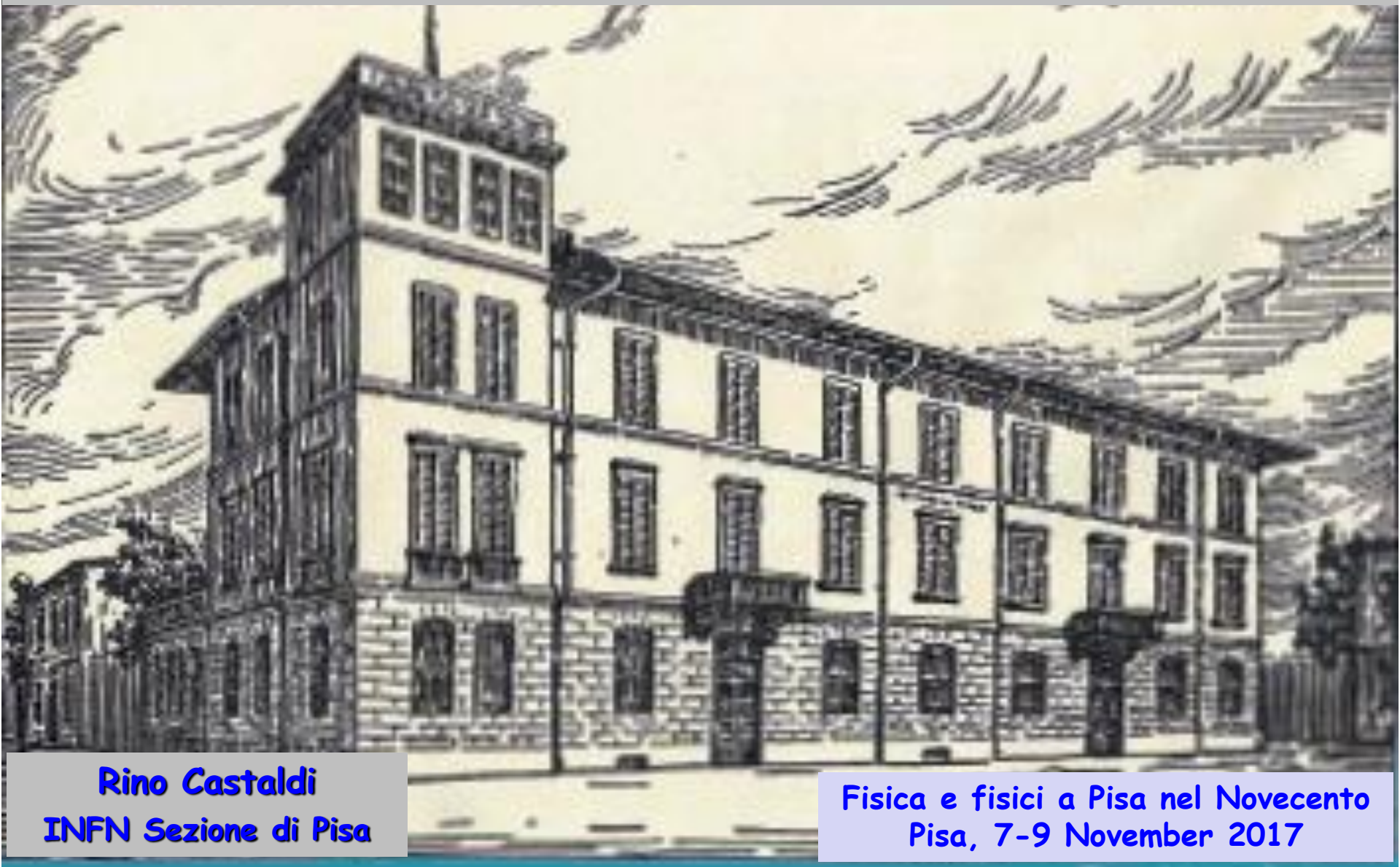
Early years of my adventure in High Energy Physics



Rino Castaldi
INFN Sezione di Pisa

Fisica e fisici a Pisa nel Novecento
Pisa, 7-9 November 2017

Early years of my adventure in High Energy Physics

Preliminary Remarks:

The experiments I am going to talk had already been presented by Giorgio Bellettini and therfore I will simply limit myself to only some personal memories and experiences in that experiments.

My first experiment was done in 1967/68 at DESY on vector meson photoproduction in nuclei. Since at that time I was still a student and not yet a "fisico a Pisa" I will not talk about this experiment altought I could report several amusing memories of this period.

First Adventure: the pp total cross section is *'rising'* ! !

10 March 1969

Proposal for an experiment on the ISR

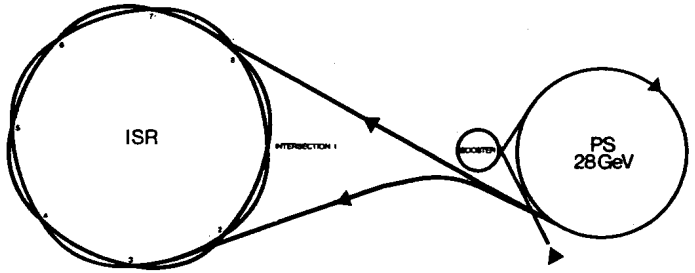
MEASUREMENT OF THE p-p TOTAL CROSS-SECTION

G. Bellettini, P.L. Braccini, C. Bradaschia,
R. Castaldi, C. Cerri, T. Del Prete, L. Foà,
A. Menzione, G. Sanguinetti and M. Valdata

Istituto di Fisica dell'Università di Pisa
Scuola Normale Superiore, Pisa
Istituto Nazionale di Fisica Nucleare, Sezione di Pisa

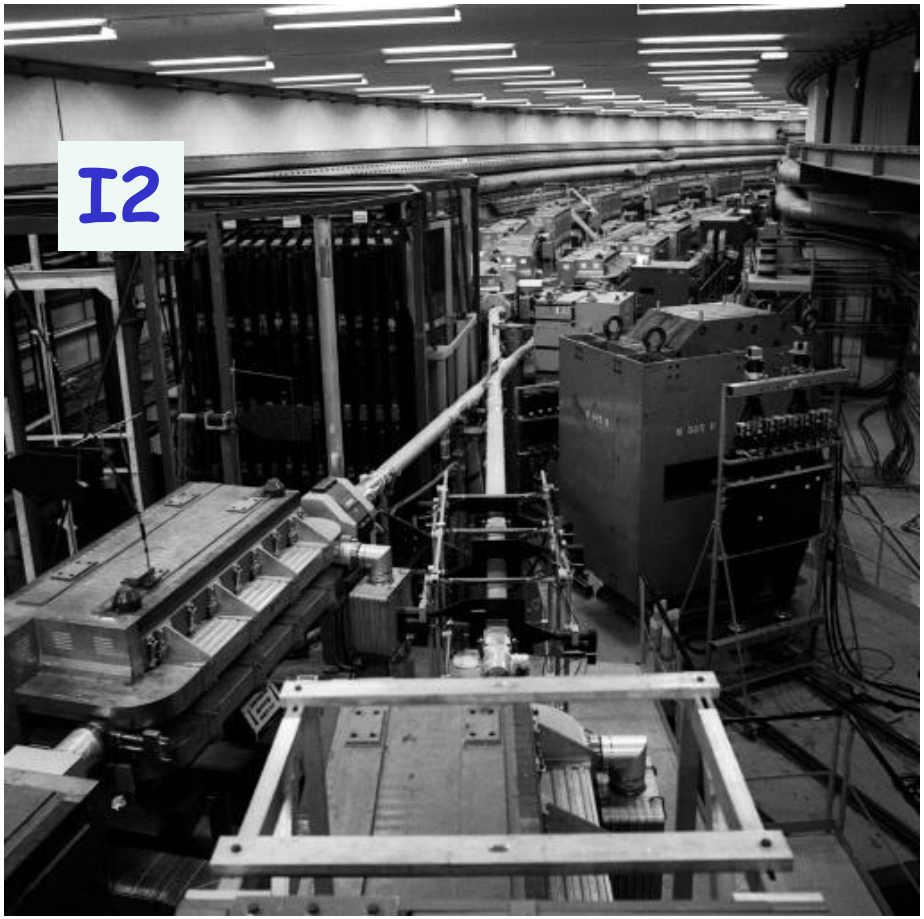
Geneva - 10 March 1969

1970 ISR in costruzione



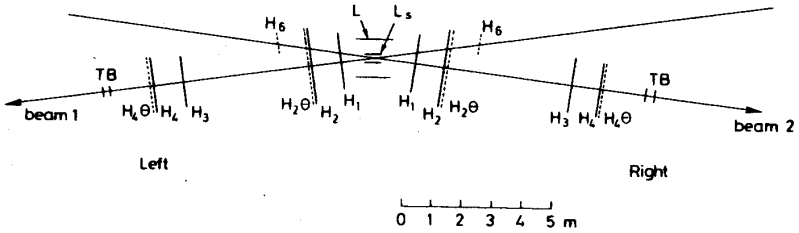
p-p up to $\sqrt{s}$ = 62 GeV !!

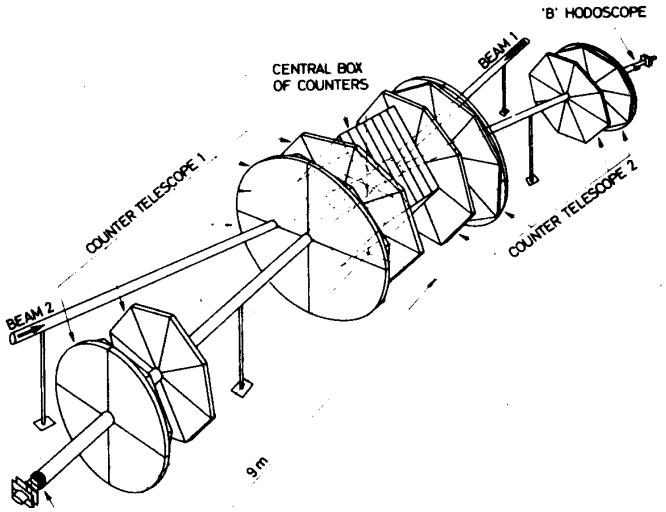
1971
All ISR intersections are ready for detector installations



