The history of the INFN Unit of Bologna at the Physics Department of the University

Graziano Bruni

INFN – Bologna

(The road to the INFN and)
The history of the INFN Unit of Bologna
at the
Physics Department of the University

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Layout

- Pre-history
  - ➢ The ”new” Institute of Physics (then the Department)
  - ➢ The road to INFN and its birth

- History
  - ➢ The birth of the Unit of Bologna
  - ➢ A glance at the main experimental activities over the years

XXI century: the new Institute - Augusto Righi

- Was one of the best experimental physicists of the time
  - He was the first to speak about the “photoelectric” effect
  - He established the new Institute of Physics (1901-1907)

  - He guided Guglielmo Marconi to the birth of wireless telecommunications (Marconi was a free visitor at the University)
    - Guglielmo Marconi and Ferdinand Braun were awarded with the Nobel Prize in 1909
    - Marconi was President of the CNR from 1927 to 1937

1921 – Albert Einstein Conferences

- About one year after Righi's death, Einstein came to Bologna for three conferences on Relativity (22,24 and 26 October 1921)

- He became a real "star" among the students

The “via Panisperna boys”

- M. Corbino – Director since 1918 of the Institute of Physics of “Via Panisperna” in Rome - aimed to set up an institute of International level. He was a real “talent scout”.

In a short time he was able to create from nothing a top level group of physicist around Enrico Fermi (chair of theoretical physics since 1926)

- Oscar d’Agostino
- Emilio Segrè
- Edoardo Amaldi
- Franco Rasetti
- Enrico Fermi
- Bruno Pontecorvo (taking the picture)

Ettore Majorana

Fermi entered in the history of physics with his discoveries of

- the properties of the interaction of the slow neutrons with the atomic nuclei
- his theory of the weak interactions

IL NUOVO CIMENTO Nuova Serie N. 1, Pag. 1–20 Anno XI - 1934

An attempt to a β rays theory

Nota di Enrico Fermi

(ricevuto 1933)

Summary. — A quantitative theory of β-rays emission is proposed in which ≪ neutrino ≫ is admitted; electrons and neutrinos emission from a nucleus at a β decay is treated with a procedure similar to the one followed for radiation theory to describe a light quantum emission by an excited atom. Formulae are derived for the mean life and for the distribution of the β-rays continuum spectrum, which are compared with experimental data.

Basic assumptions of the theory (1)

1. –

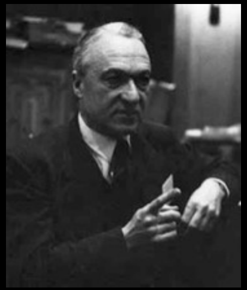
In attempting to construct a theory of nuclear electrons and of the β rays emission, two well known difficulties are encountered. The first is that the primary β rays are emitted by the nuclei with a continuous velocity distribution. If the energy conservation principle is not abandoned, we must therefore admit that a fraction of the energy made available in the β decay escapes our present observation possibilities. According to a proposal by Pauli existence can be supposed, for instance, of a new particle, the so called ≪ neutrino ≫. with a zero electric charge and a mass of the order of magnitude of the electron mass or less. One admits, furthermore, that in every β process are simultaneously emitted an electron, observed as a β ray, and a neutrino escaping observation and carrying away part of the energy.

A second difficulty for the nuclear electrons theory arises because the current relativistic theories of light particles (electrons or neutrinos) do not satisfactorily deal with the possibility that such particles could be bound into orbits of nuclear size.

As a consequence it seems more appropriate to admit with Heisenberg(2) that all nuclei only consist of heavy particles, protons and neutrons. Nevertheless to understand the possibility of β rays emission, we shall attempt the construction of a theory for the emission of light particles from a nucleus in analogy with the emission theory of a light

(1) Cfr. preliminary note in ≪ La Ricerca Scientifica ≫, **2**, n. 12, 1933.
(2) W. Heinsenberg, ≪ Zs. für Phys. ≫, **77**,1, 1932; E. Majorana, ≪ Zs. für Phys. ≫, **82**,137, 1933.

The ”Arcetri Group” – the cosmic rays group



- Another group of physicists led by Bruno Rossi was active in Florence
    - Bruno Rossi got his degree in Physics at the University of Bologna
- Since 1929 it was defined a long term research program on the “cosmic radiation”, discovered in 1912 by Victor Hess

- Members of the group were:
    - Gilberto Bernardini , Giuseppe Occhialini, Giulio Racah, Daria Bocciarelli, Guglielmo Righini, Lorenzo Emo Capodilista

Fermi: the idea of a dedicated Italian Institute

- In the second half of the 30's Fermi had clear the point that it was impossible to continue the competition with the other Countries with only University-scale laboratories and a modern accelerator facility was needed – the synchrotron was replacing the electrostatic machines

- 1937: he proposed at the CNR a National Institute of Radioactivity, for the coordination of the fundamental research as well as of the medical and biological applications
  - The sudden death of the CNR President, Gugliemo Marconi, was a complication for the project

1938 – the year of the racial laws

- Bruno Rossi lost the chair and the salary (he was professor in Padua)
  - Then he left Italy, went to the Niels Bohr Institute in Copenhagen, then in the UK and in June 1939 reached the USA
- Enrico Fermi got the Nobel Prize, and from Stockholm went directly to Chicago
  - Laura, Fermi's wife, was a Jewish
- Gilberto Bernardini came to Bologna as professor of Exp. Physics
  - 1942-1947: Director of the Institute of Physics

After the war: the CNR University Centers

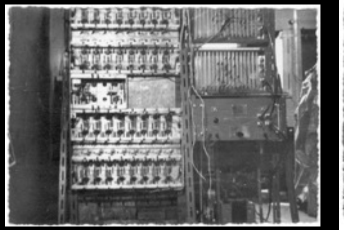
- 1945-51: CNR set up four Centers for nuclear and particle physics
  - Ruled by specific Agreements between CNR and the single Universities
  - Rome Study of Nuclear Physics (1945)
  - Padua Study of Fast Ions (1947)
  - Milan Cosmic Radiation group (1951)
  - Turin Experimental and Theoretical Physics (1951)

The “Testa Grigia” laboratory (1948)

3505 m above sea level

- It played an important aggregation role, essential to the birth of the INFN

- International groups were present at the laboratory

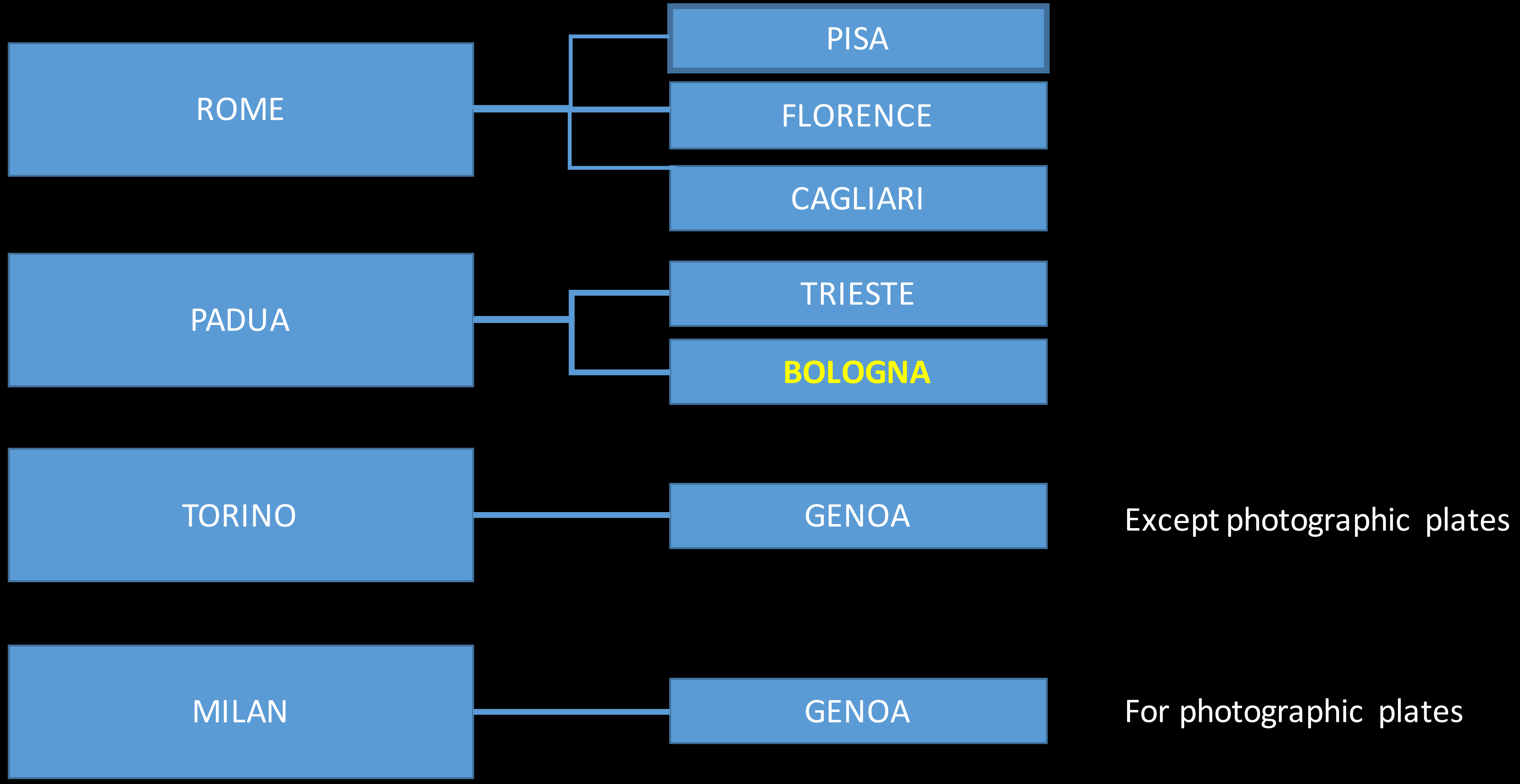


E.Amaldi, G.Bernardini, E.Pancini

The birth of INFN

- August, 8th 1951: the birth
  - The President of CNR established the Italian Institute of Nuclear Physics:
    - Its mission was the coordination of the CNR Univeristy Centers
    - The governance was guaranteed by the Board of the Directors
- July, 9th 1952: the ”new” INFN
  - Real coordination of the research and the relationships with other Organizations
  - Introduced the President of INFN (Gilberto Bernardini)
  - The four Centers became the first four Divisions of the INFN
  - The Board of Directors had the effective power of coordination of the individual divisions, by distributing locally the fractions of the overall budget

September 1952: the sub-units were introduced
("aggregate groups")

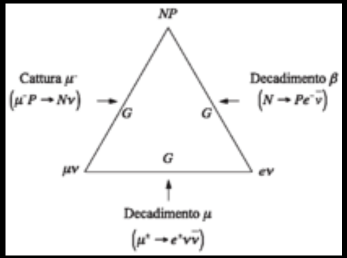


Entering in the history: the Unit of Bologna

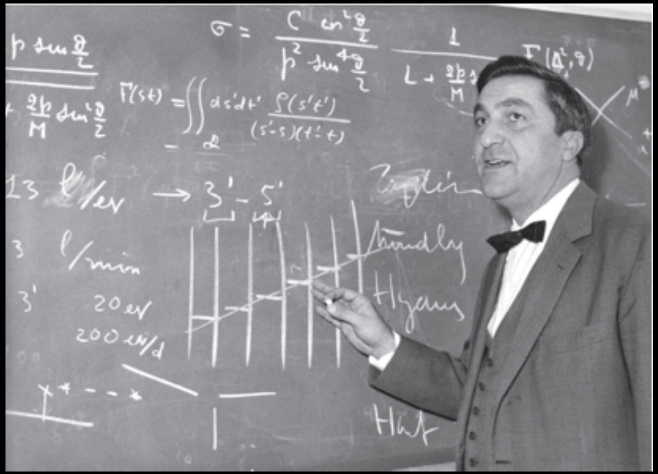
The founder: Giampietro Puppi ("Gianni")

In a work of 1948 - *Nuovo Cimento 5, 587 (1948)* on the universality of the weak interactions he demonstrated the "approximate equality" of the coupling constants of

- Nuclear β decay
- Muon β decay
- Muon nuclear capture



- 1951: Professor of Theoretical Physics in Bologna
- 1954: new director of the Institute of Physics
- 1962-63: CERN Director of Research
- 1964-65: Chair of the CERN Experimental Committee



Giampietro Puppi

- Bubble chambers (invented in 1951) were the dominant experimental devices to study particle physics at that time
- A large community of physicist operating at bubble-chamber facilities grew in Bologna, under Puppi's leadership

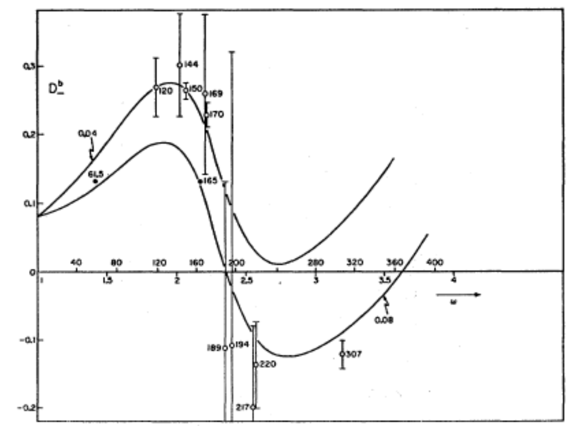


FIG. 2. The forward scattering amplitude for negative pions. The theoretical curves are calculated from Curve *A* of Fig. 1. The experimental values are as given in reference 1, except that for 307 Mev.[4] In the latter case only the statistical error is included.

[5] Beneventano, Stoppini, Tau, and Bernardini, *Proceedings of the CERN Symposium on High-Energy Accelerators and Pion Physics, Geneva, 1956* (European Organization of Nuclear Research, Geneva, 1956), Vol. 2, p. 259.

