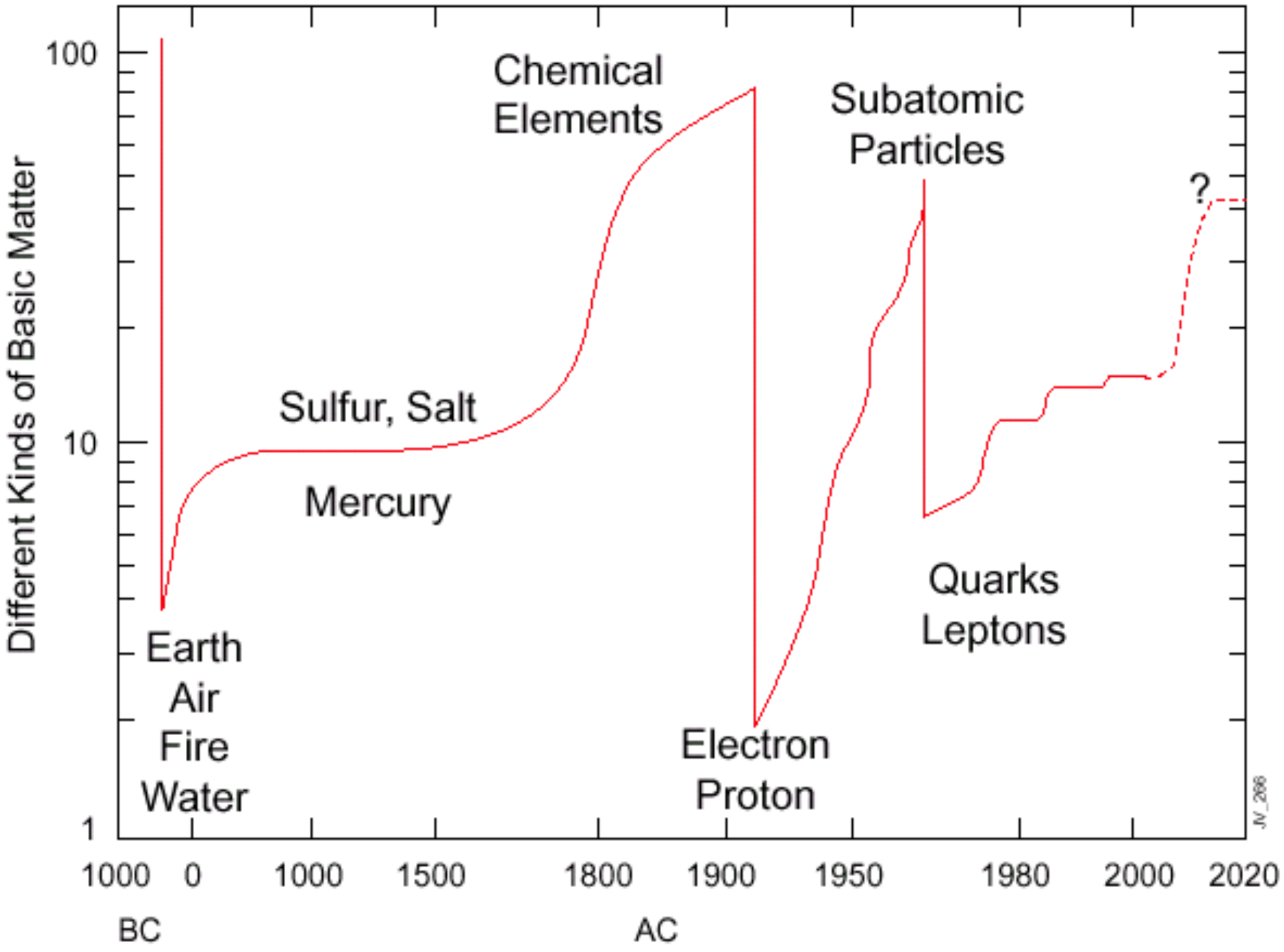
Д. Менделѣевъ

1 IA	2 IIA											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 H Hydrogen 1.00794																	2 He Helium 4.002602
3 Li Lithium 6.941	4 Be Beryllium 9.012182													7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
11 Na Sodium 22.989770	12 Mg Magnesium 24.3050														16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	Übergang metalle													34 e nium 6	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	Übergangs- metalle												ny	2 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
55 Cs Cesium 132.90545	56 Ba Barium 137.327	Übergangs- metalle	57 La											Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
		Lanthaniden	58 Ce														
87 Fr Francium (223)	88 Ra Radium (226)	Übergangs- metalle	89 Ac	112 Uub													
		Actiniden	90 Th	103 Lr													

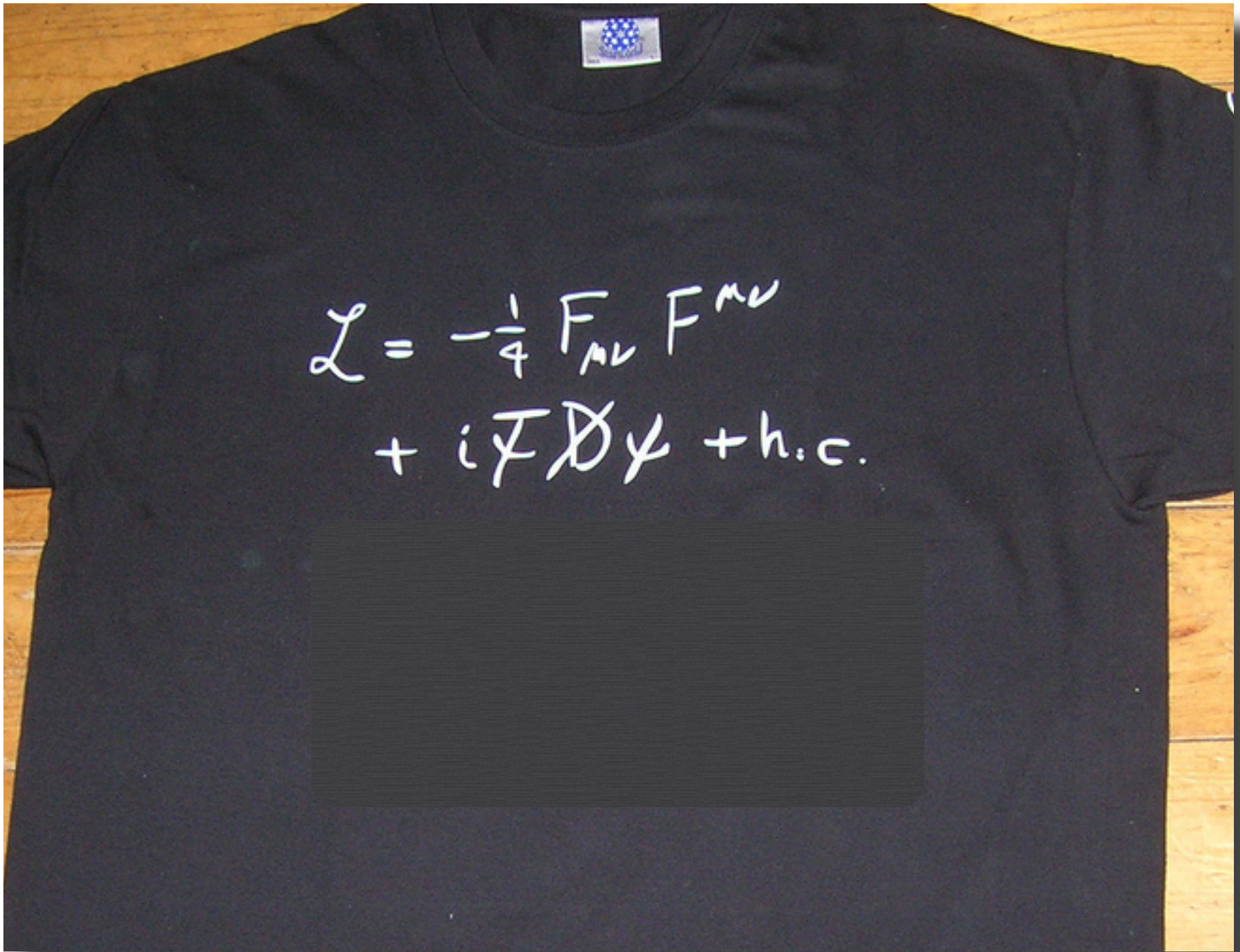
Alkalimetalle | Metalle | Nichtmetalle

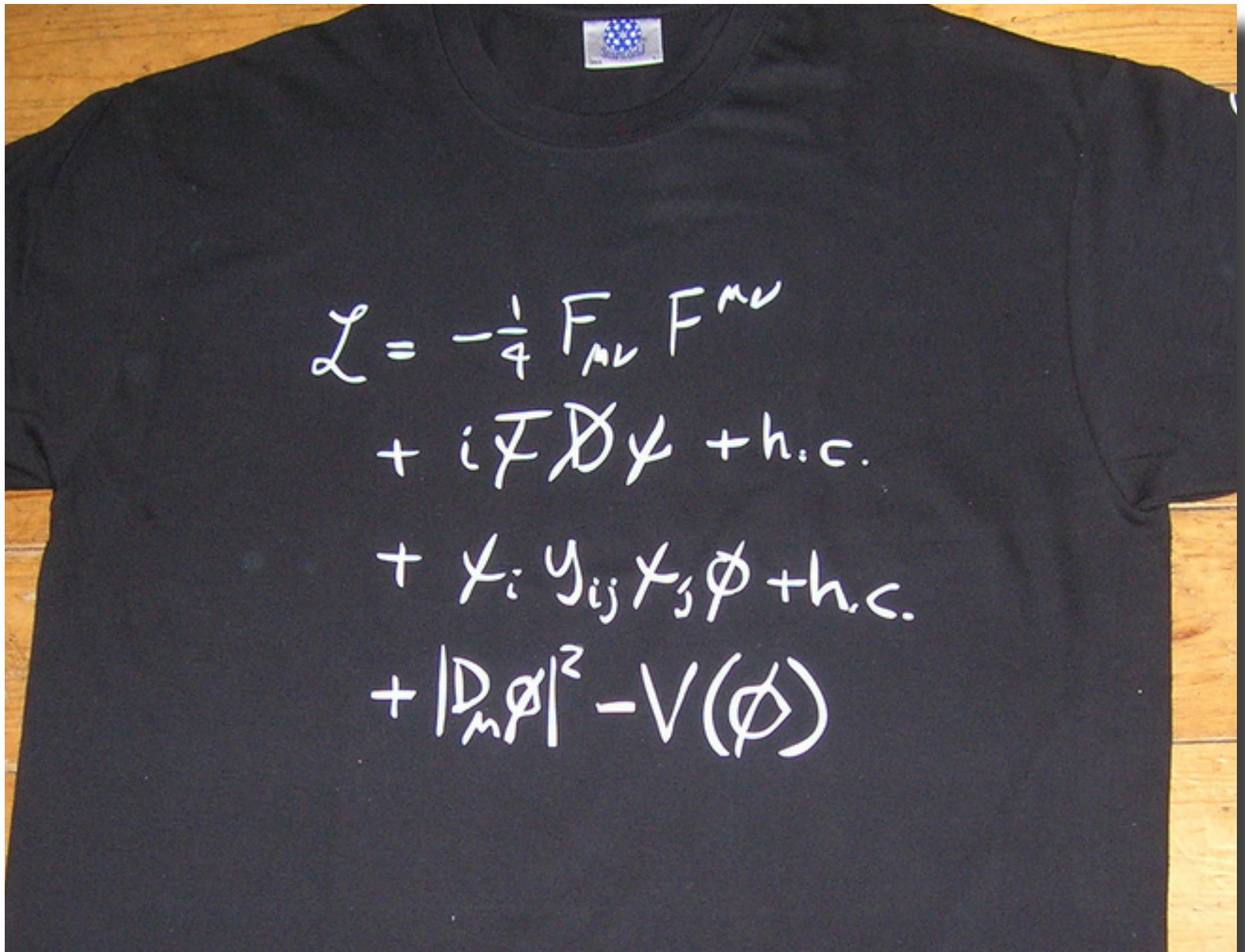
Erdalkalimetalle | Übergangsmetalle | Edelgase

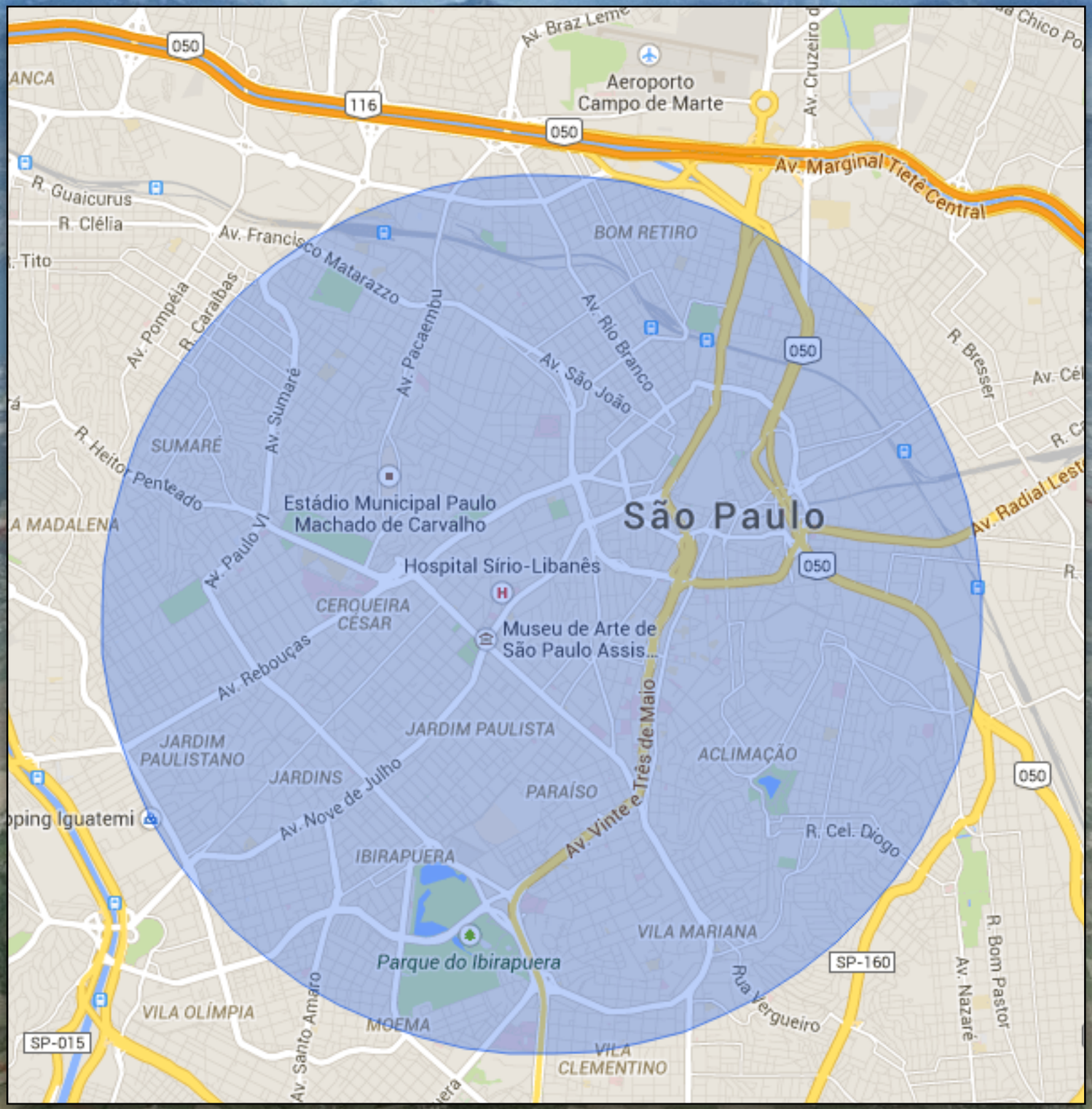
Д. Менделѣевъ


100
10
1
Different Kinds of Basic Matter
Chemical Elements
Subatomic Particles
?
Sulfur, Salt
Mercury
Earth
Air
Fire
Water
Electron
Proton
Quarks
Leptons
JV_266
1000
0
1000
1500
1800
1900
1950
1980
2000
2020
BC
AC

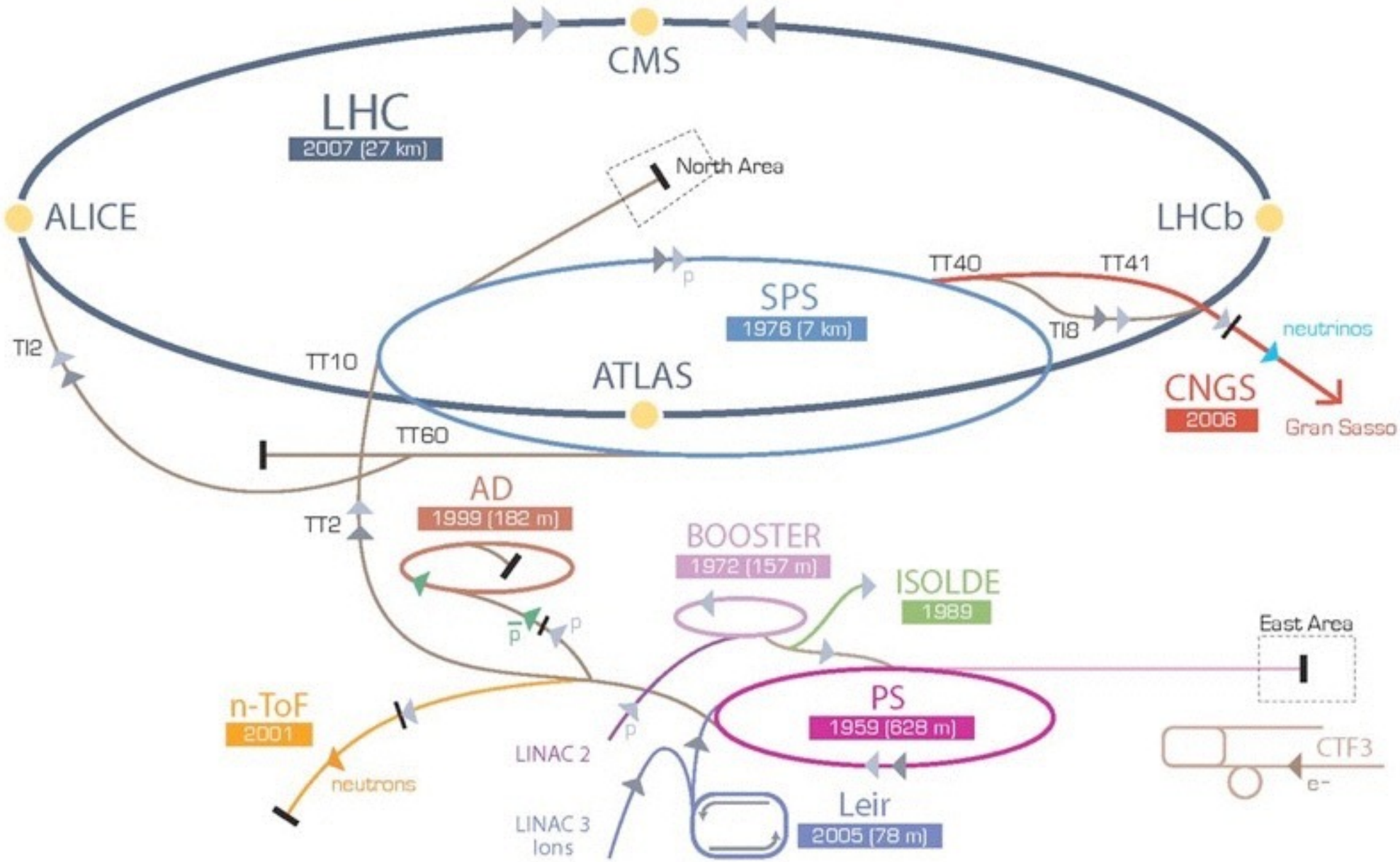
Quarks	u up	c charm	t top	γ photon	Force carriers
	d down	s strange	b bottom	Z Z boson	
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	
	e electron	μ muon	τ tau	g gluon	


$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$
$+ i\bar{\psi} \not{D} \psi + h.c.$


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


050
116
Aeroporto
Campo de Marte
Av. Marginal Tietê Central
R. Guaicurus
R. Clélia
Av. Francisco Matarazzo
BOM RETIRO
Av. Pompéia
R. Caraíbas
Av. Pacaembu
Av. Rio Branco
Av. São João
R. Bresser
SUMARÉ
Av. Sumaré
R. Heitor Penteado
Estádio Municipal Paulo
Machado de Carvalho
São Paulo
Av. Paulo VI
Hospital Sírio-Libanês
CERQUEIRA
CÉSAR
Museu de Arte de
São Paulo Assis...
Av. Rebouças
JARDIM
PAULISTANO
JARDIM PAULISTA
JARDINS
Av. Nove de Julho
PARAÍSO
ACLIMAÇÃO
Av. Vinte e Três de Maio
R. Cel. Diogo
IBIRAPUERA
VILA MARIANA
Parque do Ibirapuera
SP-160
Av. Nazaré
R. Bom Pastor
Rua Vergueiro
VILA OLÍMPIA
MOEMA
VILA
CLEMENTINO
SP-015
Av. Santo Amaro