Pisa-StonyBrook

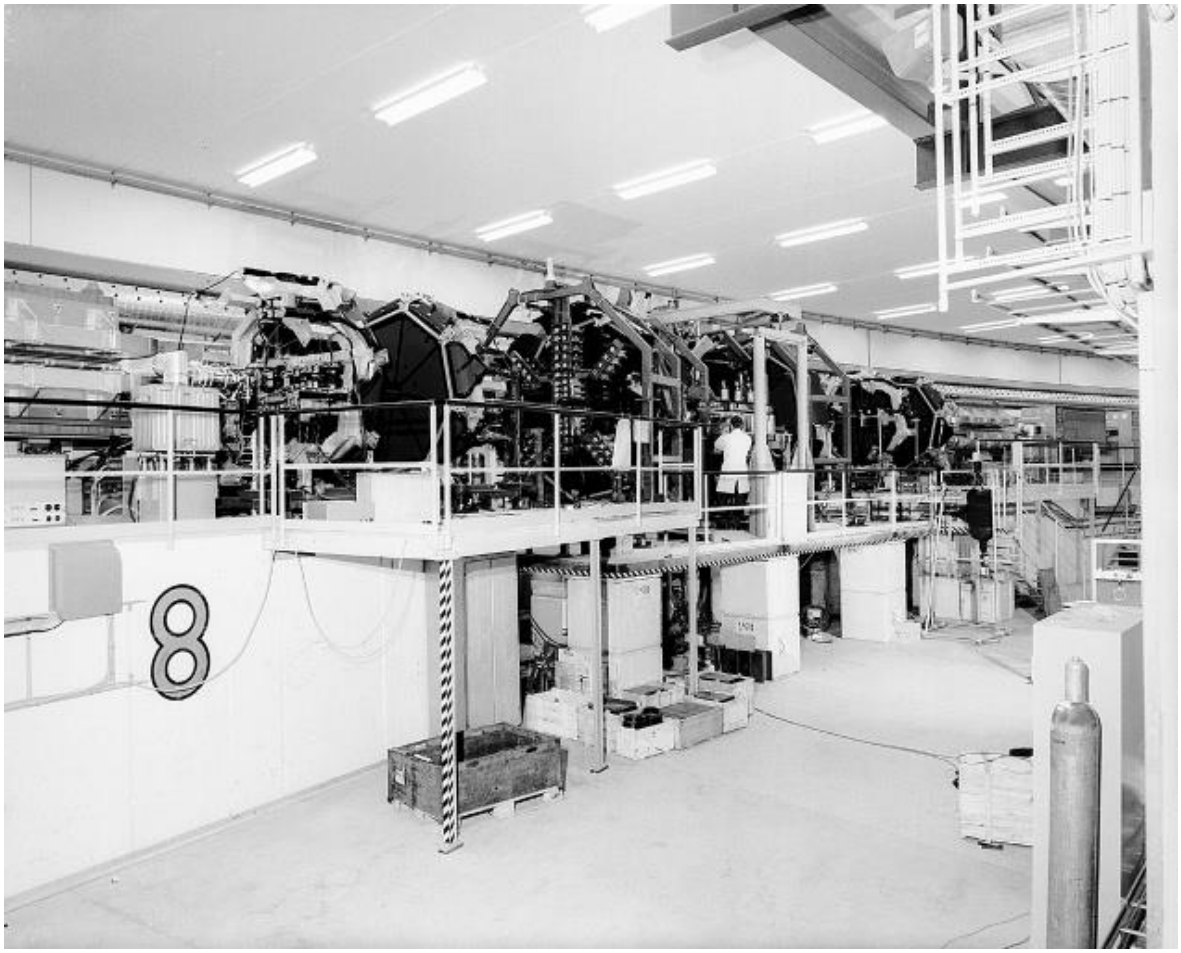
R801: a 4π detector for the measurement of the pp total cross section at ISR





Beginning 1972:

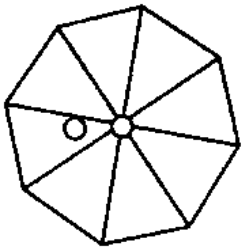
the Pisa-StonyBrook 4π detector is ready to take data in I8



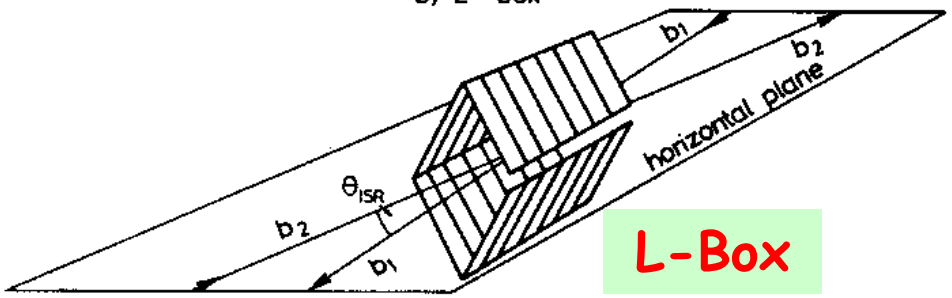
R801: 4π hodoscopes: H_φ, H_θ, TB, L-box

a) φ-hodoscope

H_φ



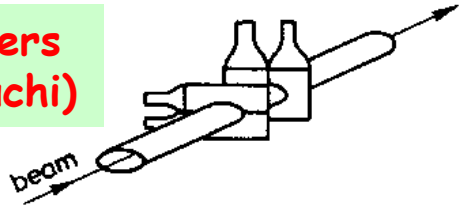
b) L - box



L-Box

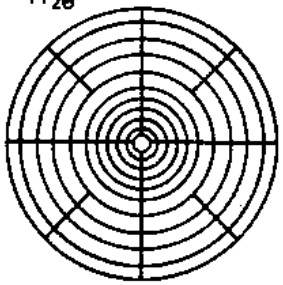
c) TB counters

TB counters (Tappa Buchi)

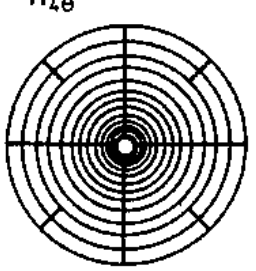


d) θ - hodoscope

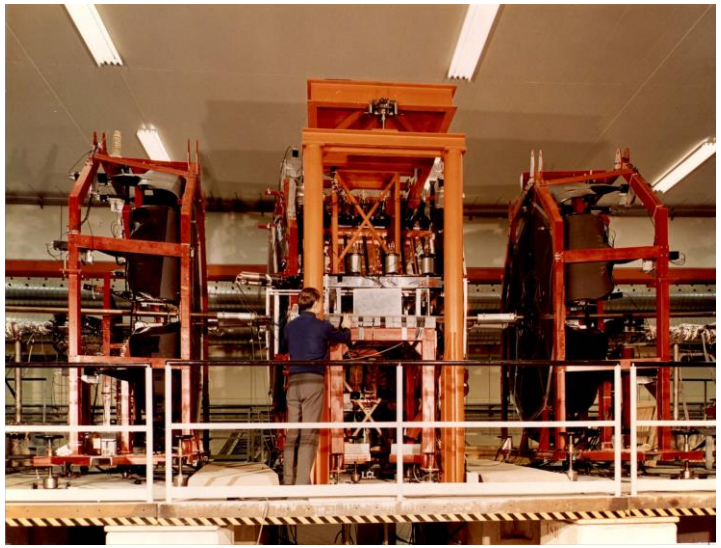
$H_{2\theta}$

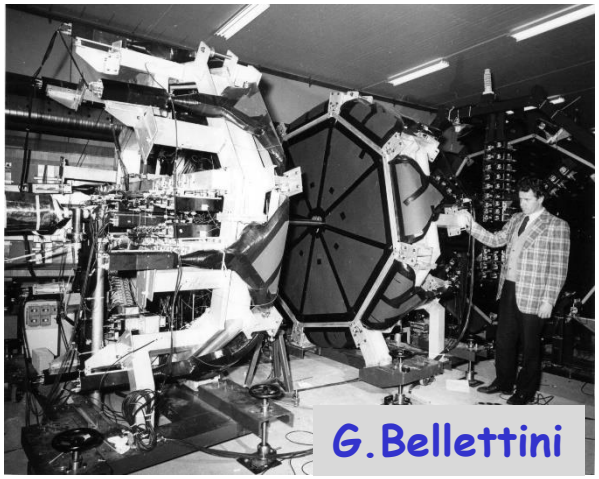


$H_{4\theta}$



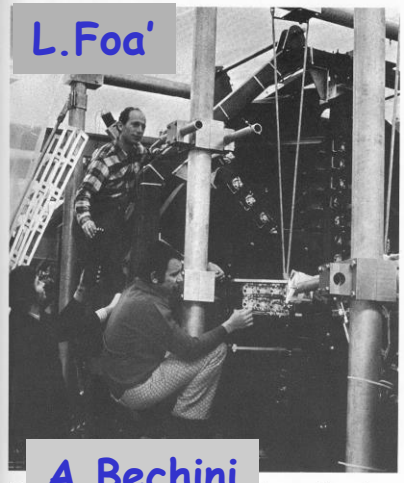
$H_{2\theta}$ $H_{4\theta}$





G.Bellettini

L.Foa'

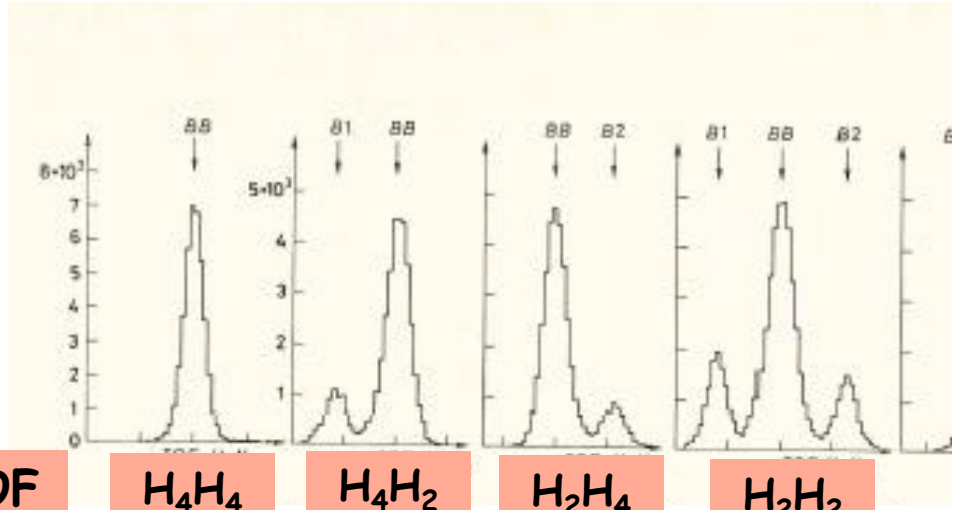


A.Bechini

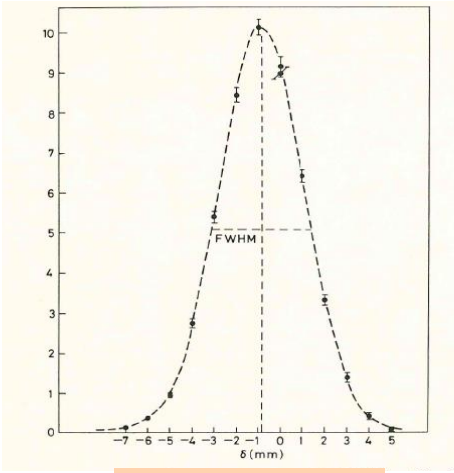
~ May 1972

Shortly after the first data taking the total cross section looks to be rising with energy !!

