



UNIVERSITÀ
DI PAVIA

Incontri di Fisica Moderna

Dip. di Fisica Pavia

21 Marzo 2023



Ai confini dell'indivisibile

C. Aimè, D. Rebutti, A. Negri

Come si fa a
confrontare le
predizioni della teoria
con i risultati di un
esperimento?

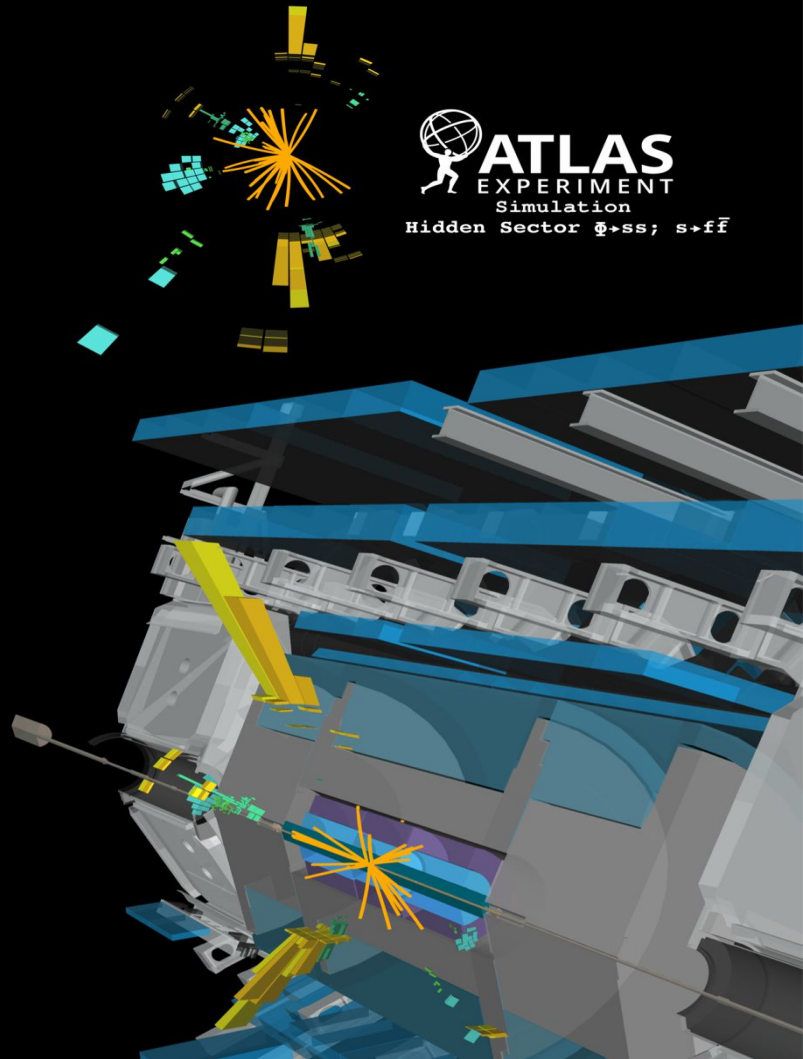


$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$

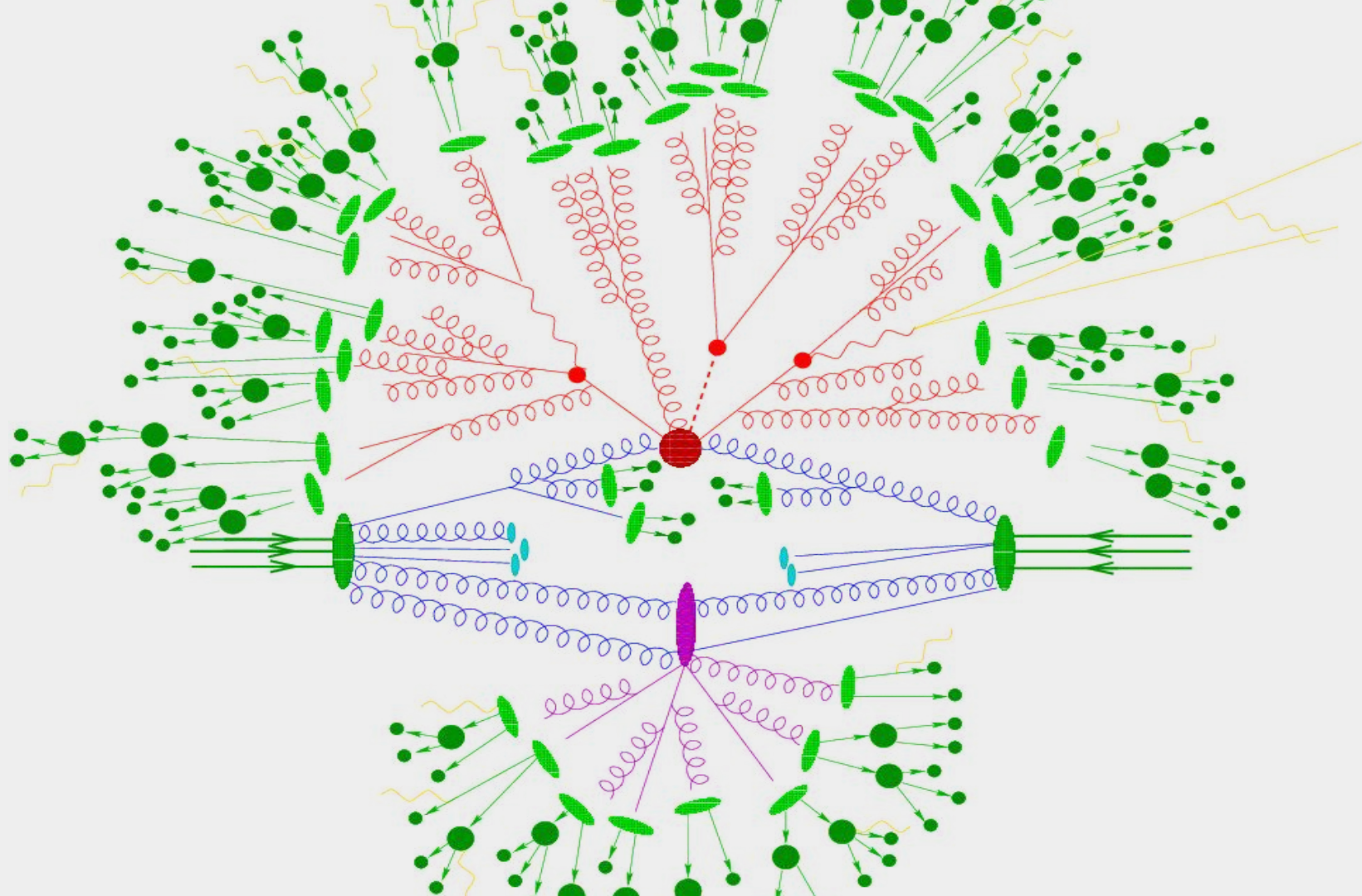
$$+ i \bar{\Psi} \not{D} \Psi + \text{h.c.}$$

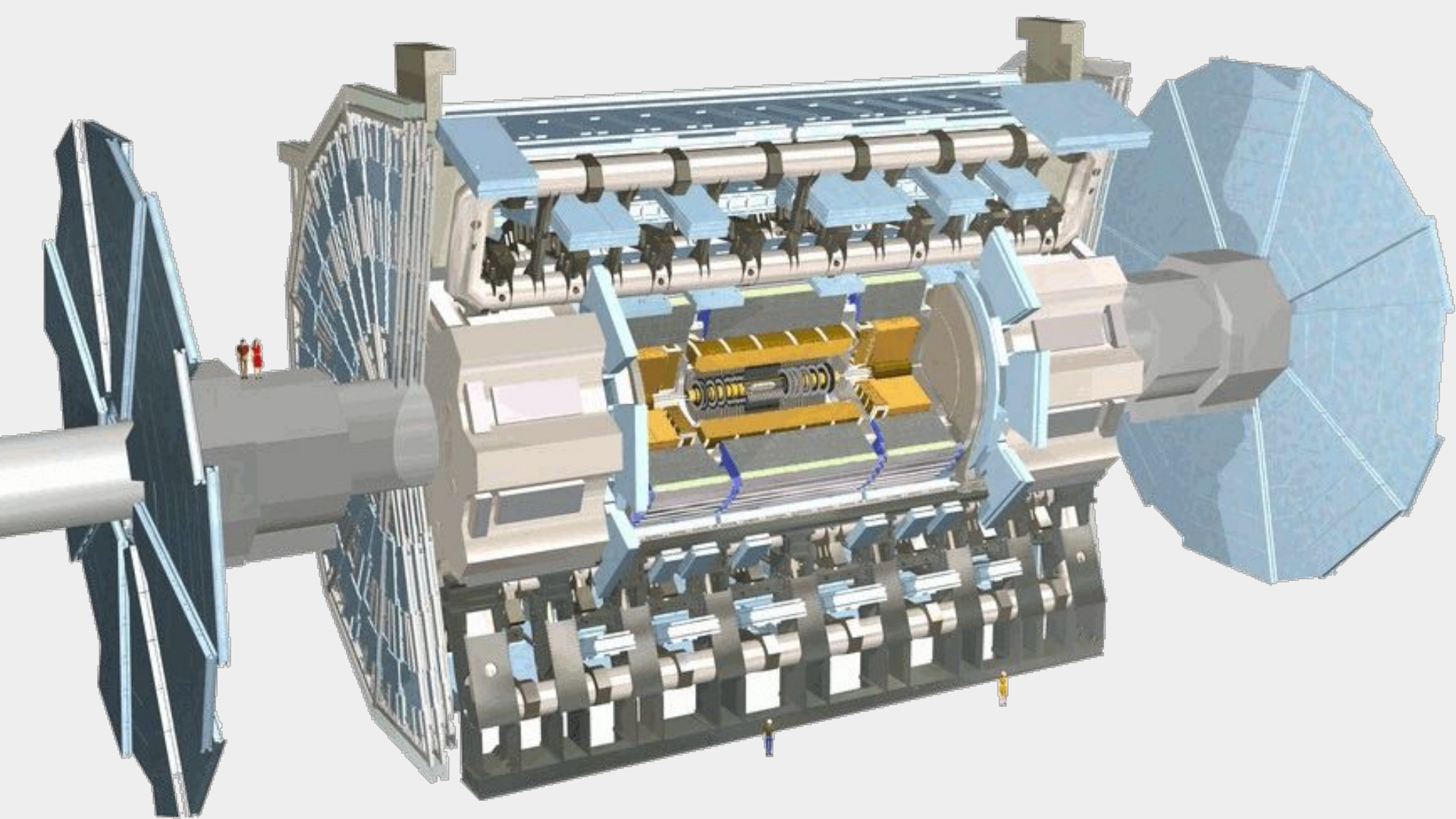
$$+ \bar{\Psi}_i \gamma_{ij} \Psi_j \phi + \text{h.c.}$$

$$+ |D_\mu \phi|^2 - V(\phi)$$



 **ATLAS**
EXPERIMENT
Simulation
Hidden Sector $\Phi \rightarrow ss; s \rightarrow f\bar{f}$



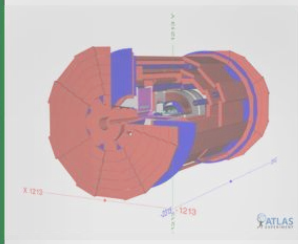


$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i\bar{\Psi}\not{D}\Psi + h.c. + \bar{\Psi}_i y_{ij} \Psi_j \phi + h.c. + \frac{1}{2} \partial_\mu \phi^2 - V(\phi)$$