Demonstration of Parity Nonconservation in Hyperon Decay*†

F. EISLER, R. PLANO, A. PRODELL, N. SAMIOS, M. SCHWARTZ, AND J. STEINBERGER, *Columbia University, New York, New York and Brookhaven National Laboratory, Upton, New York*
P. BASSI, V. BORELLI, G. PUPPI, G. TANAKA, P. WOLOSCHEK, AND V. ZOBOLI, *Istituto di Fisica, Bologna, Italy*
M. CONVERSI, P. FRANZINI, I. MANNELLI, R. SANTANGELO, AND V. SILVESTRINI, *Istituto di Fisica, Pisa, Italy*
AND
D. A. GLASER, C. GRAVES, M. L. PERL, *University of Michigan, Ann Arbor, Michigan*

(Received October 21, 1957)

AS is well known, the question of parity conservation in particle decays was raised first by the proper-

Thanks to Puppi, Bubble chamber data from the Brookhaven Cosmotron were sent to Bologna around 1955

Towards the INFN Unit

- Since 1955, Puppi established a strong relationship with the Municipality of Bologna
  - It granted a big 10 years funding for the development of the research and the physics in the University - an important step for the institution of the INFN Unit in Bologna
- July 19th, 1956: the birth

Il prof. Rostagni, vicepresidente, tratterà il
problema della amministrazione delle sottosezioni.
Bernardini dichiara che il Consiglio Direttivo
dell'INFN ravvisa che sia giunto il momento di trasfor-
mare in Sezione dell'INFN due gruppi aggregati che han-
no ormai raggiunto un notevole grado di sviluppo. Que-
sti sono il gruppo aggregato di Bologna e quello di Pi-
sa. Egli aggiunge che la trasformazione dei due gruppi

From the minutes of the Board of Directors meeting

Bernardini says that the Board of Directors of INFN judges to be the right time to transform two aggregate groups into INFN Divisions due to their impressive degree of development. These are the group of Bologna and Pisa.

Summary

Decree
CNR
President

August 8, 1951

Decree
CNR
President

Rome
Padua
Milan
Turin

CNR research
centers

INFN divisions

July 9, 1952

INFN board of directors

Sub
Divisions

CA,FI,PI
BO ,TS, ..

September, 1952

INFN board of directors

Bologna + Pisa divisions

First Director
Giampetro Puppi
(1956 – 1960)

July 19, 1956

time

INFN organization chart on December 31, 1957

TORINO UNIT
Researchers: 33
Other personnel: 20
Foreign Resarchers: 1

MILAN UNIT
Researchers: 35
Other personnel: 22
Foreign Resarchers: 1

PADUA UNIT
Researchers: 38
Other personnel: 49
Foreign Resarchers: 3

BOLOGNA UNIT
Researchers: 39
Other personnel: 49
Foreign Resarchers: 6

PISA UNIT
Researchers: 40
Other personnel: 37

ROME UNIT
Researchers: 39
Other personnel: 52

FRASCATI NATIONAL LAB
Staff with diploma: 22
Injector staff: 9
Other personnel: 44

GENOA SUB-UNIT
Researchers: 30
Other personnel: 18

TRIESTE SUB-UNIT
Researchers: 19
Other personnel: 17

FLORENCE SUB-UNIT
Researchers: 9
Other personnel: 4

ISS SUB-UNIT

SPECIALIZATION SCHOOL NAPLES
Researchers: 6
Other personnel: 1

The National Hydrogen Bubble Chamber

- During the same Board of Directors of July 1956, M. Conversi (Pisa), G. Puppi (Bologna) and G. Salvini (Frascati electro-synchrotron) presented the project of a “National Hydrogen Bubble Chamber”, that was approved and funded

- It was an important project, the first example of collaboration among different units for a National-scale project
  - Trieste, Padua, Bologna, Pisa and Rome

Pietro Bassi

Pietro Bassi was called in Bologna from Messina to lead the project, as he was an expert since when he was in Padua

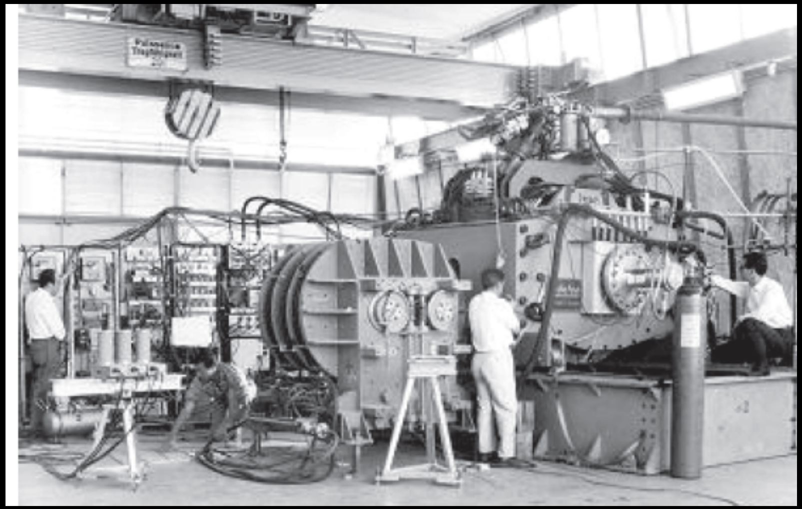
1960-1966: second director of the Unit of Bologna

1966-1970: INFN Executive Board

The device was built in Bologna between 1956 and 1958, and then moved to CERN

This project set the beginning of a tradition of design and construction of the experimental groups in Bologna

The Mechanical Workshop has its roots in this project



The bubble chamber in an experimental hall at the CERN SC at 600 MeV

SUPPLEMENTO AL VOLUME XVI, SERIE X
DEL NUOVO CIMENTO

N. 2, 1960
2° Trimestre

Three Liters Liquid Hydrogen Bubble Chamber.

P. BASSI, R. CANO, S. FOCARDI, G. GIALANELLA A. MICHELINI
and F. SAPORETTI

Istituto Nazionale di Fisica Nucleare
Sezioni di Bologna, Padova, Pisa, Roma, Trieste

(ricevuto il 5 Febbraio 1960)

Summary. — We describe a three liters liquid hydrogen bubble chamber. The total consumption of liquid hydrogen is 1.1 l/h; the distorsions are negligible.

1. – Introduction.

We have built and successfully operated a three liter liquid H_2 bubble chamber. It has been made to work with accelerators of medium energy (a few hundreds MeV), it is easy to be used and reasonably cheap. Although its building has not required special technical apparatus, the chamber disposes of all the devices necessary to make of it a precision instrument.

Here are some of its characteristics: the possibility to work in a magnetic field ((10 ÷ 20) kG); the safety of the operators against any accident due to the

IL NUOVO CIMENTO   VOL. XXVI, N. 6   16 Dicembre 1962

Proton-Proton Interaction at 560 MeV.

B. BALDONI, S. FOCARDI, H. HROMADNIK, L. MONARI and F. SAPORETTI

Istituto di Fisica dell'Università - Bologna
Istituto Nazionale di Fisica Nucleare - Sezione di Bologna

S. FEMINÒ and F. MEZZANARES

Istituto di Fisica dell'Università - Messina
Istituto Nazionale di Fisica Nucleare - Sezione Siciliana

E. BERTOLINI

Istituto di Fisica dell'Università - Padova
Istituto Nazionale di Fisica Nucleare - Sezione di Padova

G. GIALANELLA

Istituto di Fisica dell'Università - Roma
Istituto Nazionale di Fisica Nucleare - Sezione di Roma

(ricevuto il 25 Settembre 1962)

Summary. — In this paper results are given on the proton-proton interaction at 560 MeV. The experiment was performed at CERN using a hydrogen bubble chamber. The experimental results show evidence for the pion-nucleon and proton-neutron final state interactions.

Puppi acted in several directions

- Under Puppi’s initiative, physics in Bologna expanded in several fields
  - Particle and Nuclear physics
  - Electronic Microscopy (Ugo Valdrè)
  - Radioastronomy (Radiotelescope “Croce del Nord”, Marcello Ceccarelli, Gianfranco Sinigaglia, Alessandro Braccesi, Giancarlo Setti)
  - Computing (CINECA) and then the INFN center CNAF
  - Theoretical Physics (by calling Bruno Ferretti)
  - Nuclear Engineering Laboratories at Monte Cuccolino (on the Bologna hills), together with Bruno Ferretti

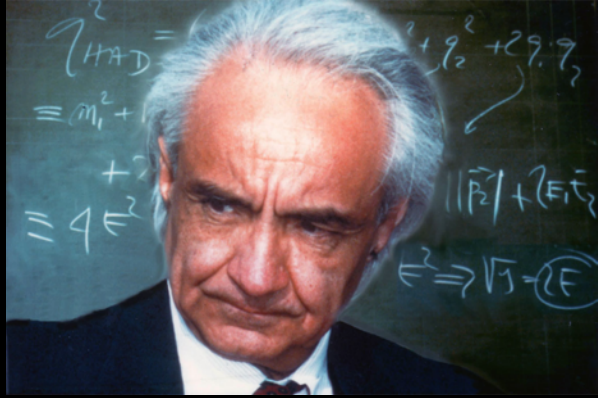
Bruno Ferretti

He played an important role in the formation of young theoreticians

- He got his degree in Bologna and in 1937 moved to Rome and joined a group led by Fermi for the study of cosmic rays (Gilberto Bernardini, Oreste Piccioni and Gian Carlo Wick)
- In 1938 he took the leadership of the group after Fermi departure for the USA

- In 1956 he became professor of Theoretical Physics in Bologna
- 1957-1959: Head of the CERN TH Division

Antonino Zichichi



➢ Third director of the Bologna INFN Unit (1967-1971)

- Professor of Physics in Bologna from 1965 (Emeritus since 2006)
- He built and is currently leading one of the bigger and older groups of Bologna

- 1977-1983: President of INFN
  - ➢ Transfer to the Italian industry of the superconducting magnets technology
  - ➢ Established the best worldwide astro-particle laboratory, the Gran Sasso Laboratory

Giorgio Giacomelli

- Director of the Institute of Physics (1975-1982)
- Director of the Department of Physics (1985-1988)

- Professor of General Physics in Bologna since 1974
- He trained many students and researchers and was leader of another large group in Bologna

Luigi Monari (“Gigi”)

- Sixth director of the INFN Unit of Bologna (1976-1982)
- Director of the Department of Physics from 1982 until his sudden death in 1985

- 1978-1982: CERN Finance Committee
- In middle ‘70s he gave origin to another group

Attilio Forino

- ➢ 7th director of the INFN Unit of Bologna (1982-1988)
- ➢ Director of the Department of Physics from (1994-2000)

- Head of a group working at fixed target experiments at CERN

Ettore Verondini - director of the Department (1988-1994)

Antonio Vitale - director of the INFN Division (1988-1994)

- Around 1995 a sizeable fraction of the nuclear group stared moving to particle physics

DEPARTMENT

Particle/Nuclear	G. Puppi (1953-1967)	INSTITUTE OF PHYSICS
Nuclear, Astronomy	M. Ceccarelli (1967-1968)	INSTITUTE OF PHYSICS
Nuclear	E. Clementel (1968-1972)	INSTITUTE OF PHYSICS
Geophysics	M. Caputo (1972-1974)	INSTITUTE OF PHYSICS
Medical Physics, C.Rays	D. Brini (1974-1975)	INSTITUTE OF PHYSICS
Particle	G. Giacomelli (1975-1982)	INSTITUTE OF PHYSICS
Particle	L. Monari (1982-1985)	DEPARTMENT OF PHYSICS
Particle	G. Giacomelli (1985-1988)	DEPARTMENT OF PHYSICS
Nuclear	E. Verondini (1988-1994)	DEPARTMENT OF PHYSICS
Particle	A. Forino (1994-2000)	DEPARTMENT OF PHYSICS
Particle	A. M. Rossi (2000-2006)	DEPARTMENT OF PHYSICS
Particle	P. Capiluppi (2006-2011)	DEPARTMENT OF PHYSICS
Particle	N. Semprini (2011-now)	DEPARTMENT OF PHYSICS AND ASTRONOMY

1952 · 1960 · 1968 · 1976 · 1984 · 1992 · 2000 · 2008 · 2016

INFN UNIT

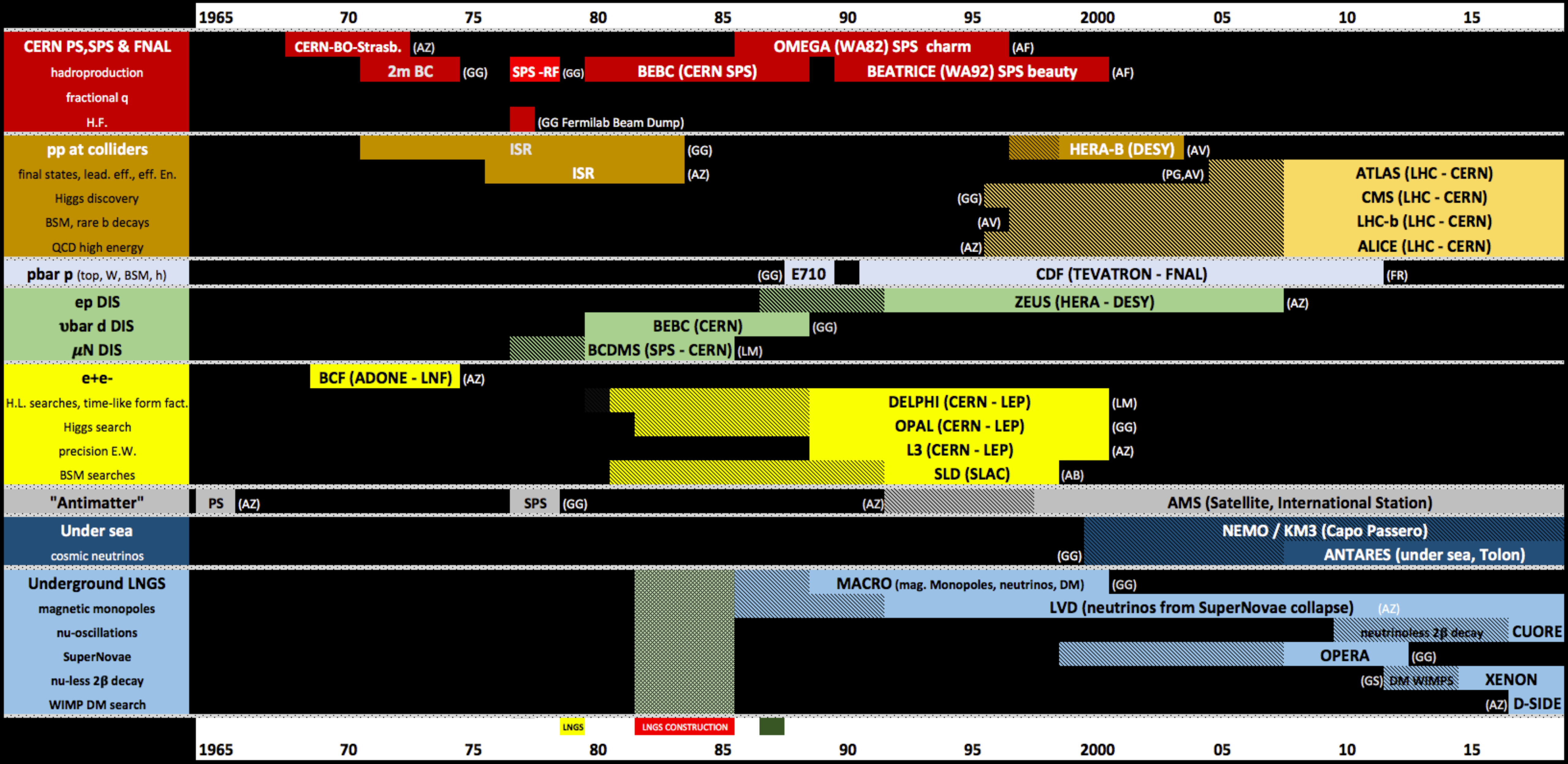
G. Puppi (1956-1960)	Particle/Nuclear
P. Bassi (1960-1966)	Particle/Nuclear
A. Zichichi (1967-1971)	Particle
P. Veronesi (1971-1973)	Nuclear
S. Focardi (1973-1976)	Particle
L. Monari (1976-1982)	Particle
A. Forino (1982-1988)	Paticle
A. Vitale (1988-1994)	Nuclear/Particle
P. Giusti (1994-2000)	Particle
M Basile (2000-2006)	Particle
A. Zoccoli (2006-2011)	Particle
GB (2012-now)	Particle