$$R_{tot} = L\,\sigma_{Tot}$$



TOF H_4H_4 H_4H_2 H_2H_4 H_2H_2

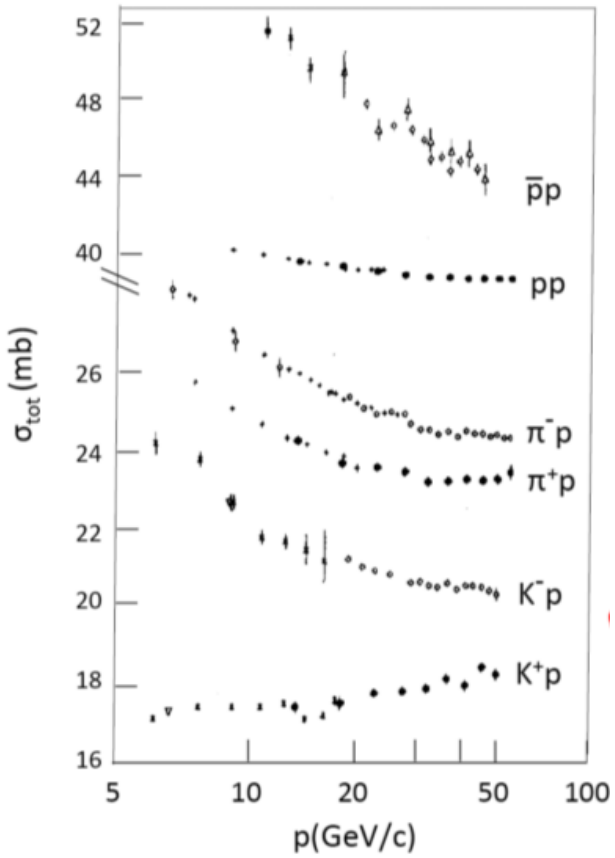


VDM scan

But the beam displacement scale will become reliable only in Autumn (hysteresis of the magnets?) **!**

Beginning 1972

A rising pp total cross section was indeed a big surprise because at that time the Regge pole theory was the only accepted description of all the small-t hadron interaction and the pomeron trajectory was clearly indicating a constant cross section with energy.



All the hadronic cross sections measured at Serpukhov were indicating to approach a costant values with increasing energy. All theoreticians and many experimentalists were convinced that at ISR energy the so called "Asimptotia" will be finally reached.

Elastic scattering in I6

Two experiments were approved in I6 to measure pp elastic differential cross section:

CERN-Roma (U. Amaldi et al.)
measurement of pp elastic differential cross section at small t with the so called "Roman Pots" (down to 1.5 mrad, enought to reach the interference region with Coulomb scattering).

ACHGT (C. Rubbia et al.)
measurement of pp elastic differential cross section at larger t (30-100 mrad). (the original proposal was to measure the whole angular range down to 1 mrad with a two-arm spectrometer using the first four magnets of the ISR and with an additional pair of magnets at larger angle…but only the detector at larger angle was approved by the committee)

Both experiments could also measure σ_{Tot} using the optical theorem and extrapolating the differential elastic cross section down to t=0

1972: rising or constant σ_{Tot} with energy ?

AGHGT (Rubbia et al.) was claiming a constant cross section with energy as foreseen by the Regge Theory in disagreement with Pisa-StonyBrook and CERN-Roma.

The debate was very very hot….

and in the meanwhile my NATO fellowship was ending in September leaving me without a salary !

Fortunately the year of leave of absence of Guido Finocchiaro was also ending and he had to go back to StonyBrook. He then proposed me to go with him with a visiting assistant position for a semester,

Since I was personally involved in the analysis of σ_{Tot} I could bring with me all the program (a couple of boxes of punched cards) and we could, far from the noise of the debate, critically revise all the steps needed to get the total cross section from the data.

I accepted entusiastically….but the total cross section continued to rise also with the analysis done at the Stonybrook computer center !

1972: rising or constant σ_{Tot} with energy ?

A few weeks later of my arrival at StonyBrook, a seminar was announced at the Brookhaven Laboratory on "Measurement of elastic and total cross sections at the ISR" by Carlo Rubbia.

The Nobel Prize C. N. Yang, all the Stony Brook physics department, including me and Guido, and a crowded audience attended the seminar.

Carlo Rubbia reported a proton-proton total cross section "clearly" constant with energy, as expected by Regge theory.
Provocatively he underlined that the Pisa-StonyBrook group is claiming that the cross section is rising, but, he added, they have big losses in the total rate because of the large holes in the detector.

Immediately I told Guido: " Guido, Guido, say everybody that he is reporting something totally false ! We do a carefully extrapolation with "i tetini", in addition we have "i Tappa Buchi" counters and, if we really lose, the lost will be larger at larger energy resulting in a flattening of the cross section. What he is saying is a non sense ! "

1972: rising or constant σ_{Tot} with energy ?

As probably many of you knows, Guido is one of the best experimental physicists but also one of the most shy person I never met….and he did'nt object to the false Rubbia statements.

Coming back to Stony Brook I said to Guido that he must absolutely make a seminar explaining to the department what we were doing and what we were finding. He agrees that a seminar should be done but I, not him, had to be the speaker !!!

I was terrified by this idea, but I was so furious that I agreed to do the seminar, even though I was sure of not being able to understand any questions that could be asked to me…..and I spent the full week before the seminar listening television in a desperate attempt to start understanding the American accent !

Luckily the seminar went well and the questions posed by Yang were, may be not in a perfect british accent, but perfectly understandable.

From that moment on, I have been no longer afraid to do a public seminar, even though my English remained very poor.

σ_{tot} is rising with energy !

Three months later, the 23 February 1973, the paper was submitted to Physics Letters simultaneously with the CERN-Roma paper

MEASUREMENT OF THE TOTAL PROTON-PROTON CROSS-SECTION AT THE ISR☆

S.R. AMENDOLIA, G. BELLETTINI*, P.L. BRACCINI, C. BRADASCHIA, R. CASTALDI, V. CAVASINNI, C. CERRI*, T. Del PRETE, L. FOA*, P. GIROMINI, P. LAURELLI, A. MENZIONE, L. RISTORI, G. SANGUINETTI, M. VALDATA,

Istituto Nazionale di Fisica Nucleare, Sezione di Pisa
Istituto di Fisica dell'Università, Pisa
Scuola Normale Superiore, Pisa, Italy

G. FINOCCHIARO, P. GRANNIS*, D. GREEN, R. MUSTARD and R. THUN
State University of New York, Stony Brook, New York, USA

Received 23 February 1973

☆Work supported in part by the Consiglio Nazionale delle Ricerche of Italy, and by the National Science Foundation, USA.

*These authors have held CERN visiting scientist positions.
Present address: State University of New York, Stony Brook, New York, USA.

The data show an increase of about 10% in σ_{tot} in the ISR energy interval

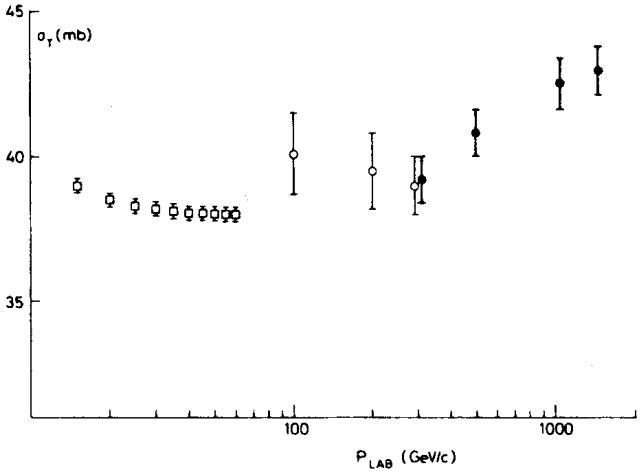


Fig. 3. Plot of the results versus equivalent beam momentum. The Serpukhov [5] and NAL [6–8] data are shown for comparison. □: Data of ref. [5]. ○: Data of refs. [6–8]. ●: This experiment.

σ_{tot} is rising with energy !

The rise of the cross section at the ISR had been confirmed by Pisa-StonyBrook and CERN-Roma groups two years later using the luminosity independent method

Volume 62B, number 4 PHYSICS LETTERS 21 June 1976

NEW MEASUREMENTS OF PROTON-PROTON TOTAL CROSS SECTION AT THE CERN INTERSECTING STORAGE RINGS

CERN[1]-Pisa[2]-Rome[3]-Stony Brook[4] Collaboration

Received 17 April 1976

Measurements of the proton-proton total cross section have been made with increased precision (±0.6%) over the ISR energy range $\sqrt{s}$ = 23.5–62.7 GeV. Two different experimental methods gave consistent results, showing that the total cross section increases 10% over the ISR range and in addition that the absolute value of the ISR luminosity can be measured to ±0.9%.

$$\sigma_{\mathrm{tot}} = 4\pi \,\mathrm{Im}[f_{\mathrm{el}}(t=0)]$$ where f_{el} is elastic amplitude

$$\sigma_{\mathrm{tot}}^2 = \frac{16\pi}{1+\rho^2}\frac{1}{L}\left(\frac{dN_{\mathrm{el}}}{dt}\right)_{t=0} \qquad \rho = \frac{\mathrm{Re}\, f(0)}{\mathrm{Im}\, f(0)}$$

$$\sigma_{\mathrm{tot}} = \frac{16\pi}{1+\rho^2}\frac{(dN_{\mathrm{el}}/dt)_{t=0}}{N_{\mathrm{tot}}}$$ luminosity independent measurement

σ_{tot} is still rising with energy !