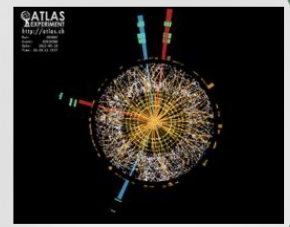
Theory



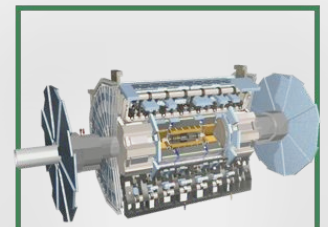
MC Event Generators



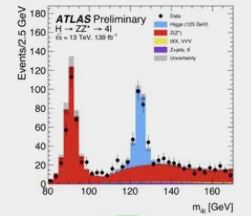
Detector Simulation



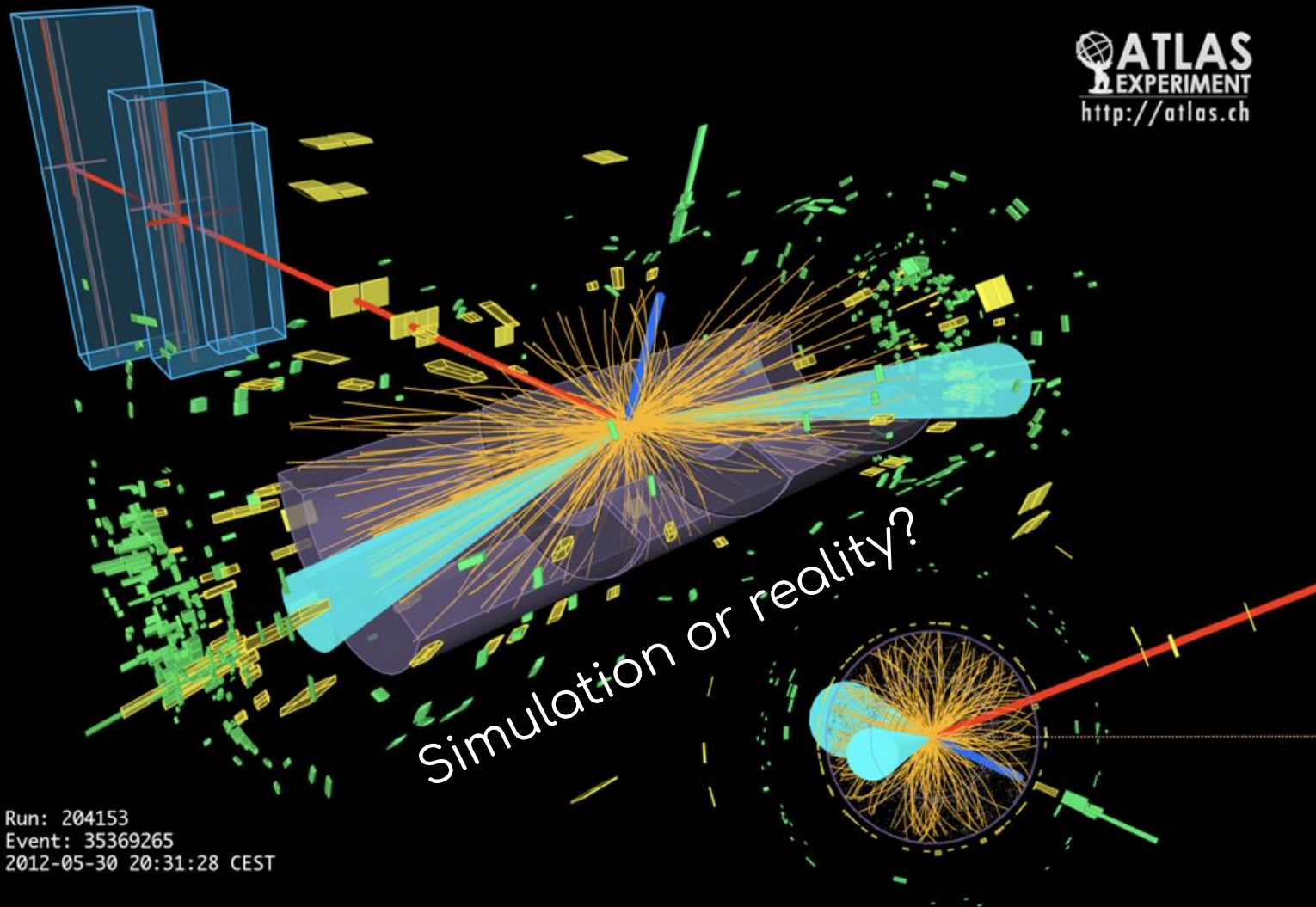
Event Reconstruction



Data

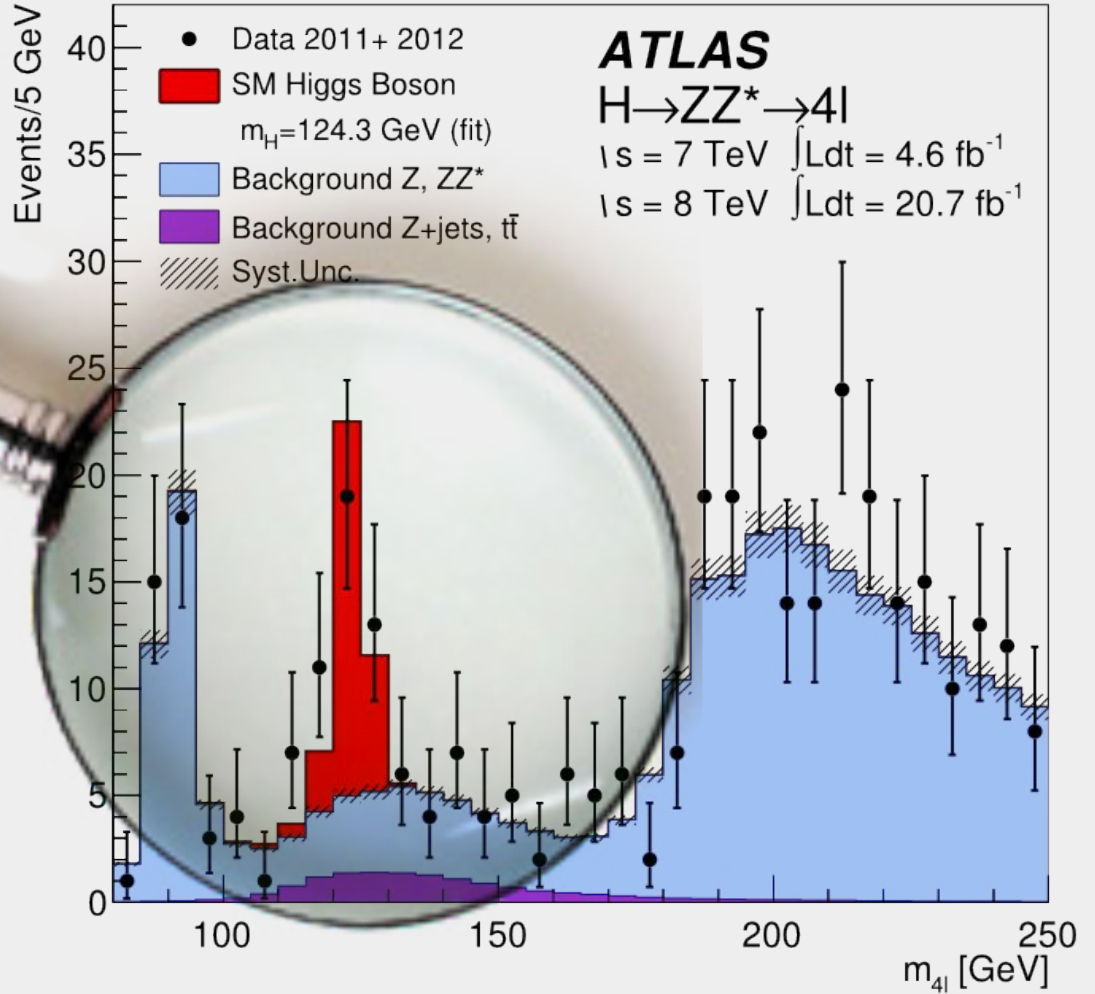
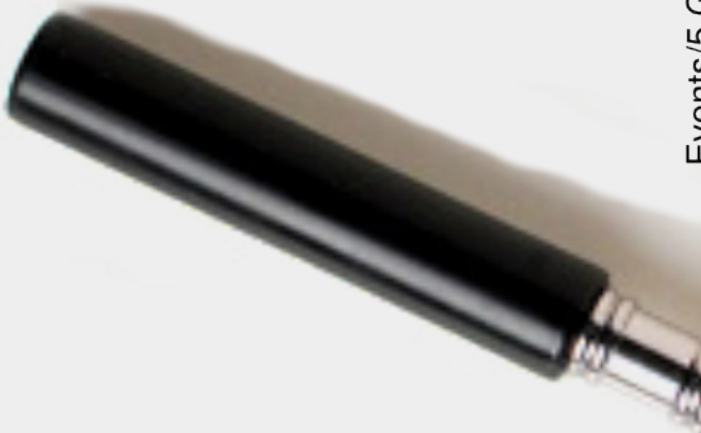


Analysis



Simulation or reality?

Run: 204153
Event: 35369265
2012-05-30 20:31:28 CEST





Oltre alla ricerca, che **lavori** può svolgere un fisico sperimentale delle particelle?