Main experimetal activities: a quick glance

Main scientific enterprises (incomplete list)

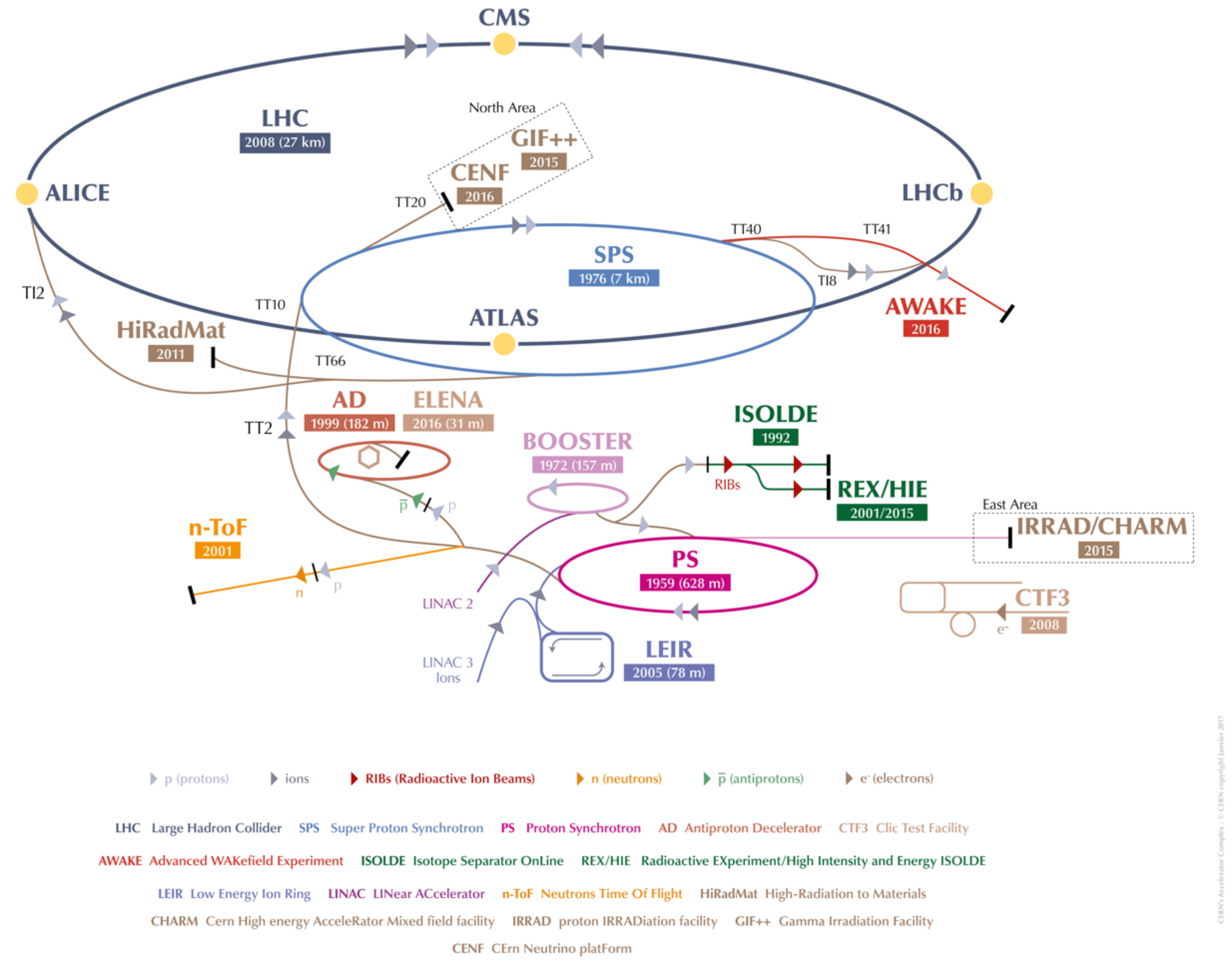
- Not touched: the early Bubble Chamber era, Nuclear Physics at low-intermediate energy, Technological and Applied research and Theoretical Physics
- Hadron physics at fixed target (CERN: PS, SPS and FNAL)
- Energy frontier and precision physics at *pp* and $p\bar{p}$ and *p-Ion* colliders (CERN: ISR, LHC, FNAL: TeVatron)
- Deep Inelastic Scattering (CERN: μ and υ beams, DESY: HERA $e^{\pm}p$ collider)
- Physics at e^+e^- colliders (Frascati: ADONE, CERN: LEP, SLAC: SLC)
- Antimatter (pioneering production experiments at CERN, search in space on satellite with AMS)
- Astroparticle, Neutrino and Dark Matter underground (LNGS) and under sea water

A 2d summary

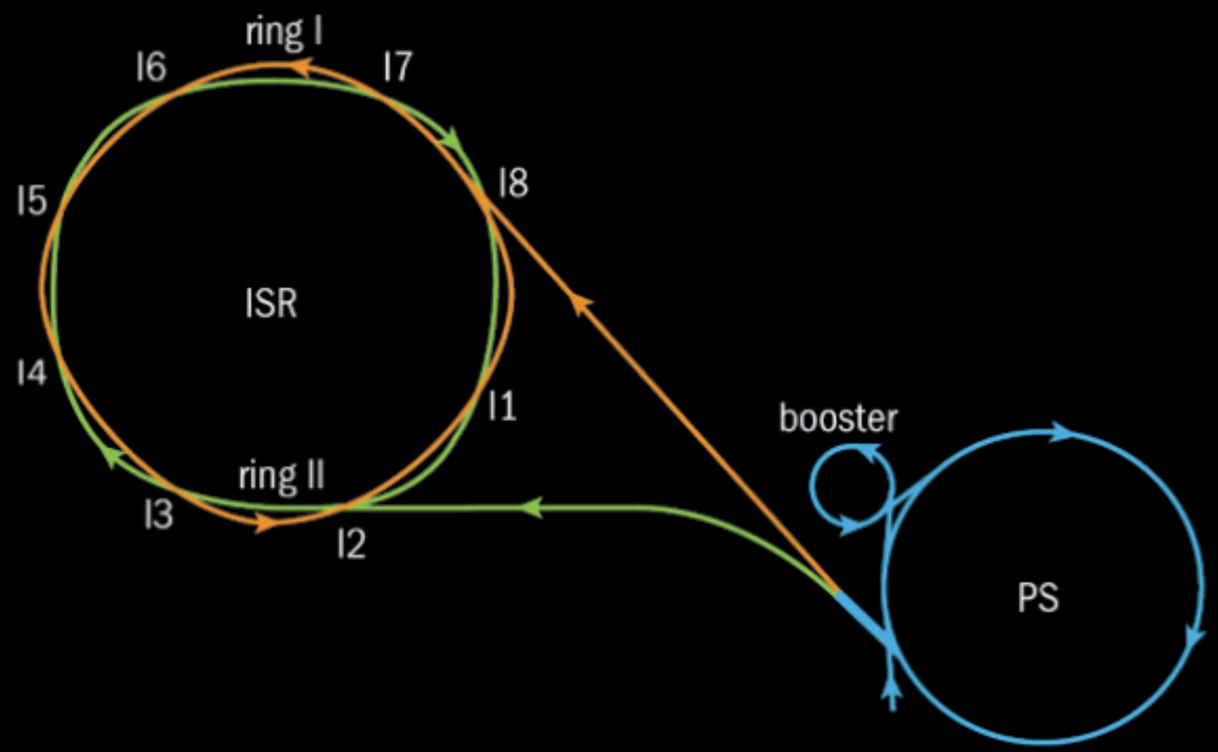


1965 70 75 80 85 90 95 2000 05 10 15
CERN PS,SPS & FNAL
hadroproduction
fractional q
H.F.
CERN-BO-Strasb. (AZ)
OMEGA (WA82) SPS charm (AF)
2m BC (GG)
SPS -RF (GG)
BEBC (CERN SPS)
BEATRICE (WA92) SPS beauty (AF)
(GG Fermilab Beam Dump)
pp at colliders
final states, lead. eff., eff. En.
Higgs discovery
BSM, rare b decays
QCD high energy
ISR (GG)
ISR (AZ)
HERA-B (DESY) (AV)
(PG,AV) ATLAS (LHC - CERN)
(GG) CMS (LHC - CERN)
(AV) LHC-b (LHC - CERN)
(AZ) ALICE (LHC - CERN)
pbar p (top, W, BSM, h)
(GG) E710
CDF (TEVATRON - FNAL) (FR)
ep DIS
νbar d DIS
μN DIS
ZEUS (HERA - DESY) (AZ)
BEBC (CERN) (GG)
BCDMS (SPS - CERN) (LM)
e+e-
H.L. searches, time-like form fact.
Higgs search
precision E.W.
BSM searches
BCF (ADONE - LNF) (AZ)
DELPHI (CERN - LEP) (LM)
OPAL (CERN - LEP) (GG)
L3 (CERN - LEP) (AZ)
SLD (SLAC) (AB)
"Antimatter"
PS (AZ)
SPS (GG)
(AZ)
AMS (Satellite, International Station)
Under sea
cosmic neutrinos
NEMO / KM3 (Capo Passero)
(GG) ANTARES (under sea, Tolon)
Underground LNGS
magnetic monopoles
nu-oscillations
SuperNovae
nu-less 2β decay
WIMP DM search
MACRO (mag. Monopoles, neutrinos, DM) (GG)
LVD (neutrinos from SuperNovae collapse) (AZ)
neutrinoless 2β decay CUORE
OPERA (GG)
(GS) DM WIMPS XENON
(AZ) D-SIDE
LNGS
LNGS CONSTRUCTION

ACCELERATORS AT CERN



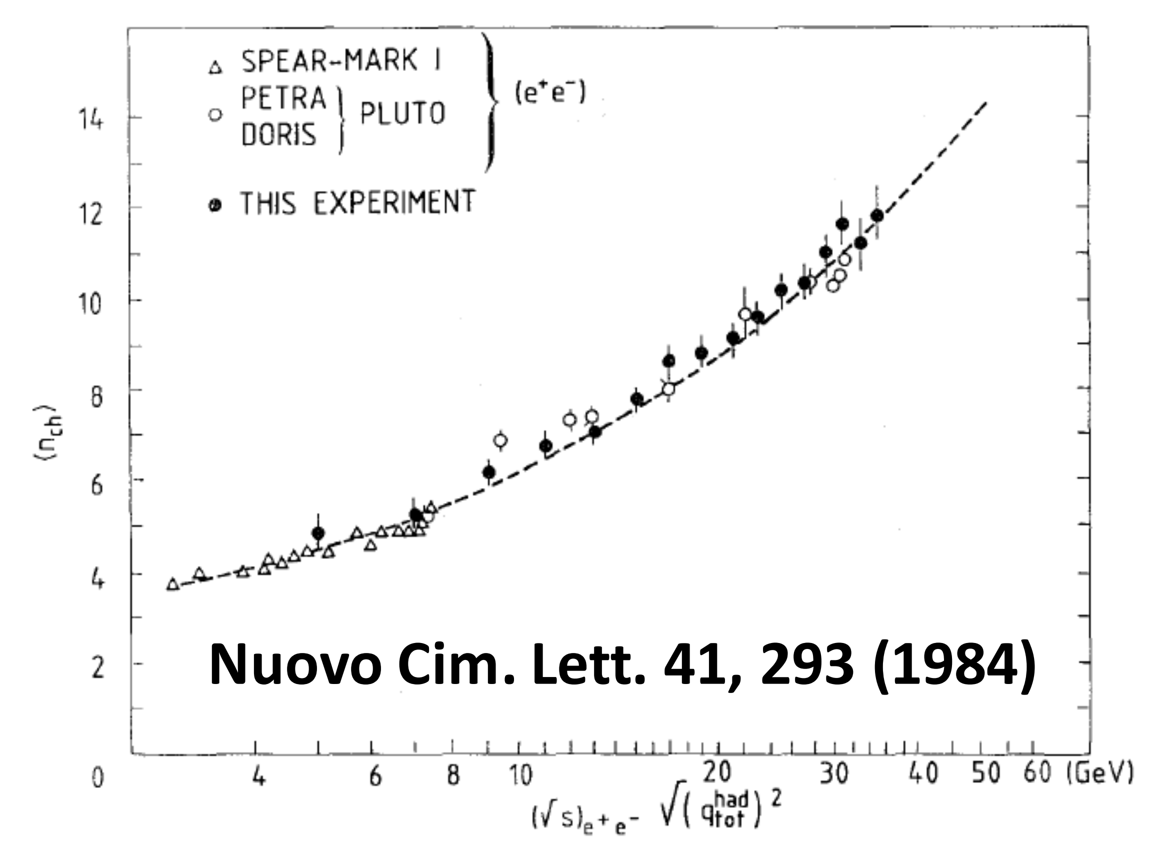
1971 - 1983
p+p 31+31 GeV max.