CERN Accelerator Complex



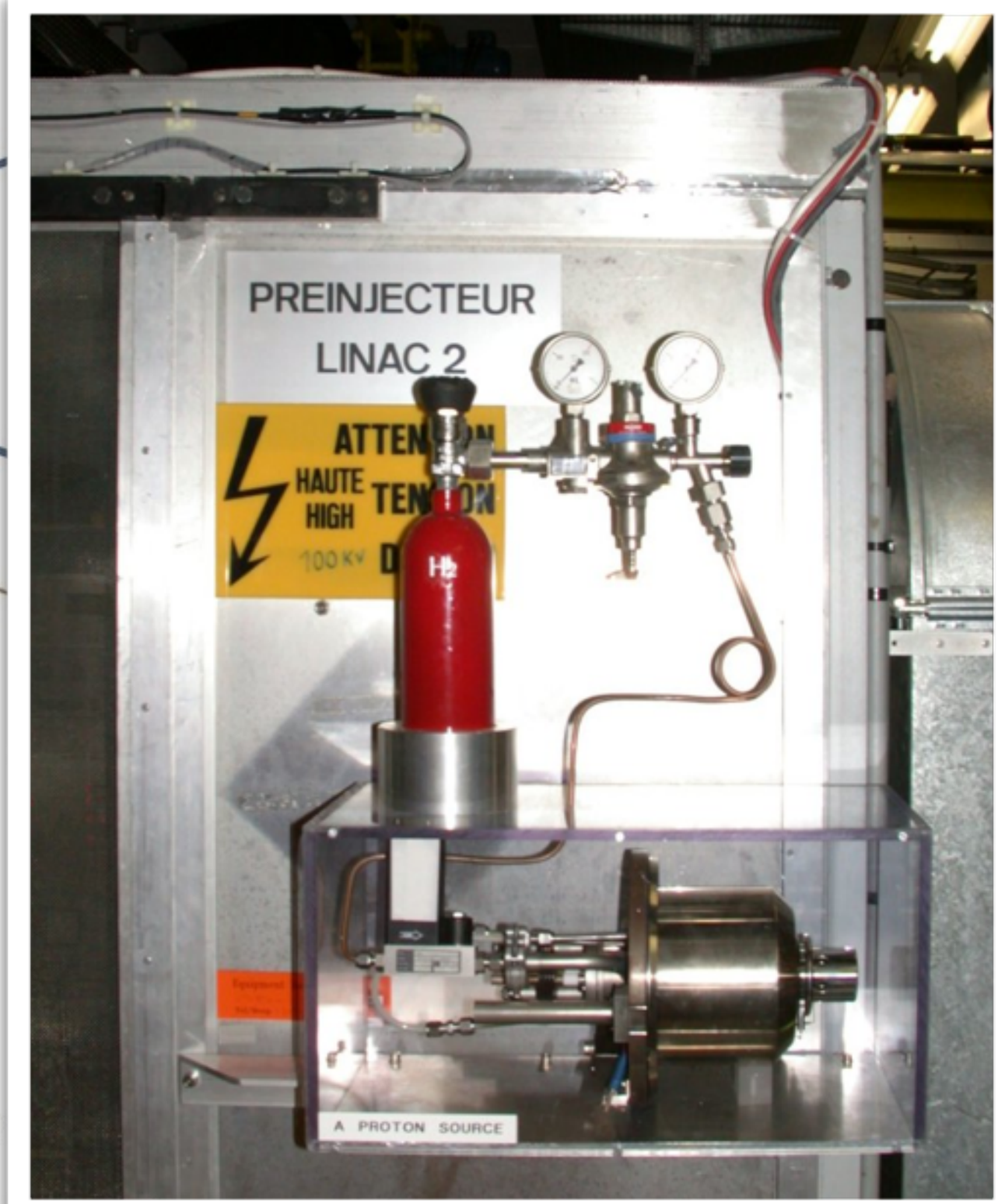
p (proton) ion neutrons p̄ (antiproton) proton/antiproton conversion neutrinos electron

LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice

LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight

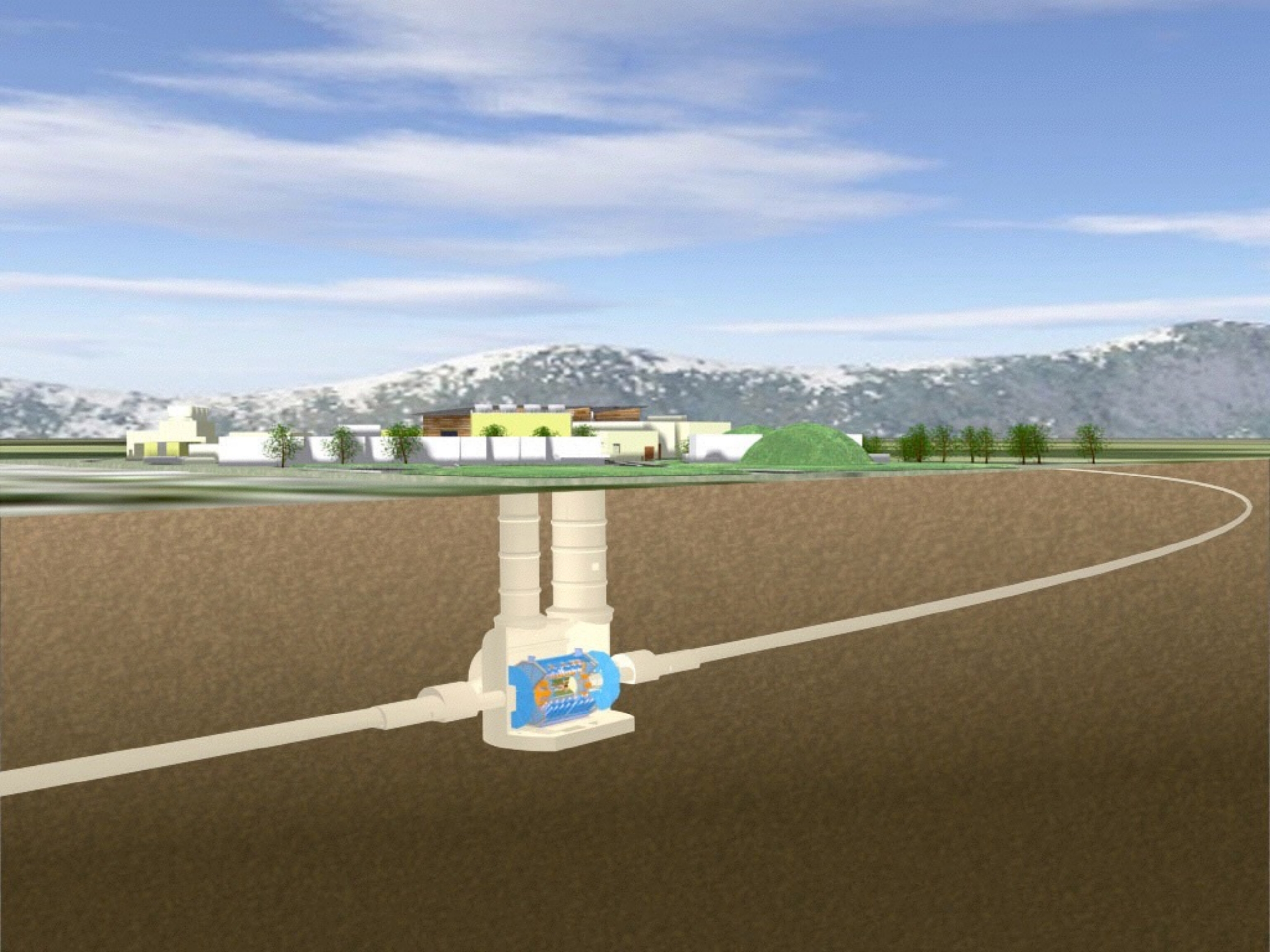
CERN Accelerator Complex



p (proton)

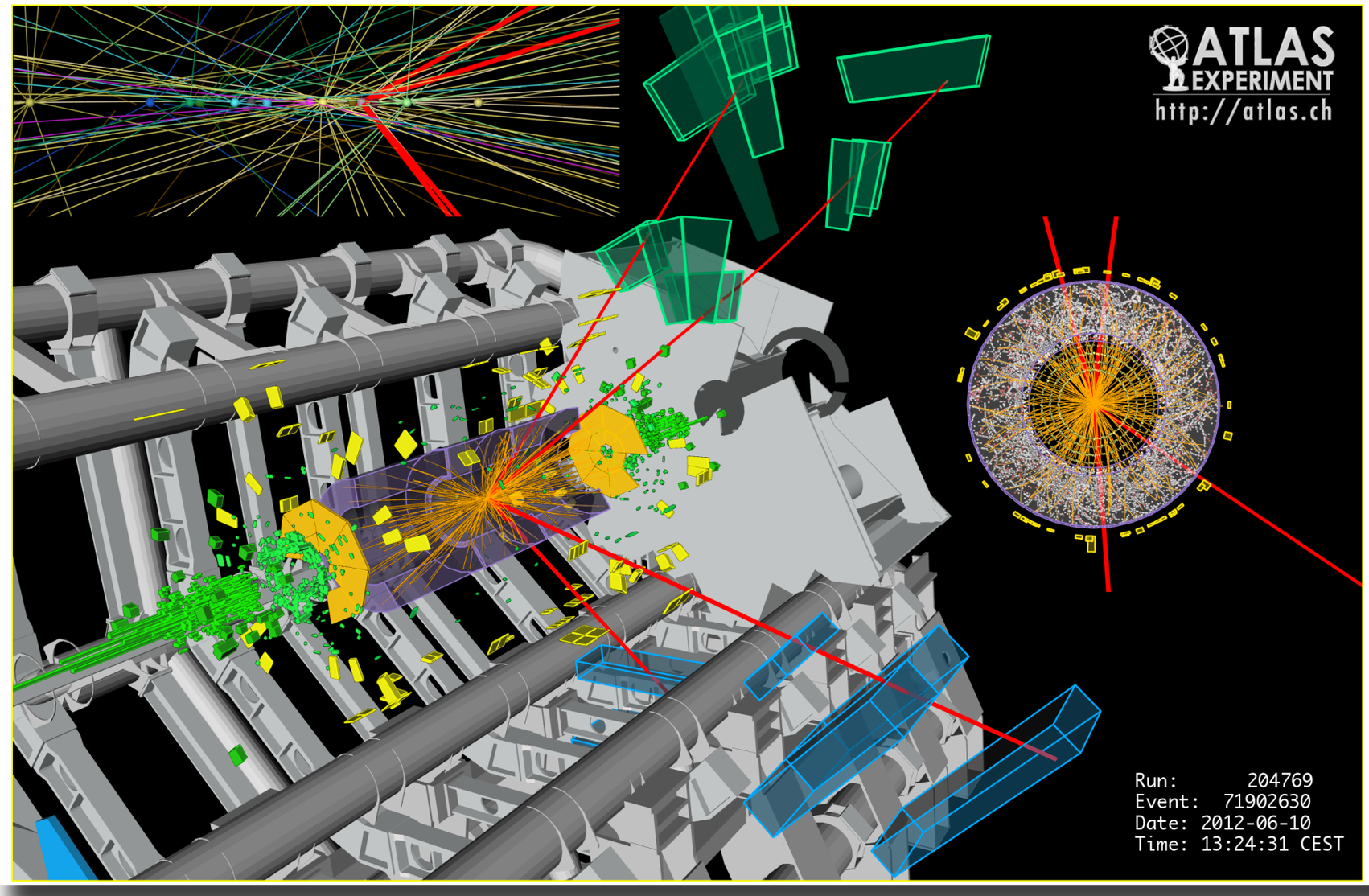
electron

AD Antiproton Decelerator CTF3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice
LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight



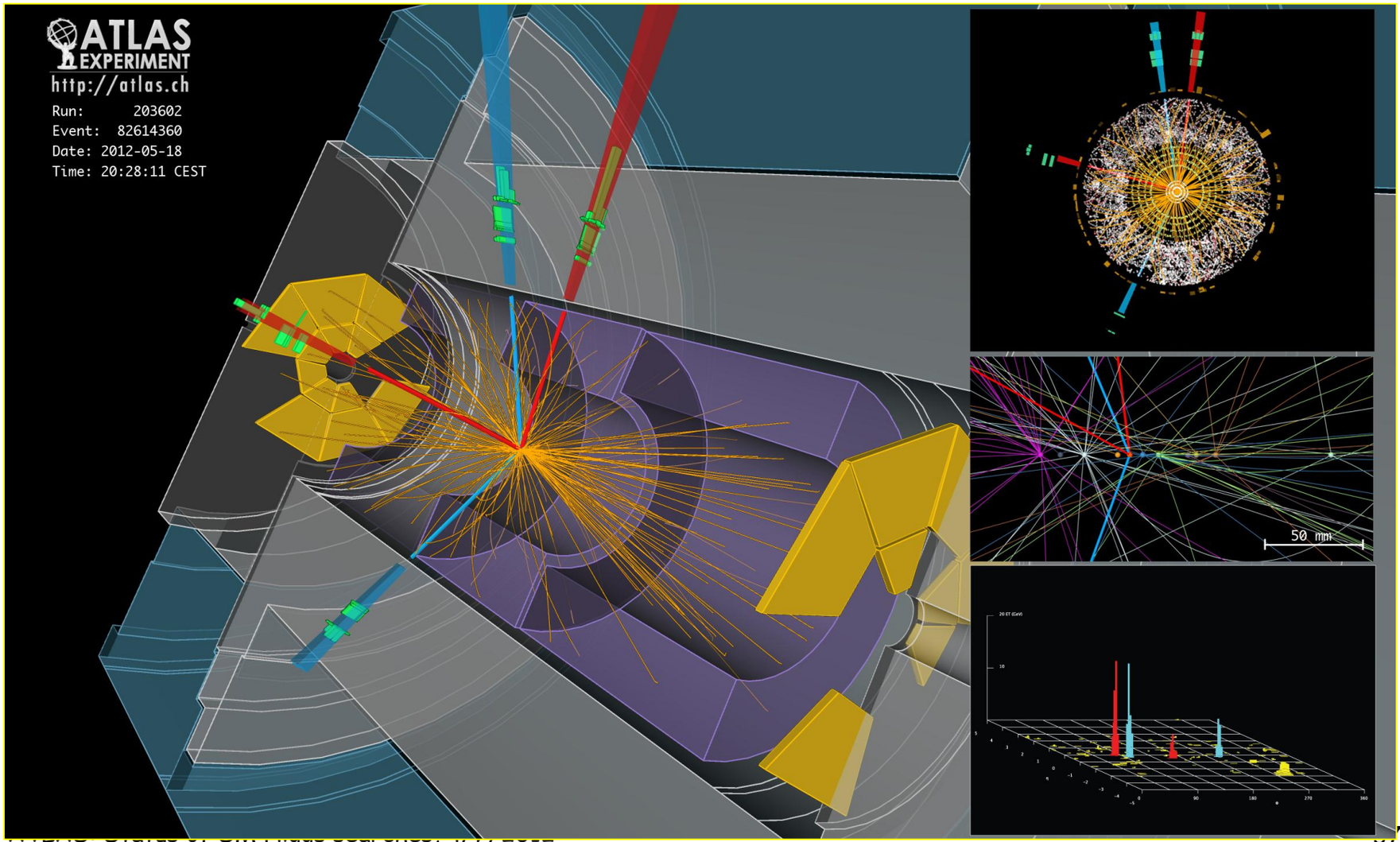
4μ candidate with $m_{4\mu}$= 125.1 GeV

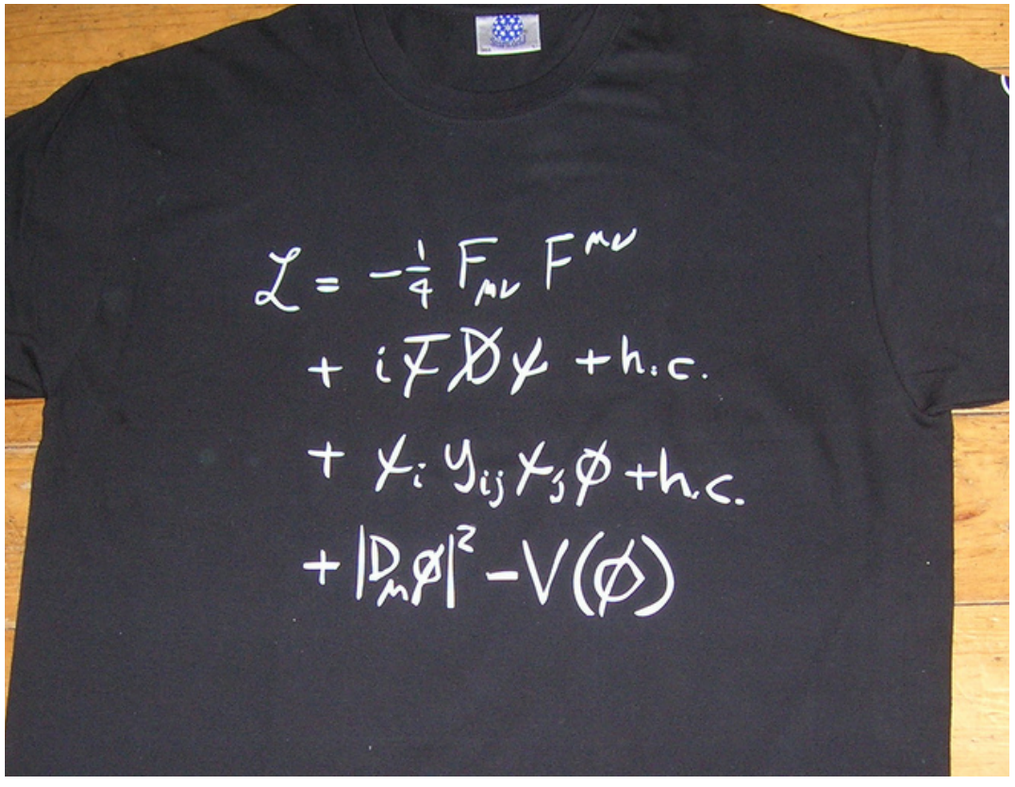
p_T (muons)= 36.1, 47.5, 26.4, 71 .7GeV m_{12}= 86.3 GeV, m_{34}= 31.6 GeV
15 reconstructed vertices

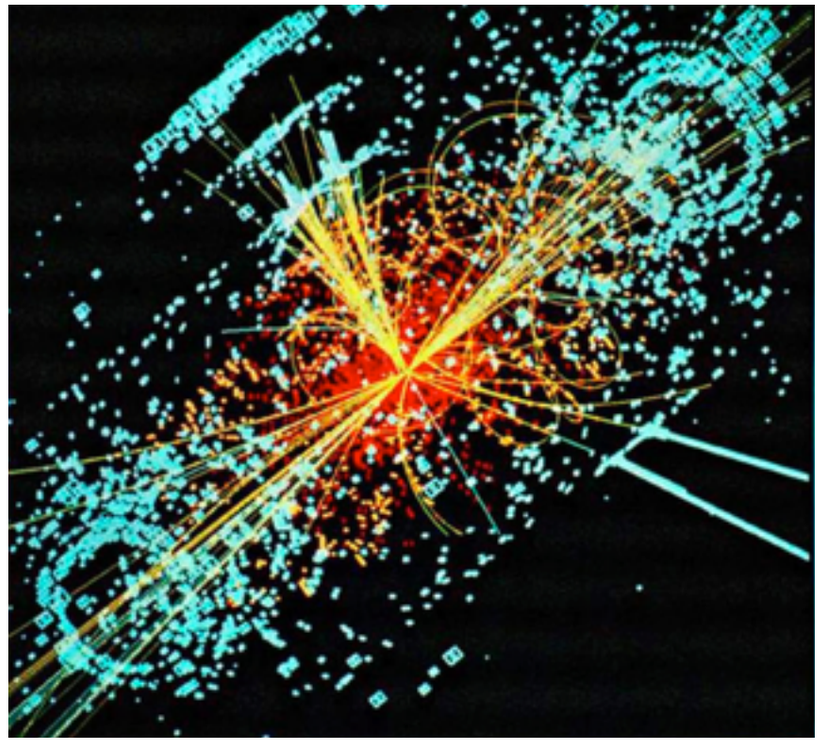


4e candidate with m_{4e}= 124.6 GeV

p_T (electrons)= 24.9, 53.9, 61.9, 17.8 GeV m_{12}= 70.6 GeV, m_{34}= 44.7 GeV
12 reconstructed vertices