Utilizzo particelle

Informatica

Elettronica

Telecomunicazioni

Finanza

Industria.*

Agricoltura



Analisi dati

Gestione dati

R&D Rivelatori

Gestione e coordinamento

Problem Solving





Ambiente: giovane, internazionale, challenging

R&D



Big Data





CERN
Ginevra

CHE COS'È

È una **rete planetaria** che unisce e utilizza contemporaneamente la potenza di calcolo e la memoria di decine di migliaia di differenti computer sparsi nel mondo

Nodi di I livello

- CNAF - Bologna, ITA
- In2p3 - Lione, FRA
- SARA - Amsterdam, OLA
- Ral - Oxford, GBR
- GridKa, Karlsruhe - Stoccarda, GER
- Fermilab - Chicago, USA
- Triumf - Vancouver, CAN
- Brookhaven - Long Island, USA
- Nordic - SVE-FIN-NOR
- Pic - Barcellona, SPA
- Assc - Taiwan, CIN

Fibra ottica
dedicata
per i nodi
di I livello



L'utente può collegarsi alla Grid dal proprio pc e usare le risorse di calcolo che gli servono



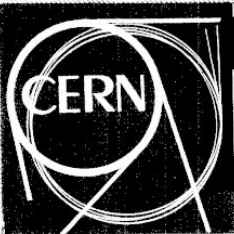
140 centri
di calcolo
in 33 Paesi



Oltre 10.000
gli utenti che
utilizzano Grid



La potenza
di calcolo prodotta
è pari a quella di **100.000** computer



AT0000083

290

Cours/Lecture Series

1993 - 1994

1993 - 1994 ACADEMIC TRAINING PROGRAMME



LECTURE SERIES

NEW DATES

SPEAKER : F. JAMES / CERN-CN
 TITLE : Introduction to Neural Networks
 TIME : 31 January, 2, 3 & 4 February from 11.00 to 12.00 h
 PLACE : Auditorium

Introduction to Neural Networks

ABSTRACT

In this series of 4 lectures, the emphasis will be on solving real problems using multi-layer feed-forward networks. Using the general theory of inverse problems and recent theoretical results on computational complexity in neural networks, we try to develop ways of understanding in what sense a problem is solvable and what network architecture is necessary to solve it.

1. Introduction and overview of Artificial Neural Networks.
- 2, 3. The Feed-forward Network as an Inverse Problem, and results on the computational complexity of network training.
4. Physics applications of neural networks.

Higgs challenge




the HiggsML challenge

May to September 2014

When High Energy Physics meets Machine Learning

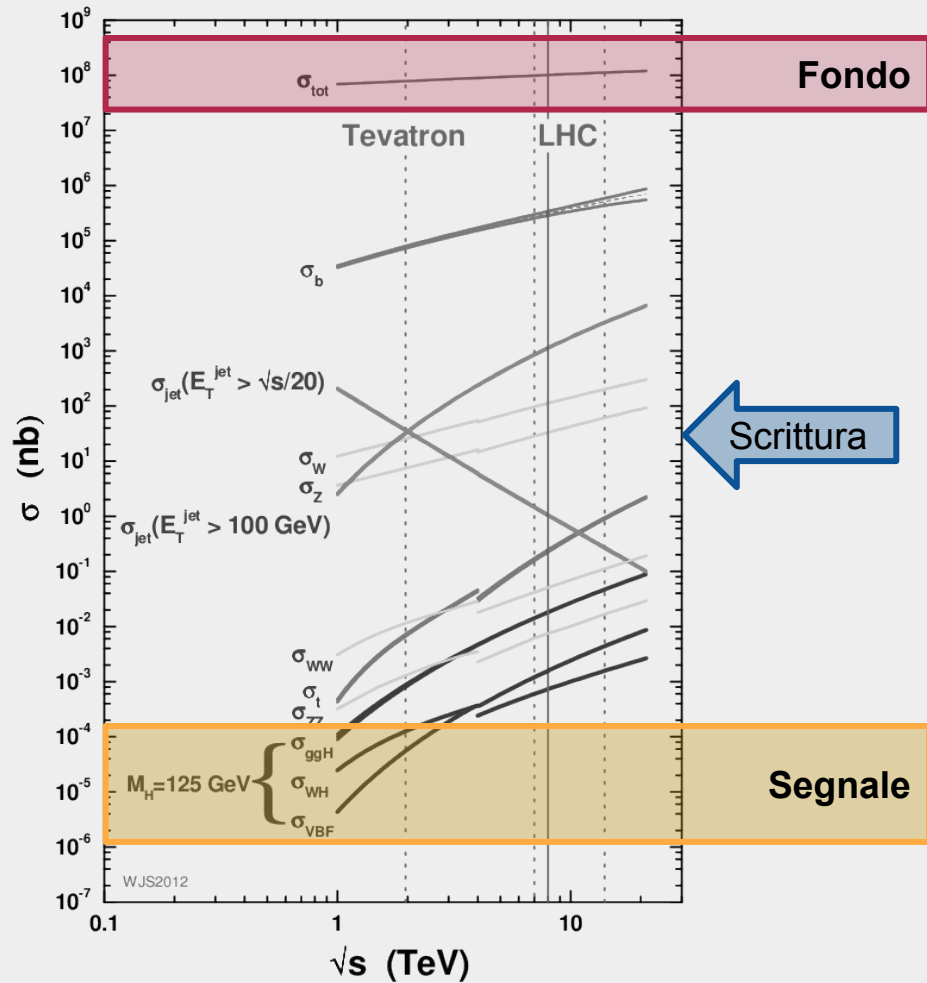


SandboxAQ: Solving challenging problems with AI + Quantum for positive impact

[Get AQ](#)[Find out more](#) 

SandboxAQ is an enterprise SaaS company combining AI + Quantum tech to solve hard problems impacting society. Our solutions include post-RSA cybersecurity modules that migrate enterprises to higher levels of security. These SandboxAQ modules enable post-quantum cryptography (PQC) in line with the new standards that are now emerging in this field.

proton - (anti)proton cross sections





Qual è la **giornata** tipo
di un fisico sperimentale
delle particelle?

21

Martedì
Marzo 2023

06:00

07:00

08:00

09:00

10:00

11:00

12:00

13:00

14:00

15:00

16:00

17:00

18:00

19:00

20:00

21:00

22:00

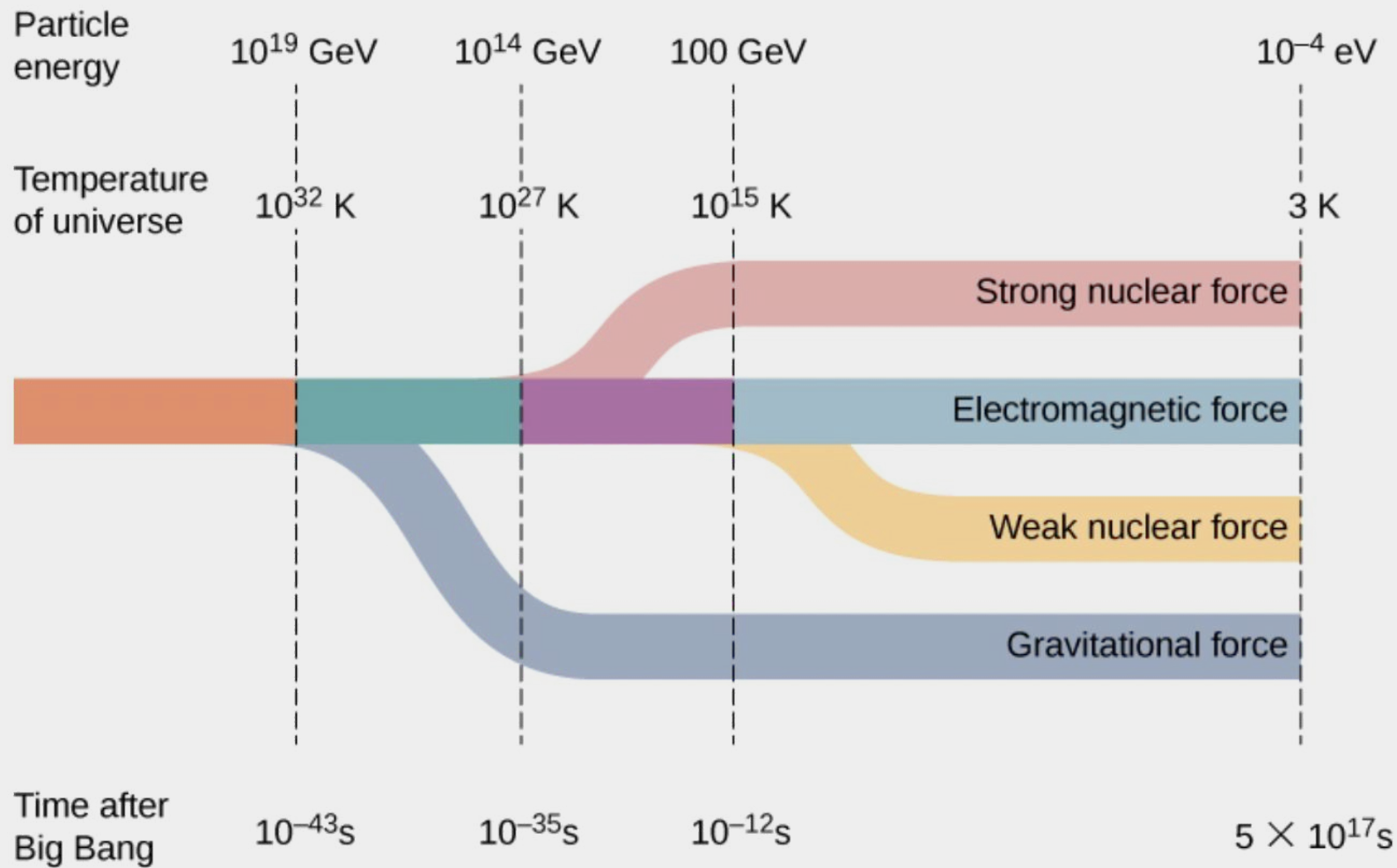
23:00

Fare

Appunti

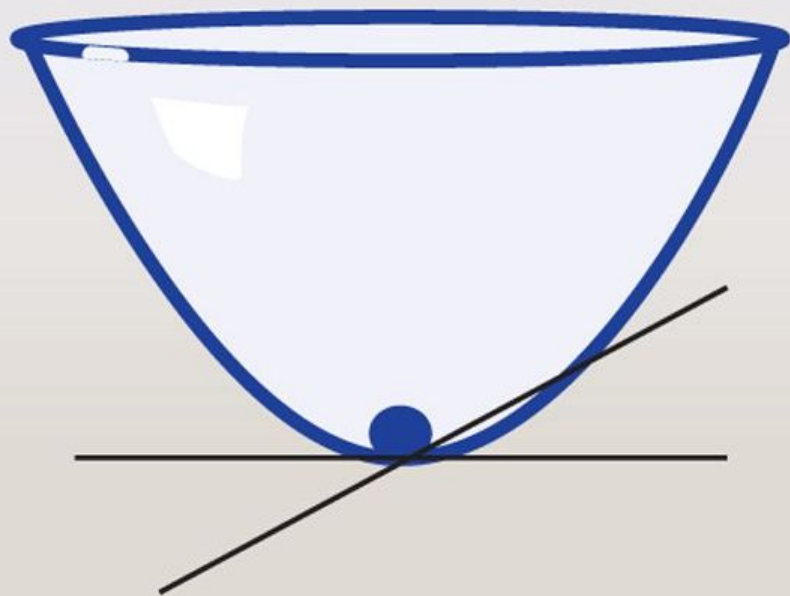
Come funziona il
campo di **Higgs**?