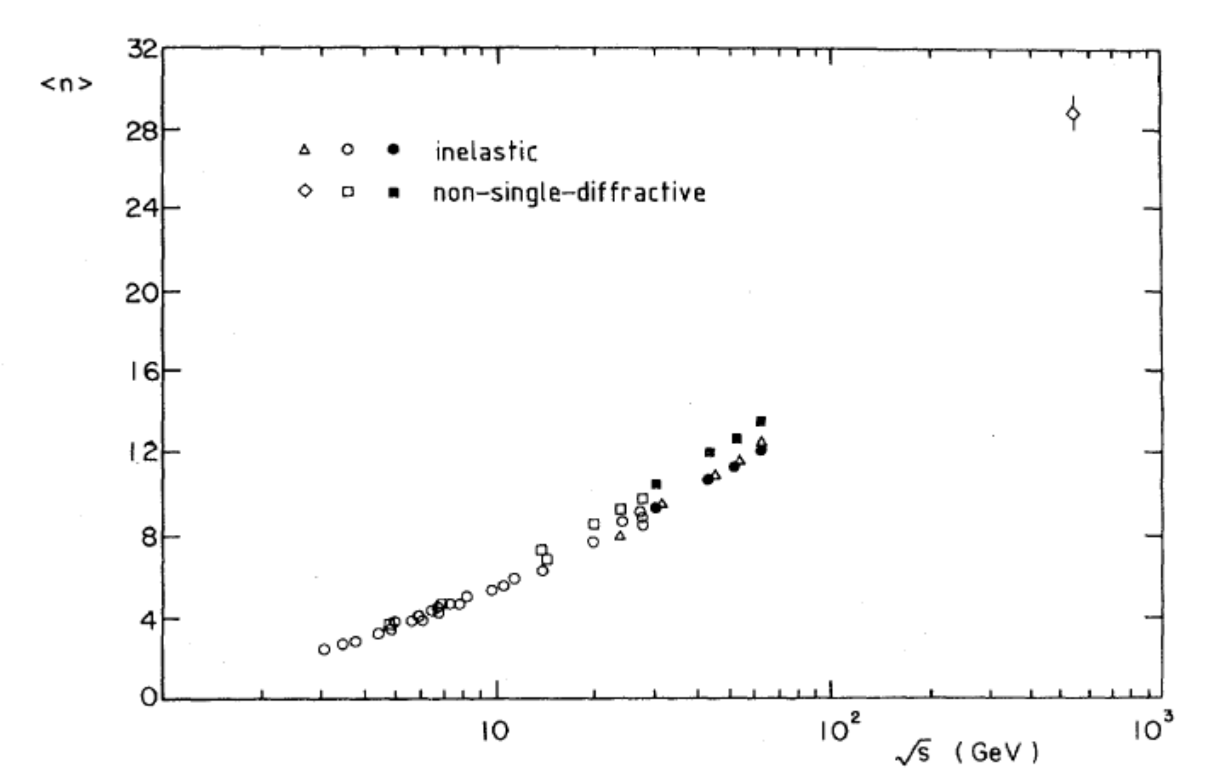
Hadron colliders

ISR

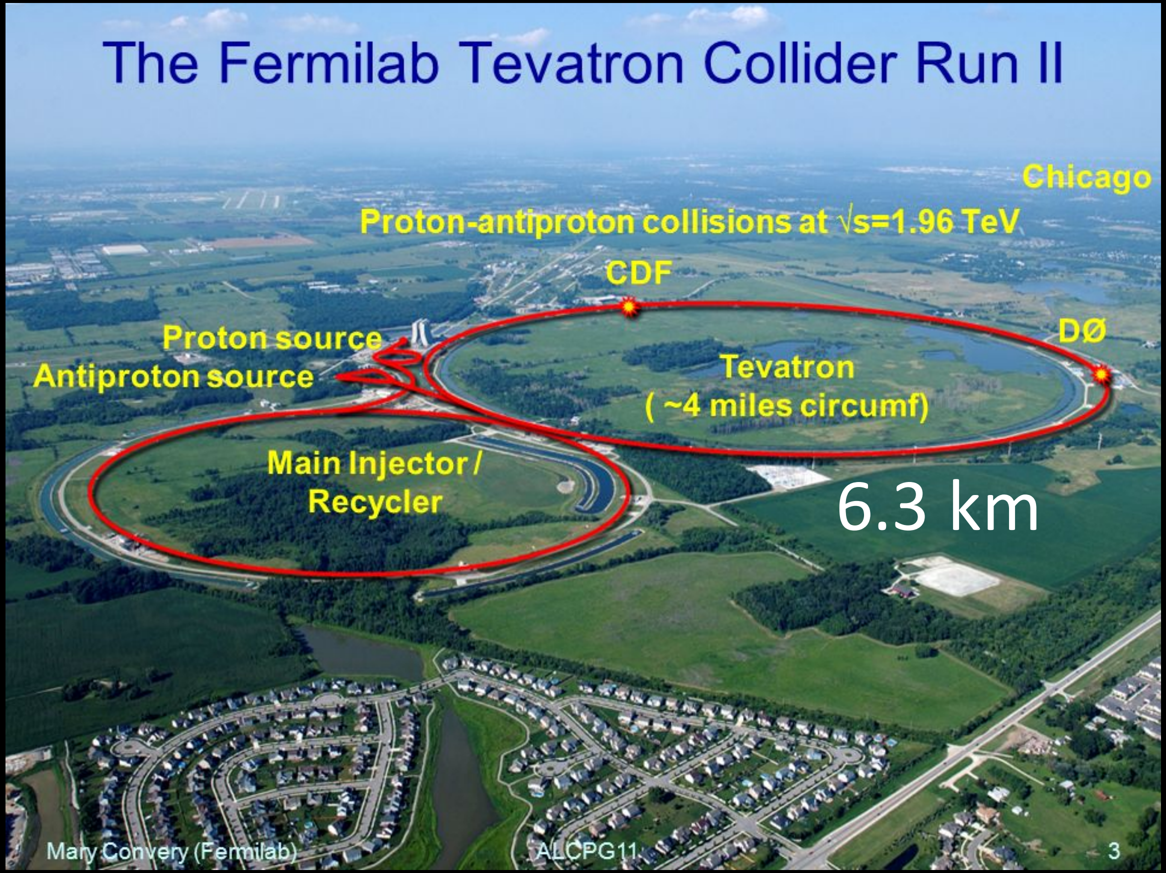
F. Noferini talk



Nuovo Cim. Lett. 41, 293 (1984)



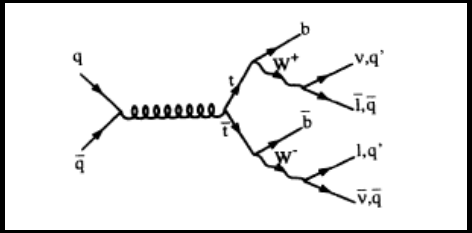
Phys. Rev. D 30, 528 (1984)



Completed in 1983

Main injector 1994-1999

Terminated on 30/9/2011 after 28 years



CDF, 1994

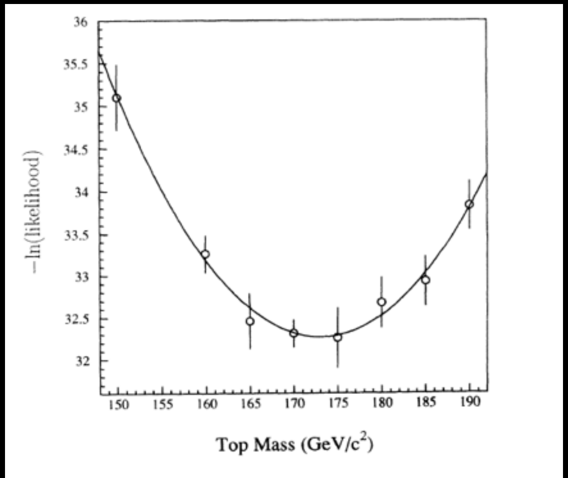


FIG. 62. Likelihood fit of the top mass.

PHYSICAL REVIEW D — VOLUME 50, NUMBER 5 — 1 SEPTEMBER 1994

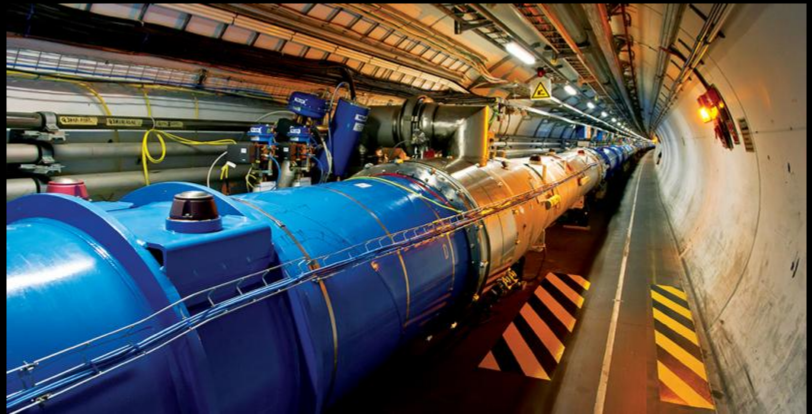
ARTICLES

Evidence for top quark production in $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV

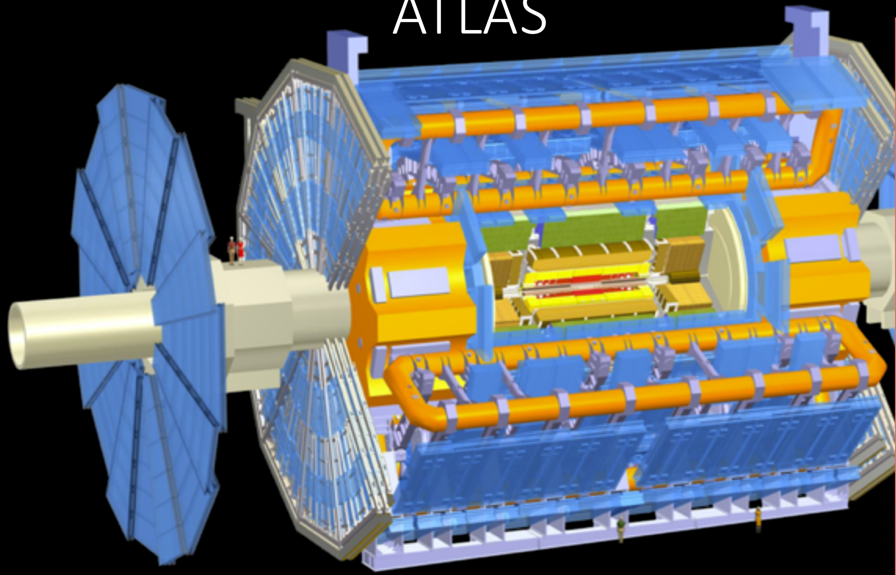
The Large Hadron Collider (LHC)