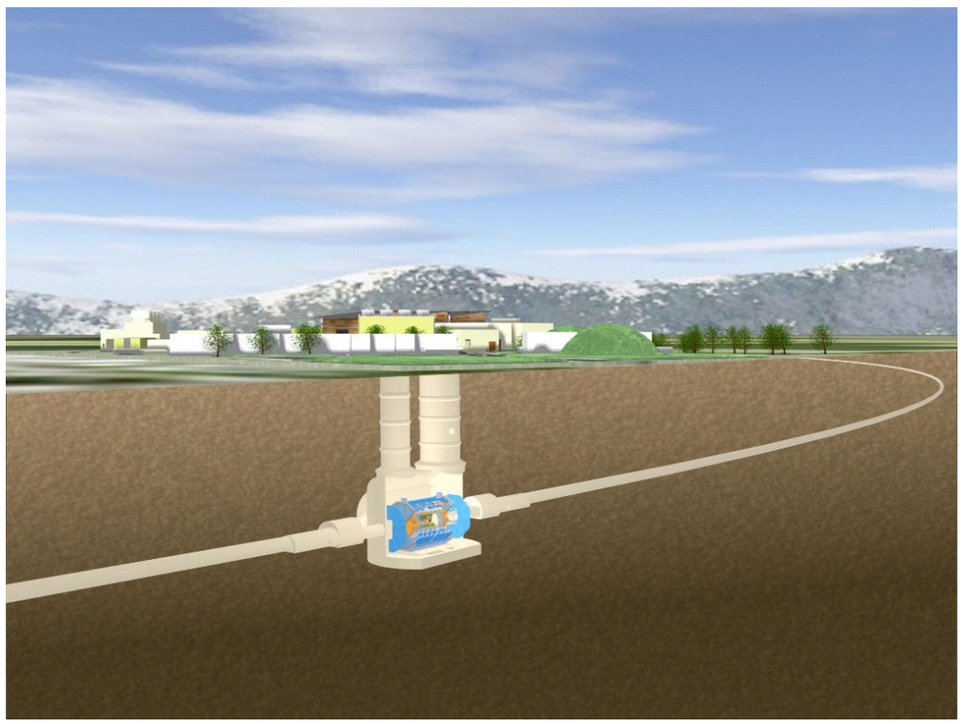


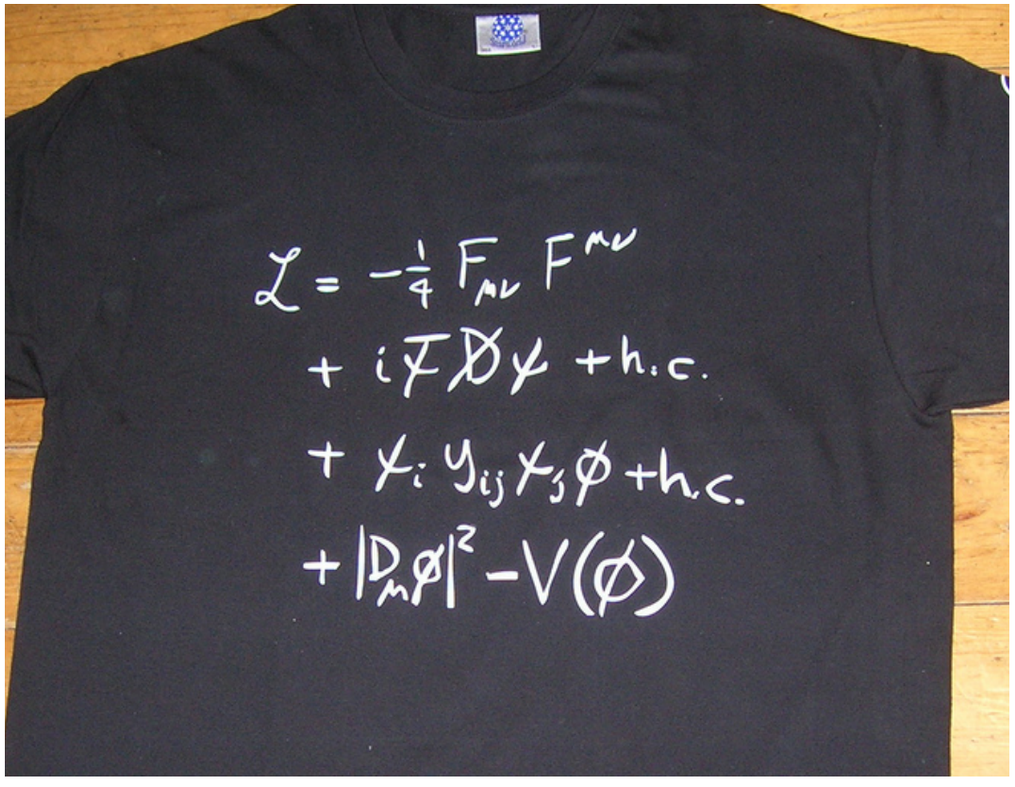


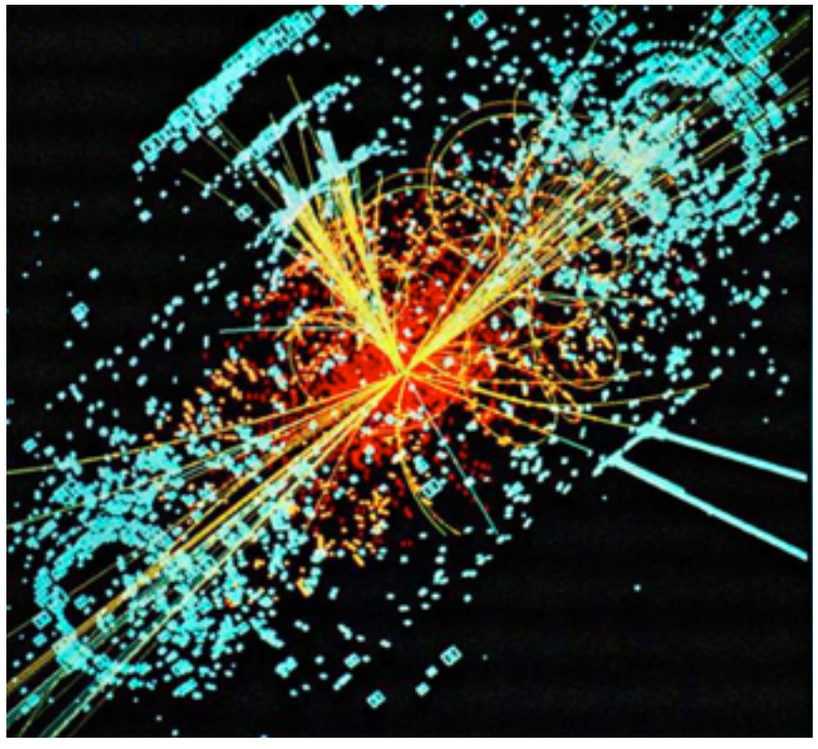


Theory

Experiment

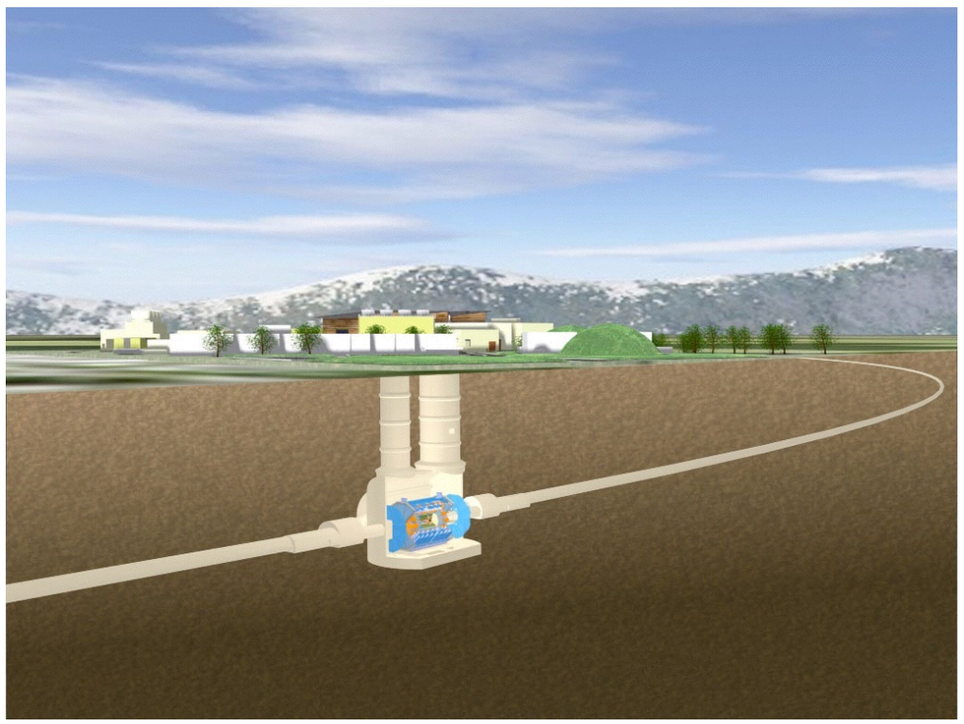






?