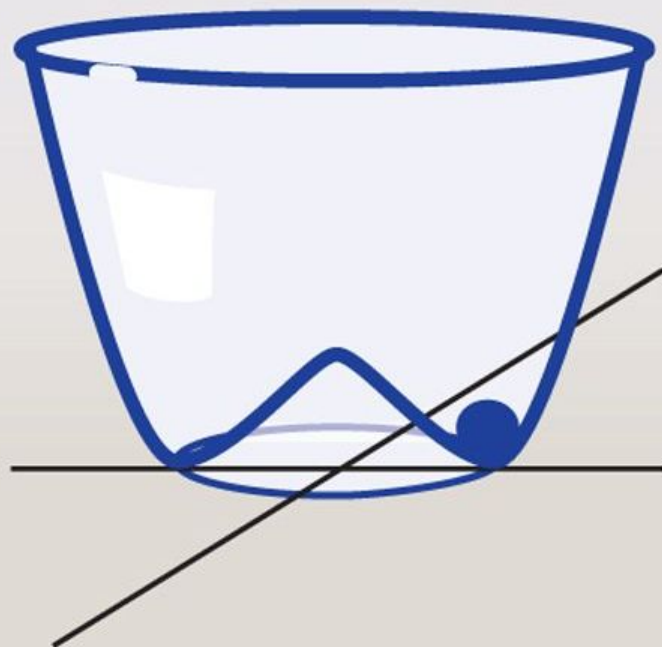


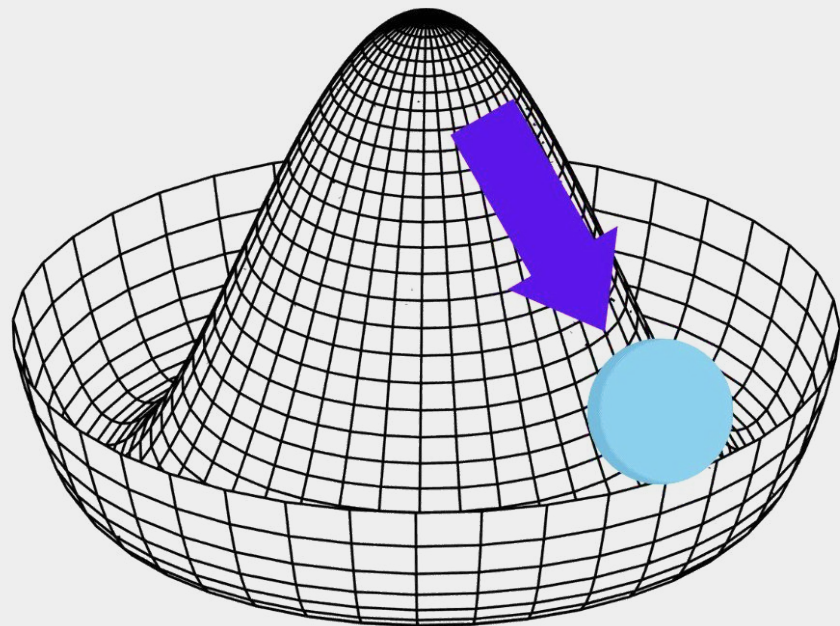
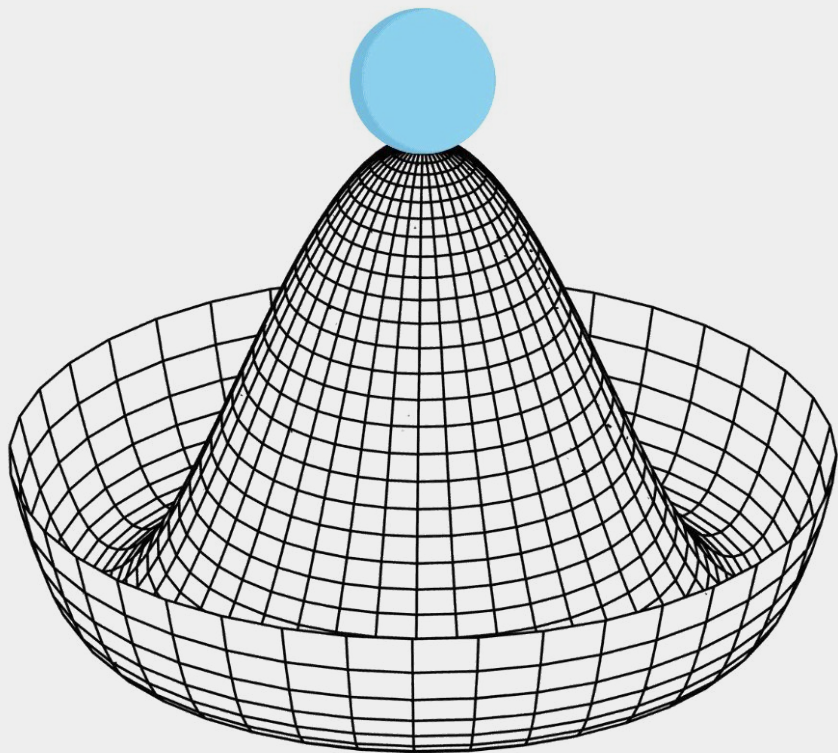
$$\begin{aligned}\mathcal{L} = & -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} \\ & + i \bar{\psi} \not{D} \psi + \text{h.c.} \\ & + \bar{\psi}_i \gamma_{ij} \psi_j \phi + \text{h.c.} \\ & + |D_\mu \phi|^2 - V(\phi)\end{aligned}$$

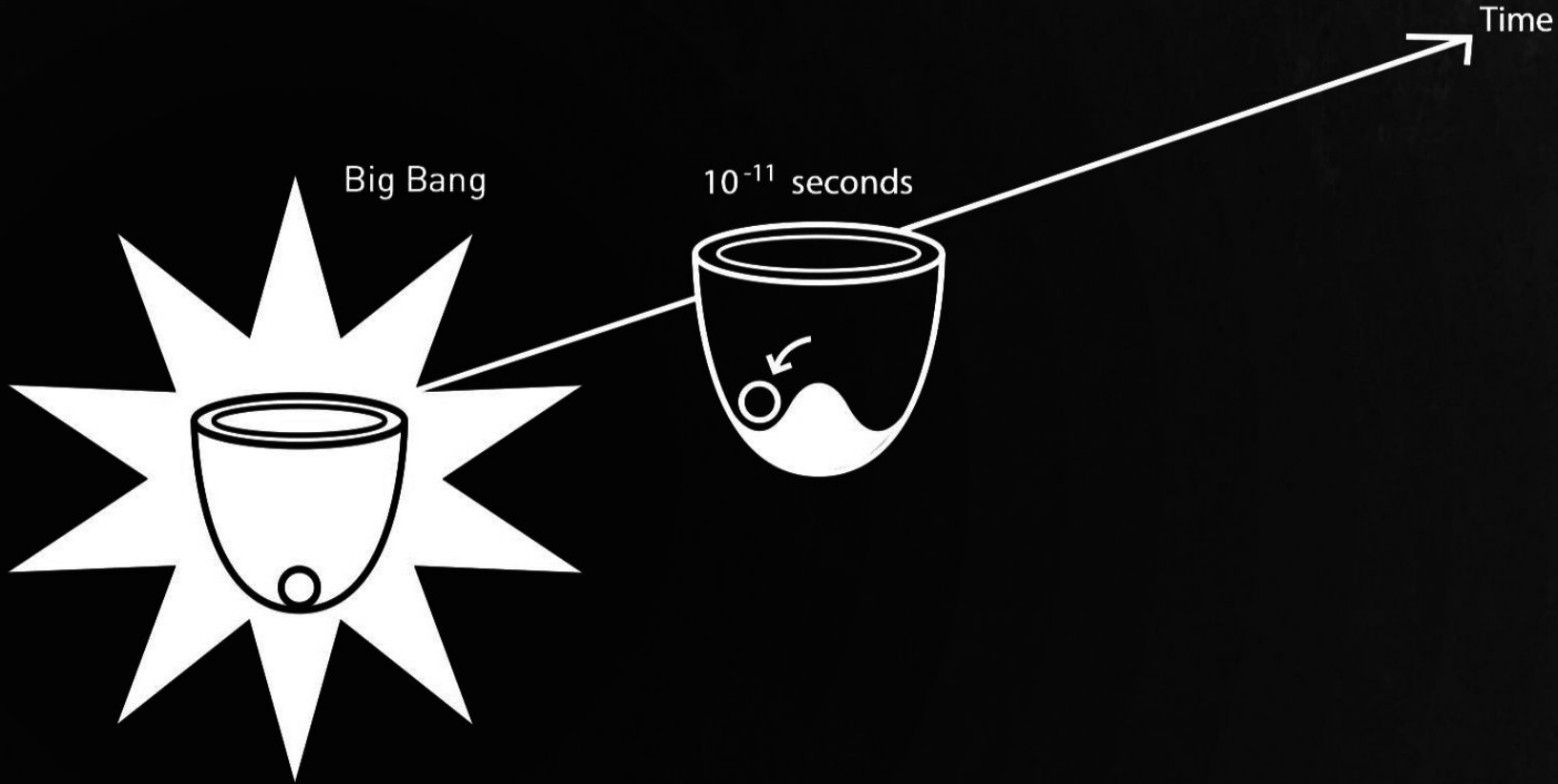
Unbroken symmetry



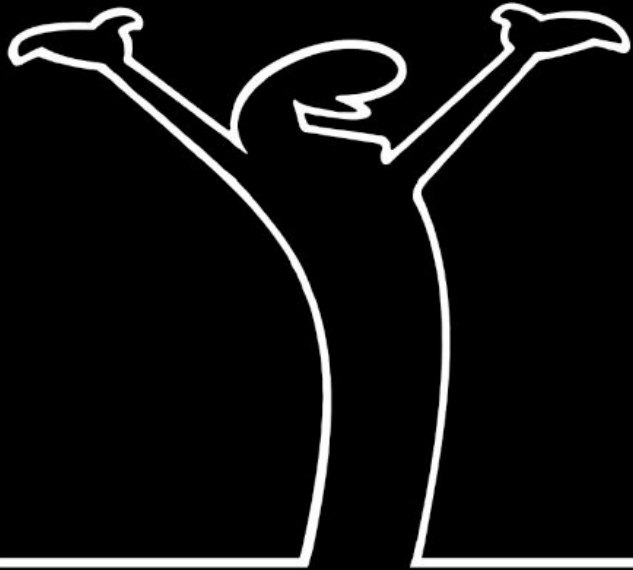
Spontaneously broken symmetry







Voi che c'eravate come
l'avete vissuta?