Started 2009

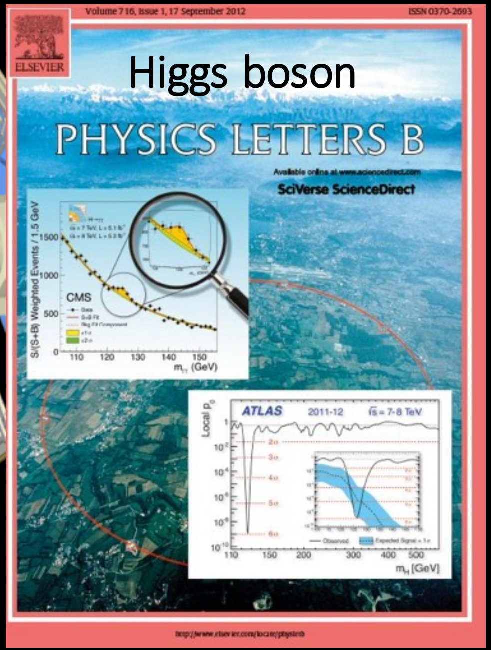
CM Energy 13 TeV from May, 2015



ATLAS



Higgs boson


Volume 716, Issue 1, 17 September 2012

ISSN 0370-2693

ELSEVIER

PHYSICS LETTERS B

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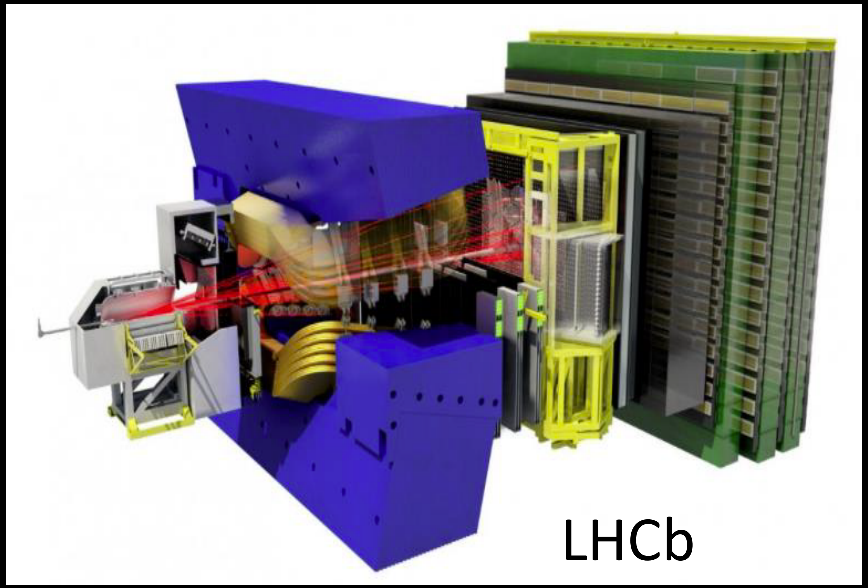
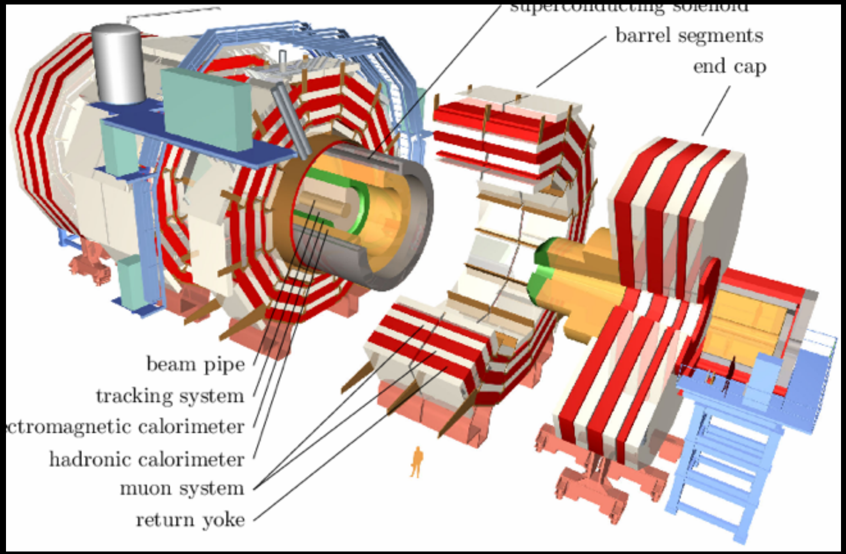
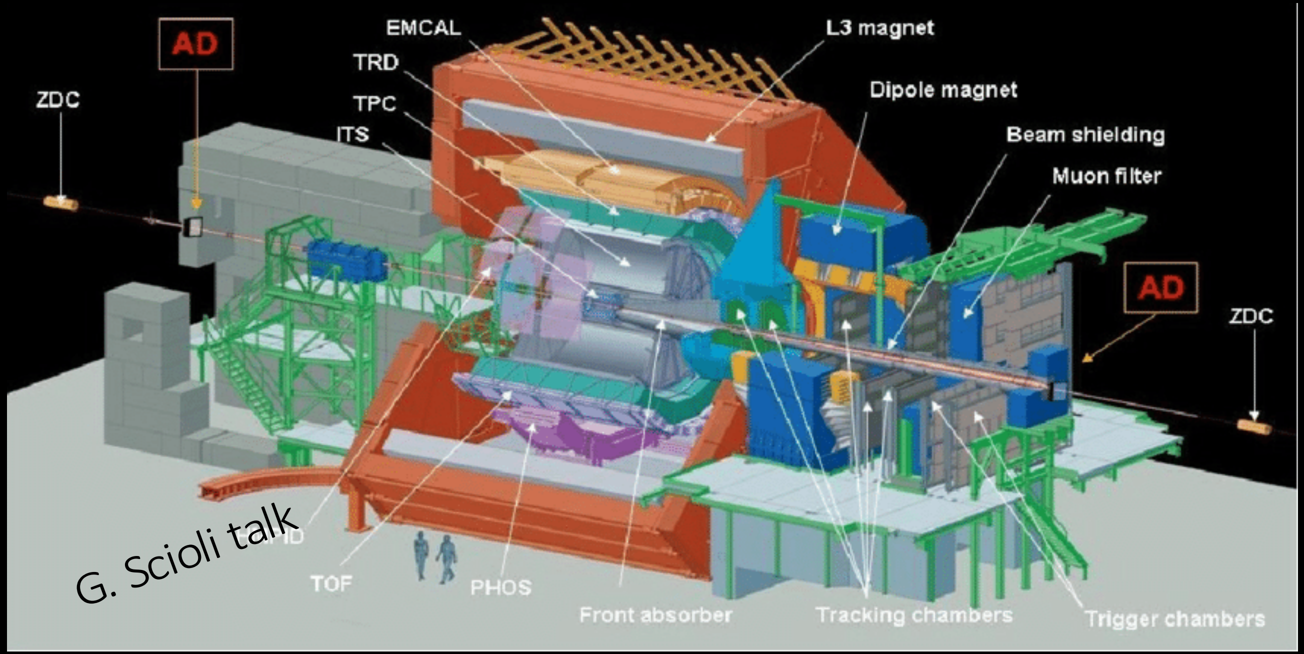


CMS

ALICE





G. Scioli talk

Combined Measurement of the Higgs Boson Mass in pp Collisions at $\sqrt{s} = 7$ and 8 TeV with the ATLAS and CMS Experiments

The ATLAS and CMS Collaborations*

Phys.Rev.Lett. 114 (2015) 191803

Abstract

A measurement of the Higgs boson mass is presented based on the combined data samples of the ATLAS and CMS experiments at the CERN LHC in the $H \to \gamma\gamma$ and $H \to ZZ \to 4\ell$ decay channels. The results are obtained from a simultaneous fit to the reconstructed invariant mass peaks in the two channels and for the two experiments. The measured masses from the individual channels and the two experiments are found to be consistent among themselves. The combined measured mass of the Higgs boson is $m_H = 125.09 \pm 0.21\,(\text{stat.}) \pm 0.11\,(\text{syst.})$ GeV.

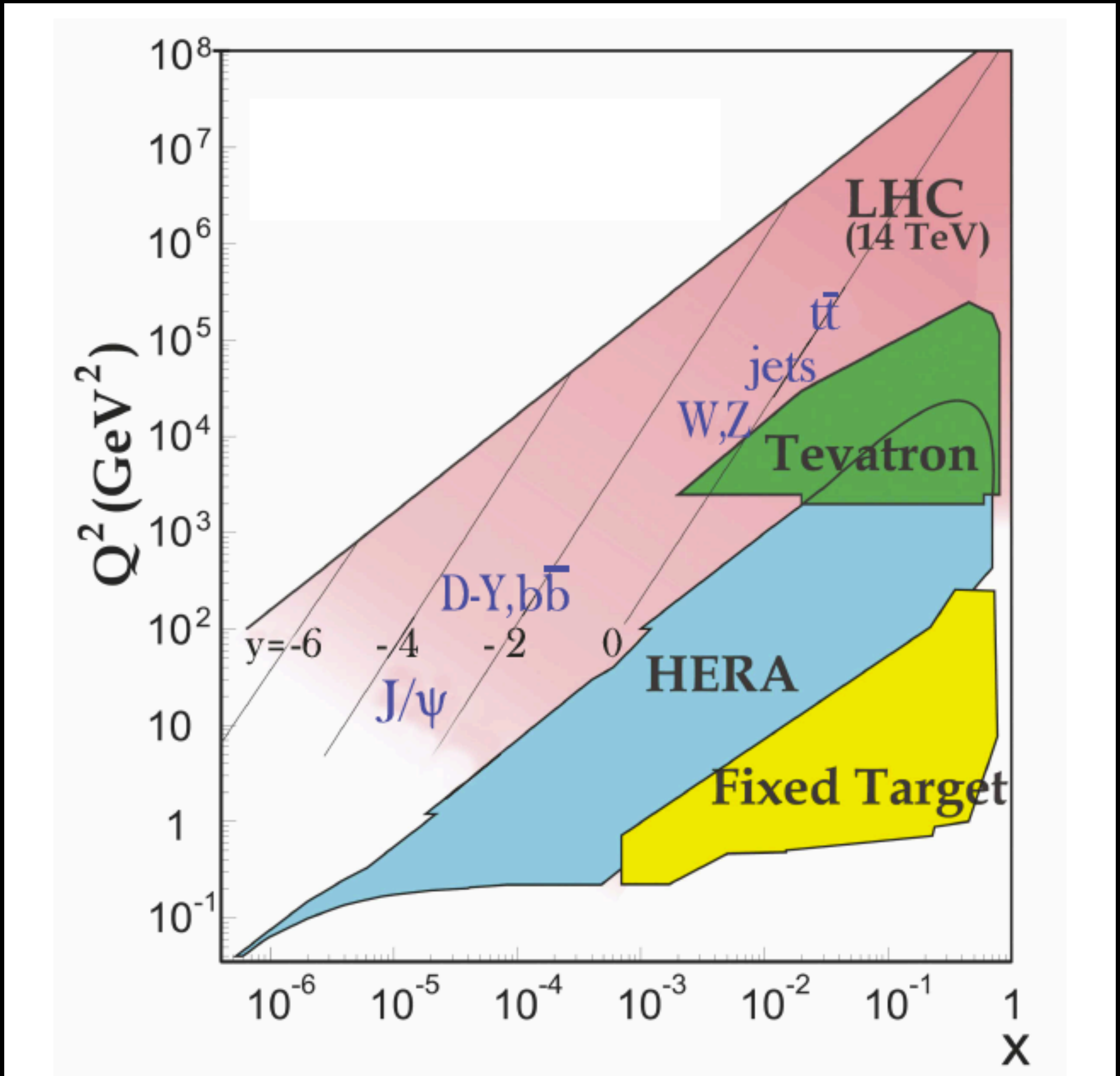
Run 1 data

$H \to \gamma\gamma$

$H \to ZZ \to 4\ell$

$$m_H = 125.09 \pm 0.24 \text{ GeV}$$
$$= 125.09 \pm 0.21\,(\text{stat.}) \pm 0.11\,(\text{syst.}) \text{ GeV}$$

DIS lepton-nucleon



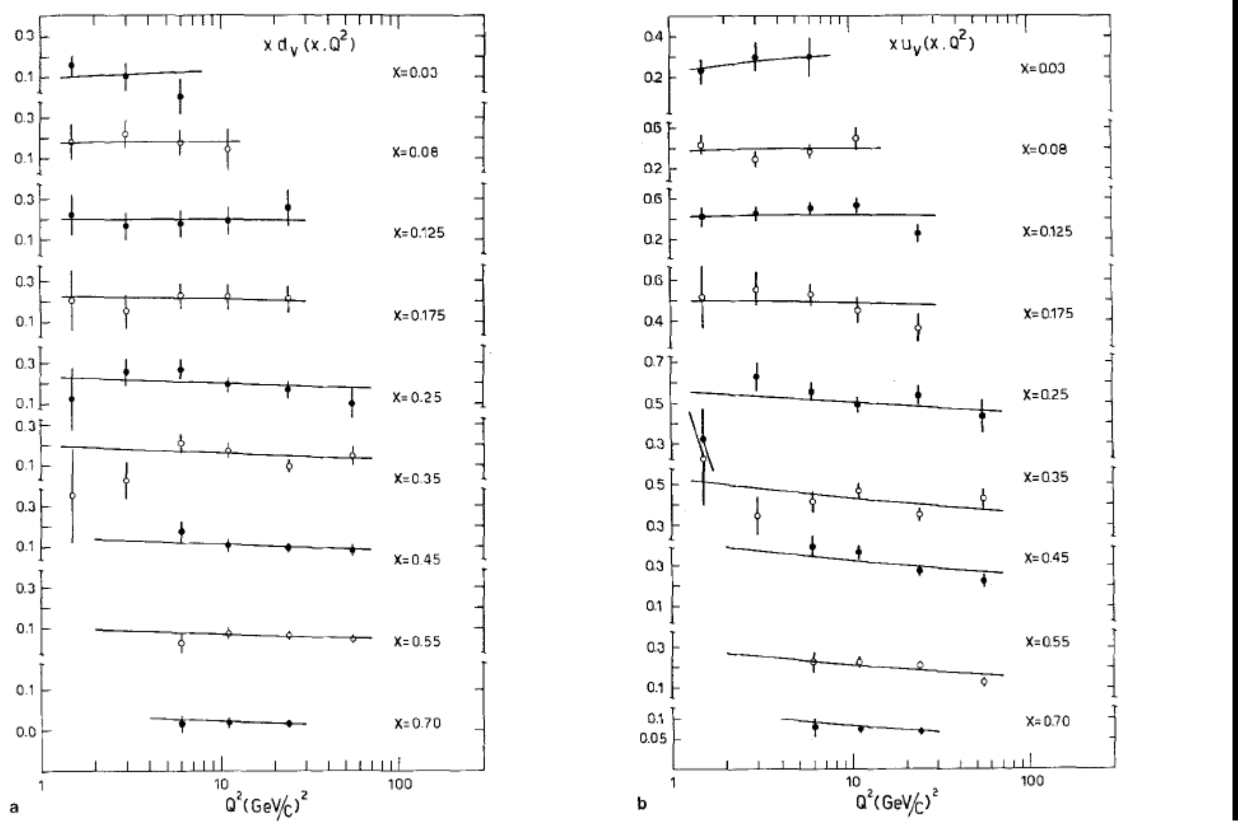


Fig. 3a and b. x and Q^2 dependence of the se
obtained with $W^2 > 3$ GeV^2, using $F_2^{\nu n}/2$ and F_2

BEBC

Z. Phys. C – Particles and Fields 28, 321–333 (1985)

Zeitschrift für Physik C Particles and Fields

1985

Q^2 Dependence of the Proton and Neutron Structure Functions from Neutrino and Antineutrino Scattering in Deuterium

D. Allasia[7], C. Angelini[5], A. Baldini[5], L. Bertanza[5], A. Bigi[5], V. Bisi[7], F. Bobisut[4], T. Bolognese[6], A. Borg[6], E. Calimani[4], P. Capiluppi[3], R. Casali[5], S. Ciampolillo[4], R. Cirio[7a], J. Derkaoui[3b], M.L. Faccini-Turluer[6], V. Flaminio[5], A.G. Frodesen[2], D. Gamba[7], G. Giacomelli[3], H. Huzita[4], B. Jongejans[1], I. Lippi[6c], M. Loreti[4], C. Louedec[6], G. Mandrioli[3], A. Margiotta[3], A. Marzari-Chiesa[7], A. Nappi[5], R. Pazzi[5], L. Riccati[7], A. Romero[7], A.M. Rossi[3], A. Sconza[4], P. Serra-Lugaresi[3], A. Tenner[1], G.W. van Apeldoorn[1], P. van Dam[1], N. van Eijndhoven[1], D. Vignaud[6], C. Visser[1d], R. Wigmans[1a]