Theory ⟷ Experiment

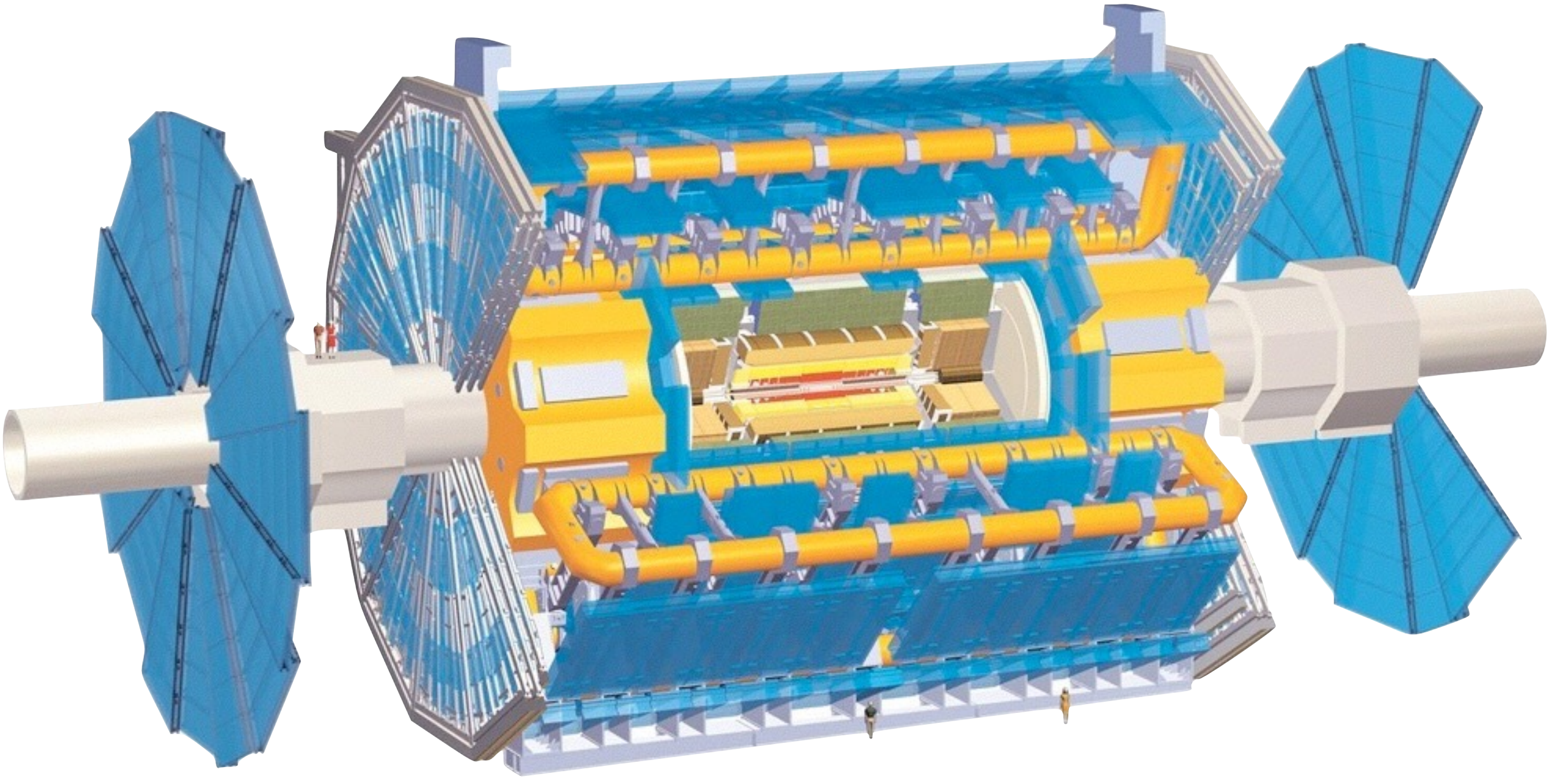


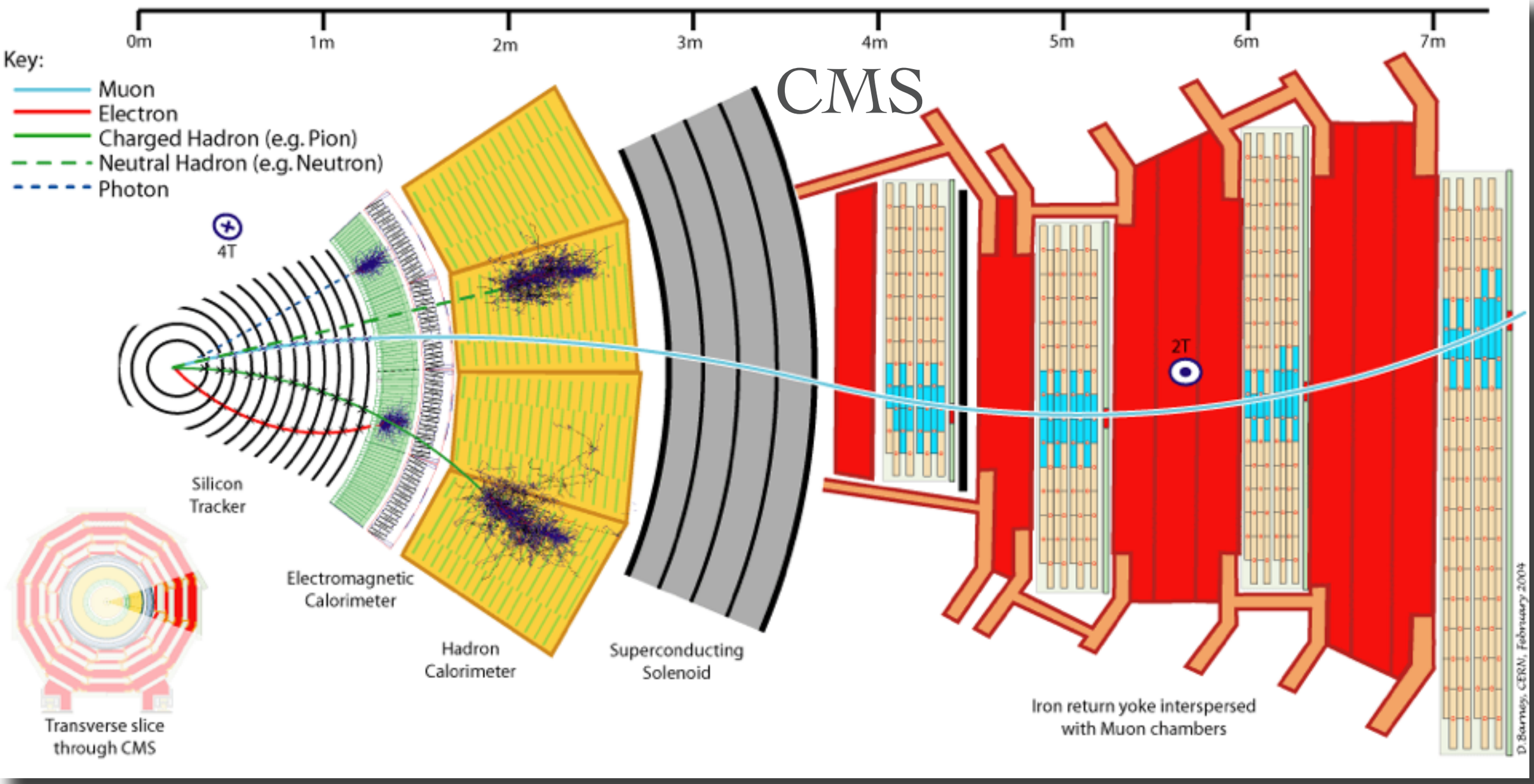
Proton bunches 25 ns apart

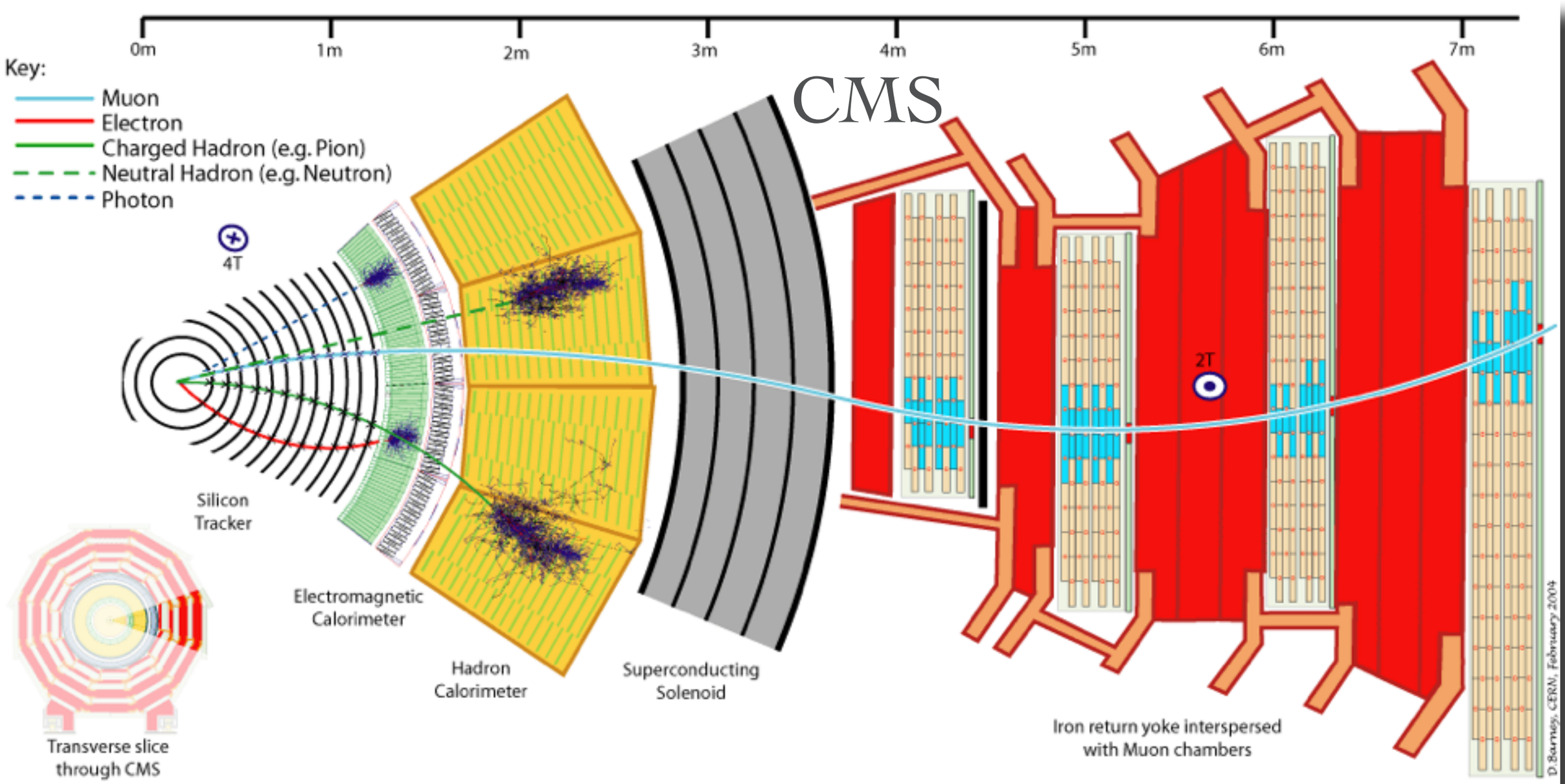
10^{11} protons per bunch

~25 collisions per crossing

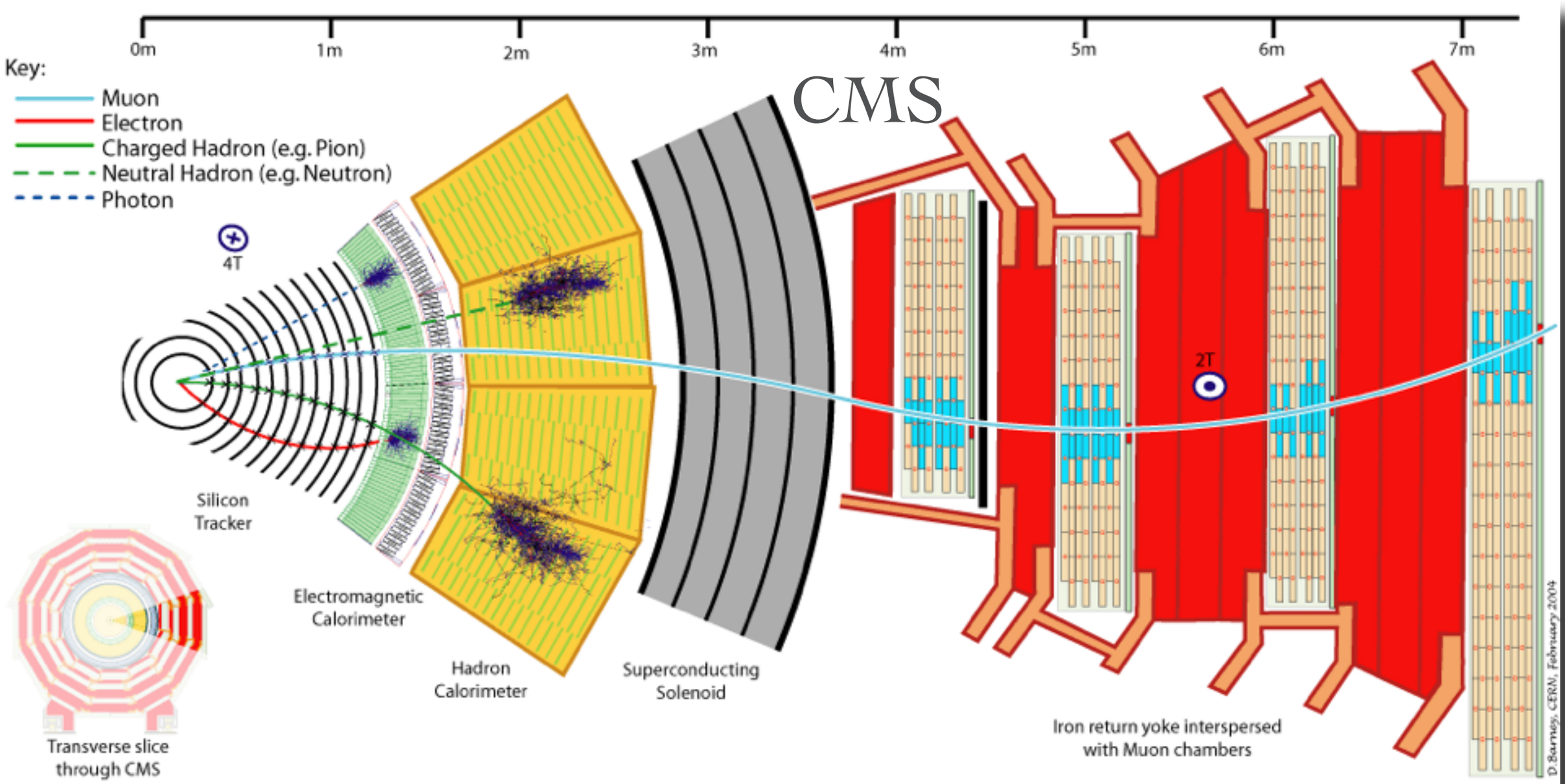
~100 million readout channels, every 25 ns




0m
1m
2m
3m
4m
5m
6m
7m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon
CMS
4T
2T
Silicon
Tracker
Electromagnetic
Calorimeter
Hadron
Calorimeter
Superconducting
Solenoid
Iron return yoke interspersed
with Muon chambers
Transverse slice
through CMS
D.Barney, CERN, February 2004

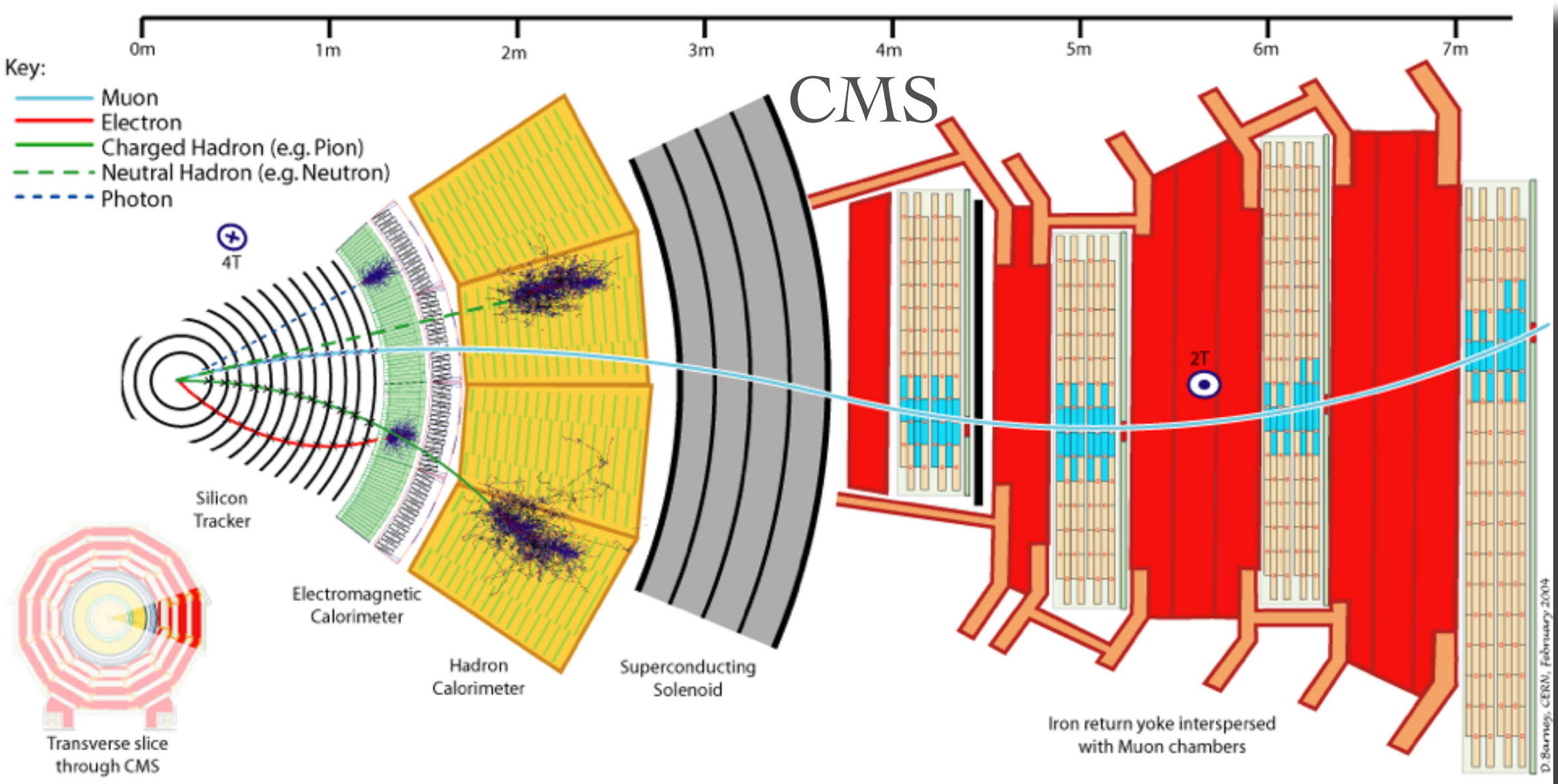


After zeroes removed, 1.6 MB / event



After zeroes removed, 1.6 MB / event

* 40 M events / s = 64 TB / s ?



After zeroes removed, 1.6 MB / event

* 40 M events / s = 64 TB / s ?

Can't save everything

Trigger system to keep only interesting events

	Incoming event rate per second	Outgoing event rate per second	Reduction factor
Level 1	40 000 000	100 000	400
Level 2	100 000	3 000	30
Level 3	3 000	200	15

Trigger system to keep only interesting events

	Incoming event rate per second	Outgoing event rate per second	Reduction factor
Level 1	40 000 000	100 000	400
Level 2	100 000	3 000	30
Level 3	3 000	200	15

200 events / s * 1.6 MB / event = 320 MB / s

Trigger system to keep only interesting events

	Incoming event rate per second	Outgoing event rate per second	Reduction factor
Level 1	40 000 000	100 000	400
Level 2	100 000	3 000	30
Level 3	3 000	200	15

200 events / s * 1.6 MB / event = 320 MB / s

= ~ 3200 TB / year raw data

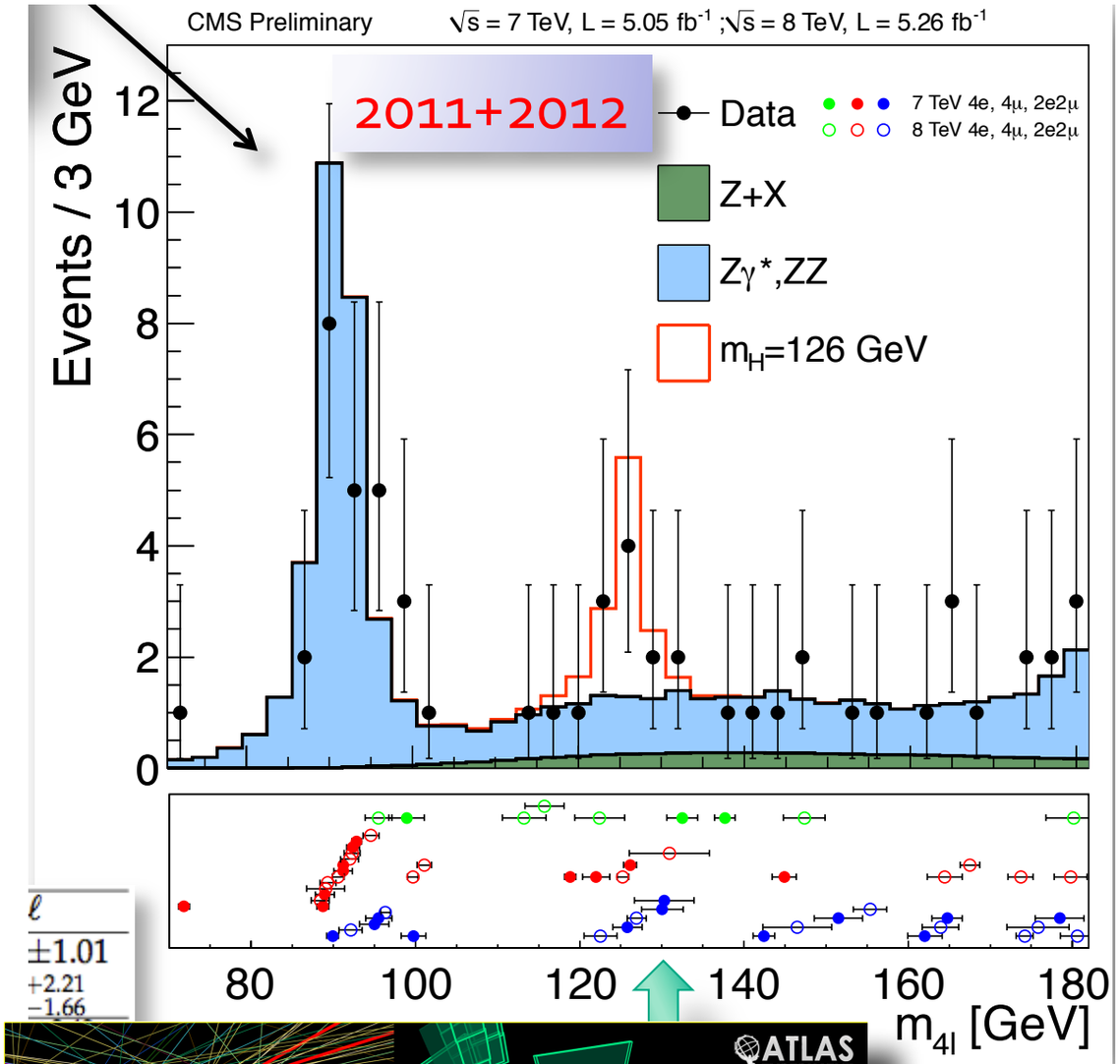
Trigger system to keep only interesting events

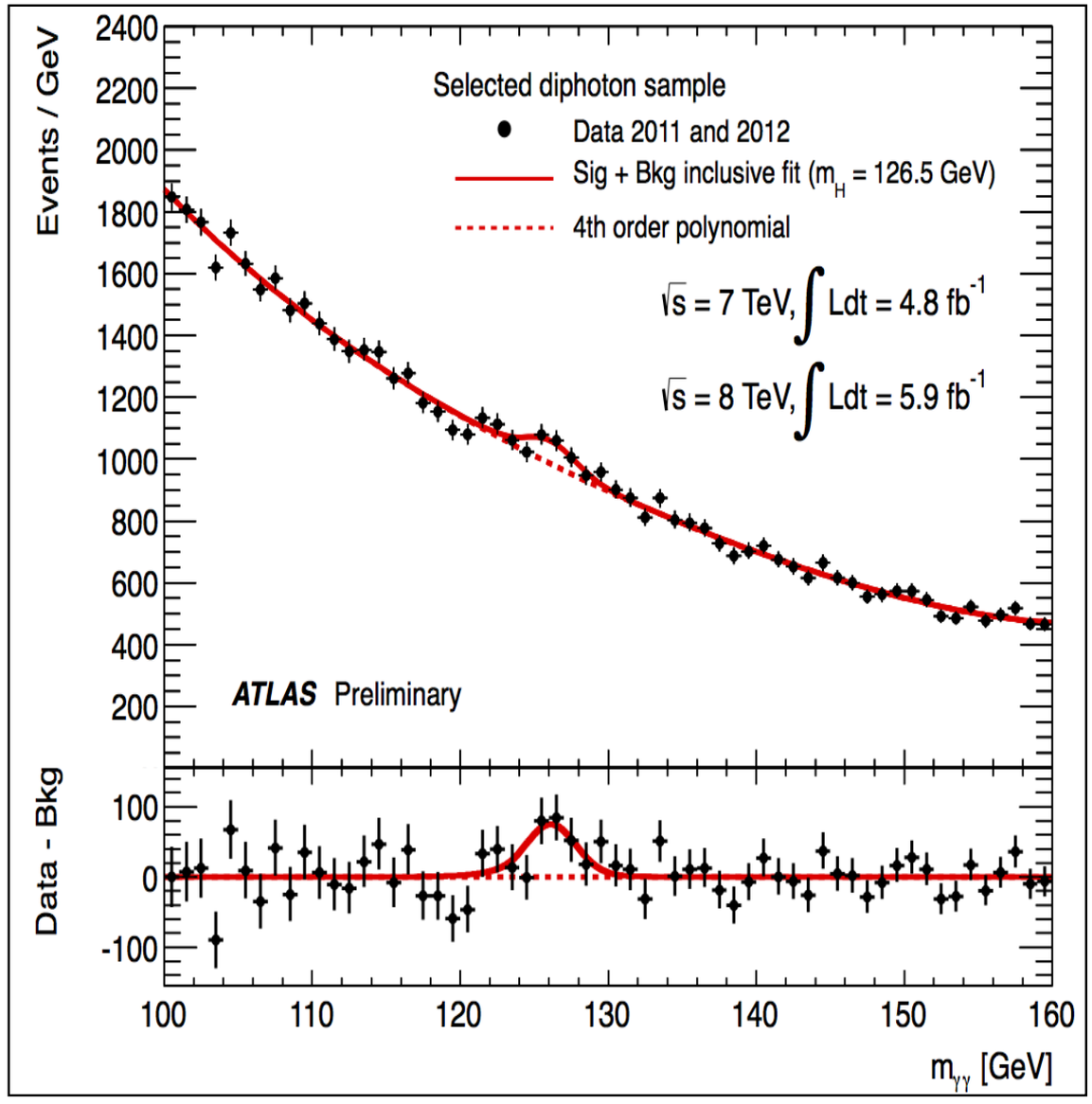
	Incoming event rate per second	Outgoing event rate per second	Reduction factor
Level 1	40 000 000	100 000	400
Level 2	100 000	3 000	30
Level 3	3 000	200	15

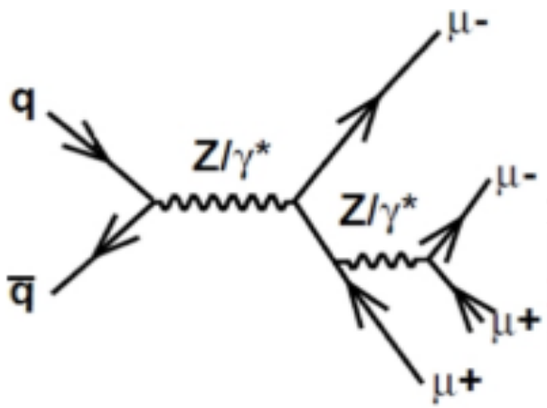
200 events / s * 1.6 MB / event = 320 MB / s

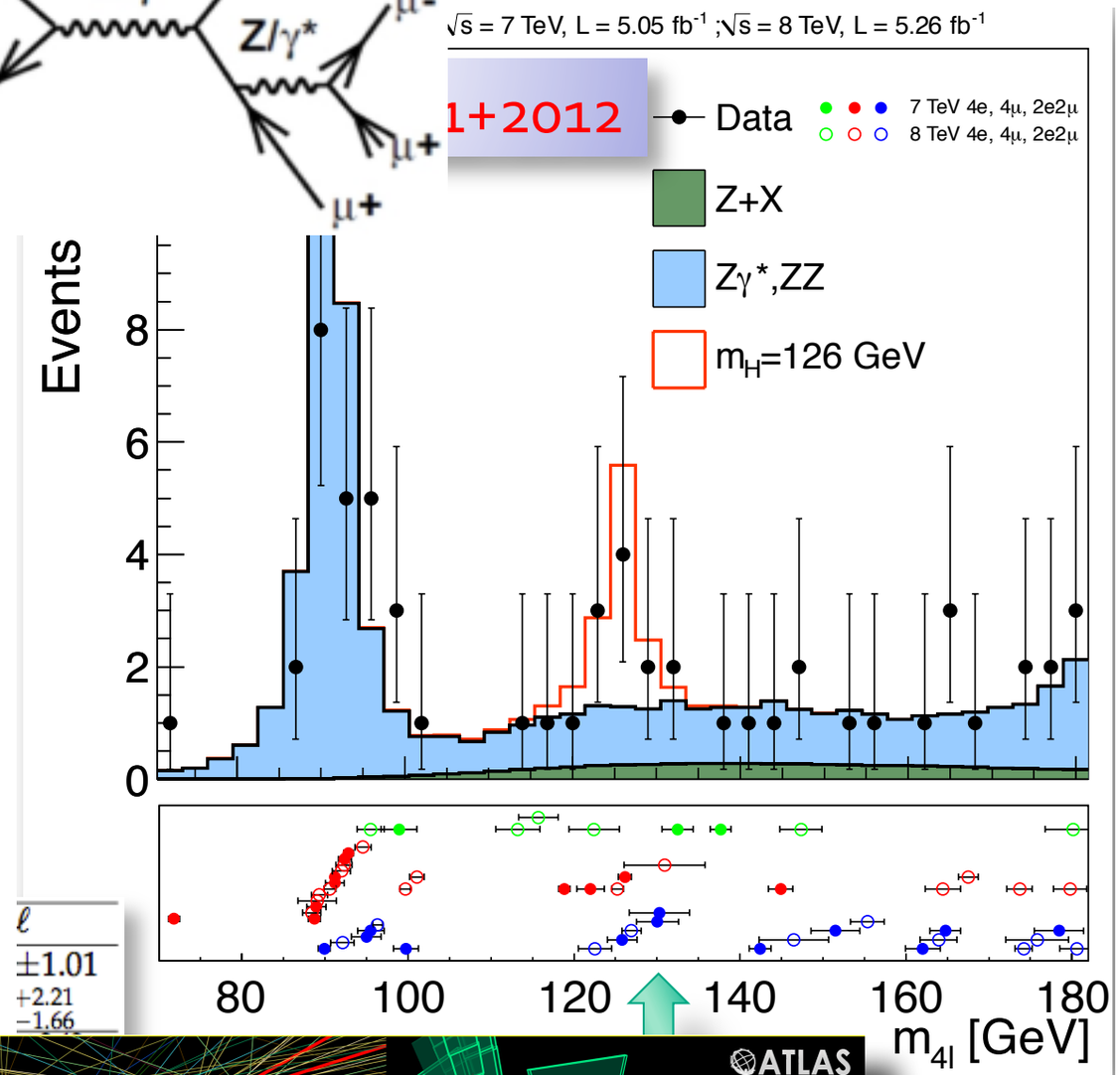
= ~ 3200 TB / year raw data

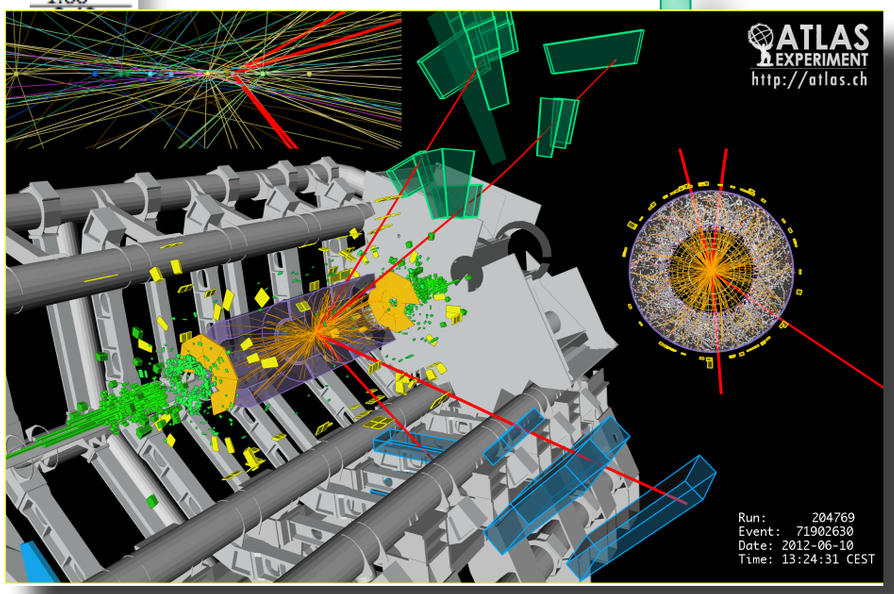
Analysis is done offline,
~3000 collaboration members should have
equal access to data worldwide