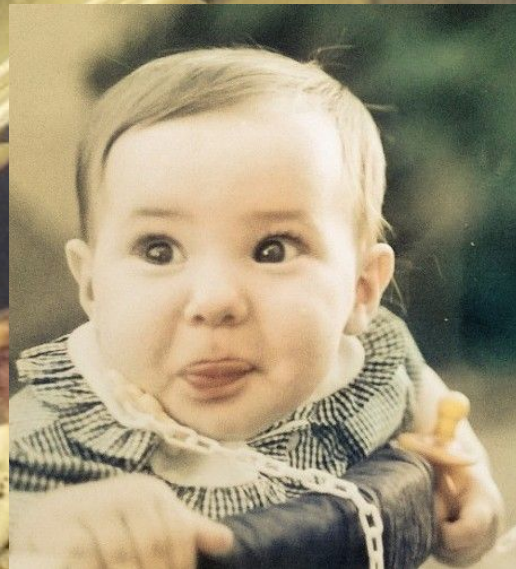




1996



1996



2009



2009



2010

Physics
Control room

ATLAS
EXPERIMENT

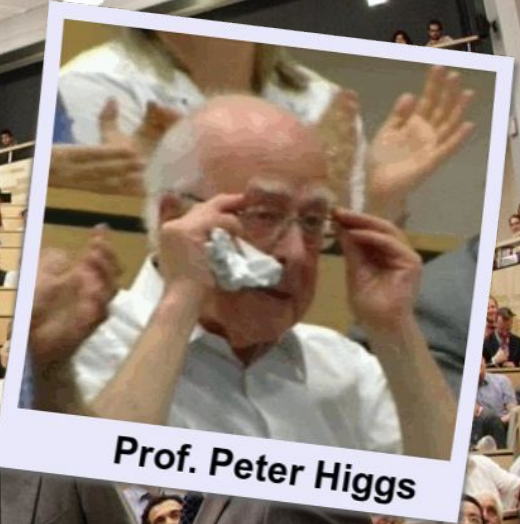
ATLAS Control Room
30-3-10 6:01



4/7/2012@Cern



4/7/2012@Cern



Prof. Peter Higgs

4/7/2012@PV

Mercoledì 4 luglio 2012, ore 9:00

DIPARTIMENTO DI FISICA

Aula A102

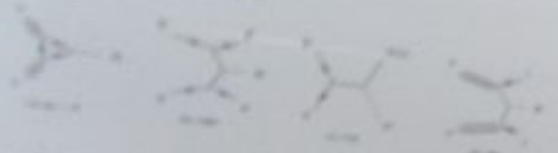
**Presentazione dei recenti
risultati sulla ricerca del
Bosone di Higgs a LHC**

Collegamento con il CERN

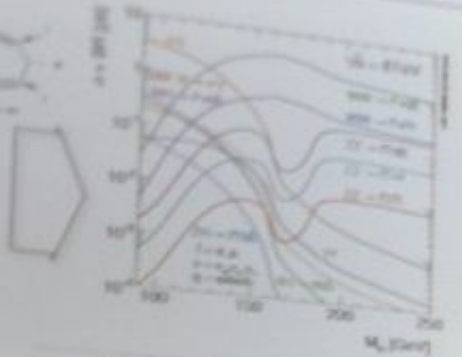
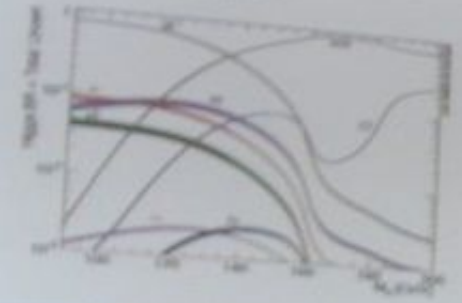
Il bosone di Higgs nel range di basse mass

Il bosone di Higgs nel range di basse mass

• Canali di produzione



• Canali di decadimento



Canali principali in $120 < M_H < 130$ GeV:
 $W/Z \rightarrow W/Z$, $bb \rightarrow H \rightarrow \tau\tau$, $H \rightarrow \tau\tau$
 $H \rightarrow ZZ^{*} \rightarrow 4l/2\nu$, $H \rightarrow WW^{*} \rightarrow l\nu\nu/l\nu/l\nu$

4/7/2012@PV

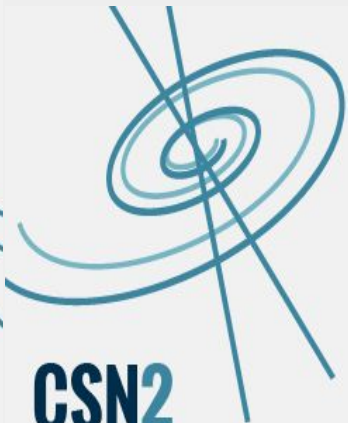




Quali sono i principali **esperimenti** di fisica delle particelle che si stanno svolgendo in Italia e nel mondo?



CSN1
Fisica delle
Particelle



CSN2
Fisica delle
Astroparticelle



CSN3
Fisica
Nucleare



Istituto Nazionale di Fisica Nucleare



CSN4
Fisica
Teorica



CSN5
Ricerca
Tecnologica



CSN1

Fisica delle

Particelle

Frontiera dell'energia

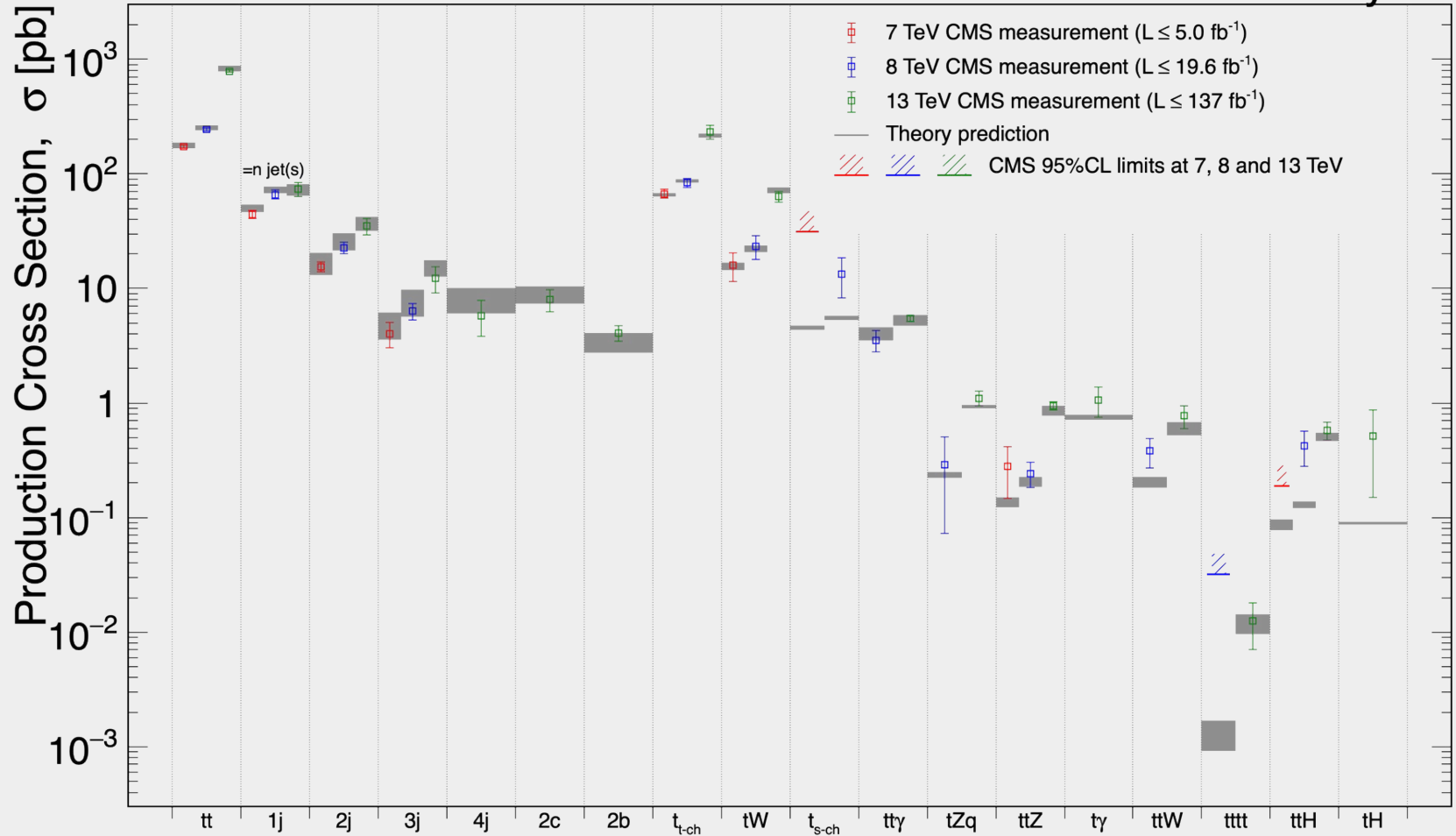
ALICE^(gr3), ATLAS, CMS, LHC-b
LHC-f , SNDLHC

Frontiera dell'intensità

BELLE2, BESIII, KLOE, NA62
GMINUS2, MUONE
MEG, Mu2e
AMBER, PADME

May 2021

CMS Preliminary



All results at: <http://cern.ch/go/pNj7>

“Qualcosa” non torna

- Materia e energia oscura
- Antimateria
- Neutrini
- Momento magnetico anomalo del muone
- Unificazione forze
- Quark indivisibili
- Altre dimensioni