The pp total cross section is still rising at LHC energy

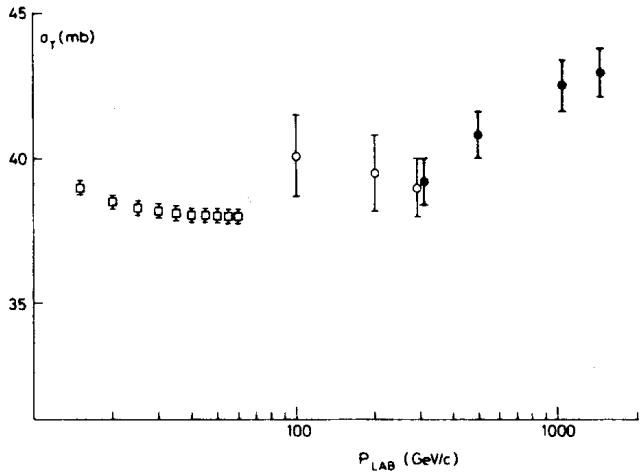
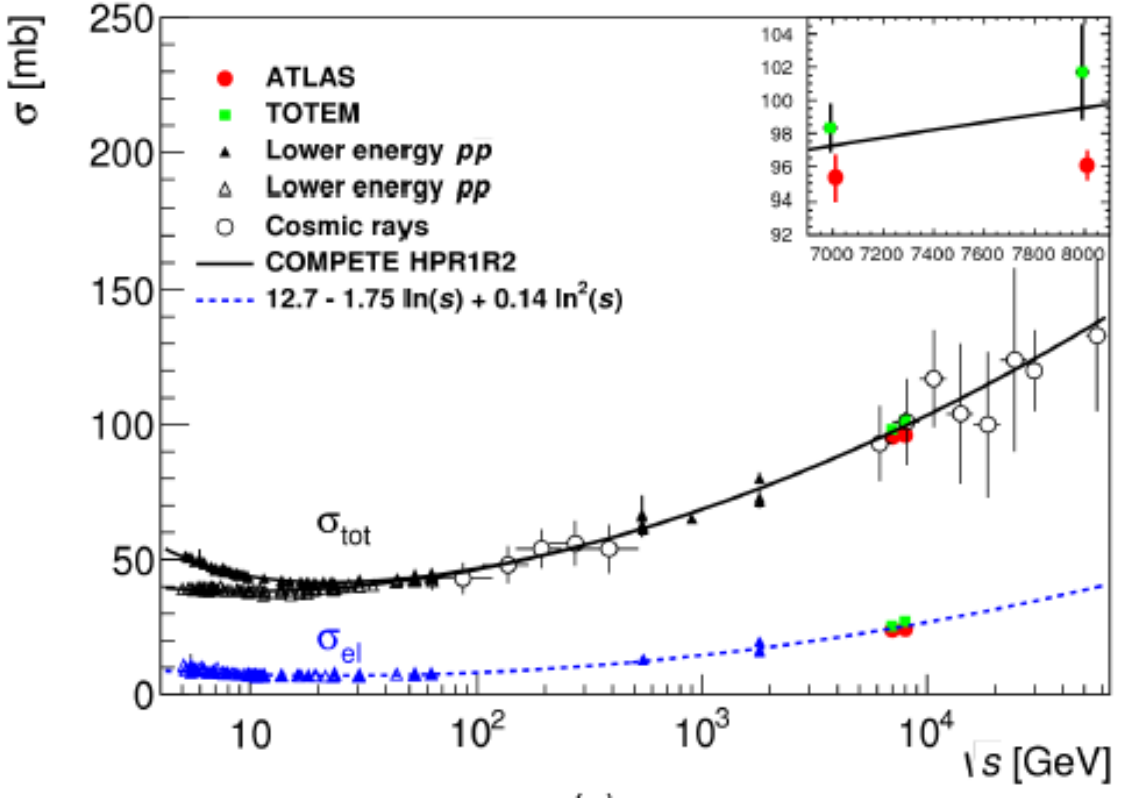


Fig. 3. Plot of the results versus equivalent beam momentum. The Serpukhov [5] and NAL [6–8] data are shown for comparison. □: Data of ref. [5]. ○: Data of refs. [6–8]. ●: This experiment.



Second Adventure: "the 1^- heavy photon…."

At the end of my semester at Stony Brook I got a CERN fellowship, I bougth my first BMW, and I continued to work in R801.
In october 1973 I was in my new office at "Il Castello" near to I8 when S.C.C.Ting enters in the room saying "BONGIONO" as usual with the Italians. He had learned this word in 1967 at DESY where the Pisa group was doing photoproduction experiments on the same beam line of Ting experiment. At that time I was working on my thesis on photoproduction of vector mesons with P. Braccini as supervisor. When it happned that I met Ting, he was always practicing with me the pronuntiation of BUNGIONO…and therefore I was not surprised if he was trying again to improve his italian…

On the contrary I was rather surprised when Prof. S.C.C.Ting went to the blackboard and wrote "1^- heavy photon" saying "there must be a family of 1^- and we should look for it in $\mu^+\mu^-$ or in e^+e^-. The surprise was that he, a rather important professor, was trying to convince me, the last researcher politically irrelevant, of the need to do the search of muon pair at the ISR !

"….and we are compatible"

I knew that Ting was discussing with Bellettini e Braccini on the possibility to collaborate in an experiment of mu pair production at the ISR, whose proposal had already been submitted for approval the 1st October 1973. Now the discussion was to submit a joint proposal to include the Pisa 4π detector in I8 as an extension of the mu pair experiment. This second proposal was indeed submitted the 3 November 1973. The experiment was foreseen to be ready in summer 1975.From now on Ting was saying to everybody the sentence

"We (MIT&Pisa) are compatible"

To be compatible with the Pisa 4π detector who was already in I8 was clearly a strong political point in order to be approved by the ISR Committee because of the very limited intersection region available.

Nonetheless the experiment was approved in I2 as R209

In the proposal we read:

"The reaction $pp \rightarrow \gamma_V(q^2)$ + hadrons which we are preparing to study at the ISR up to $q^2 \approx 100\ GeV^2$, is connected by certain models to the two particle inclusive annihilation $e^+e^- \rightarrow \gamma_V(q^2)$ + a+ b+ hadrons."

The sentence is an illuminating anticipation of the new physics to come.

"….and we are compatible"

CERN/ISRC 73-28 Add. 1
9 November 1973

PROPOSAL FOR AN EXTENSION OF THE μ-PAIR EXPERIMENT
TO INCLUDE CORRELATIONS WITH THE ASSOCIATED HADRONS

G. Diambrini-Palazzi, U.J. Becker, P.J. Biggs, A. Cook,
G. Everhart, P. Goldhagen, R. Little, K. Strauch
and S.C.C. Ting

Genova-Harvard-MIT Collaboration

and

G. Bellettini, P.L. Braccini, R. Castaldi, V. Cavasinni,
T. Del Prete, P. Laurelli, G. Sanguinetti and M. Valdata

Pisa

Here is the original proposal to install the μ-pair experiment in I8, beeing compatible with the R801 4π detector.
The experiment was instead approved in I2 as R209 and the Pisa group responsibility was to build a central vertex-tracking detector. This detector had to be inserted in a very narrow space left open by the huge iron magnet surrounding the beam pipe,

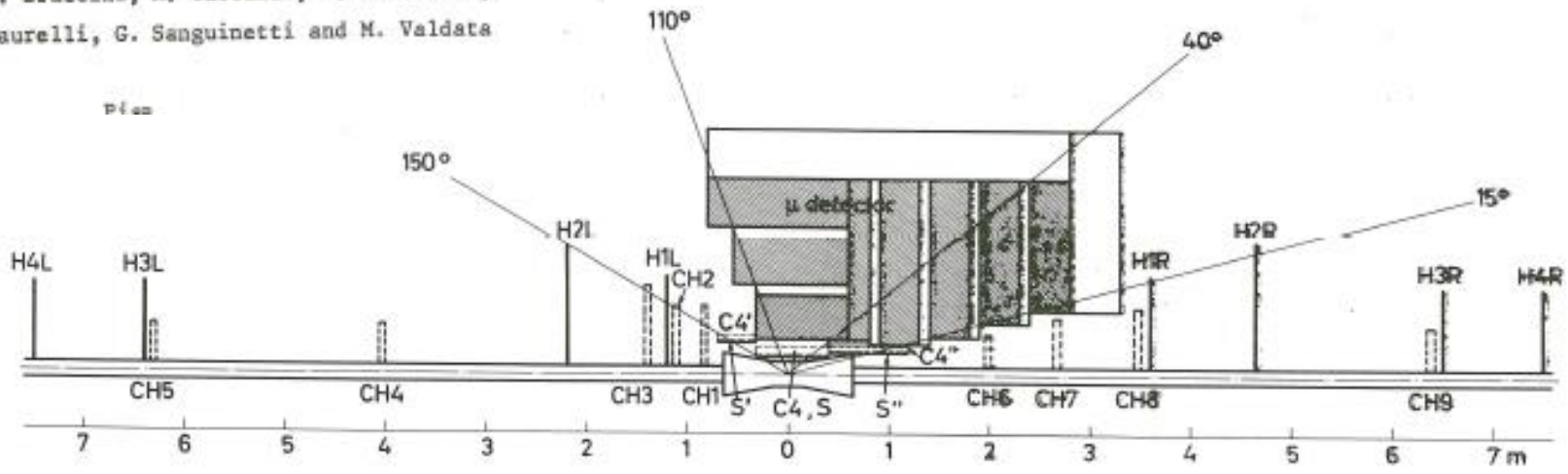
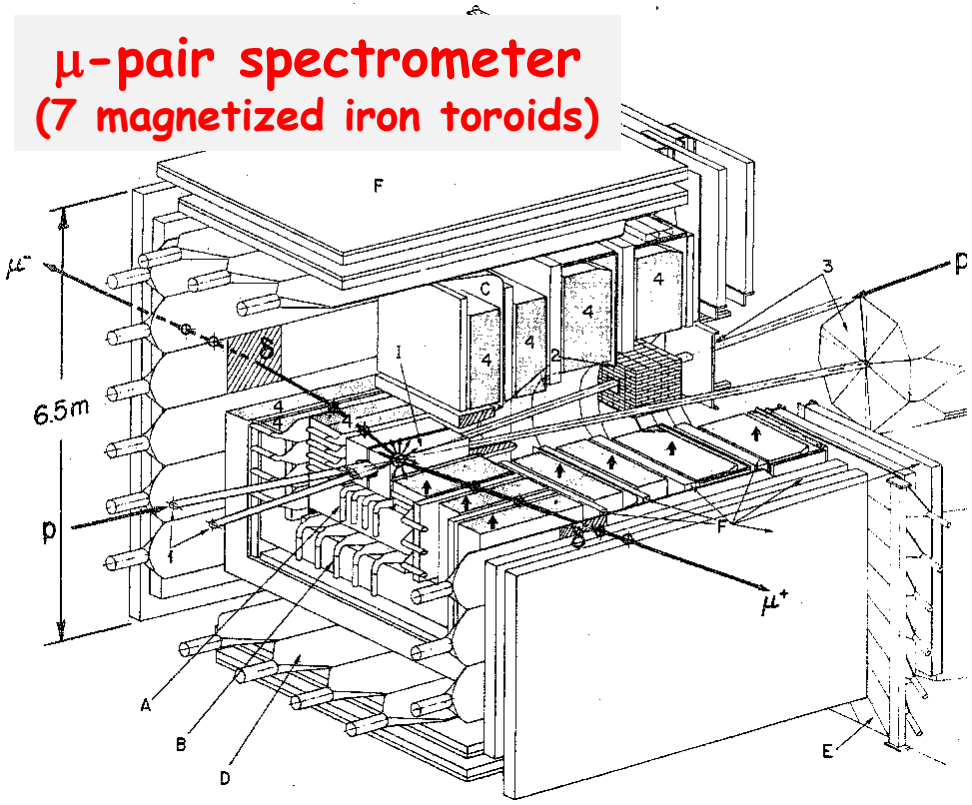
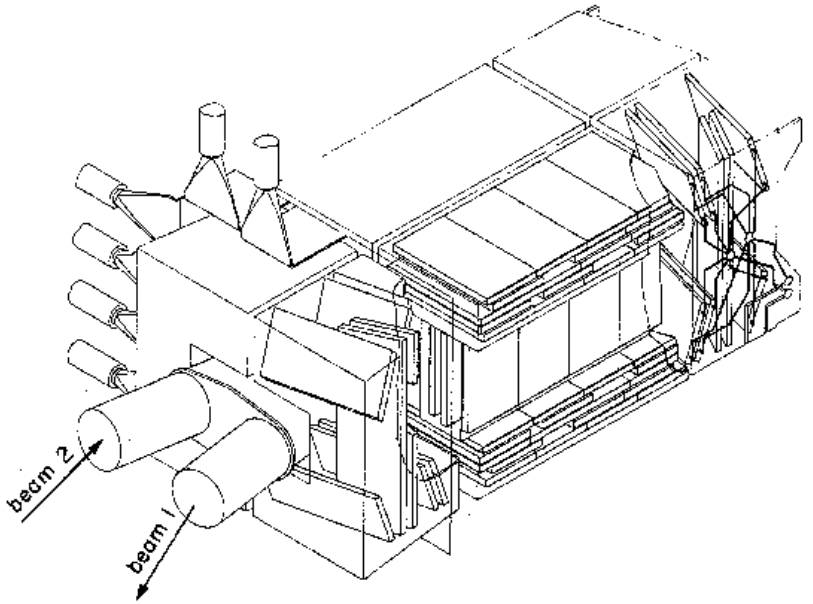