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Received 8 March 1985

$\mu N \to \mu X$ BCDMS, CERN-NA4

Volume 223, number 3,4 PHYSICS LETTERS B 15 June 1989

1989

A HIGH STATISTICS MEASUREMENT OF THE PROTON STRUCTURE FUNCTIONS $F_2(x, Q^2)$ AND R FROM DEEP INELASTIC MUON SCATTERING AT HIGH Q^2

BCDMS Collaboration

A.C. BENVENUTI, D. BOLLINI, G. BRUNI, T. CAMPORESI, L. MONARI [1], F.L. NAVARRIA
Dipartimento di Fisica dell'Università and INFN, I-40126 Bologna, Italy

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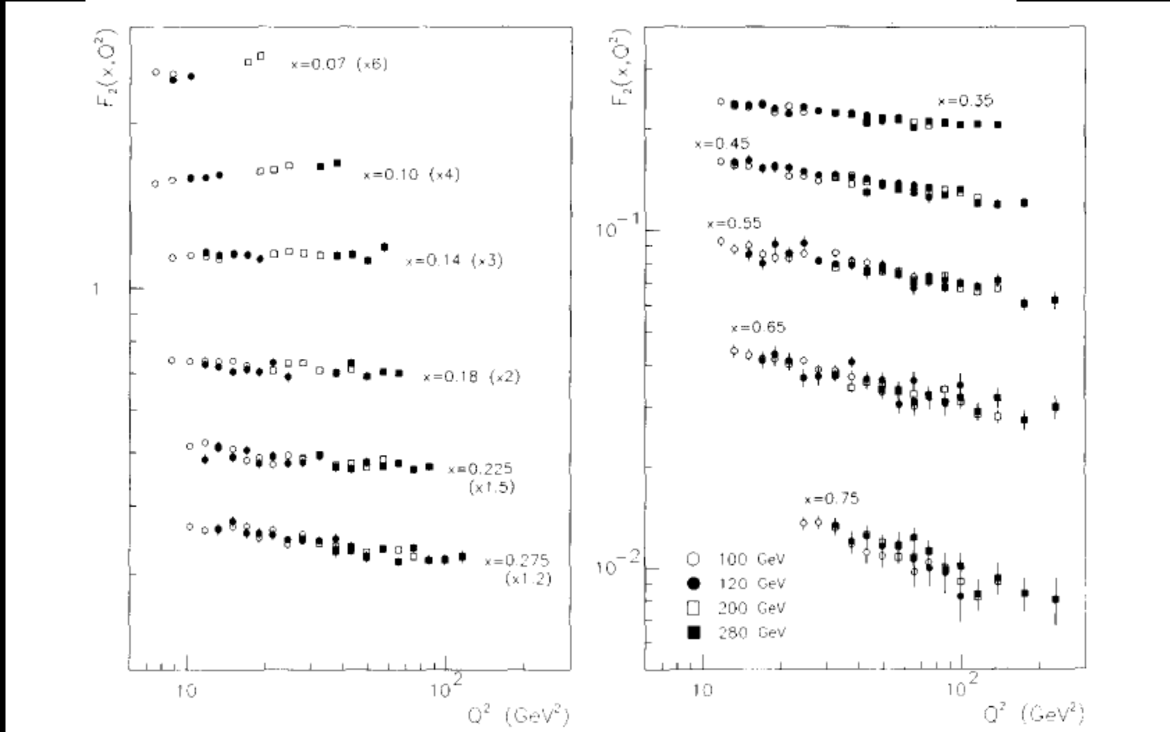
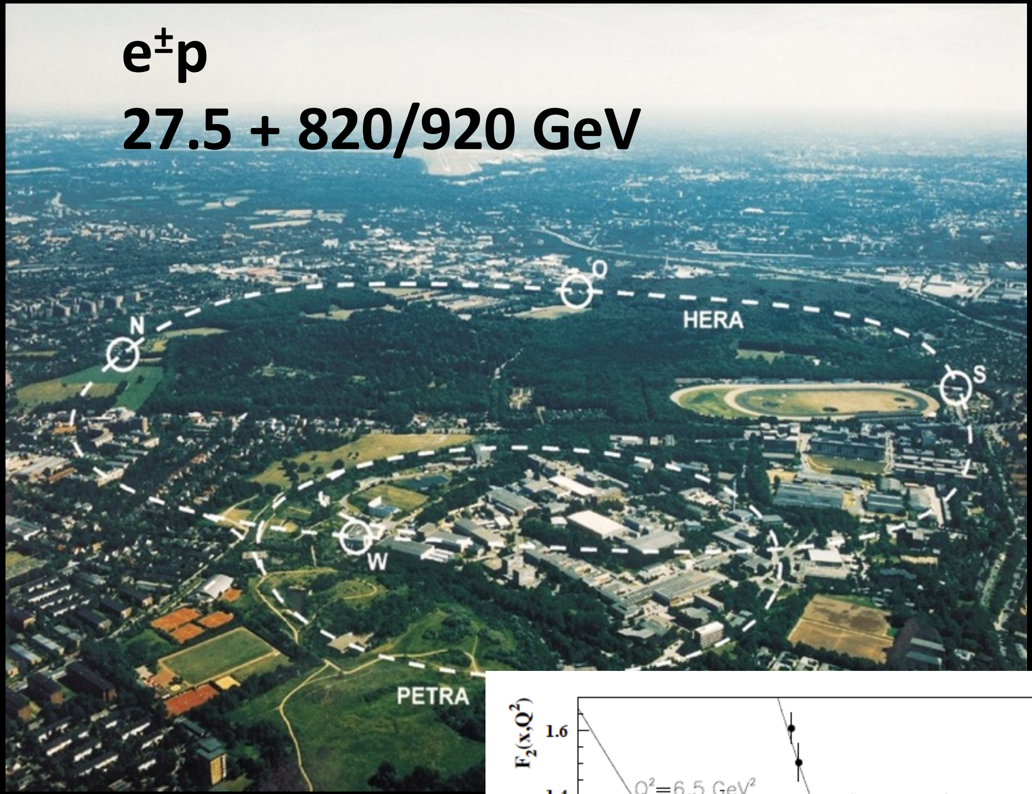
Sektion Physik der Universität, D-8000 Munich, Fed. Rep. Germany [11]

M. CRIBIER, J. FELTESSE, A. MILSZTAJN, A. OURAOU, P. RICH-HENNION, Y. SACQUIN, G. SMADJA and M. VIRCHAUX
DPhPE, CEN Saclay, F-91191 Gif-sur-Yvette Cedex, France

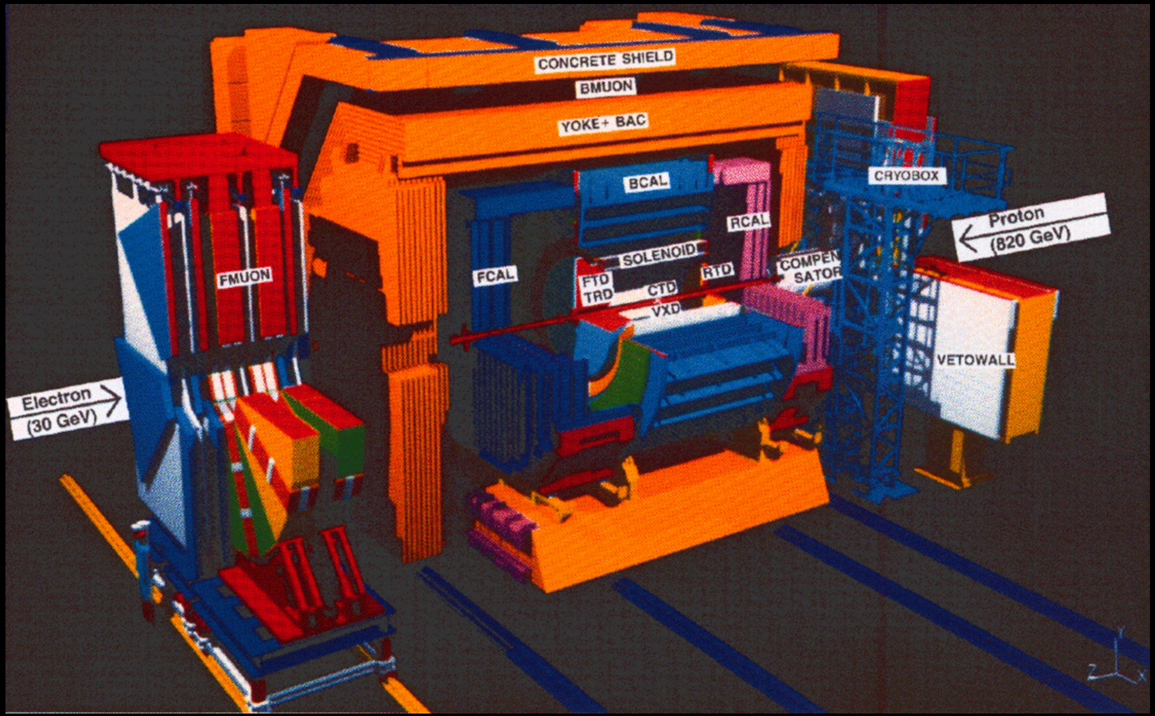
Received 8 March 1989

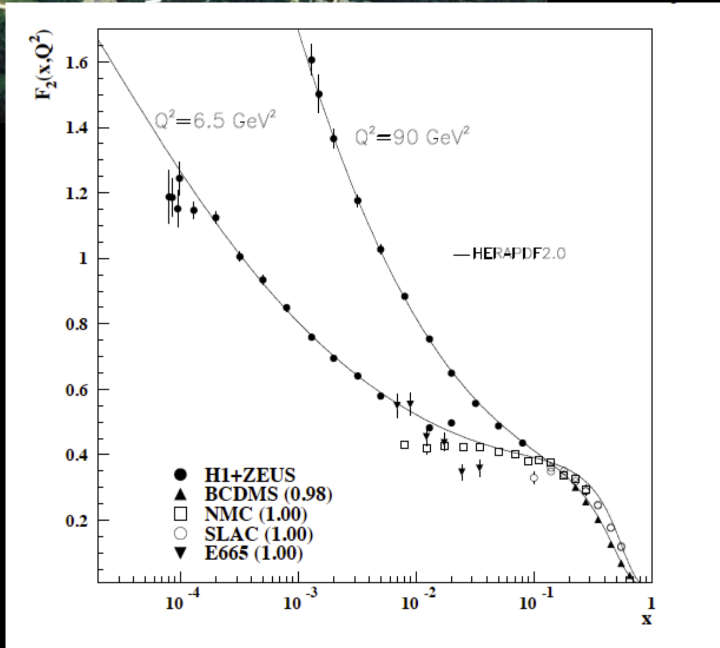


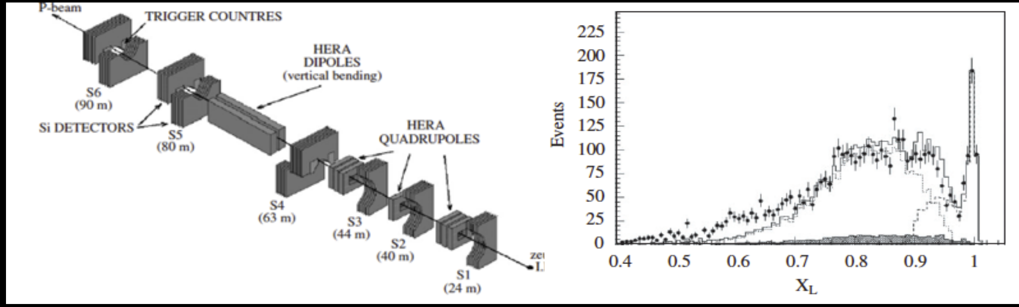
HERA ep collider DESY



1992 - 2007

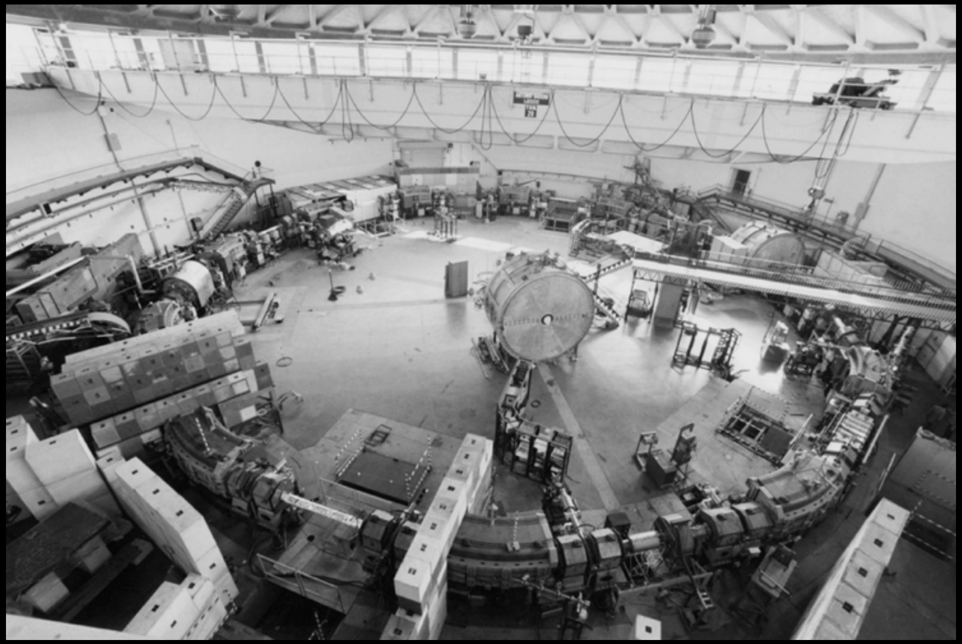






Physics at e^+e^- colliders: ADONE (early days)