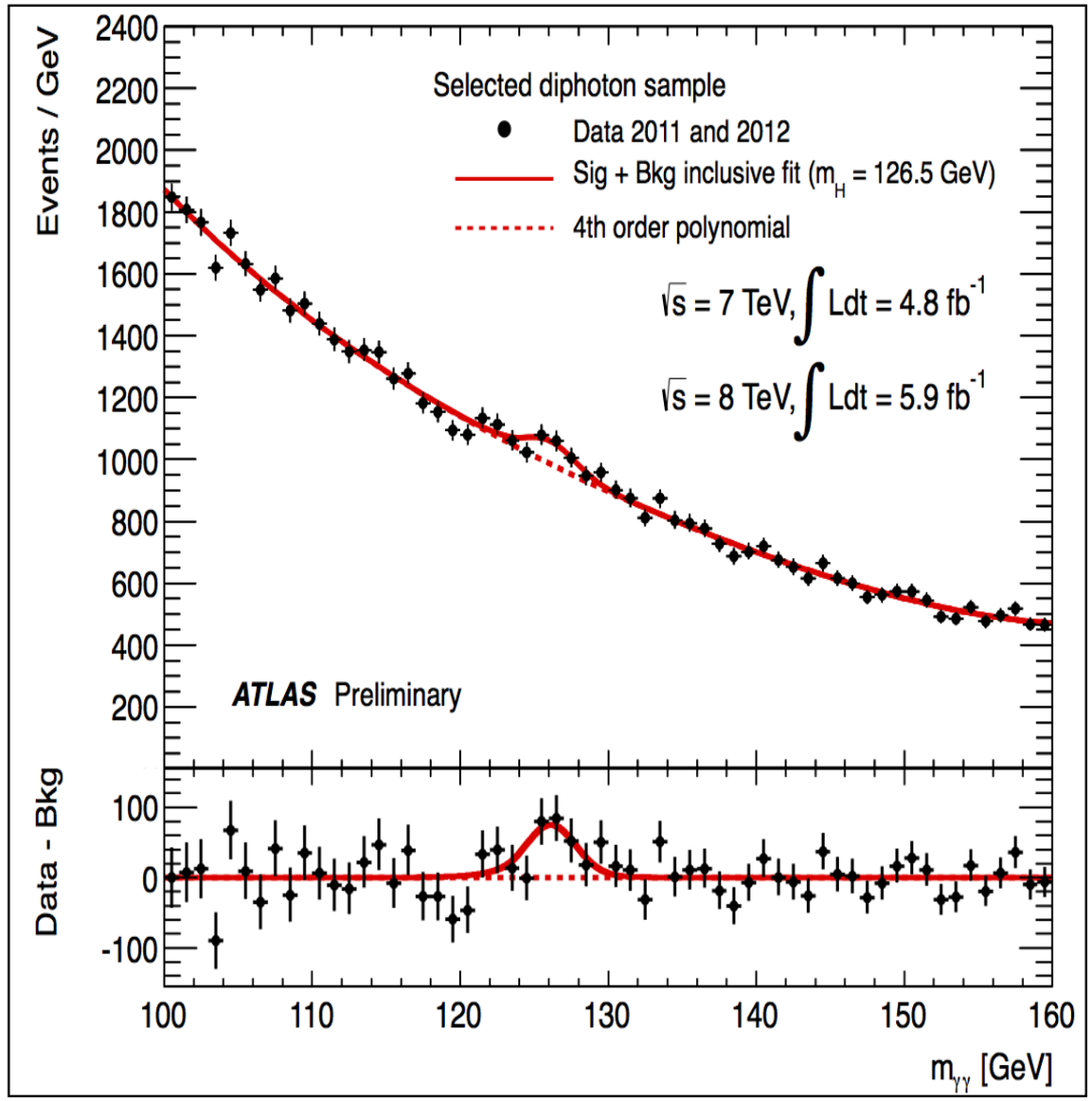

CMS Preliminary
√s = 7 TeV, L = 5.05 fb-1 ;√s = 8 TeV, L = 5.26 fb-1
2011+2012
Data
7 TeV 4e, 4μ, 2e2μ
8 TeV 4e, 4μ, 2e2μ
Z+X
Zγ*,ZZ
mH=126 GeV
Events / 3 GeV
m4l [GeV]
ATLAS EXPERIMENT
http://atlas.ch
Run: 204769
Event: 71902630
Date: 2012-06-10
Time: 13:24:31 CEST

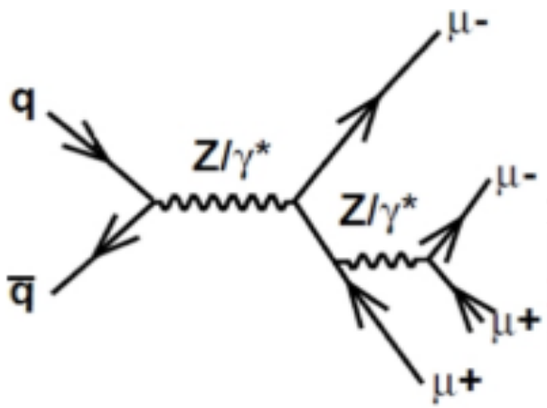

Selected diphoton sample
Data 2011 and 2012
Sig + Bkg inclusive fit (mH = 126.5 GeV)
4th order polynomial
√s = 7 TeV, ∫ Ldt = 4.8 fb-1
√s = 8 TeV, ∫ Ldt = 5.9 fb-1
ATLAS Preliminary
Events / GeV
Data - Bkg
mγγ [GeV]

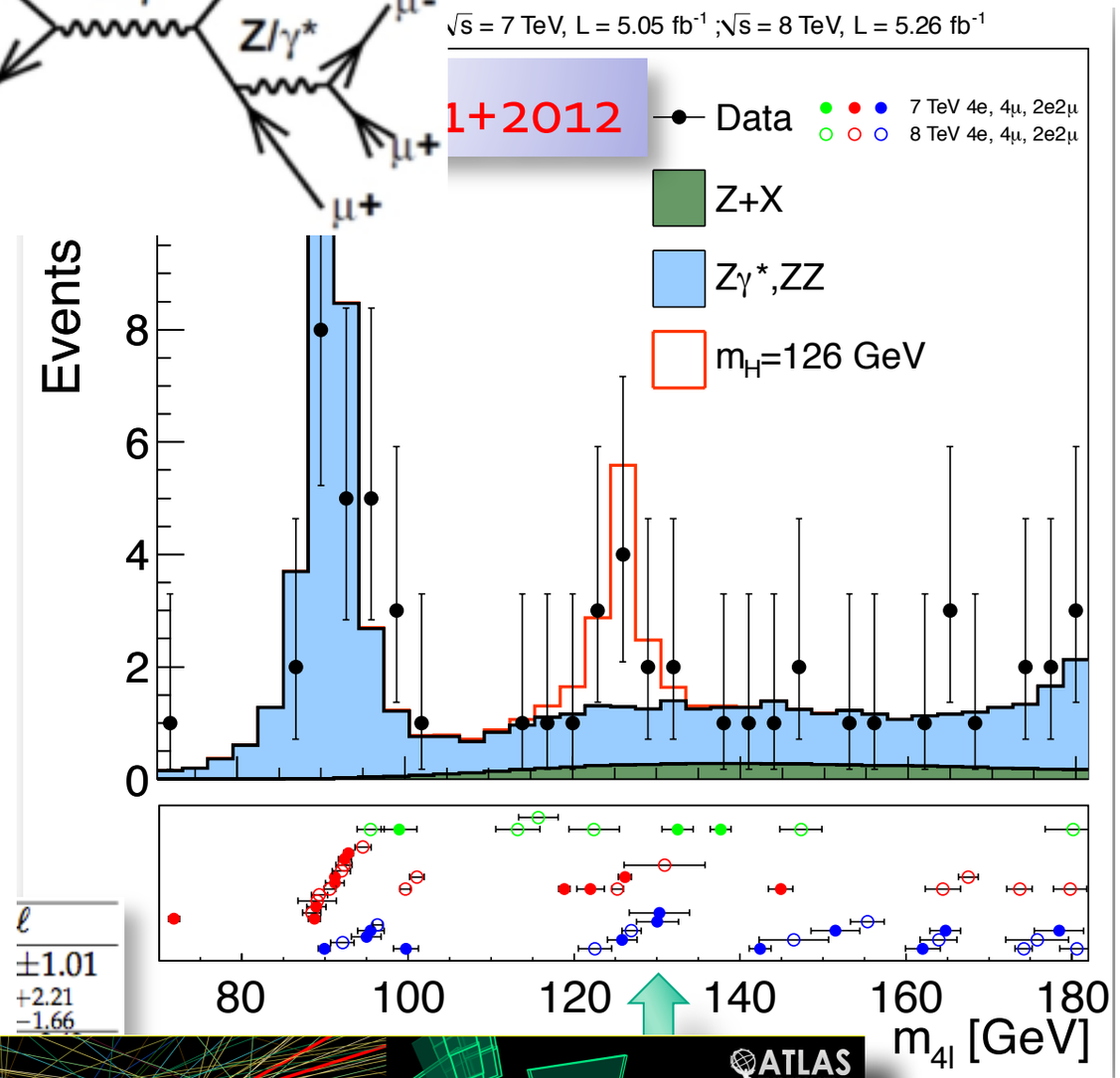

q
q̄
Z/γ*
Z/γ*
μ-
μ-
μ+
μ+

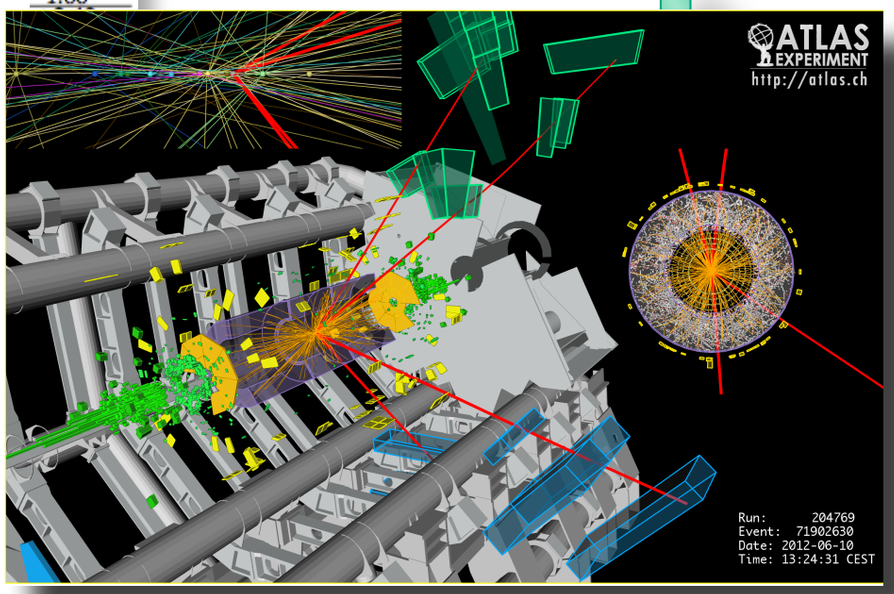

√s = 7 TeV, L = 5.05 fb-1 ;√s = 8 TeV, L = 5.26 fb-1
1+2012
Data
7 TeV 4e, 4μ, 2e2μ
8 TeV 4e, 4μ, 2e2μ
Z+X
Zγ*,ZZ
mH=126 GeV
Events
0
2
4
6
8
80
100
120
140
160
180
m4l [GeV]
ℓ
±1.01
+2.21
−1.66


ATLAS
EXPERIMENT
http://atlas.ch
Run: 204769
Event: 71902630
Date: 2012-06-10
Time: 13:24:31 CEST

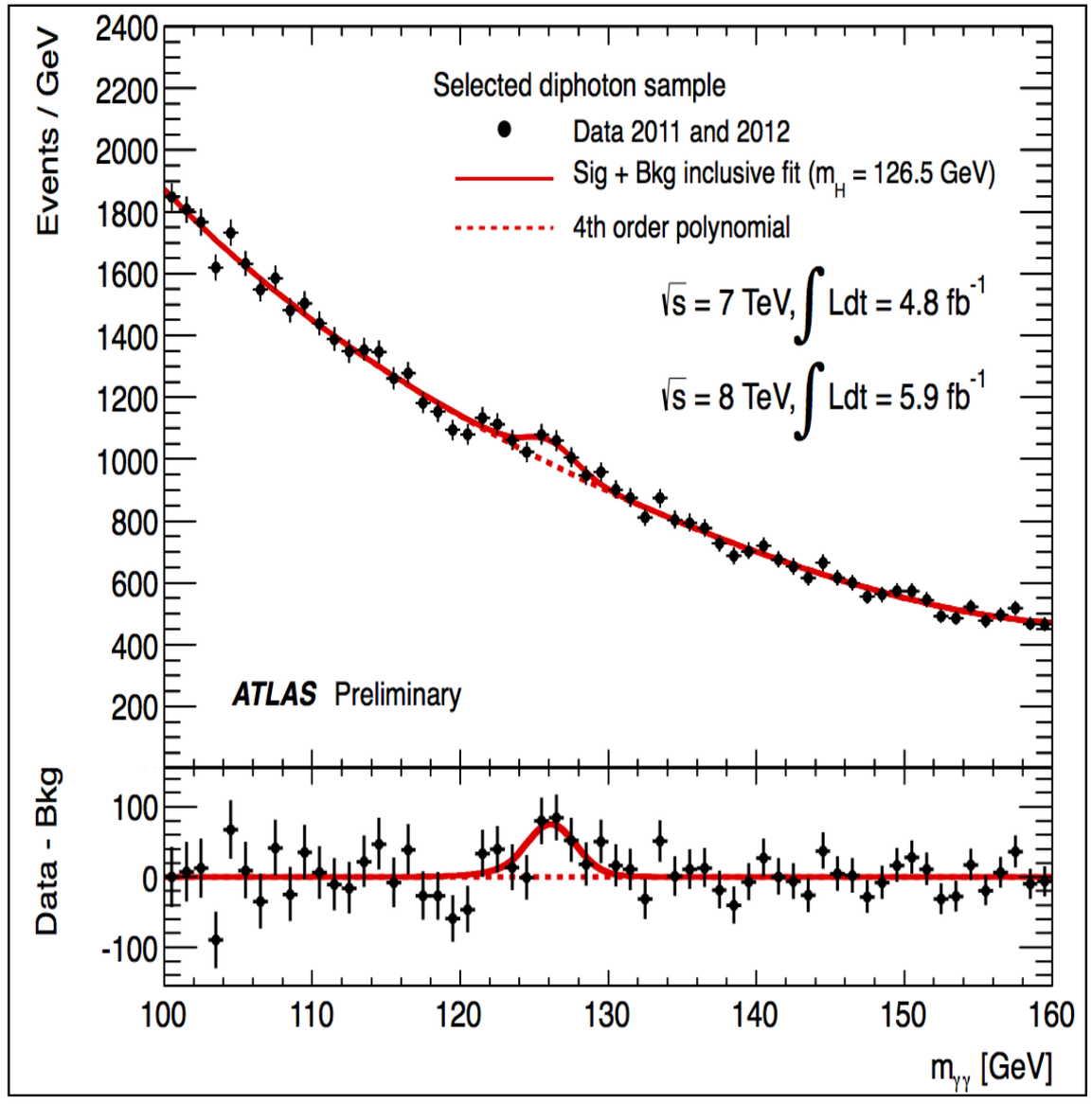

Selected diphoton sample
Data 2011 and 2012
Sig + Bkg inclusive fit (mH = 126.5 GeV)
4th order polynomial
√s = 7 TeV, ∫ Ldt = 4.8 fb-1
√s = 8 TeV, ∫ Ldt = 5.9 fb-1
ATLAS Preliminary
Events / GeV
Data - Bkg
mγγ [GeV]

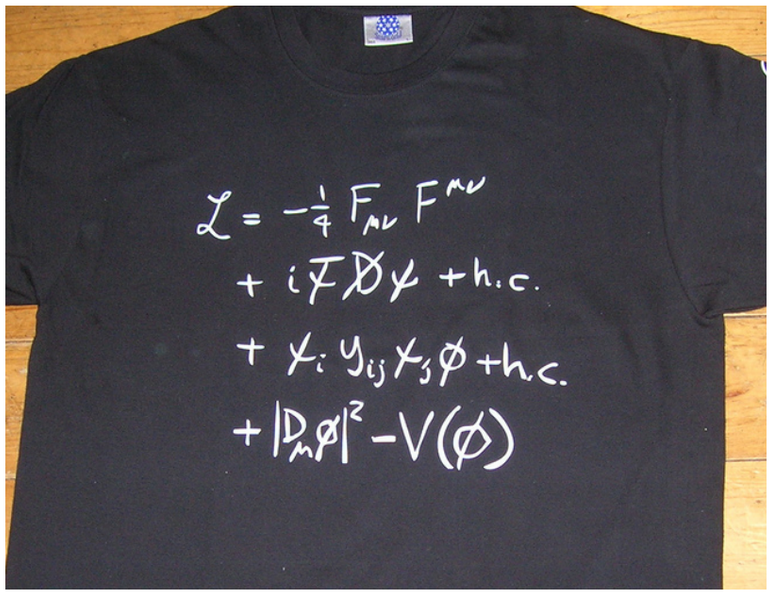


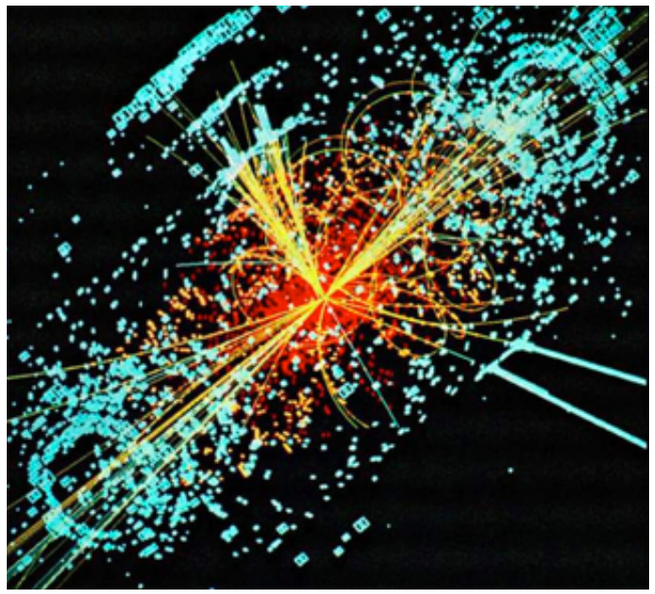


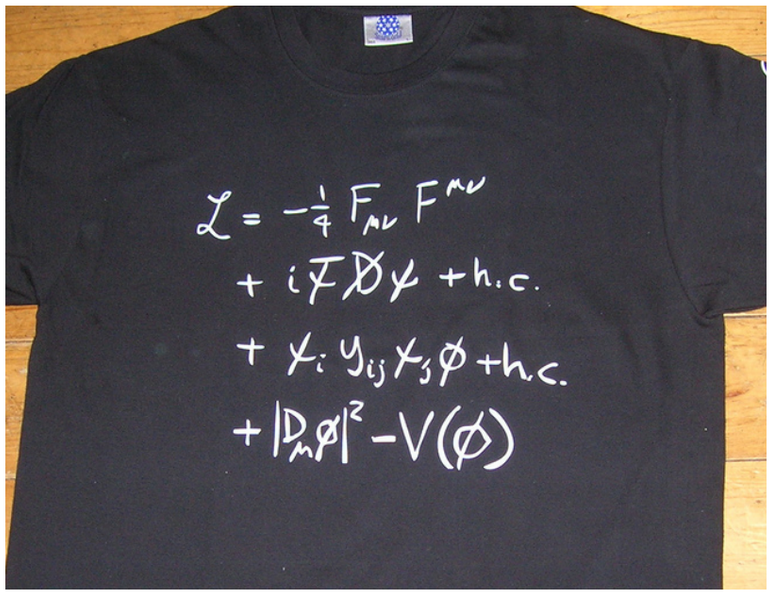


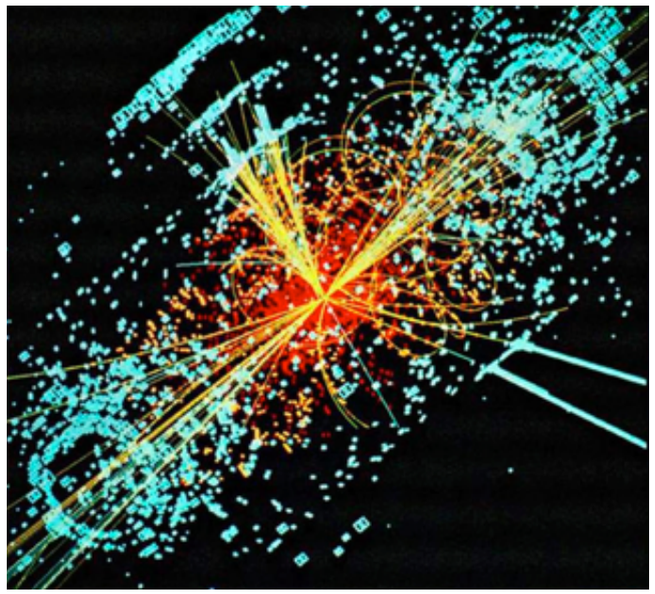
Need to get theory predictions.