FIG.1 Side view of the combined arrangement of the μ - detector and hadron detector.

R209: μ-pair production at the ISR

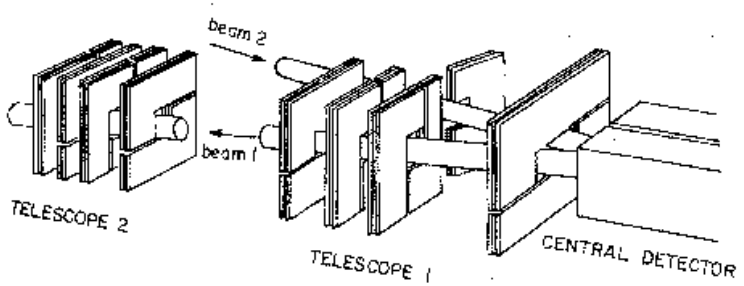
μ-pair spectrometer (7 magnetized iron toroids)





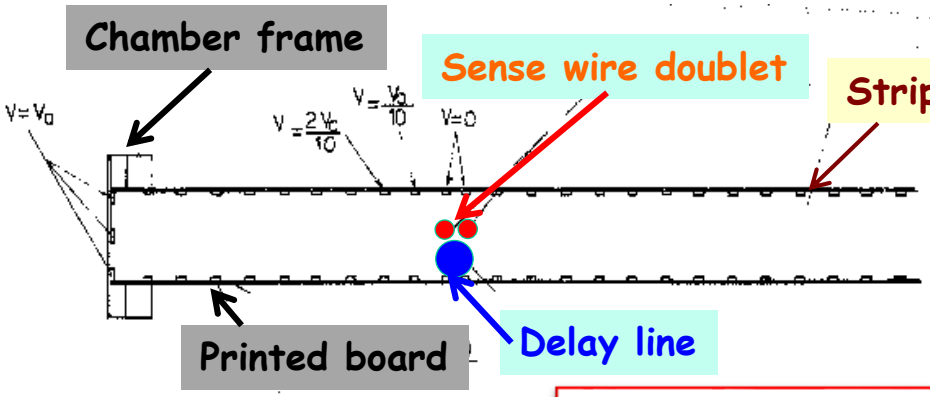
Pisa vertex-tracking detector (≈150cm X 70X70cm² available)

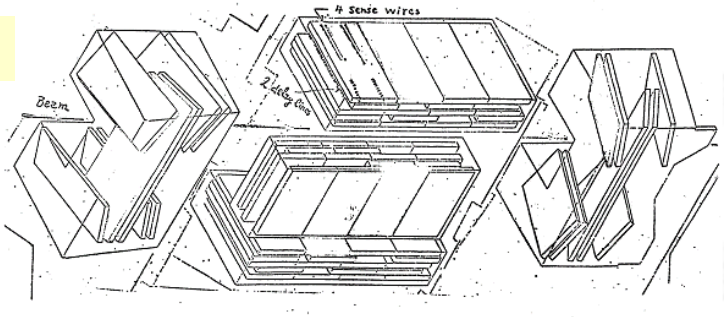
Pisa group: G.Bellettini, P.L.Braccini, R.Carrara, R.Castaldi, V.Cavasinni. F.Cervelli, T.Del Prete, P.Laurelli, M.M.Massai, M.Morganti, G.Sanguinetti, M.Valdata-Nappi, C.Vannini



Naples telescopes

The first Pisa vertex-tracking detector at an hadron Collider (modular&compact)





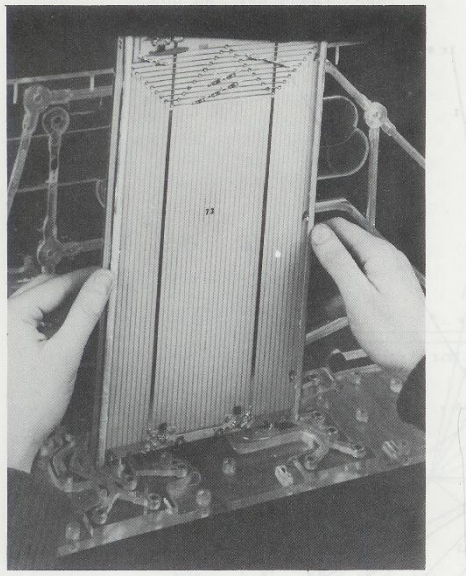


Fig. 3. Housing of the modules inside the vertex-detector containers.

A MODULAR DRIFT-CHAMBER VERTEX DETECTOR AT THE CERN ISR

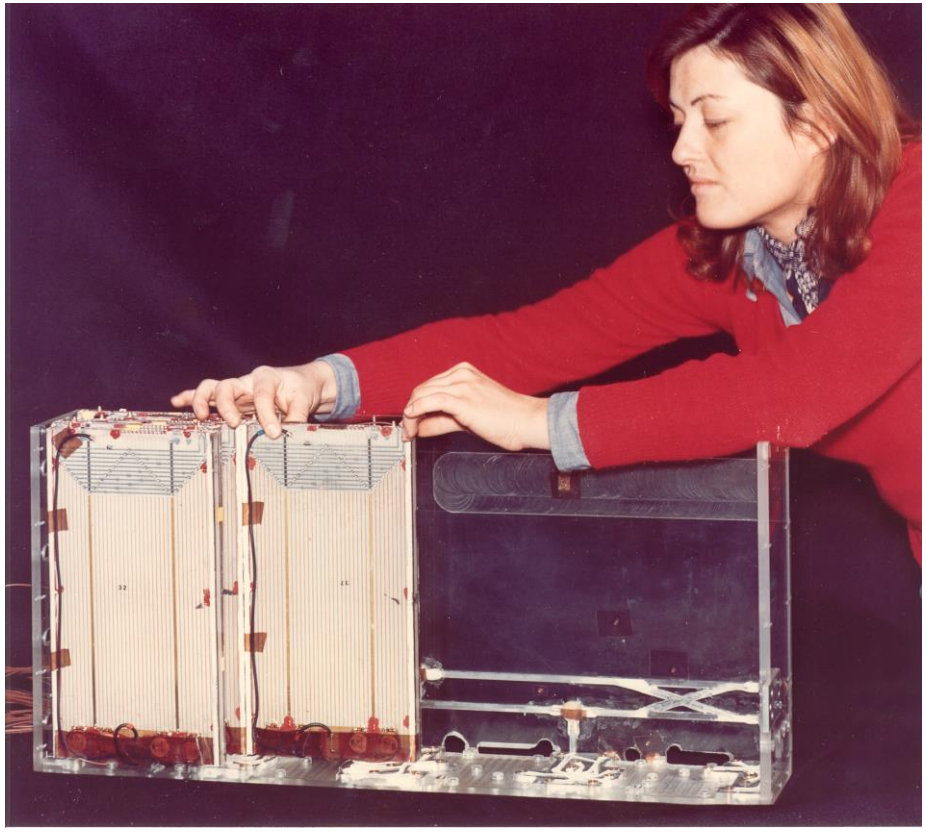
A. BECHINI, C. BETTI, F. BOSI, P. L. BRACCINI, R. CARRARA, R. CASTALDI, V. CAVASINNI, F. CERVELLI, G. CIANCAGLINI, T. DEL PRETE, P. LAURELLI, P. MARCHI, M. M. MASSAI, M. MORGANTI, G. SANGUINETTI, M. VALDATA-NAPPI and C. VANNINI

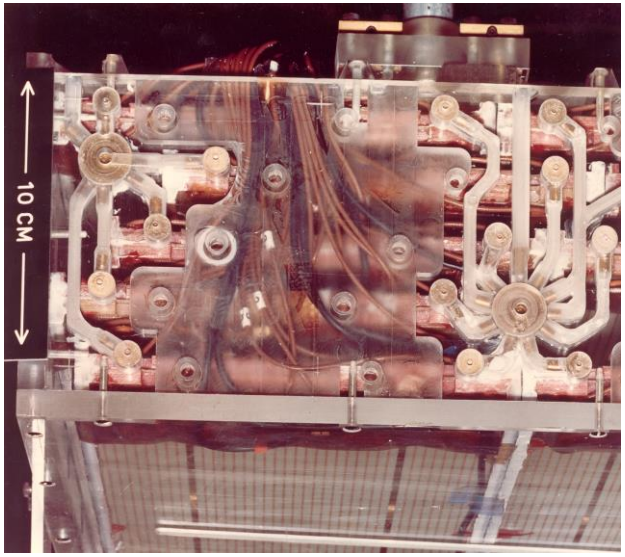
CERN, Geneva, Switzerland and Istituto di Fisica dell'Università di Pisa, Scuola Normale Superiore, Pisa, Sezione di Pisa dell'INFN, Italy

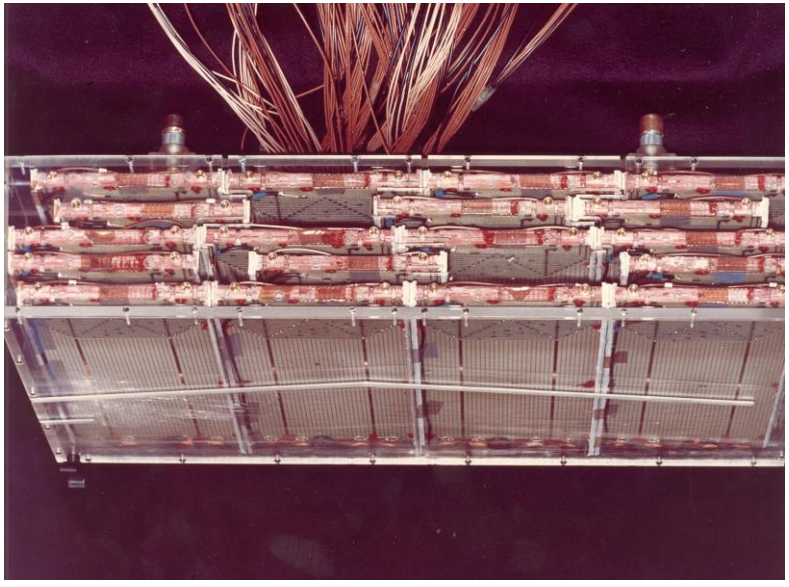
A modular system of 136 small drift chambers, assembled around the the ISR intersection region in a very narrow space left open between the iron magnet and the beam pipe, had to measure the directions of the muon pairs, the vertex and the other charged particle of the event. Because of the limited space and the rather high multiplicity of the events we had to reconstract the space point directly on the camber. Each module contains two doublets of sense wires, each associated to a delay line in order to reconstruct the space points wthout left right ambiguities.