	Model	Signature	$\int \mathcal{L} dt$ [fb $^{-1}$]	Mass limit	Reference					
Inclusive Searches	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q\tilde{\chi}_1^0$	mono-jet	2-6 jets	E_T^{miss}	36.1	\tilde{q} [2x, 8x Degen.]	0.9	1.55	$m(\tilde{\chi}_1^0) < 100$ GeV	1712.02332
				E_T^{miss}	36.1	\tilde{q} [1x, 8x Degen.]	0.43	0.71	$m(\tilde{q})-m(\tilde{\chi}_1^0)=5$ GeV	1711.03301
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}\tilde{\chi}_1^0$	0 e, μ	2-6 jets	E_T^{miss}	36.1	\tilde{g}	2.0		$m(\tilde{\chi}_1^0) < 200$ GeV	1712.02332
						\tilde{g}	Forbidden	0.95-1.6		$m(\tilde{\chi}_1^0)=900$ GeV
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}(\ell\ell)\tilde{\chi}_1^0$	3 e, μ	4 jets	E_T^{miss}	36.1	\tilde{g}	1.85		$m(\tilde{\chi}_1^0) < 800$ GeV	1706.03731
						\tilde{g}	Forbidden	1.2		$m(\tilde{g})-m(\tilde{\chi}_1^0)=50$ GeV
	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\tilde{q}WZ\tilde{\chi}_1^0$	0 e, μ	7-11 jets	E_T^{miss}	36.1	\tilde{g}	1.8		$m(\tilde{\chi}_1^0) < 400$ GeV	1708.02794
						\tilde{g}	Forbidden	1.15		$m(\tilde{g})-m(\tilde{\chi}_1^0)=200$ GeV
$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t\tilde{t}\tilde{\chi}_1^0$	0-1 e, μ	3 b	E_T^{miss}	79.8	\tilde{g}	2.25		$m(\tilde{\chi}_1^0) < 200$ GeV	ATLAS-CONF-2018-041	
					\tilde{g}	Forbidden	1.25		$m(\tilde{g})-m(\tilde{\chi}_1^0)=300$ GeV	ATLAS-CONF-2019-015
3 rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow b\tilde{\chi}_1^0/\tilde{\chi}_1^\pm$	Multiple	Multiple	E_T^{miss}	36.1	\tilde{b}_1	Forbidden	0.9	$m(\tilde{\chi}_1^0)=300$ GeV, BR($b\tilde{\chi}_1^0$)=1	1708.09266, 1711.03301
						\tilde{b}_1	Forbidden	0.58-0.82	$m(\tilde{\chi}_1^0)=300$ GeV, BR($b\tilde{\chi}_1^0$)=BR($\mu\tilde{\chi}_1^\pm$)=0.5	1708.09266
						\tilde{b}_1	Forbidden	0.74	$m(\tilde{\chi}_1^0)=200$ GeV, $m(\tilde{\chi}_1^\pm)=300$ GeV, BR($\mu\tilde{\chi}_1^\pm$)=1	ATLAS-CONF-2019-015
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1 \rightarrow b\tilde{\chi}_2^0 \rightarrow bh\tilde{\chi}_1^0$	0 e, μ	6 b	E_T^{miss}	139	\tilde{b}_1	Forbidden	0.23-0.48	$\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0)=130$ GeV, $m(\tilde{\chi}_1^0)=100$ GeV	SUSY-2018-31
						\tilde{b}_1	Forbidden	0.23-1.35	$\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0)=130$ GeV, $m(\tilde{\chi}_1^0)=0$ GeV	SUSY-2018-31
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	0-2 e, μ	0-2 jets/1-2 b	E_T^{miss}	36.1	\tilde{t}_1	1.0		$m(\tilde{\chi}_1^0)=1$ GeV	1506.08616, 1709.04183, 1711.11520
						\tilde{t}_1	0.44-0.59		$m(\tilde{\chi}_1^0)=400$ GeV	ATLAS-CONF-2019-017
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow Wb\tilde{\chi}_1^0$	1 e, μ	3 jets/1 b	E_T^{miss}	139	\tilde{t}_1	1.16		$m(\tilde{\tau}_1)=800$ GeV	1803.10178
						\tilde{t}_1	0.46	0.85	$m(\tilde{\chi}_1^0)=0$ GeV	1805.01649
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow \tilde{\tau}_1 b\nu, \tilde{\tau}_1 \rightarrow \tau\tilde{G}$	1 $\tau + 1 e, \mu, \tau$	2 jets/1 b	E_T^{miss}	36.1	\tilde{t}_1	0.43		$m(\tilde{t}_1, \tilde{\tau})-m(\tilde{\chi}_1^0)=50$ GeV	1805.01649
						\tilde{t}_1	0.43		$m(\tilde{t}_1, \tilde{\tau})-m(\tilde{\chi}_1^0)=5$ GeV	1711.03301
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + h$	0 e, μ	mono-jet	E_T^{miss}	36.1	\tilde{t}_2	0.32-0.88		$m(\tilde{\chi}_1^0)=0$ GeV, $m(\tilde{t}_1)-m(\tilde{\chi}_1^0)=180$ GeV	1706.03986
\tilde{t}_2						Forbidden	0.86	$m(\tilde{\chi}_1^0)=360$ GeV, $m(\tilde{t}_1)-m(\tilde{\chi}_1^0)=40$ GeV	ATLAS-CONF-2019-016	
EW direct	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ via WZ	2-3 e, μ	E_T^{miss}	36.1	$\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$	0.6		$m(\tilde{\chi}_1^0)=0$	1403.5294, 1806.02293	
					$\tilde{\chi}_1^\pm/\tilde{\chi}_2^0$	0.205		$m(\tilde{\chi}_1^0)=5$ GeV	ATLAS-CONF-2019-014	
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$ via WW	2 e, μ	E_T^{miss}	139	$\tilde{\chi}_1^\pm$	0.42		$m(\tilde{\chi}_1^0)=0$	ATLAS-CONF-2019-008	
					$\tilde{\chi}_1^\pm$	Forbidden	0.74	$m(\tilde{\chi}_1^0)=70$ GeV	ATLAS-CONF-2019-019, ATLAS-CONF-2019-XYZ	
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^0$ via Wh	0-1 e, μ	2 $b/2 \gamma$	E_T^{miss}	139	$\tilde{\chi}_1^\pm$	1.0		$m(\tilde{\chi}_1^0)=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2019-008
						$\tilde{\chi}_1^\pm$	0.16-0.3	0.12-0.39	$m(\tilde{\chi}_1^0)=0$	ATLAS-CONF-2019-018
	$\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$ via $\tilde{\ell}_L/\tilde{\nu}$	2 e, μ	E_T^{miss}	139	$\tilde{\chi}_1^\pm$	0.7		$m(\tilde{\chi}_1^0)=0$	ATLAS-CONF-2019-008	
					$\tilde{\chi}_1^\pm$	0.256		$m(\tilde{\chi}_1^0)=0$	ATLAS-CONF-2019-014	
	$\tilde{\tau}\tilde{\tau}, \tilde{\tau} \rightarrow \tau\tilde{\chi}_1^0$	2 τ	E_T^{miss}	139	$\tilde{\tau}$	[$\tilde{\tau}_L, \tilde{\tau}_{R,L}$]	0.16-0.3	0.12-0.39	$m(\tilde{\chi}_1^0)=0$	ATLAS-CONF-2019-018
					$\tilde{\tau}$	0.256		$m(\tilde{\chi}_1^0)=0$	ATLAS-CONF-2019-014	
$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell} \rightarrow \ell\tilde{\chi}_1^0$	2 e, μ	0 jets	E_T^{miss}	139	$\tilde{\ell}$	0.29-0.88		$m(\tilde{\ell})-m(\tilde{\chi}_1^0)=10$ GeV	1806.04030	
					$\tilde{\ell}$	0.13-0.23	0.3	BR($\tilde{\chi}_1^0 \rightarrow hZ$)=1	1804.03602	
$\tilde{H}\tilde{H}, \tilde{H} \rightarrow h\tilde{G}/Z\tilde{G}$	0 e, μ	$\geq 3 b$	E_T^{miss}	36.1	\tilde{H}	0.3		BR($\tilde{\chi}_1^0 \rightarrow hZ$)=1	1804.03602	
					\tilde{H}	0.13-0.23	0.3	BR($\tilde{\chi}_1^0 \rightarrow ZG$)=1	1804.03602	
Long-lived particles	Direct $\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	E_T^{miss}	36.1	$\tilde{\chi}_1^\pm$	0.15	0.46	Pure Wino	1712.02118
						$\tilde{\chi}_1^\pm$	0.15	0.46	Pure Higgsino	ATL-PHYS-PUB-2017-019
						\tilde{g}	2.0			1902.01636, 1808.04095
Stable \tilde{g} R-hadron	Multiple	Multiple	E_T^{miss}	36.1	\tilde{g}	2.0			1902.01636, 1808.04095	
					\tilde{g} ($\tau(\tilde{g}) \approx 10$ ns, 0.2 ns)	2.05	2.4	$m(\tilde{\chi}_1^0)=100$ GeV	1710.04901, 1808.04095	