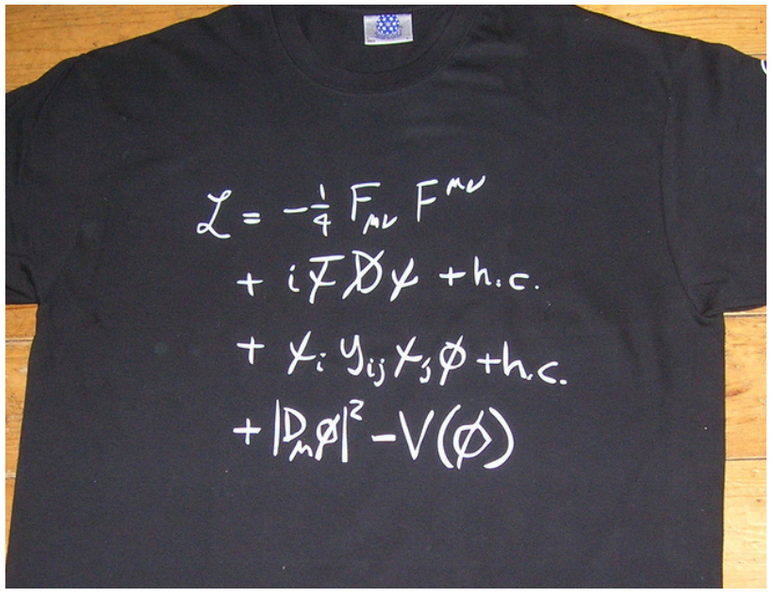


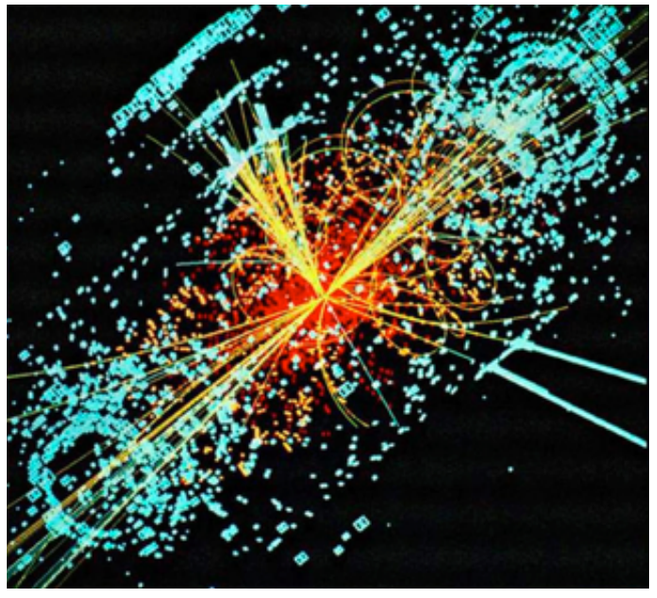

$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$
$+ i\bar{\psi} \not{D} \psi + h.c.$
$+ \psi_i y_{ij} \psi_j \phi + h.c.$
$+ |D_\mu \phi|^2 - V(\phi)$

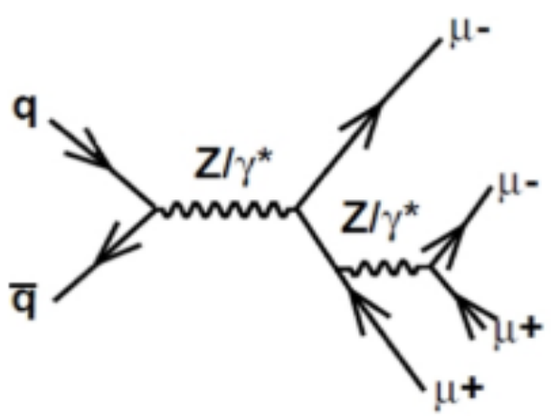



$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$
$+ i\bar{\mathcal{F}} \not{D} \mathcal{F} + h.c.$
$+ \mathcal{F}_i y_{ij} \mathcal{F}_j \phi + h.c.$
$+ |D_\mu \phi|^2 - V(\phi)$