Space resolution ≈ ± 0.2 mm in the drift and ± 2 mm in the delay line

The first Pisa vertex-tracking detector at an hadron Collider (modular&compact)







Main actors

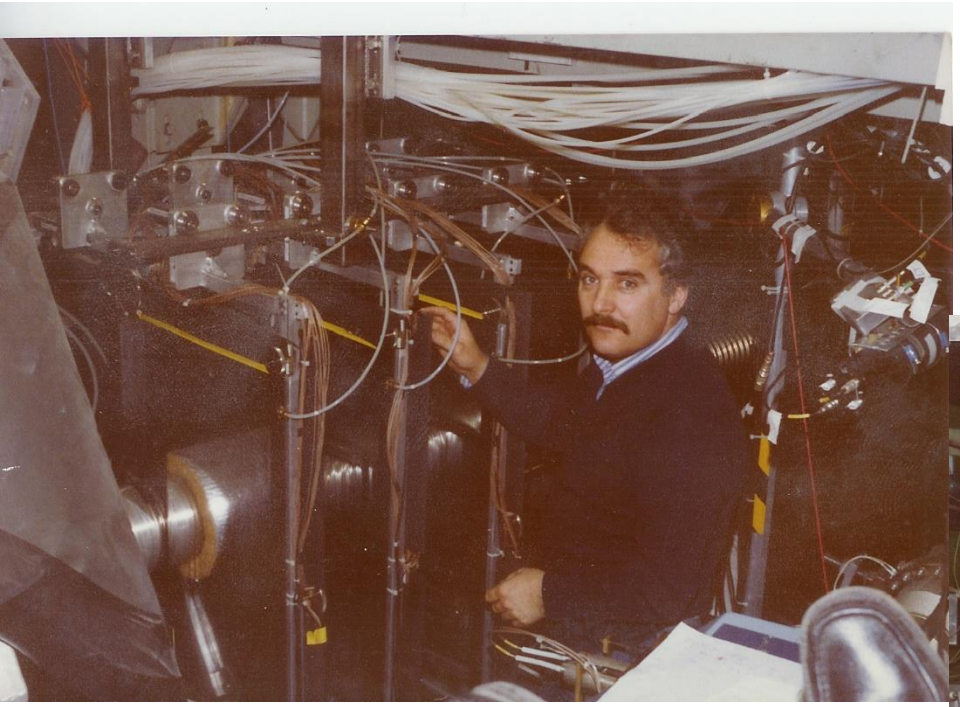
R. Castaldi
F. Cervelli
M.M.Massai
M.Morganti
C.Vannini