*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

Pavia: **60** persone

Frontiera dell'energia

ALICE^(gr3), **ATLAS**, **CMS**, LHC-b
LHC-f , SNDLHC

Frontiera dell'intensità

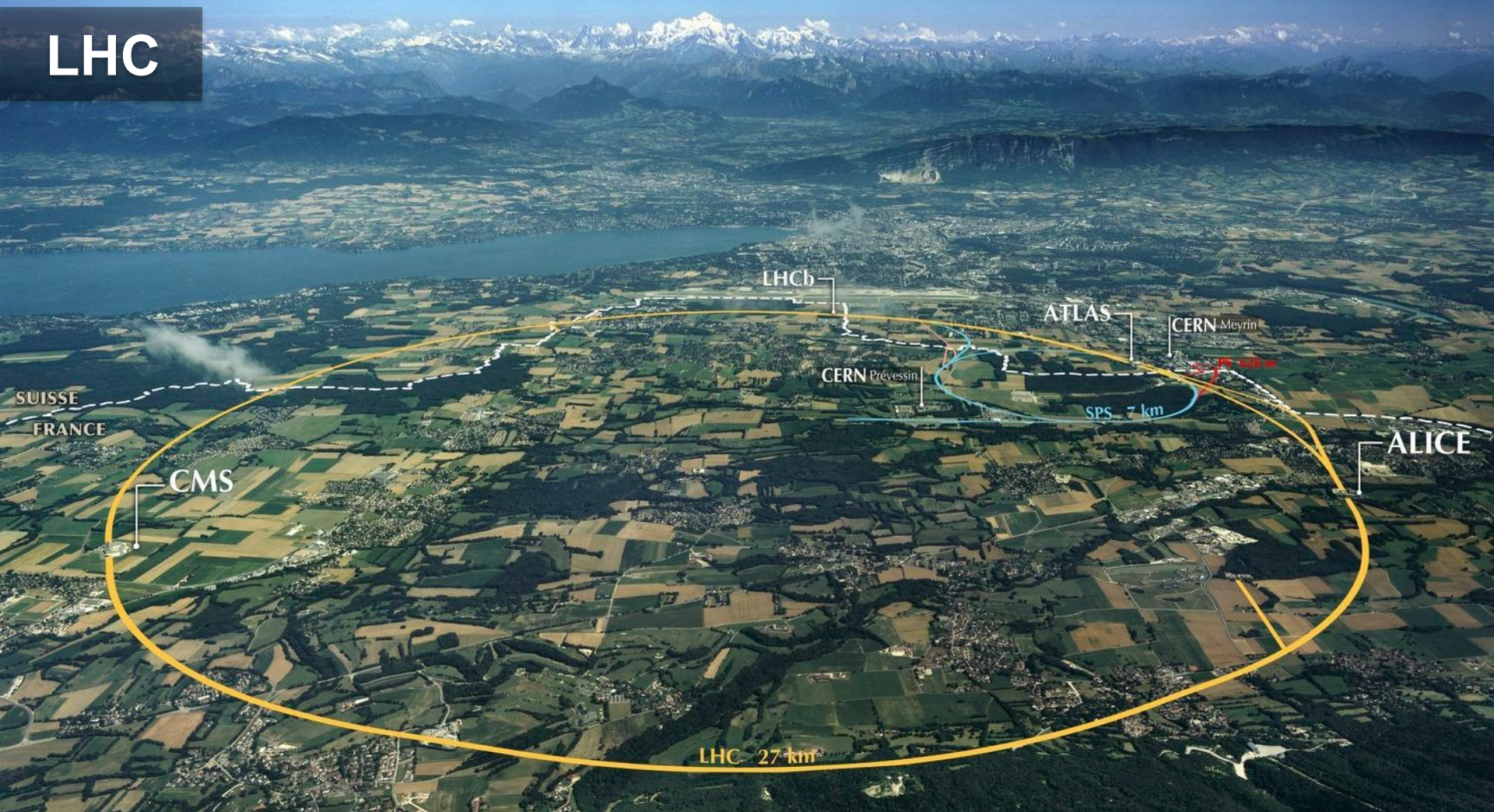
BELLE2, BESIII, KLOE, NA62
GMINUS2, MUONE
MEG, Mu2e
AMBER, PADME