Monte Carlo event generators

Nature

Theory model

Event generator

Detector

Trigger

Simulated events

Reconstructed events

Analysis

Event generator

Matrix element

Parton shower

Hadronization

Decays

Event generator

Matrix element

Monte-Carlo integration

Parton shower

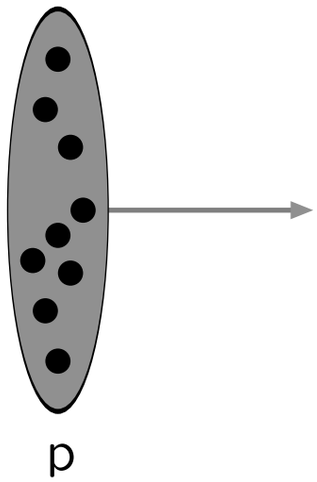
Markov chain

Hadronization

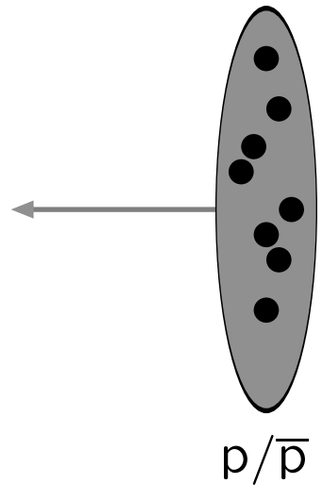
book-keeping

Decays

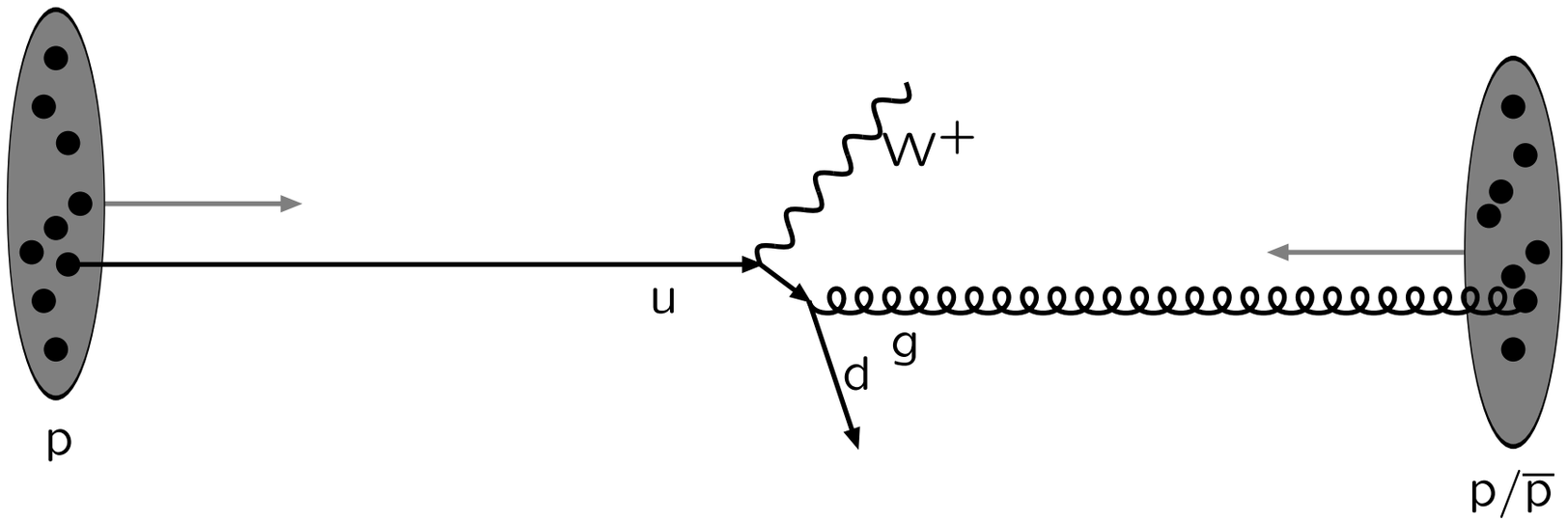
Monte-Carlo integration

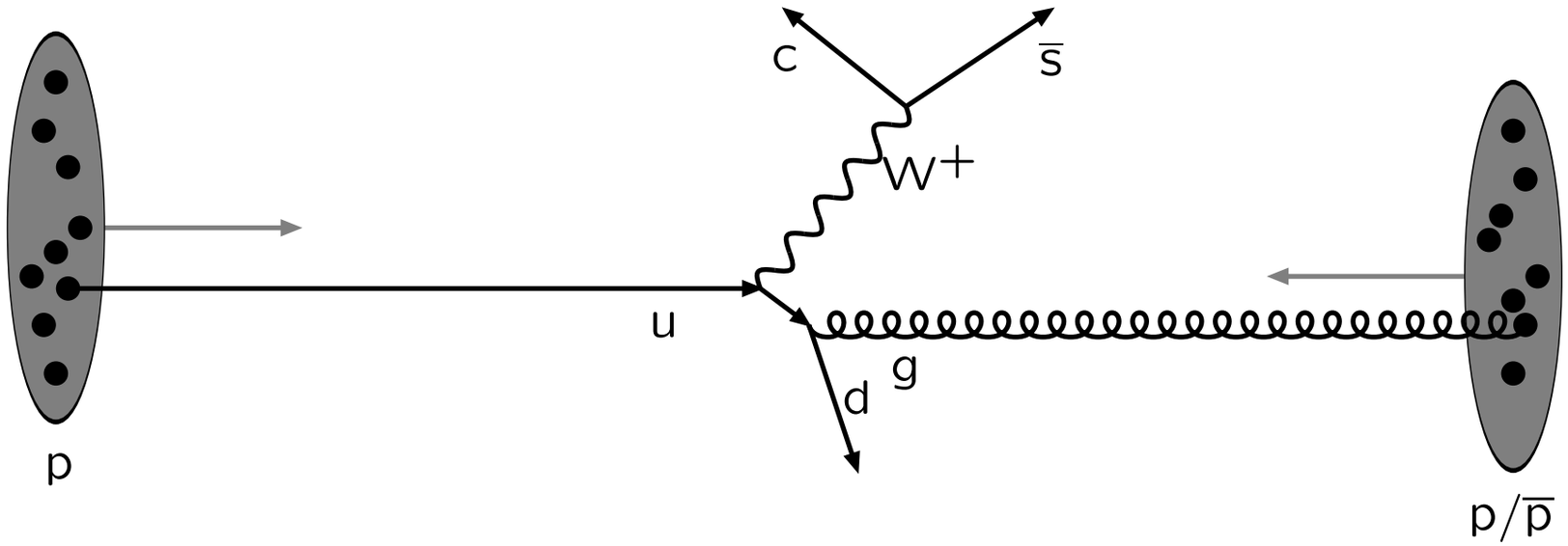


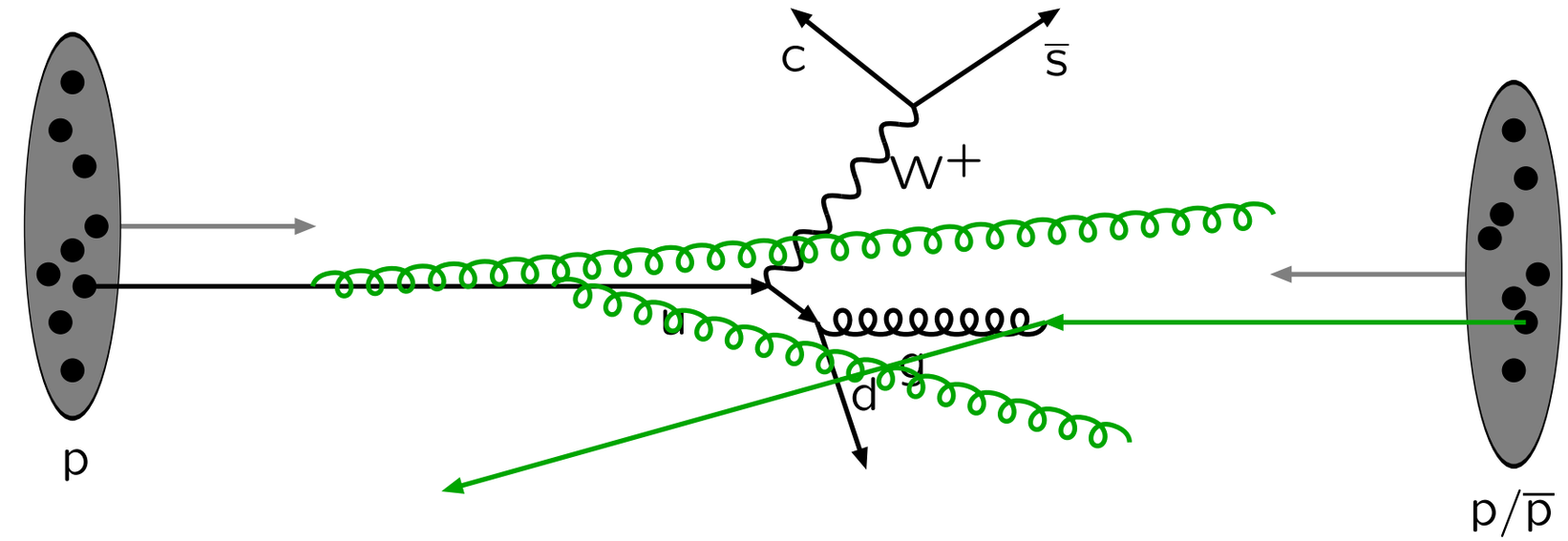
p

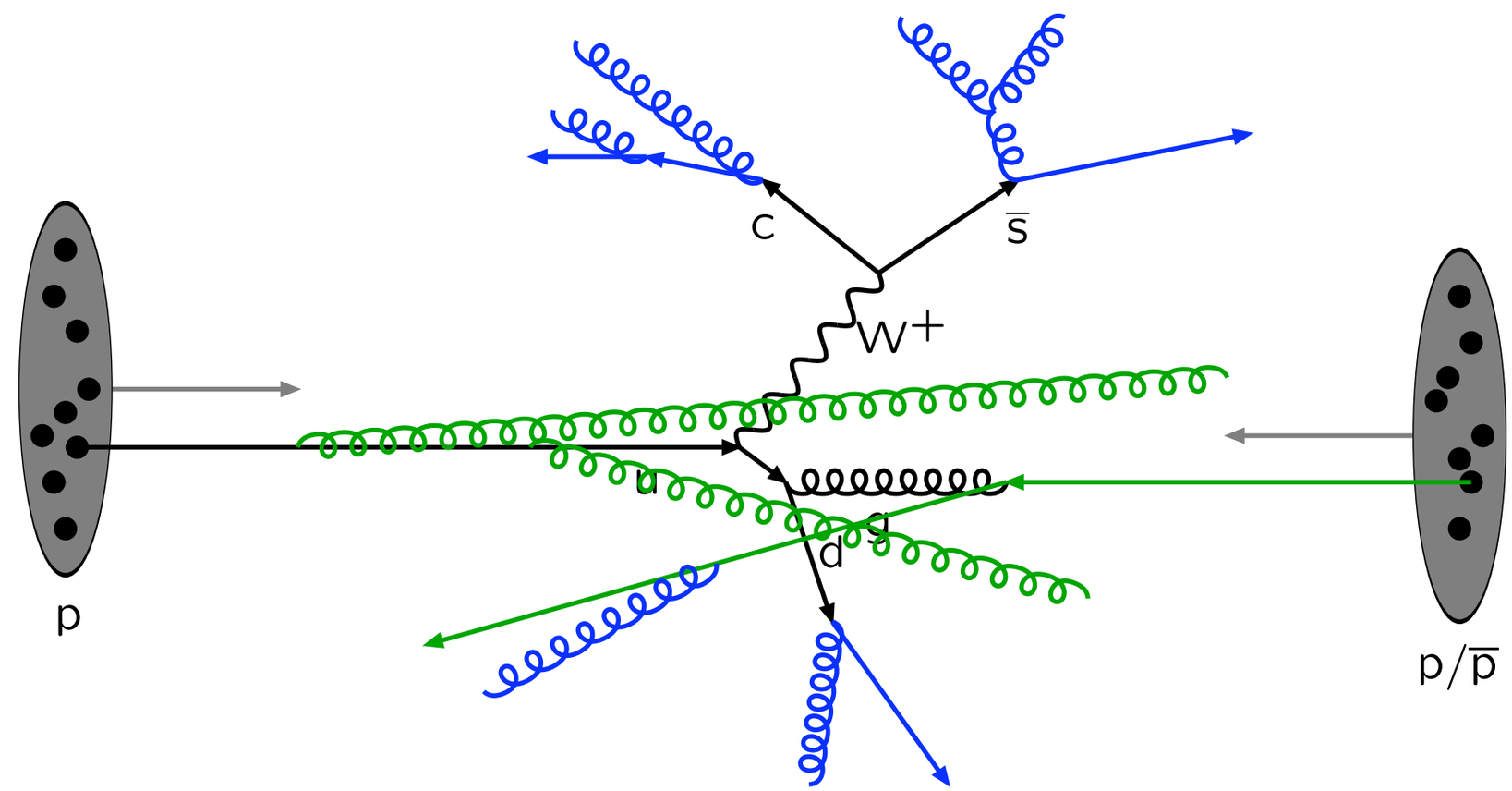


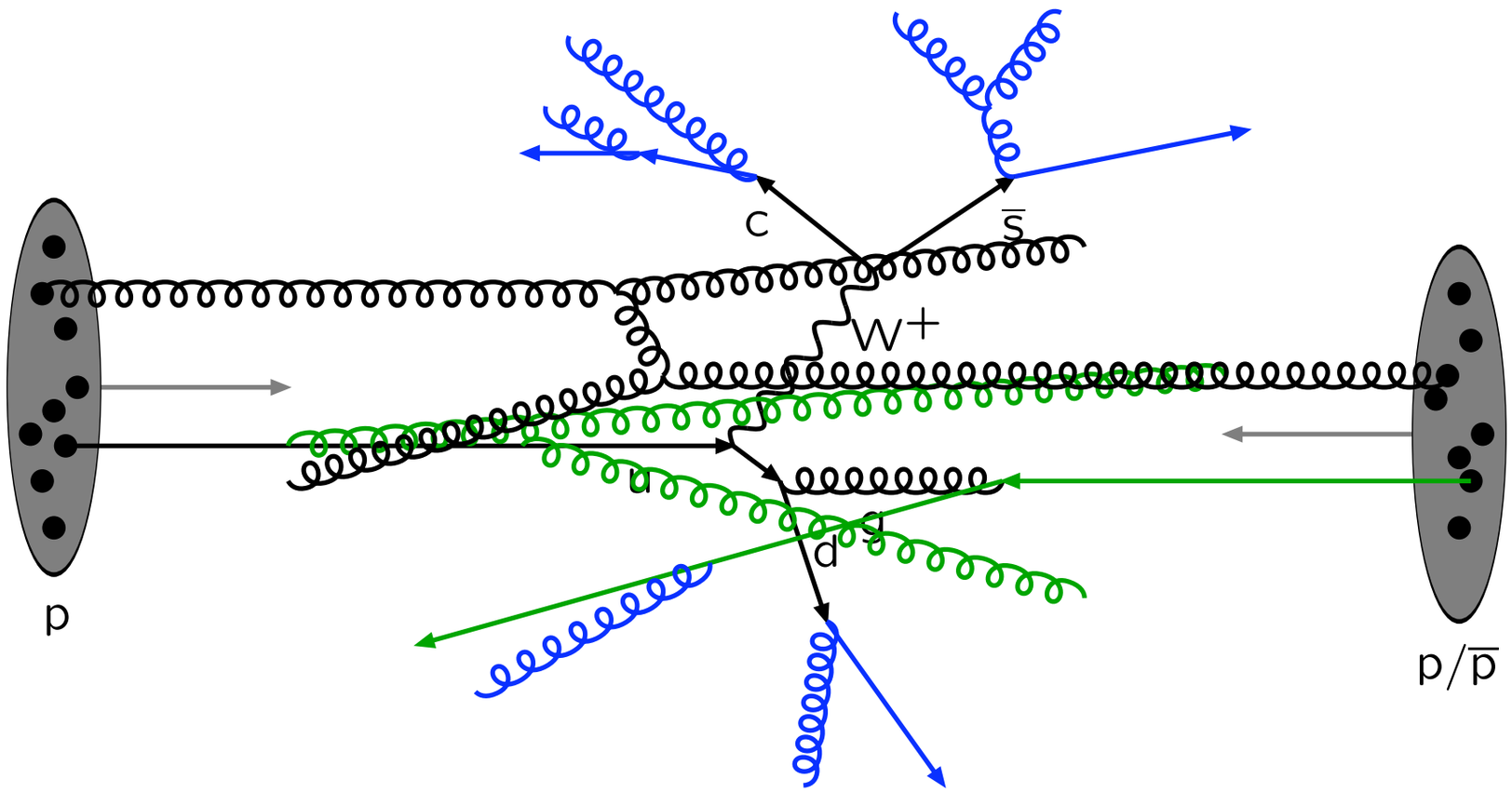
$p/\overline{p}$

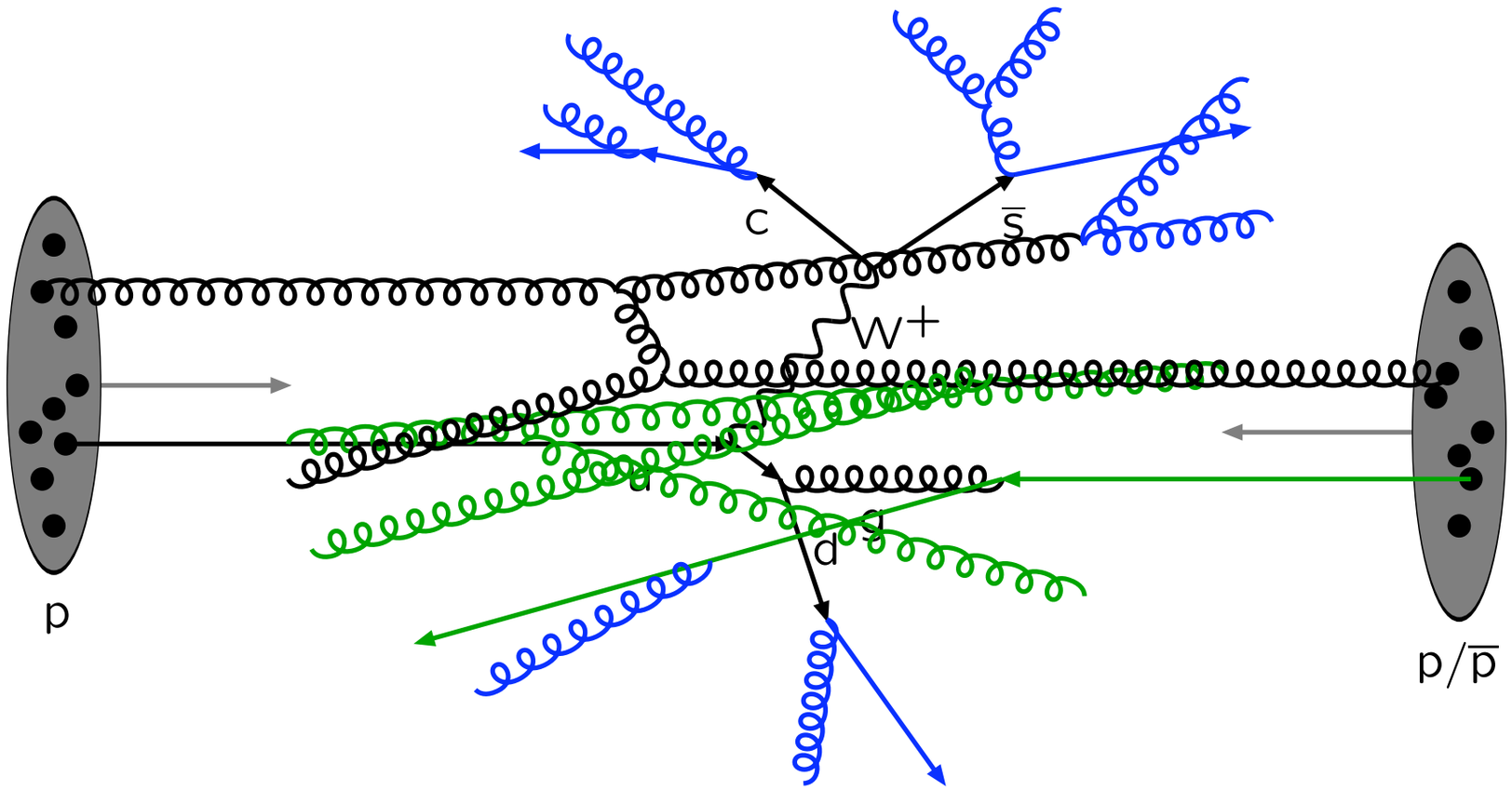

W+
u
d
g
p
p/p̄

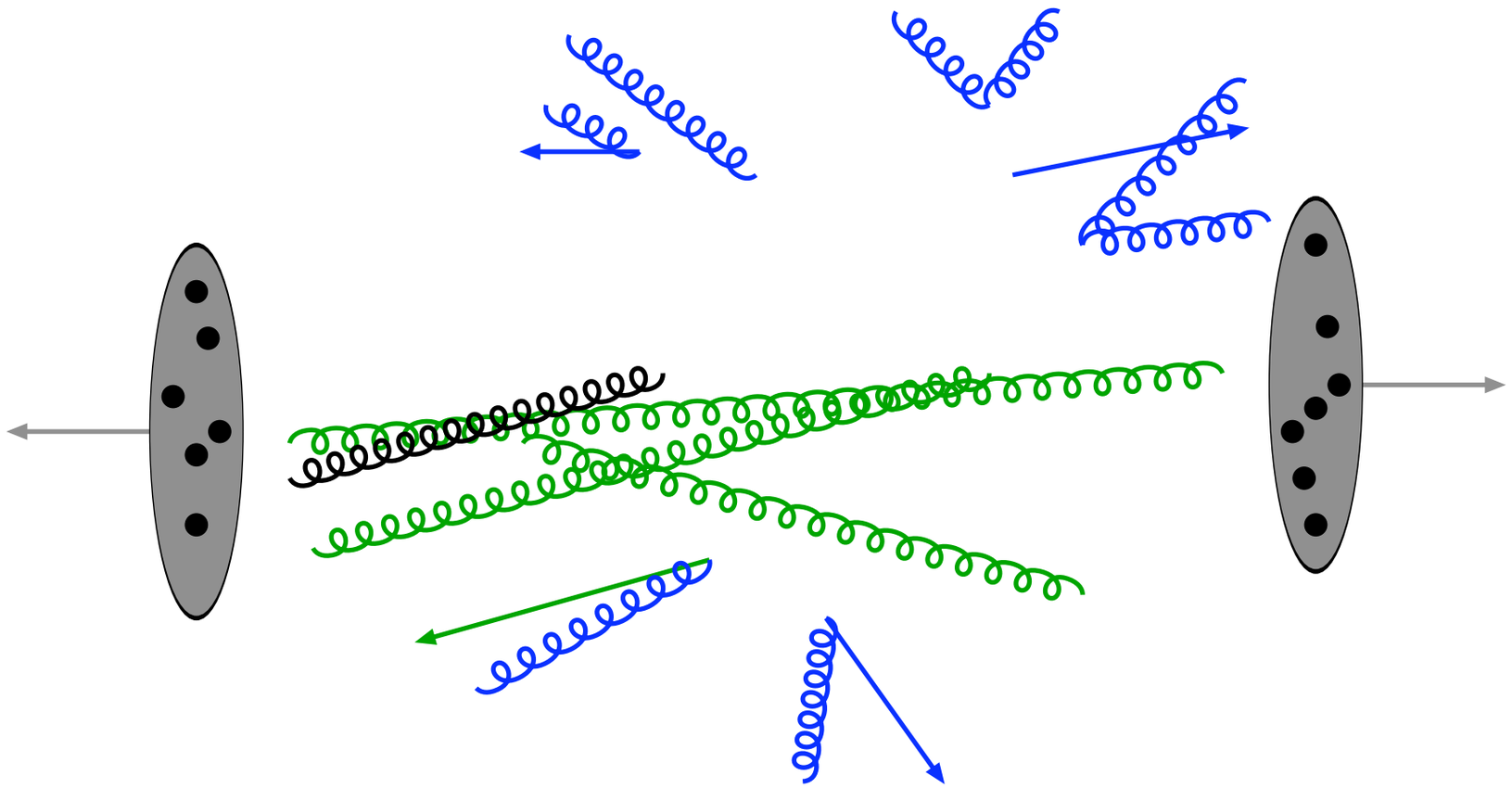

c
$\bar{s}$
W+
u
g
d
p
p/$\bar{p}$

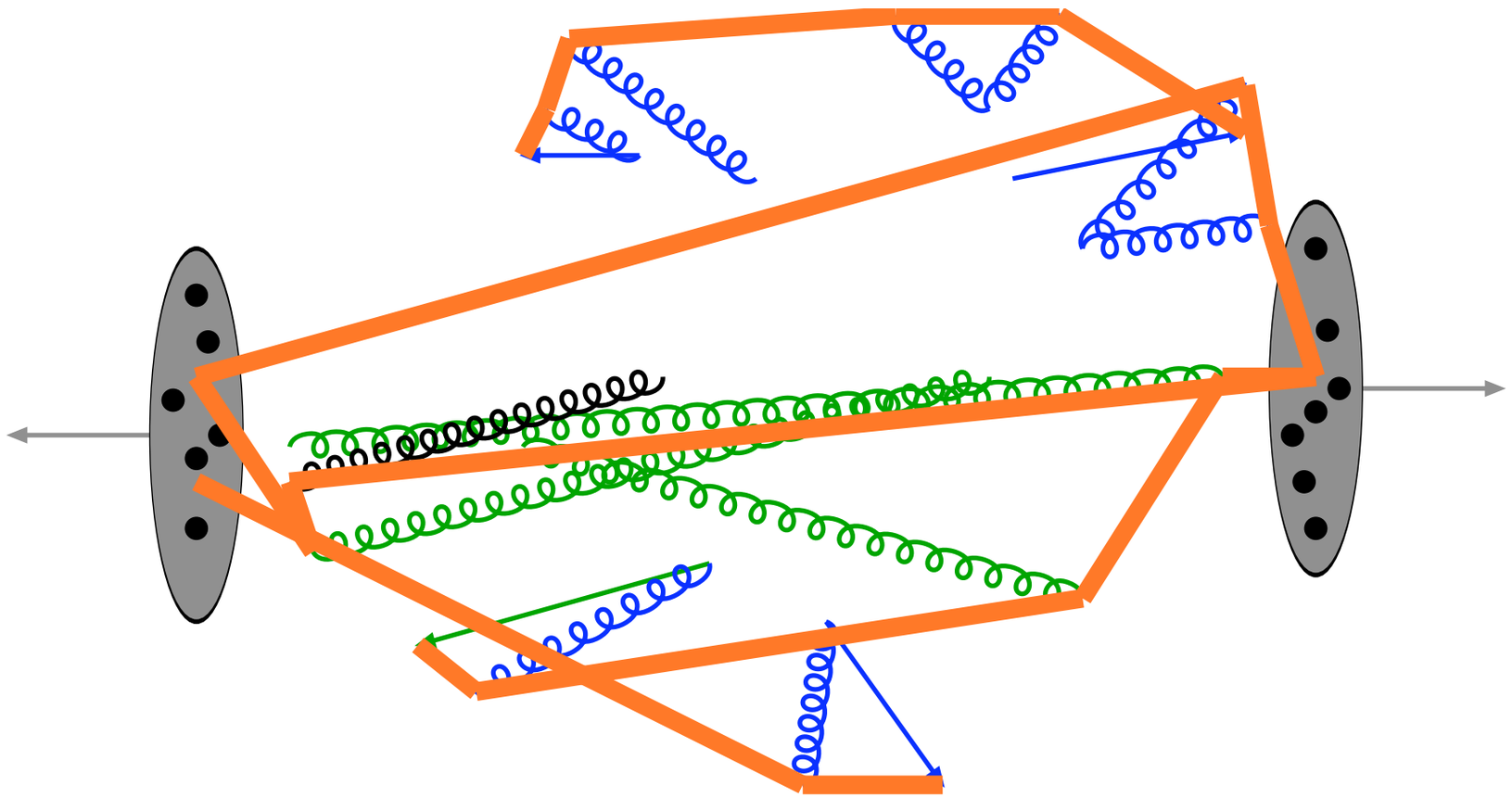

c
$\bar{s}$
W+
u
d
$\bar{d}$
p
$p/\bar{p}$

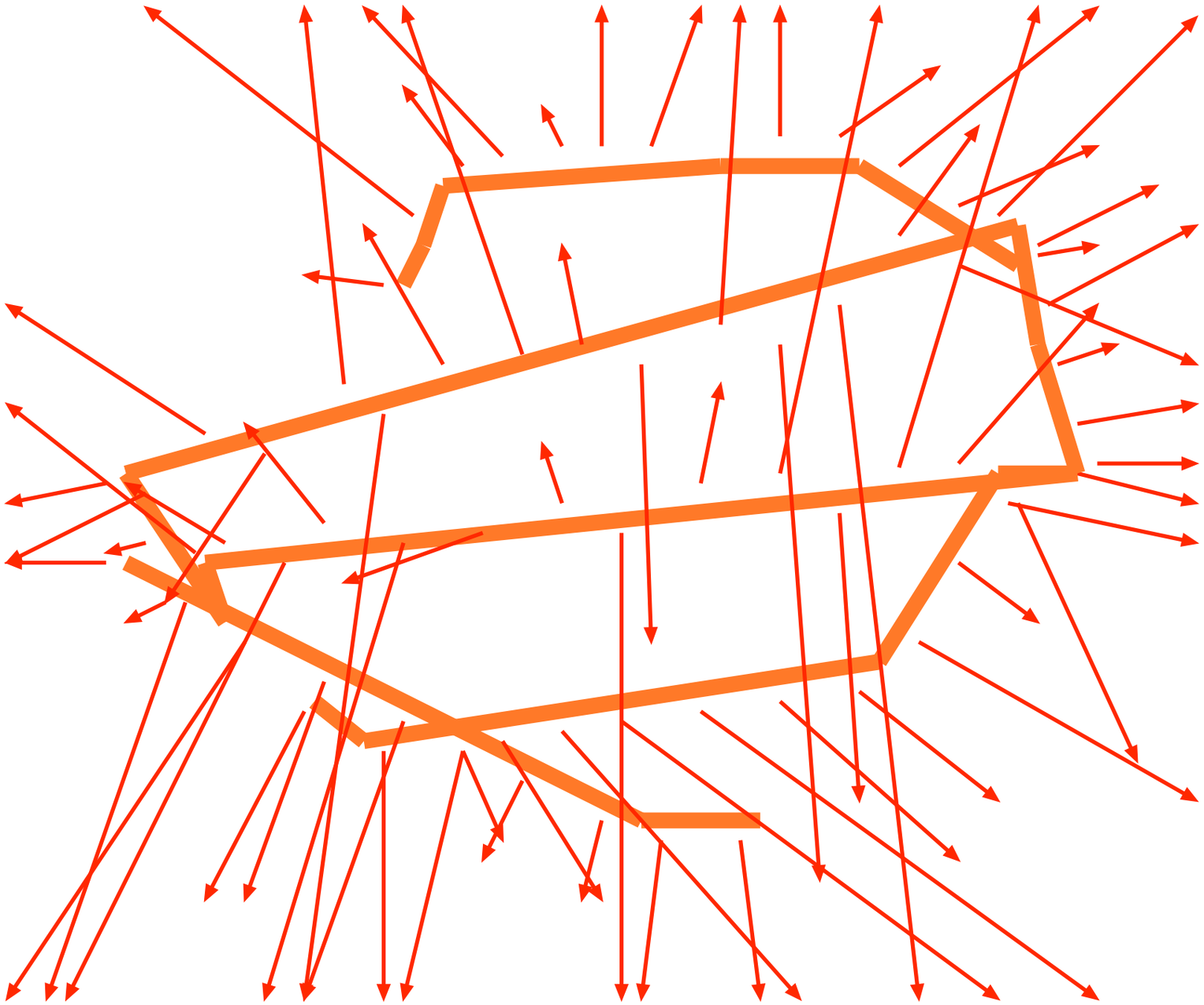

c
s̄
W+
u
d̄
d
p
p/p̄

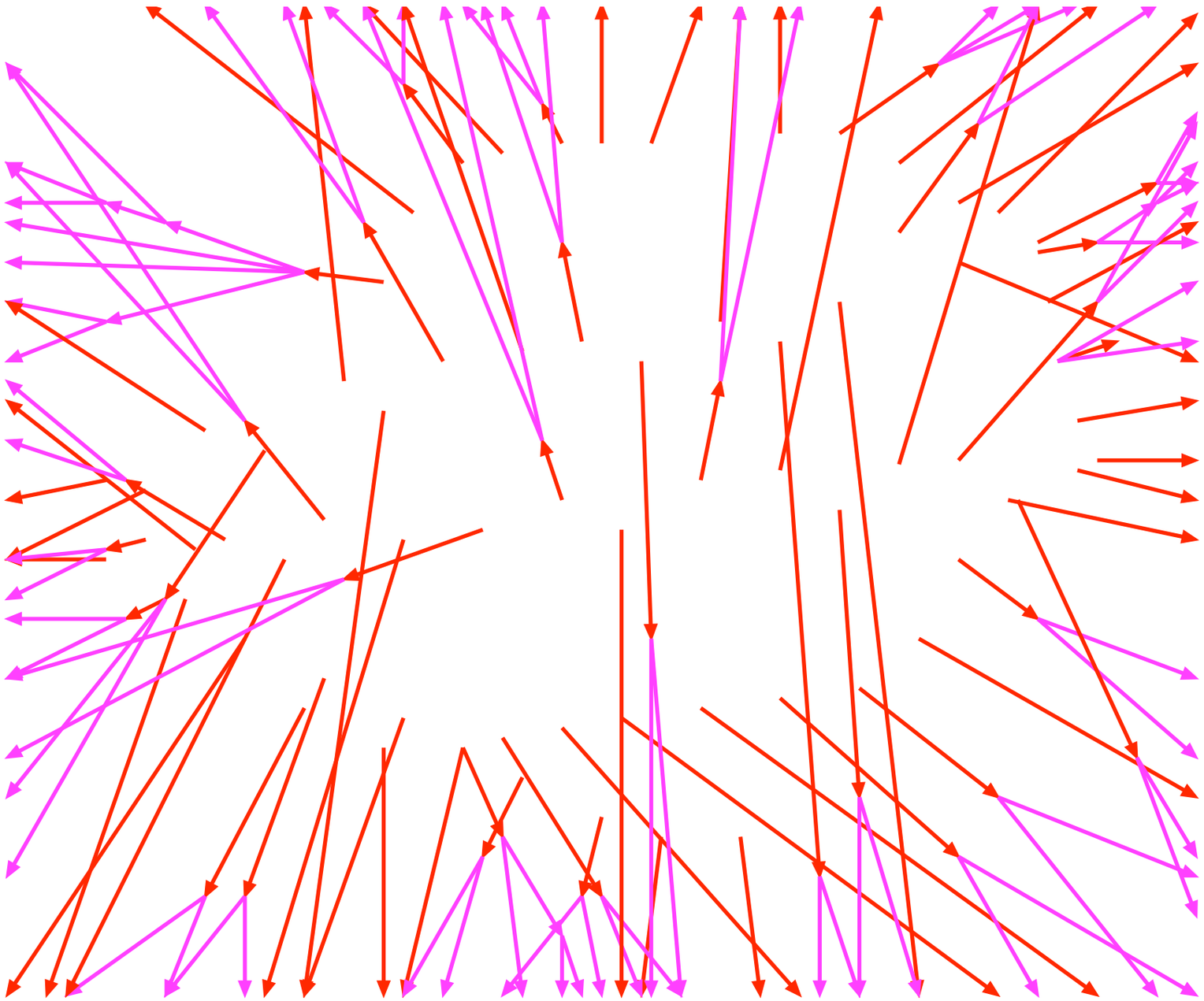

c
s̄
W+
u
d
s
p
p/p̄

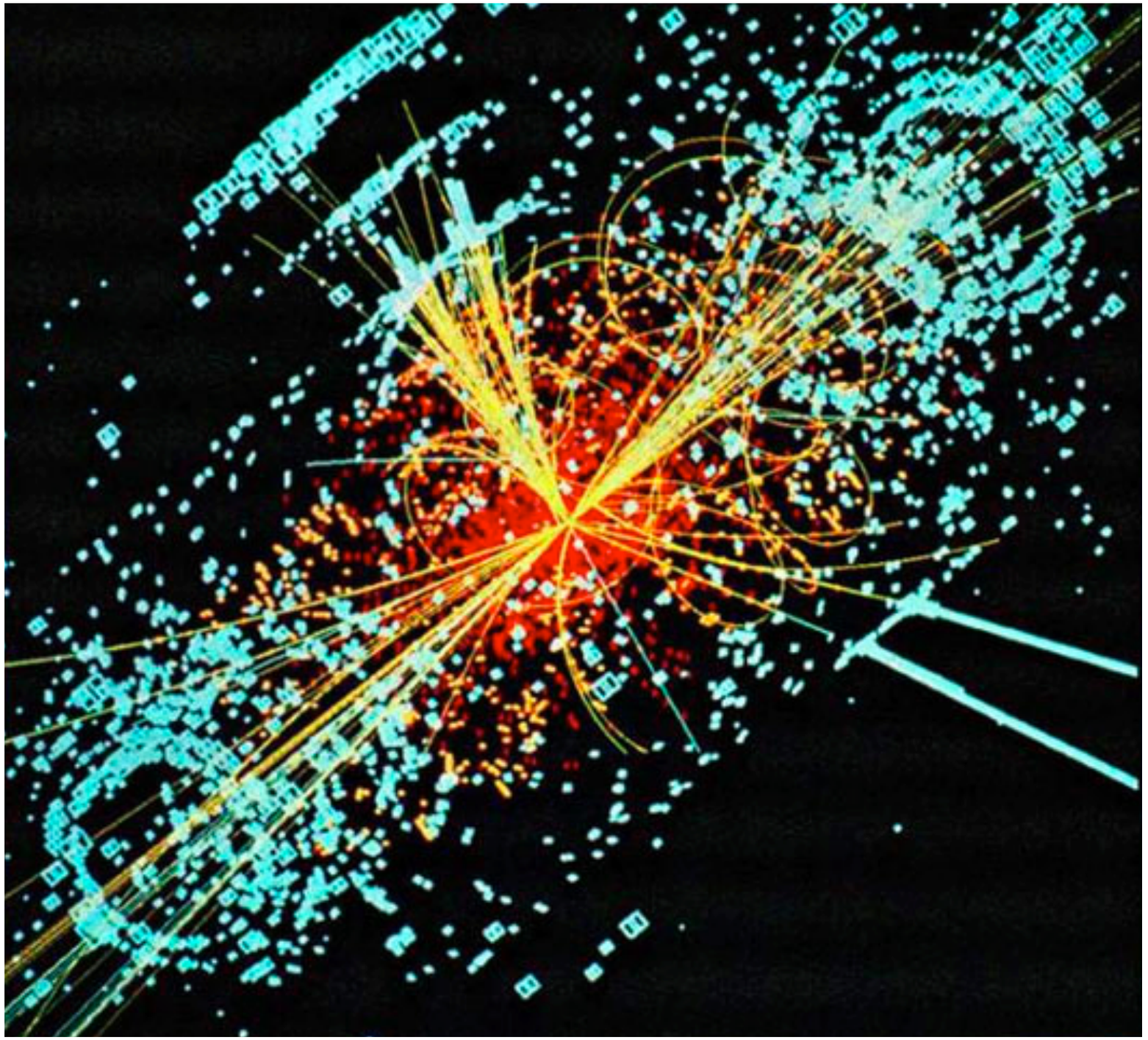

c
s̄
W+
d
d̄
p
p/p̄

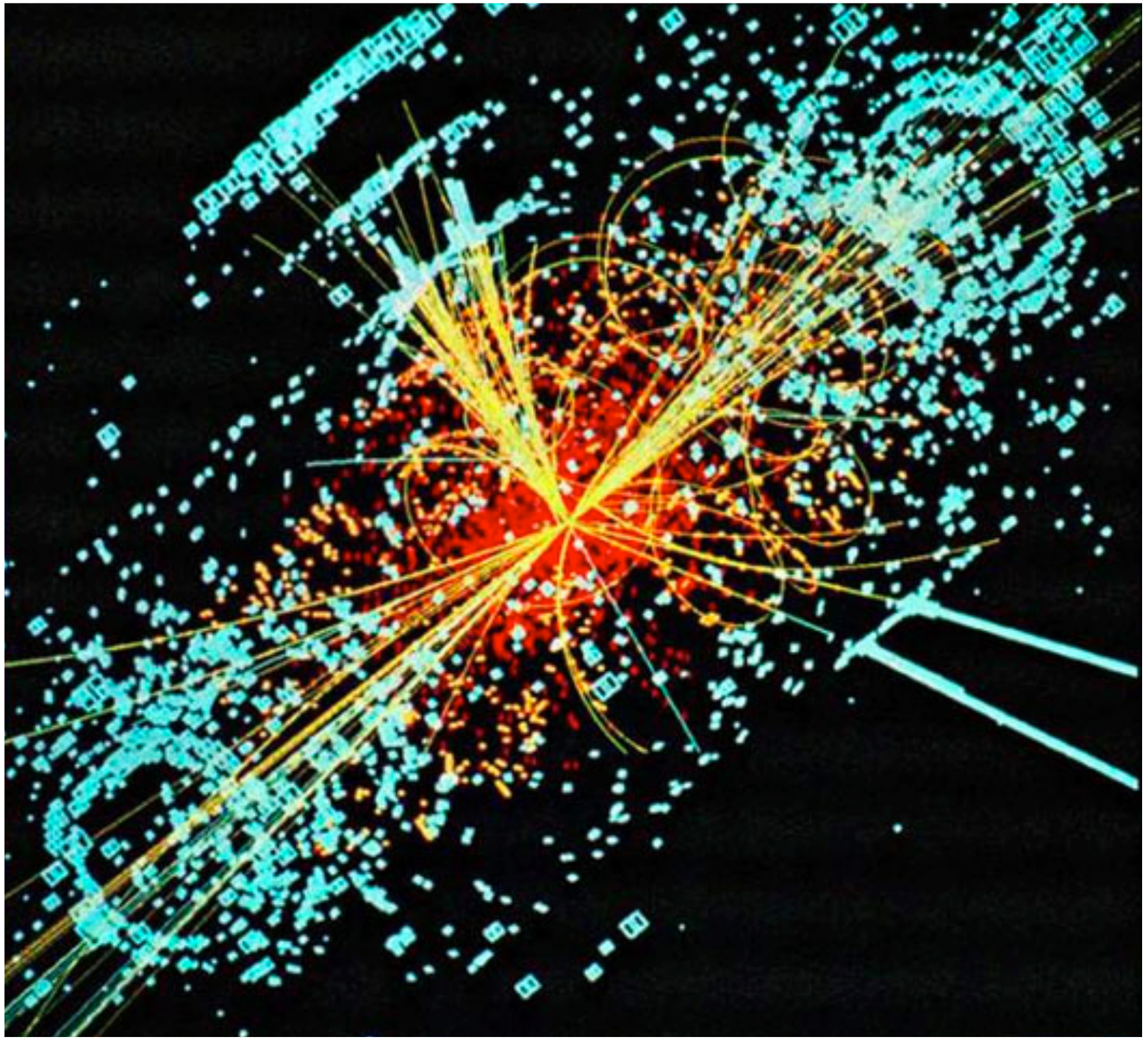












Simulated data sets of millions of events

Nature

Detector

Trigger

Reconstructed events

Theory model

Event generator

Simulated events

Analysis

Nature

Detector

Trigger

Reconstructed events

Theory model

Event generator

Simulated events

need millions!

~15 s per event