F.Bosi

A.Bechini
C.Betti
P.Marchi

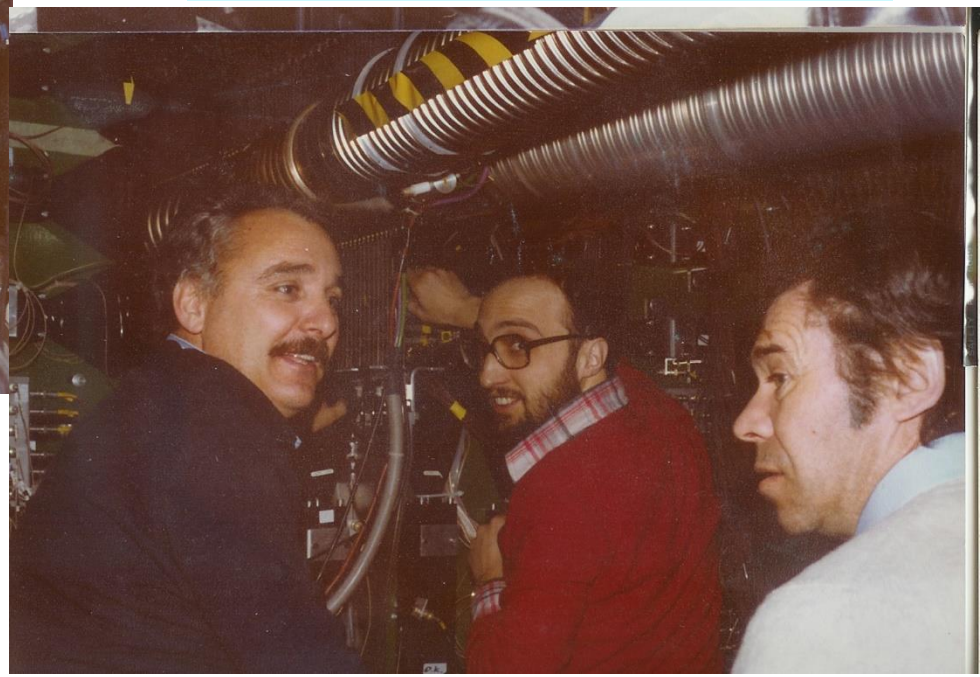
Support by
Favatino
Favatone
U.Cazzola

R209: μ-pair production at the ISR

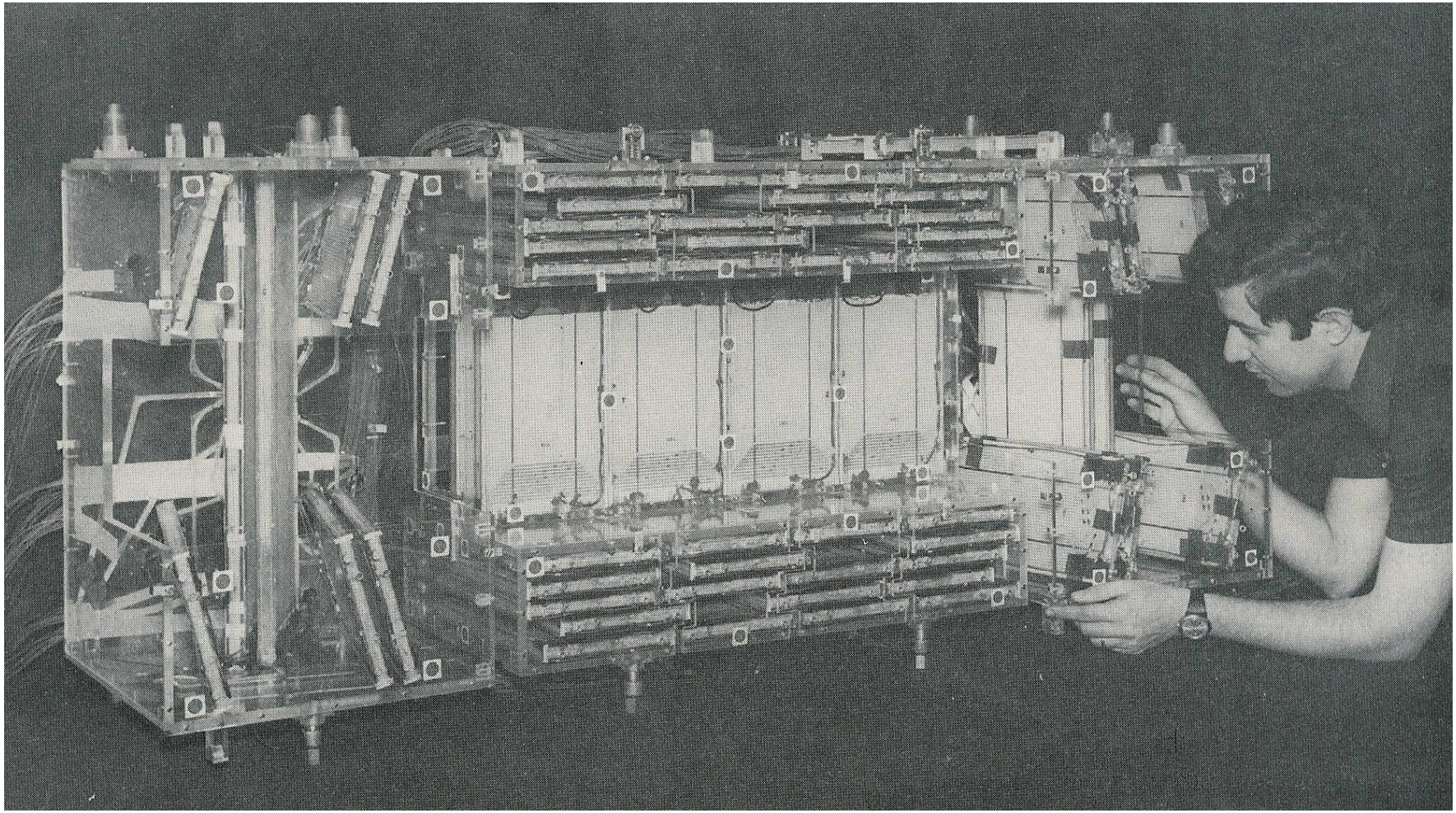


Ugo Cazzola with the mustache next to the spillantini chambers

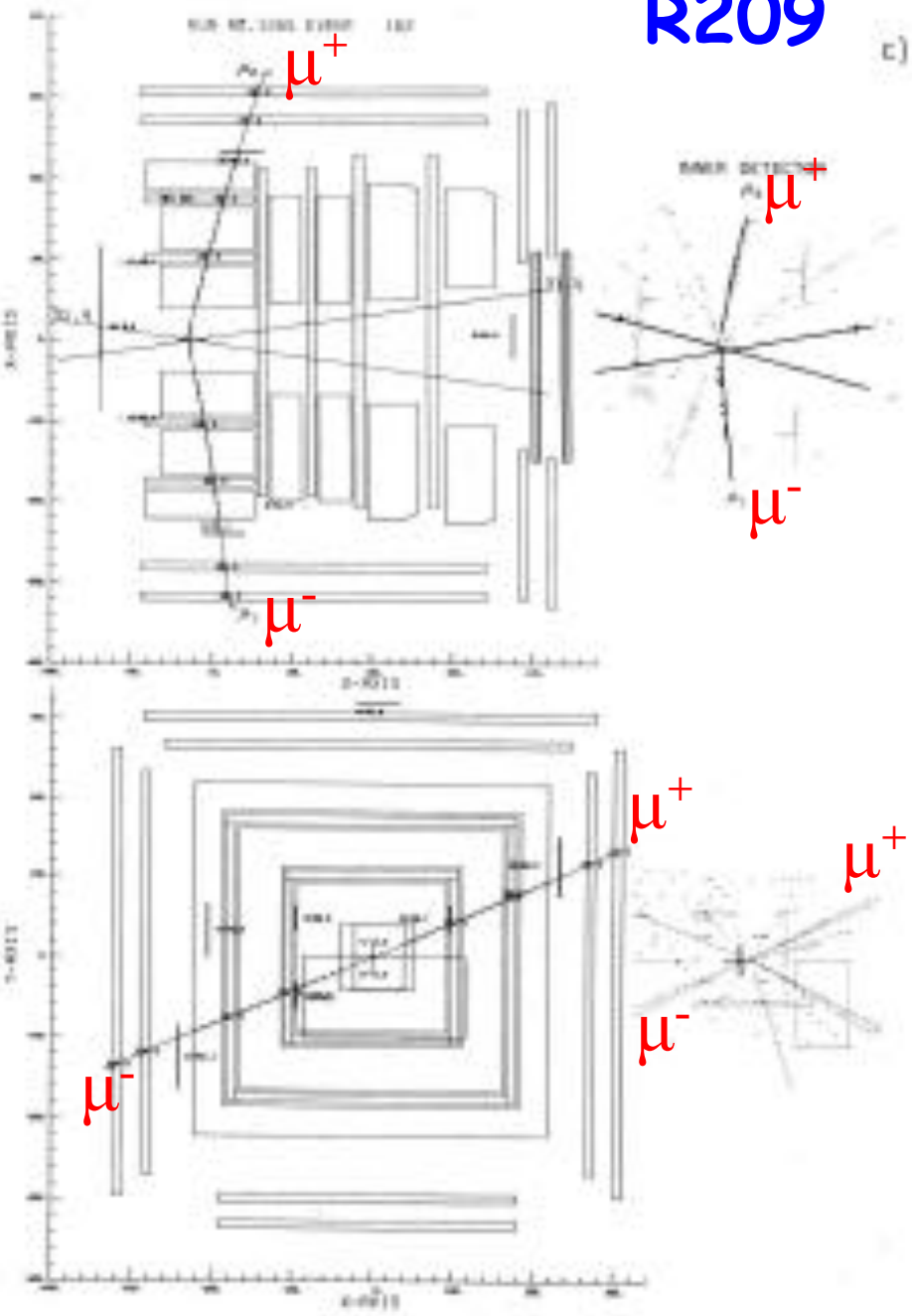
Ugo con Cavasinni e Betti



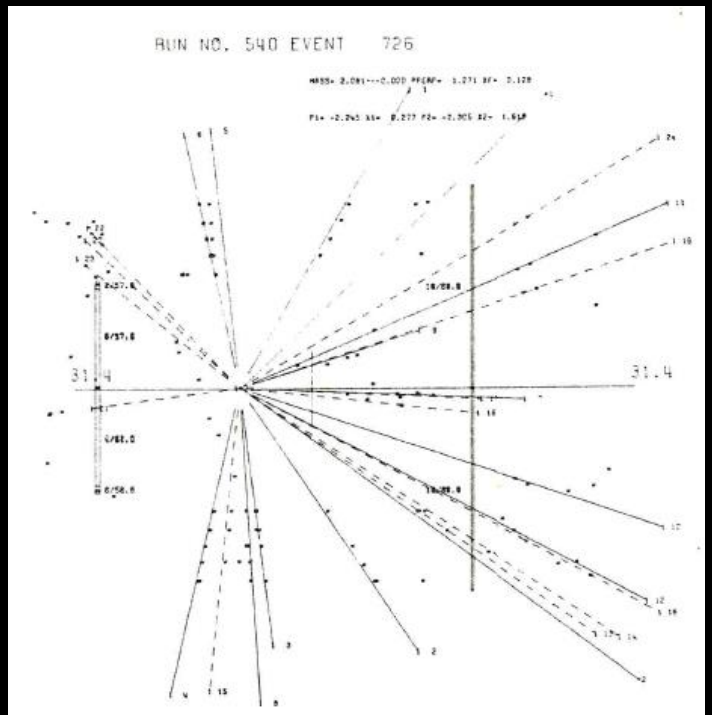
Pisa vertex-tracking detector at CERN ready for installation (one half)



R209



μ-pair event reconstructed in the R209 spectrometer with an exploded view of the Pisa vertex-tracking central detector



Minimum bias event (<n>≈ 12) reconstructed in the Pisa vertex-tracking detector

R 209: μ-pair production at $s^{1/2}$ = 62 GeV

VOLUME 45, NUMBER 11 PHYSICAL REVIEW LETTERS 15 SEPTEMBER 1980

Measurement of Dimuon Production at $s^{1/2} = 62$ GeV

D. Antreasyan, W. Atwood, R. Battiston, U. Becker, G. Bellettini, P. L. Braccini, J. G. Branson, J. D. Burger, F. Carbonara, R. Carrara, R. Castaldi, V. Cavasinni, F. Cervelli, M. Chen, G. Chiefari, T. Del Prete, E. Drago, M. Fujisaki, M. F. Hodous, T. Lagerlund, P. Laurelli, O. Leistam, R. Little, D. Luckey, M. M. Massai, T. Matsuda, L. Merola, M. Morganti, M. Napolitano, H. Newman, D. Novikoff, J. A. Paradiso, L. Perasso, K. Reibel, J. P. Revol, R. Rinzivillo, T. Sanford, G. Sanguinetti, I. Schulz, G. Sciacca, P. Spillantini, M. Steuer, K. Strauch, S. Sugimoto, Samuel C. C. Ting, W. Toki, M. Valdata-Nappi, C. Vannini, F. Vannucci, F. Visco, and S. L. Wu

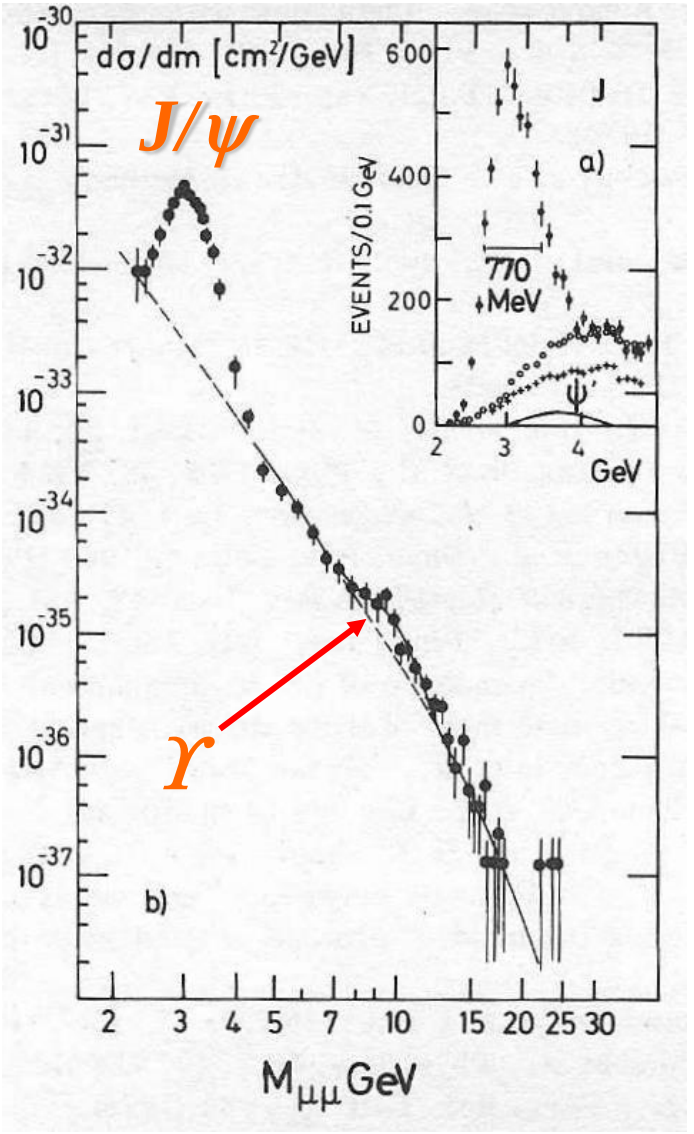
CERN, CH-1211 Geneva, Switzerland, and Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, and Laboratoire de Physique des Particules, F-74019 Annecy-le-Vieux, France, and Harvard University, Cambridge, Massachusetts 02138, and Istituto di Fisica Sperimentale dell'Università and Istituto Nazionale di Fisica Nucleare, I-80138 Napoli, Italy, and Istituto di Fisica dell'Università and Istituto Nazionale di Fisica Nucleare, I-56100 Pisa, Italy

(Received 22 May 1980)

Prompt dimuon production has been measured. Events with mass up to 25 GeV/c^2 are observed, as well as the J and Υ resonances. Cross sections are given for J and Υ production. For the continuum, the scaling function $F(\tau)$ is measured at very small values of $\sqrt{\tau} = m/\sqrt{s}$ covering the range $0.05 < \sqrt{\tau} < 0.20$.

Results are published in May 1980: J/ψ and Υ resonances are observed.

The R209 was supposed to be ready in summer 1975 but we have been 2 years late (In the meantime S.C.C.Ting in 1974 was discovering the J particle: Nobel 1976). The Υ was discovered in 1977 by L. Lederman at Fermilab.