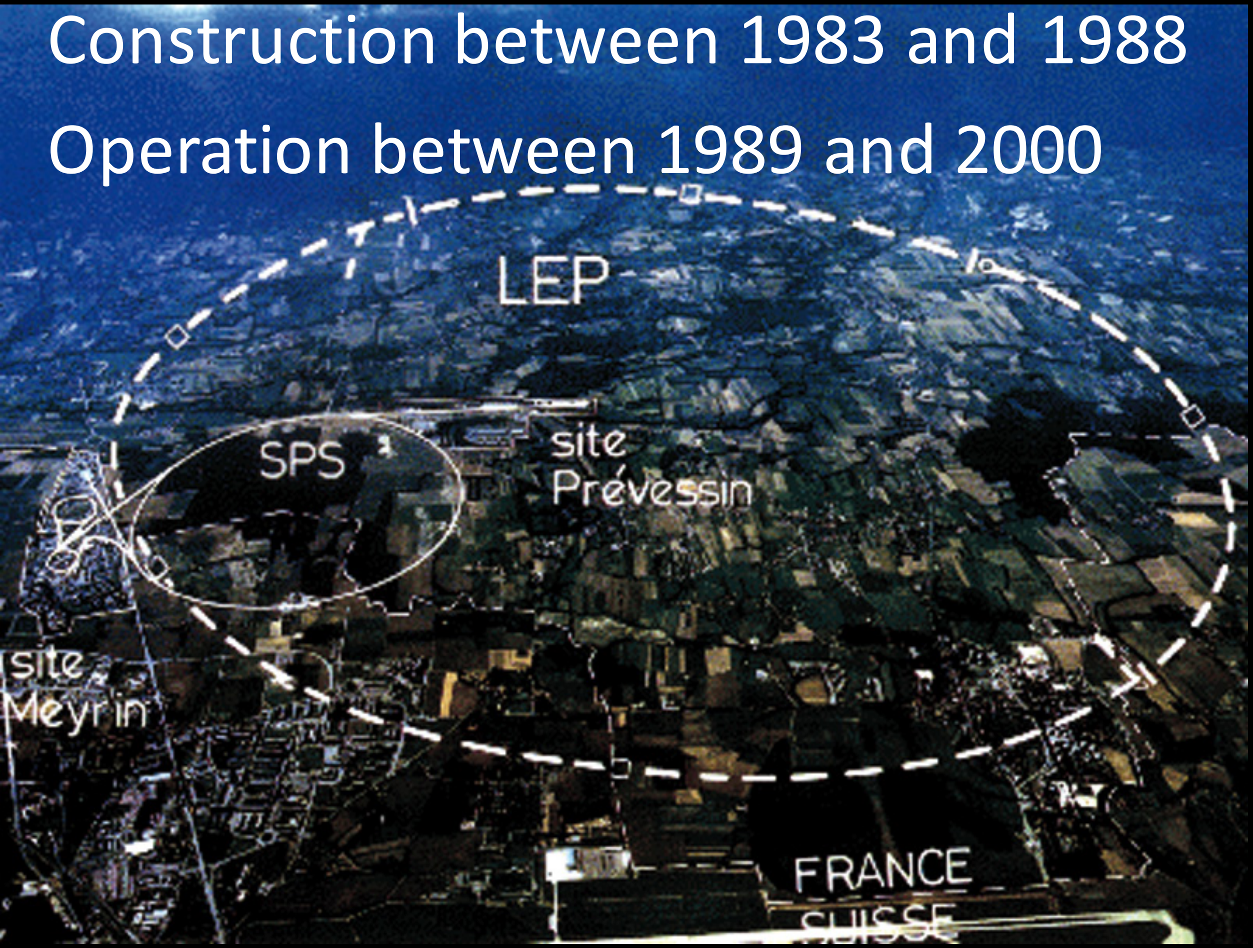
At the end of 1969 the first world "big" e^+e^- collider Adone was ready to do physics in Frascati (1.5 + 1.5 GeV)



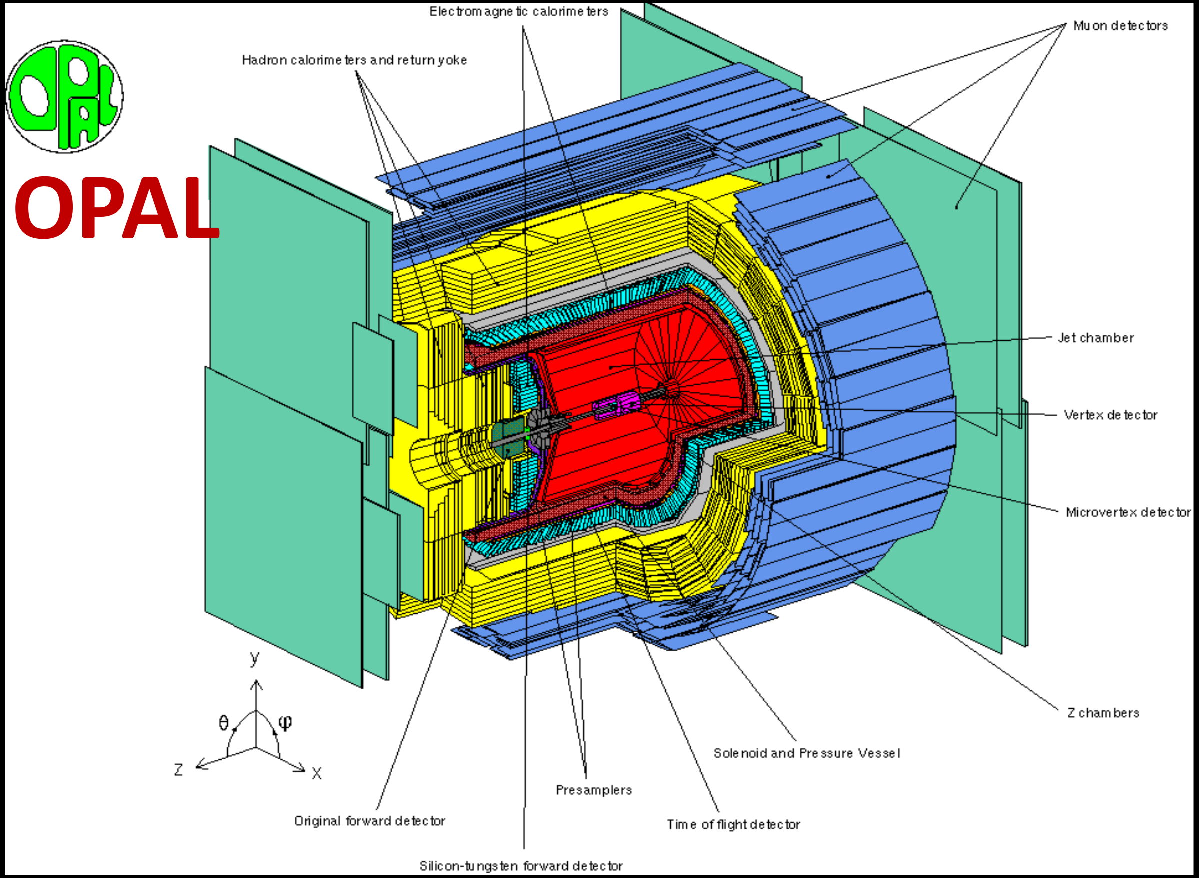
F. Palmonari talk

- Four groups were selected for physics
  - Frascati-Rome: $\gamma\gamma$ experiment – neutral final states
  - Frascati-Napels-Pavia-Rome: charged and pp final states
  - Frascati-Padua-Rome: "$\boldsymbol{\mu}\gamma$" experiment, $\boldsymbol{\mu}$, π and K pairs
  - Bologna-Cern-Frascati (BCF): π and K form factors, search for a heavy-lepton (A.Z.)

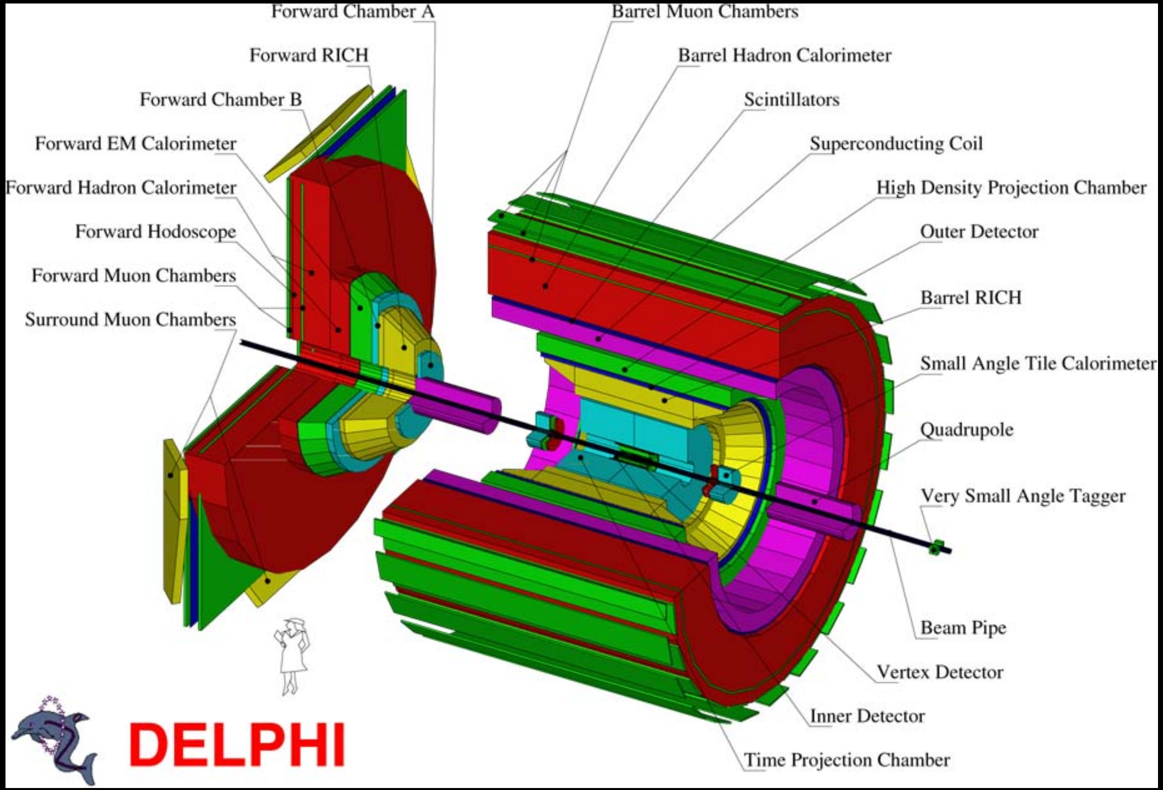
Physics at e^+e^- colliders: LEP (~ 1989 – 2000)



- cms Energy 91 GeV (1989) – 209 GeV (2000)
- Huge amount of physics at the electroweak scale
- 3 groups in Bologna
  - DELPHI (construction and analysis) - LM
  - OPAL (construction and analysis) - GG
  - L3 (analysis) - AZ



Bologna group (GG): Hadron Calorimeter (LST-iron), Luminosity monitor, Endcap Scintillating Tiles (phase 2)



Bologna group (LM, FLN): High Projection Chamber, taggers, trigger

Search for SM Higgs Boson at LEP

ALEPH, DELPHI, L3, OPAL

Phys.Lett. B565 (2003) 61-75

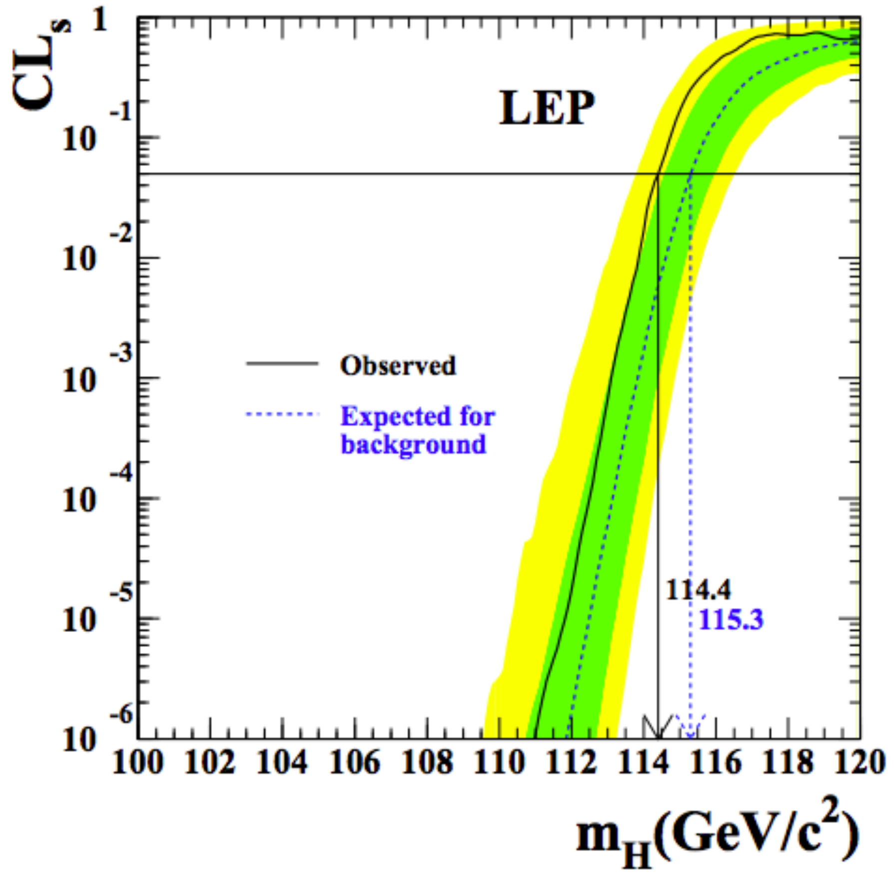


Figure 9: The ratio $CL_s = CL_{s+b}/CL_b$ for the signal plus background hypothesis. Solid line: observation; dashed line: median background expectation. The dark and light shaded bands around the median expected line correspond to the 68% and 95% probability bands. The intersection of the horizontal line for $CL_s = 0.05$ with the observed curve is used to define the 95% confidence level lower bound on the mass of the Standard Model Higgs boson.

Precision Electroweak Measurements on the Z Resonance

Phys.Rept. 427 (2006) 257-454

The ALEPH, DELPHI, L3, OPAL, SLD Collaborations,[1]
the LEP Electroweak Working Group,[2]
the SLD Electroweak and Heavy Flavour Groups

$$m_Z = 91.1875 \pm 0.0021 \text{ GeV}$$
$$\Gamma_Z = 2.4952 \pm 0.0023 \text{ GeV}$$
$$\rho_\ell = 1.0050 \pm 0.0010$$
$$\sin^2\theta_{\text{eff}}^{\text{lept}} = 0.23153 \pm 0.00016\,.$$

ANTIMATTER

IL NUOVO CIMENTO Vol. XXXIX, N. 1 1° Settembre 1965

1965, p Be collisions at the CERN PS

Experimental Observation of Antideuteron Production.