Analysis

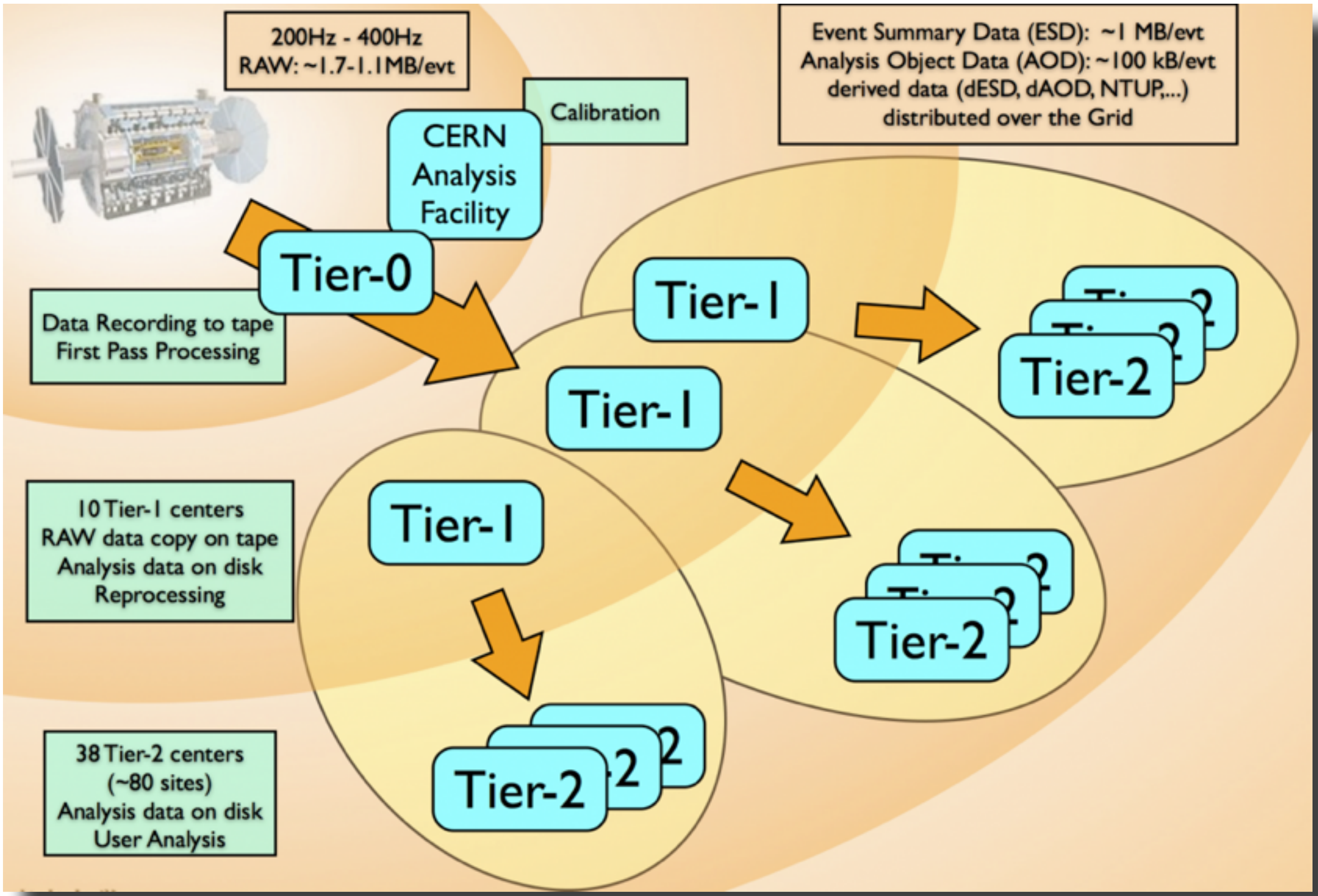
Each event independent

Batch farms are OK, but typical university clusters not large enough

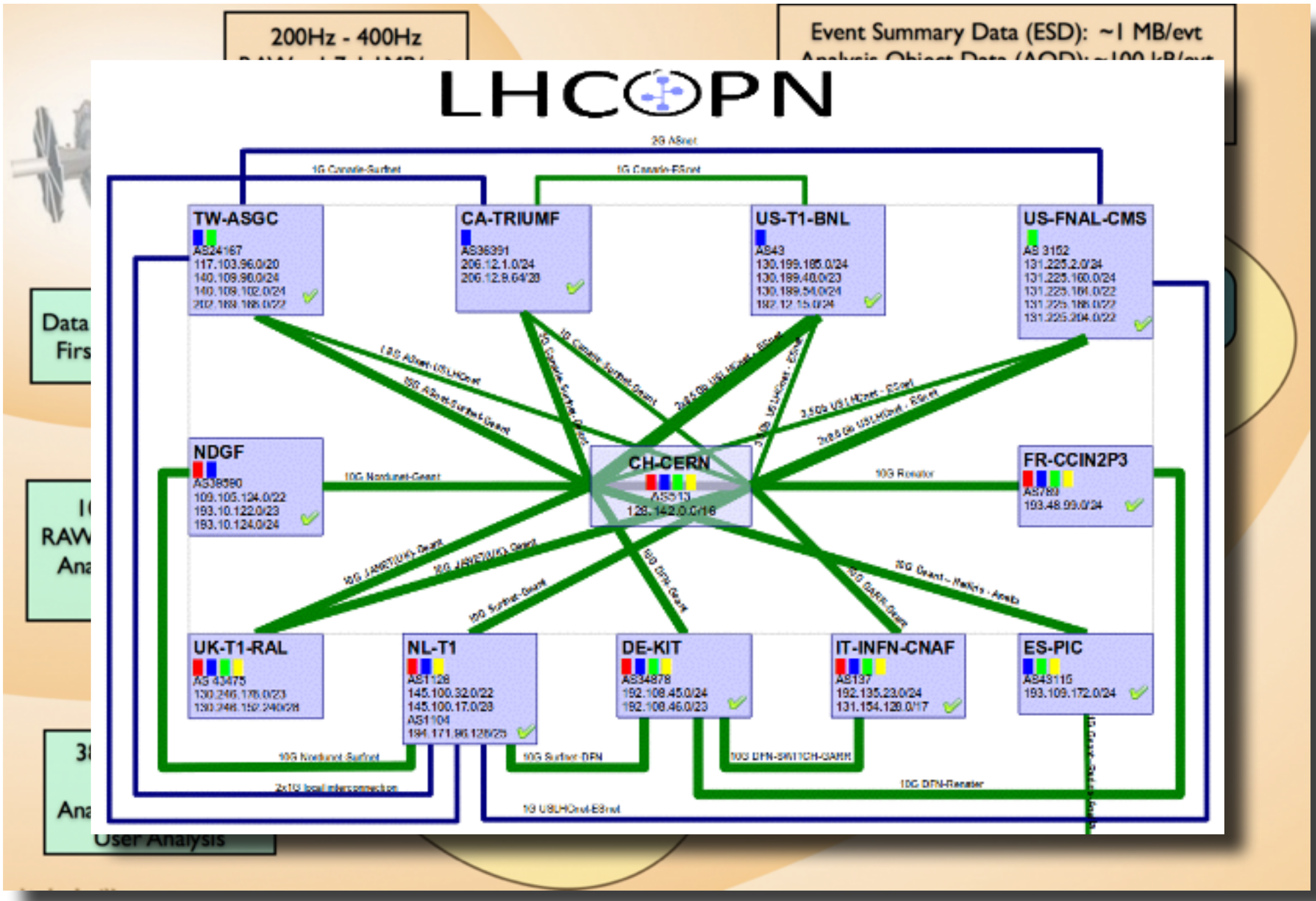
Connect all participants transparently:

Worldwide LHC Computing Grid

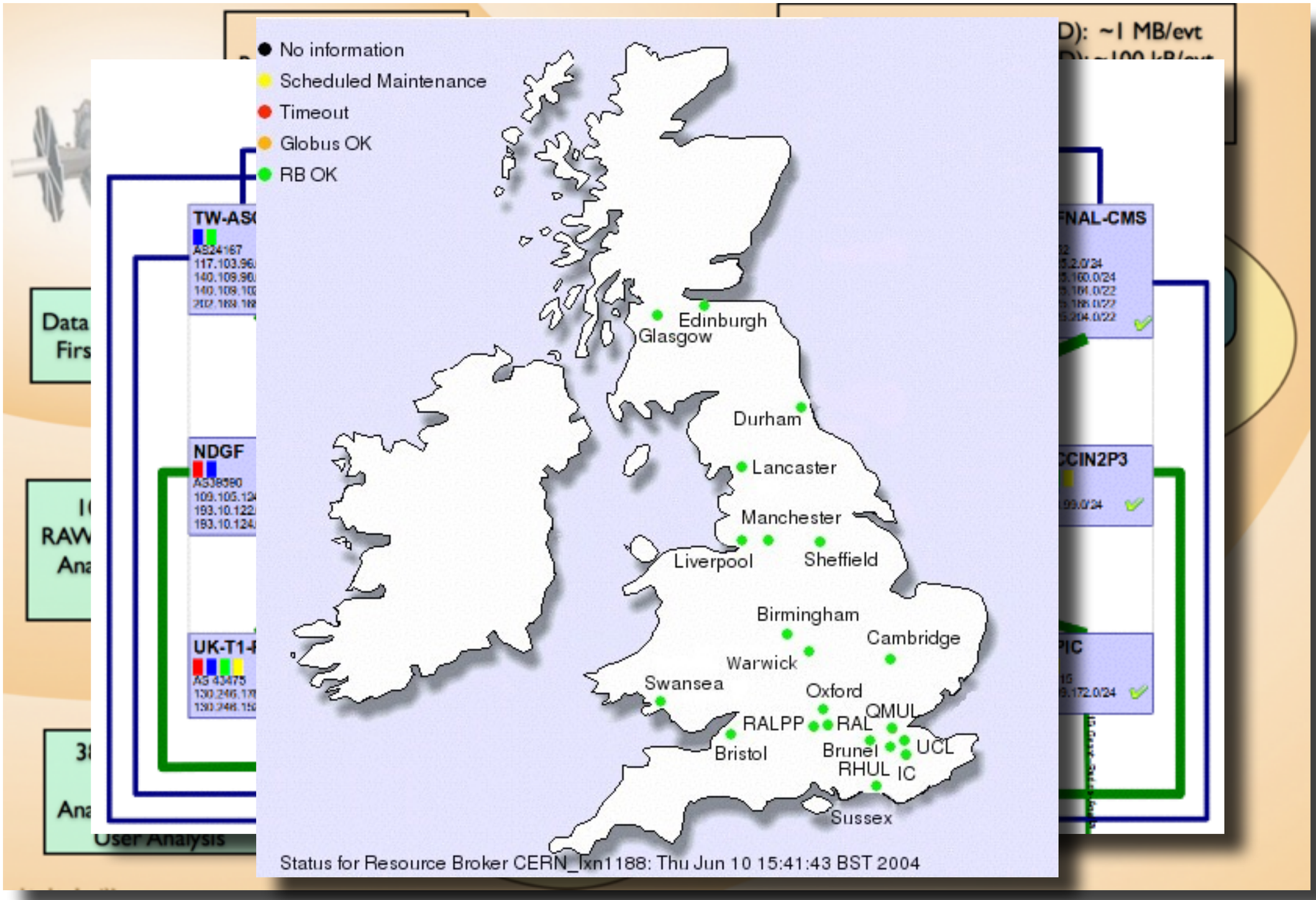
WLCG tiered structure



WLCG tiered structure



WLCG tiered structure



WLCG tiered structure

World Wide Web

The WorldWideWeb (W3) is a wide-area hypermedia information retrieval initiative aiming to give universal access to a large universe of documents.

Everything there is online about W3 is linked directly or indirectly to this document, including an executive summary of the project, Mailing lists , Policy , November's W3 news , Frequently Asked Questions .

What's out there?
: Pointers to the world's online information, subjects , W3 servers, etc.

Help
: on the browser you are using

Software Products
: A list of W3 project components and their current state. (e.g. Line Mode ,X11 Viola , NeXTStep , Servers , Tools , Mail robot , Library)

Technical
: Details of protocols, formats, program internals etc

Bibliography
: Paper documentation on W3 and references.

People
: A list of some people involved in the project.

History
: A summary of the history of the project.

How can I help ?
: If you would like to support the web..

Getting code
: Getting the code by anonymous FTP , etc.