CSN1

Fisica delle
Particelle

LHC



LHCb

ATLAS

CERN Meyrin

CERN Prévessin

SPS 7 km

SUISSE
FRANCE

CMS

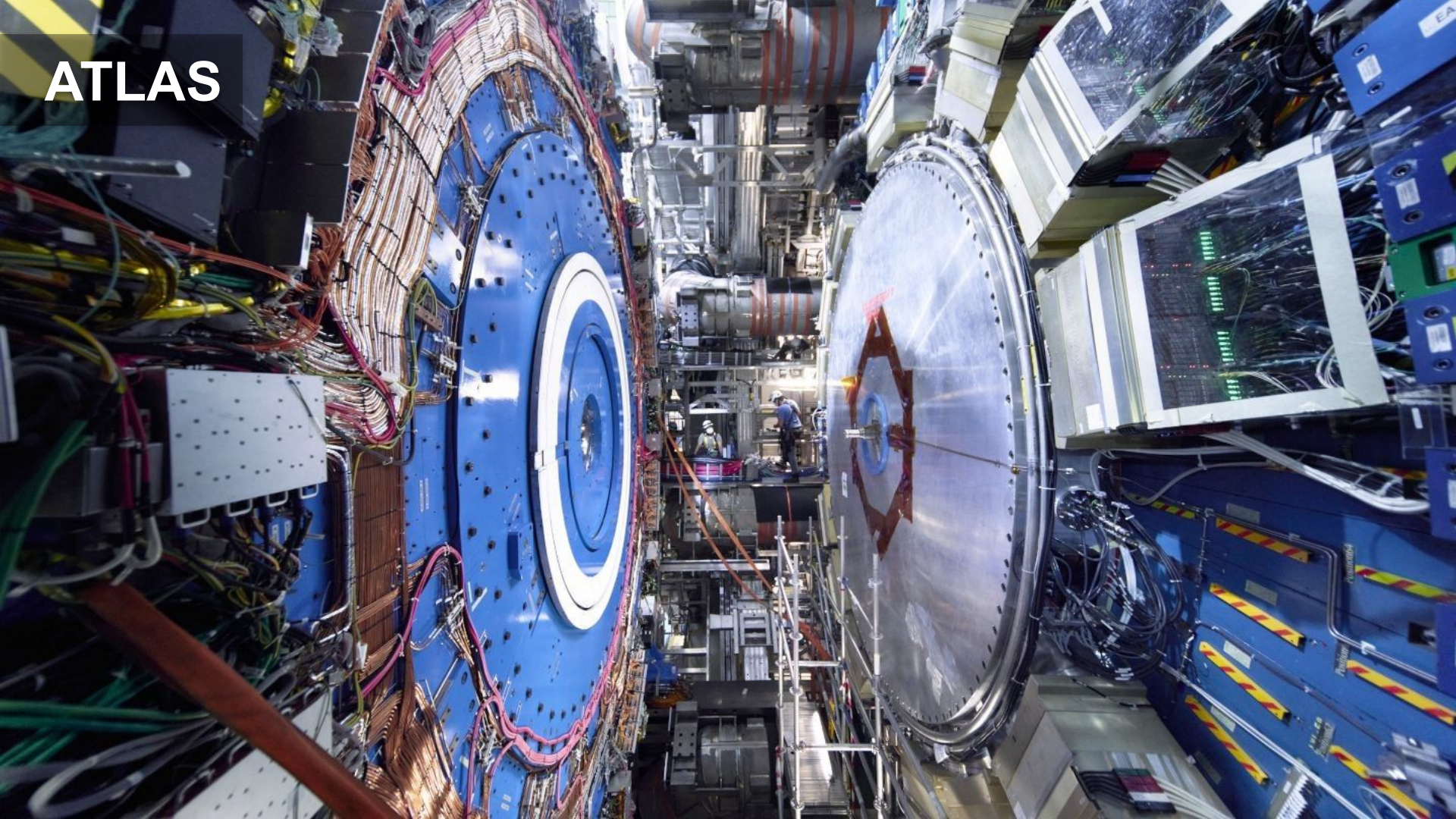
ALICE

LHC 27 km

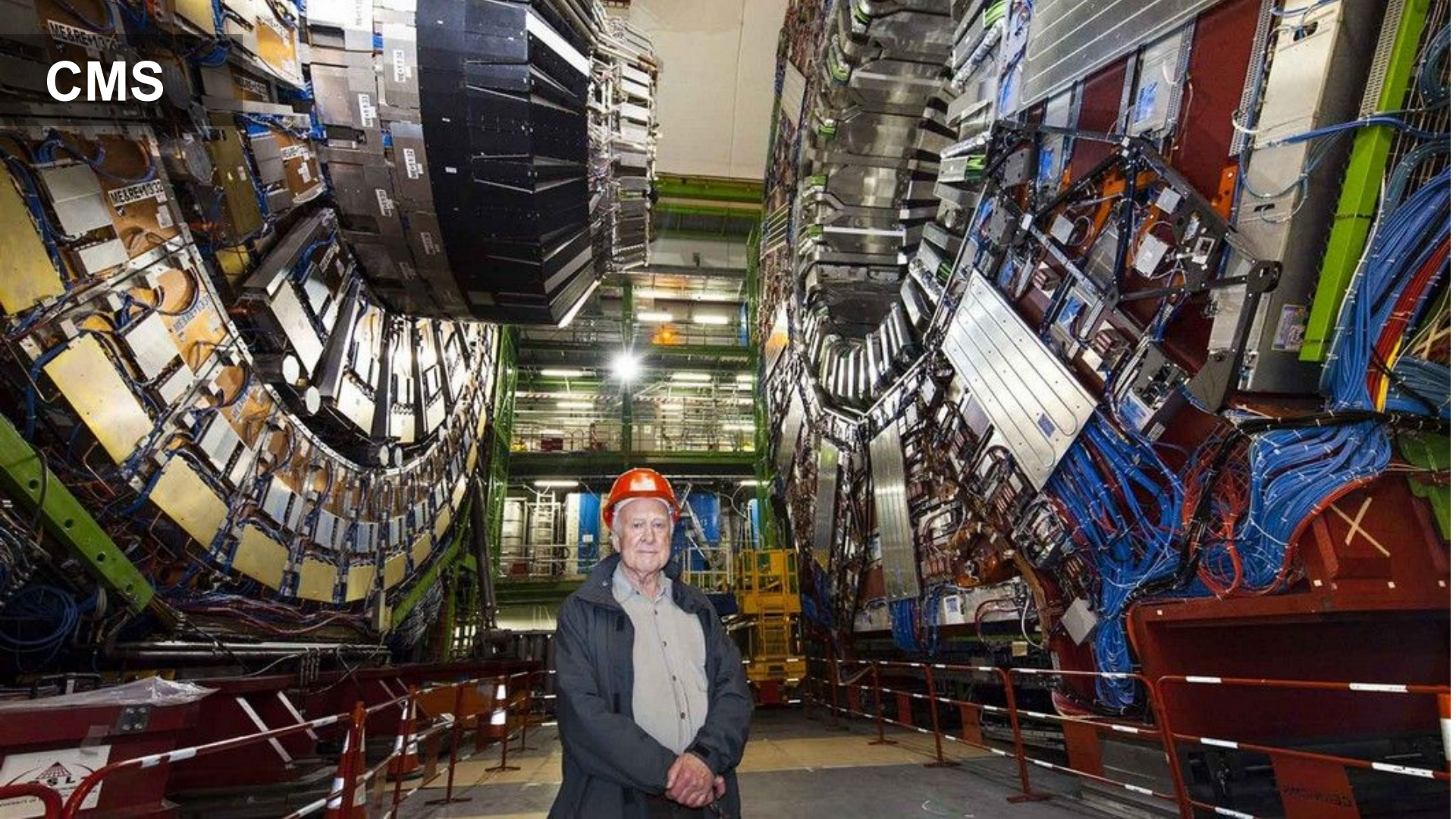
ALICE



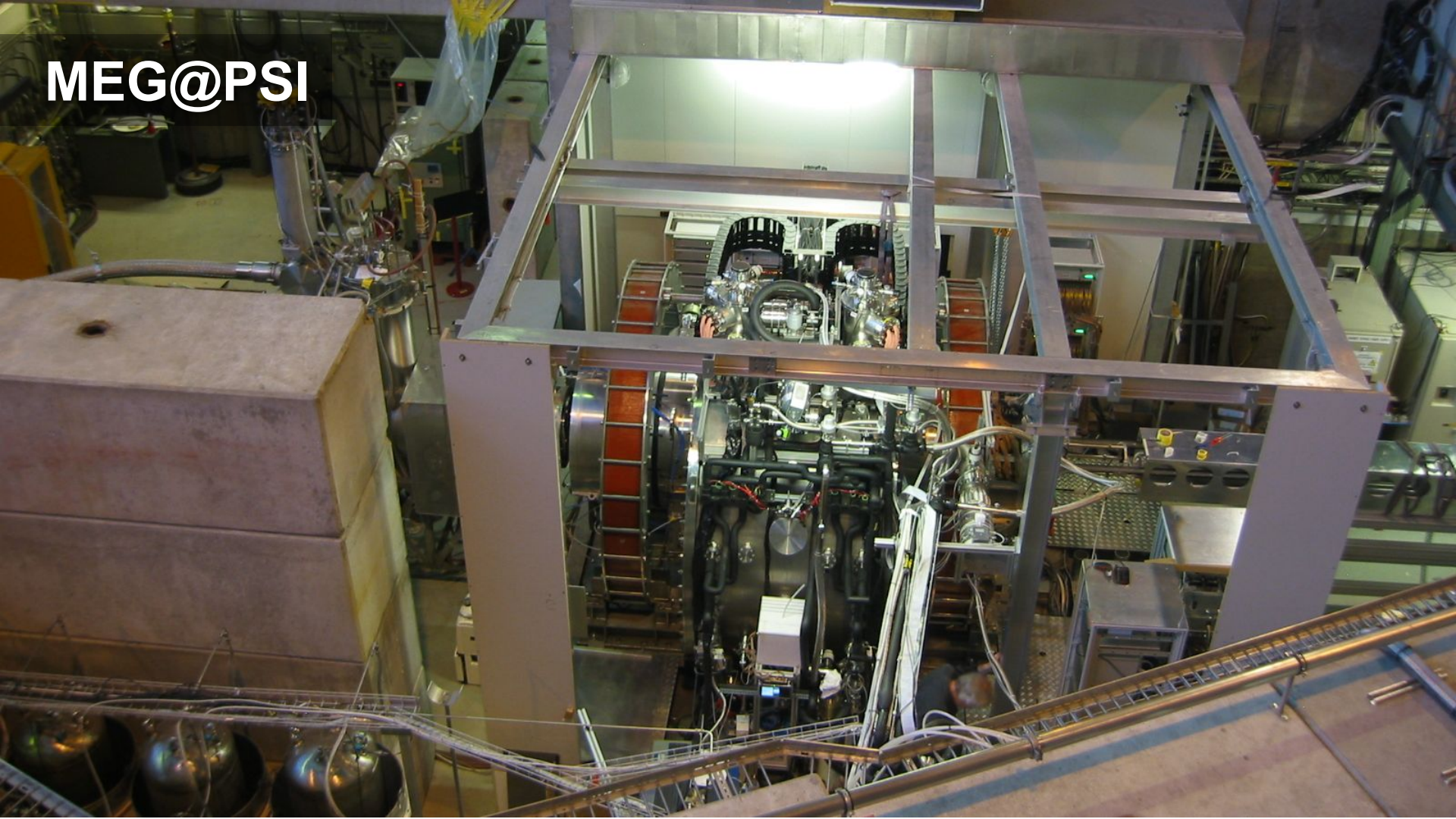
ATLAS



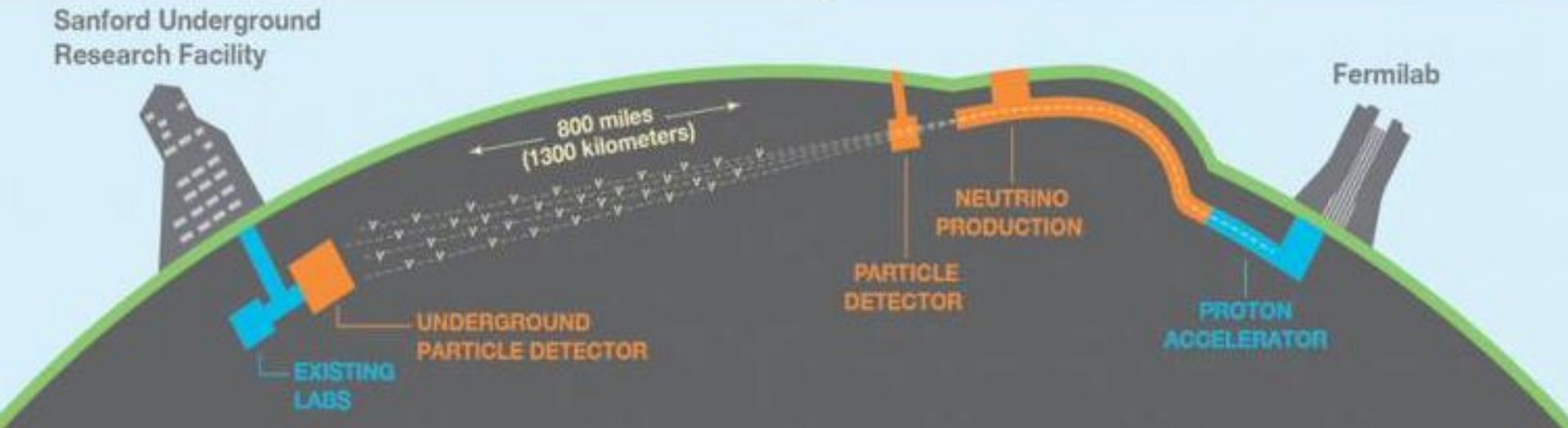
CMS



MEG@PSI



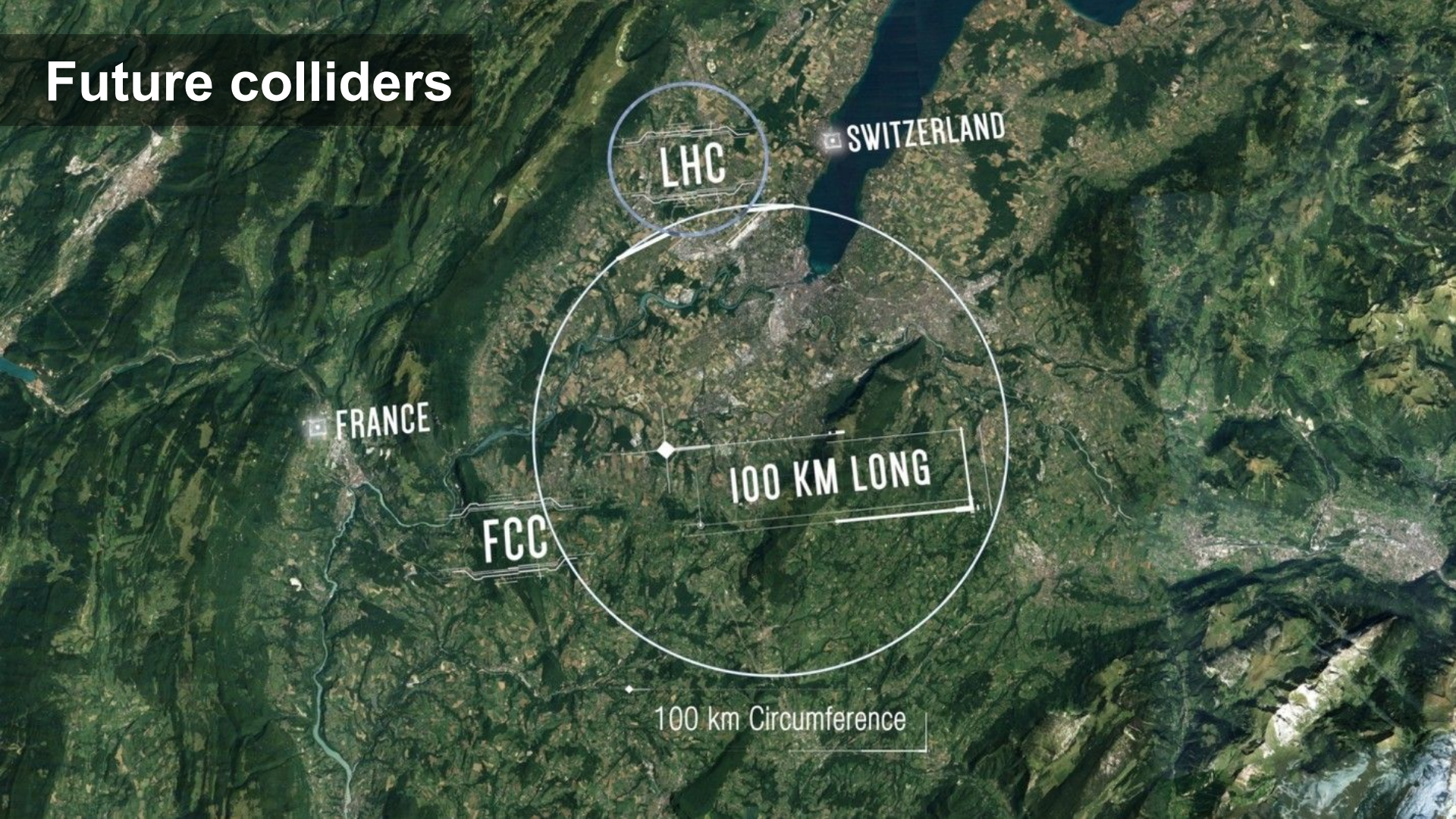
Deep Underground Neutrino Experiment



Quali sono i
programmi **futuri**?



Future colliders



LHC

SWITZERLAND

FRANCE

FCC

100 KM LONG

100 km Circumference

Physics Opportunities





May 30, 2022

<https://muoncollider.web.cern.ch>

Muon Collider Physics Summary

Submitted to the Proceedings of the US Community Study
on the Future of Particle Physics (Snowmass 2021)

PARTICLE PHYSICS

Electronic
Microscope

Muon Tomography

Climatology

Cyclotron

Cloud

MonteCarlo Simulation

Pattern Recognition

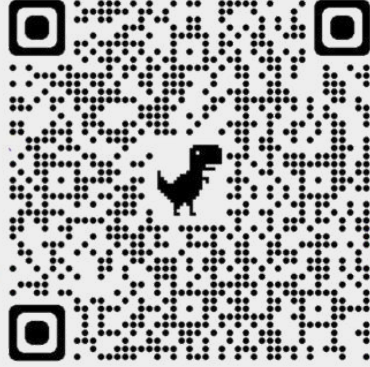
ARTIFICIAL INTELLIGENCE

Synchrotron

CULTURAL
HERI-
TAGE

Radio-
active
dating

LASER



X-rays

Electronics

TAC

Hadron Therapy

Space
Discovery

Big Data

WWW

NMR

Proximity
Sensors

STELLA

cellulose
near
lives with
xtend
ednologies to
mart

Algorithms

Computing
GRID

PET

RADIO-
THERAPY

Data
Mining

Touch Screen

Machine Learning