T. Massam, Th. Muller (*), B. Righini, M. Schneegans (*) and A. Zichichi
CERN - Geneva

(ricevuto il 13 Marzo 1965)

Summary. — The results of an experiment which show the existence of antideuterons in the production process proton-beryllium are reported.

We report here the results of an experiment on the production of antideuterons in proton-beryllium collisions. The beam used for the investigation was the high-intensity, partially-separated negative beam of the CERN Proton-Synchrotron. The beam layout is shown in Fig. 1 and its caracteristics are summarized in Table I. The details of the beam are described elsewhere [1], so we will mention only the points relevant to the detection of antideuterons

Table I. – *Basic parameters of the beam.*

Production angle	111 mrad
Target	Be; ∅ 1×20 mm; at 100 mrad
Horizontal angular acceptance	±32 mrad
Vertical angular acceptance	±6.2 mrad
Maximum momentum band	±2%
Total length	61 m
Beam size in the experimental area	horizontal 3 cm; vertical 2.2 cm

Nuclear Physics B144 (1978) 317–328

1978, p Be - p Al collisions , CERN SPS beam

PRODUCTION OF d, t, ^{3}He, $\bar{d}$, $\bar{t}$ and $\overline{^3\text{He}}$ BY 200 GeV PROTONS

W. BOZZOLI *, A. BUSSIÈRE ***, G. GIACOMELLI *, E. LESQUOY **, R. MEUNIER **, L. MOSCOSO **, A. MULLER **, F. RIMONDI * and S. ZYLBERAJCH *

Received 14 April 1978
(Revised 20 July 1978)

Data are presented on the yields of d, t, ^{3}He, $\bar{d}$, $\bar{t}$ and $\overline{^3\text{He}}$ with laboratory momenta between 12 and 37 GeV/*c* produced by 200 GeV protons on beryllium and aluminium. The production yield of nuclei depends significantly on the target nucleus, while the $\bar{d}$ production is independent of target material. The mass dependence of the production cross section is exponential for both nuclei and antinuclei.

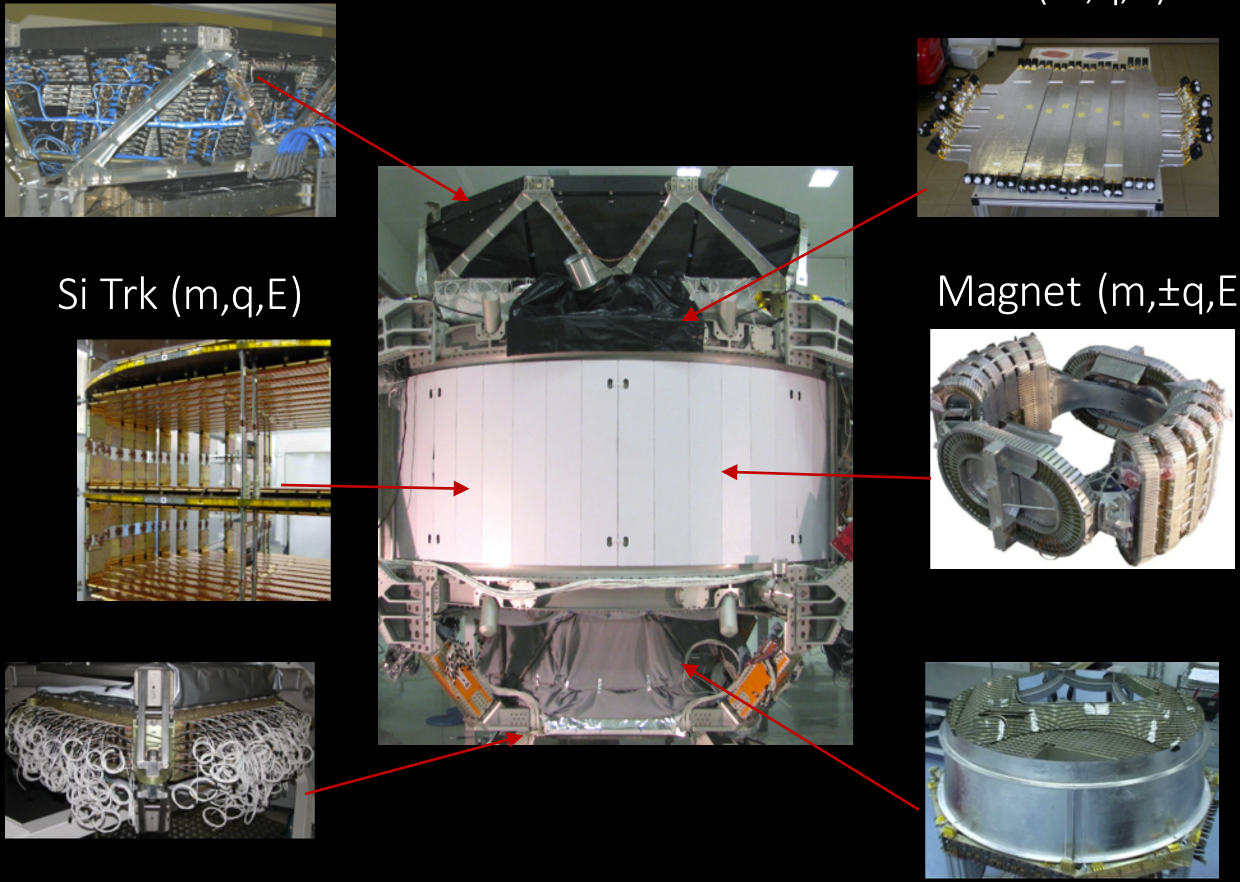
1. Introduction

We report experimental results on the 0° production of d, t, ^{3}He, $\bar{d}$, $\bar{t}$ and $\overline{^3\text{He}}$ with momenta between 12 and 37 GeV/*c* in p-beryllium and p-aluminium collisions at 200 GeV/*c*.

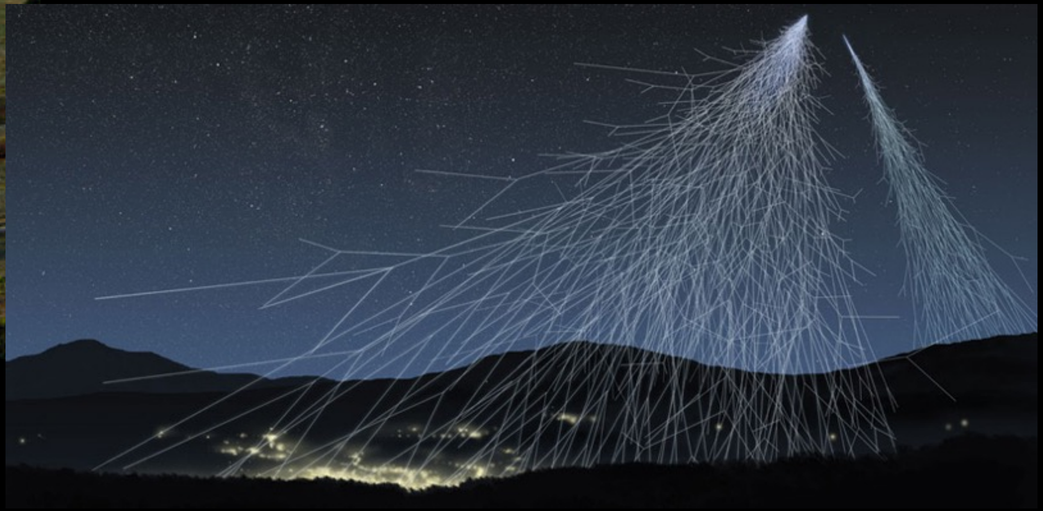
These data were obtained in the S_1 beam of the CERN-SPS during a particle search experiment (WA 33) [1].

Search in space with AMS

A. Contin Talk

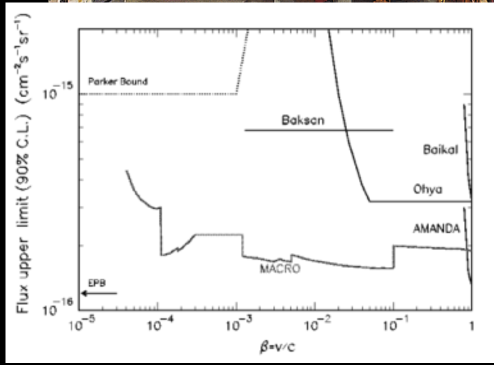


Gran Sasso National Laboratories

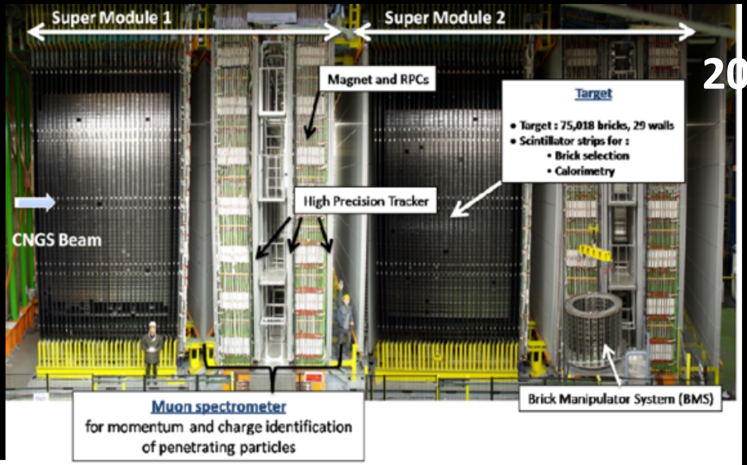



© Franco Fasciolo
INFN-LABORATORI
NAZIONALI
DEL GRAN SASSO

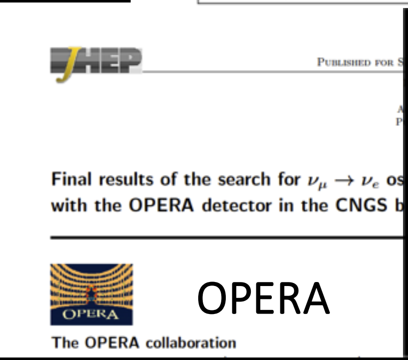
MACRO 1995-2000



E. Scapparone talk



2003-2008

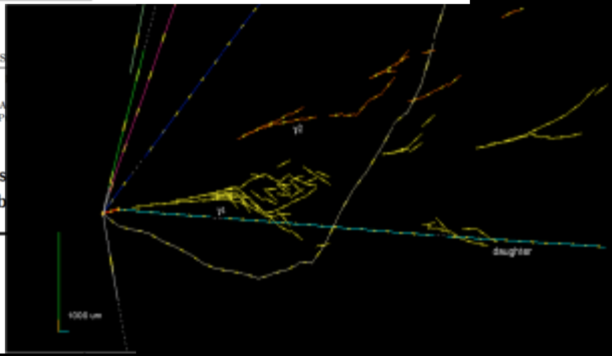

JHEP

Published for S

Final results of the search for $\nu_\mu \rightarrow \nu_e$ os
with the OPERA detector in the CNGS b

The OPERA collaboration

OPERA



CUORE

E. Scapparone talk

LVD, 1990 →

XENON 1T, running

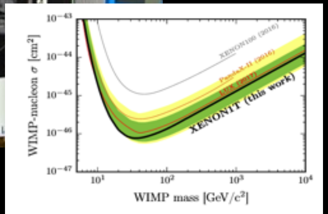
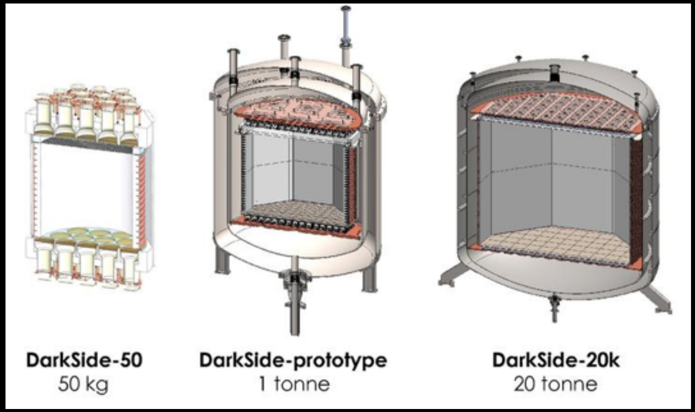
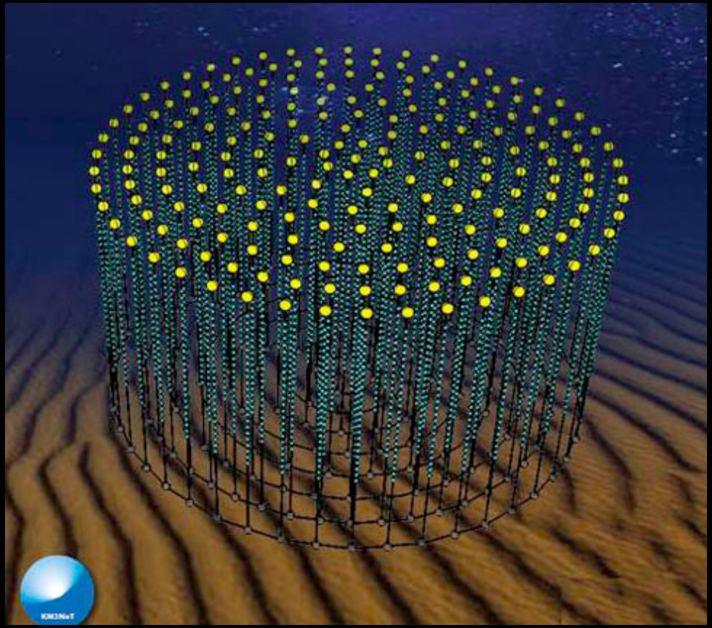


FIG. 4: The spin-independent WIMP-nucleon cross section limits as a function of WIMP mass at 90% confidence level (black) for this run of XENON1T. In green and yellow are the 1- and 2σ sensitivity bands. Results from LUX [27] (red), PandaX-II [28] (brown), and XENON100 [23] (gray) are shown for reference.



Undersea – Antares and km3



The End