≈1979: visit to the cavern of UA2/UA4 at P-P^{bar} Collider

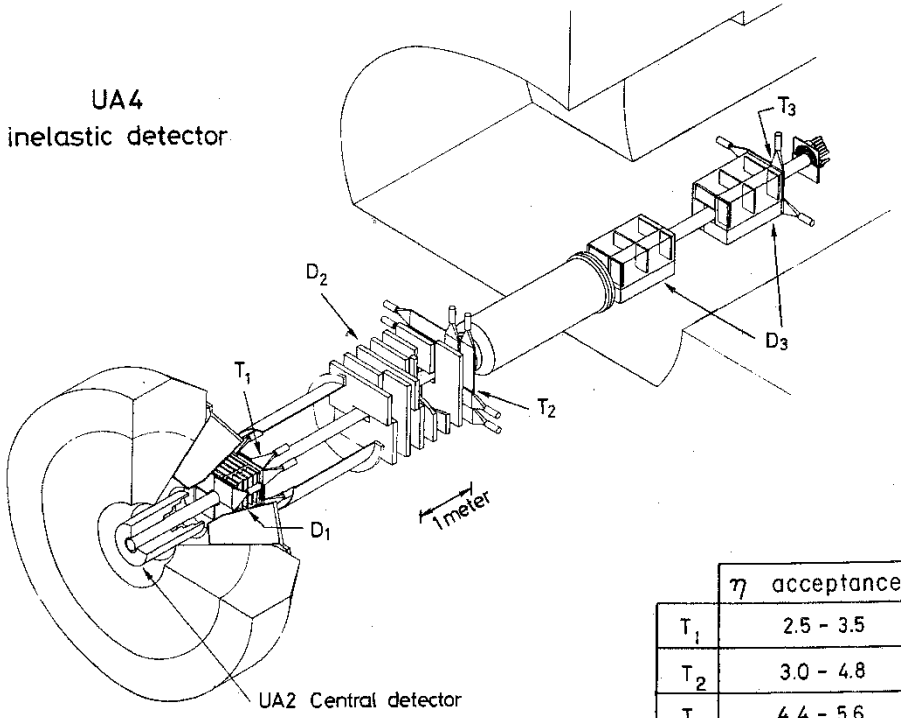
AA

SPS

1979, UA4 proposal: P-P^{bar} measurement of elastic scattering and σ_{tot} at $s^{1/2}$ = 546 GeV

(Amsterdam-CERN-Genova-Napoli-Pisa)

Pisa group:
R. Battiston
P.L.Braccini
R.Carrara
R.Castaldi
F.Cervelli
G.Sanguinetti
C.Vannini
P.G.Verdini



	η acceptance
T_1	2.5 - 3.5
T_2	3.0 - 4.8
T_3	4.4 - 5.6

Fig. 1. Layout of one arm of the inelastic detector; the assembly is symmetric with respect to the crossing region. The central detector of experiment UA2 placed in the same intersection region is also sketched. The η acceptance of the trigger planes T_1, T_2 and T_3 is indicated.

$$\sigma_t^{\,2} = \frac{16\pi}{1+\rho^2}\left(c.\hbar/2\pi\right)^2 \frac{1}{L}\left(\frac{dR_{el}}{dt}\right)_{t=0}$$

$$\sigma_t = \frac{R_{el}+R_{inel}}{L}$$

$$\sigma_t\left(1+\rho^2\right) = 16\pi\left(c.\hbar/2\pi\right)^2 \frac{bN_{el}}{N_{el}+N_{inel}}$$

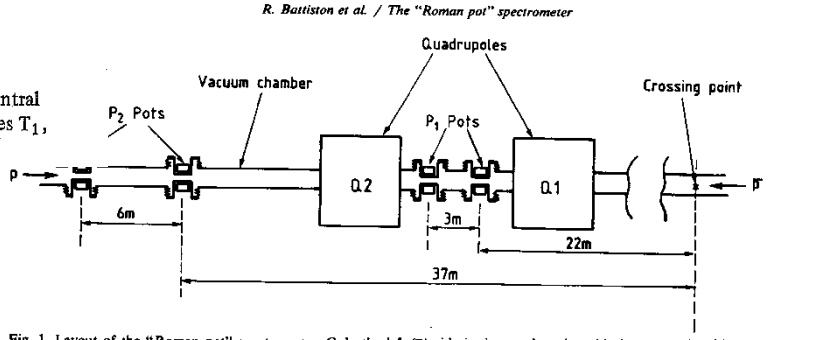
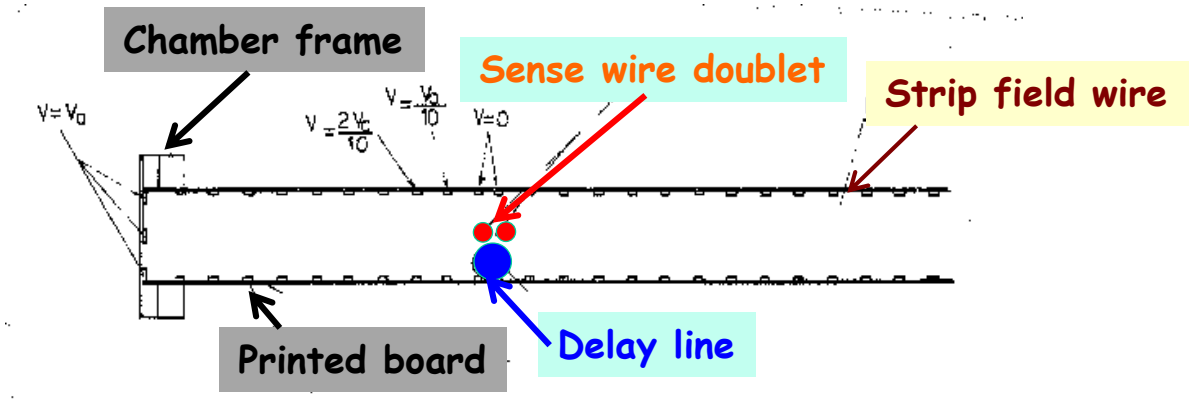
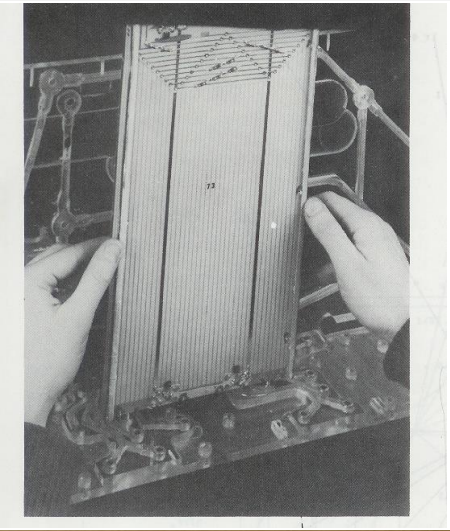


Fig. 1. Layout of the "Roman pot" spectrometer. Only the left ($\bar{p}$) side is shown, the other side is symmetric with respect to the interaction point. Q_1 and Q_2 represent two pairs of machine quadrupoles. The detectors are placed inside the pots, arranged in telescopes P_1 and P_2.

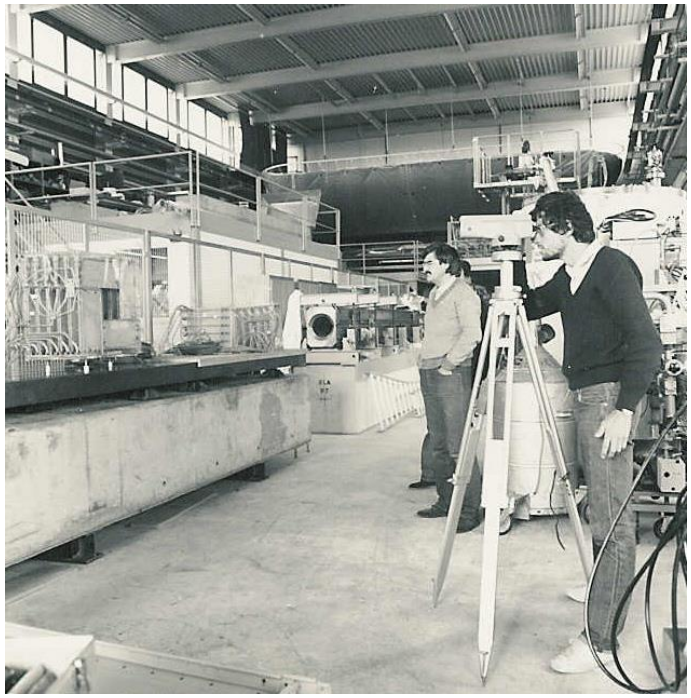
UA4: the same modular drift chambers are used at the PPbar Collider for the UA4 total rate telescopes.





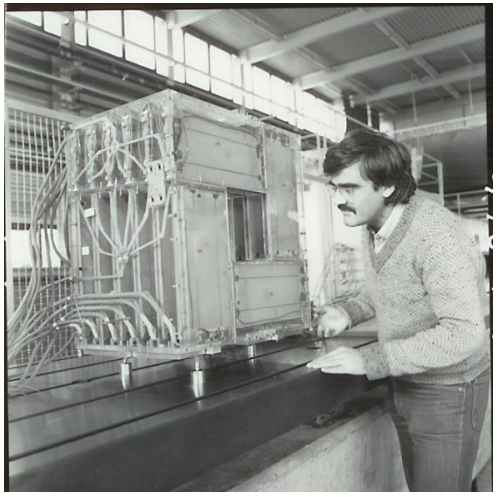
Favatino Castaldi Favatone all are working while Bechini is supervising

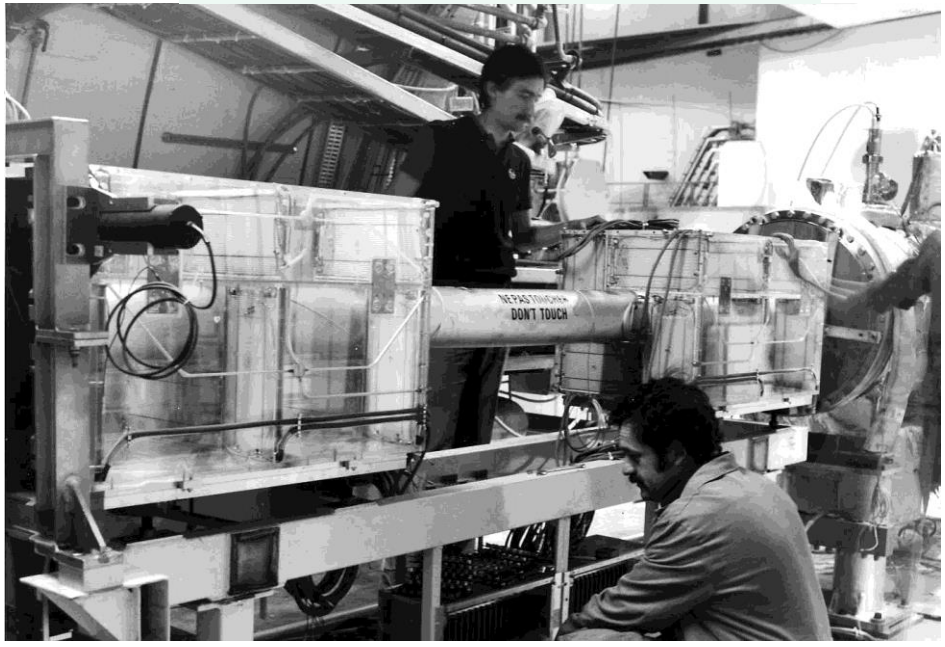
UA4: the total rate telescope survey and installation



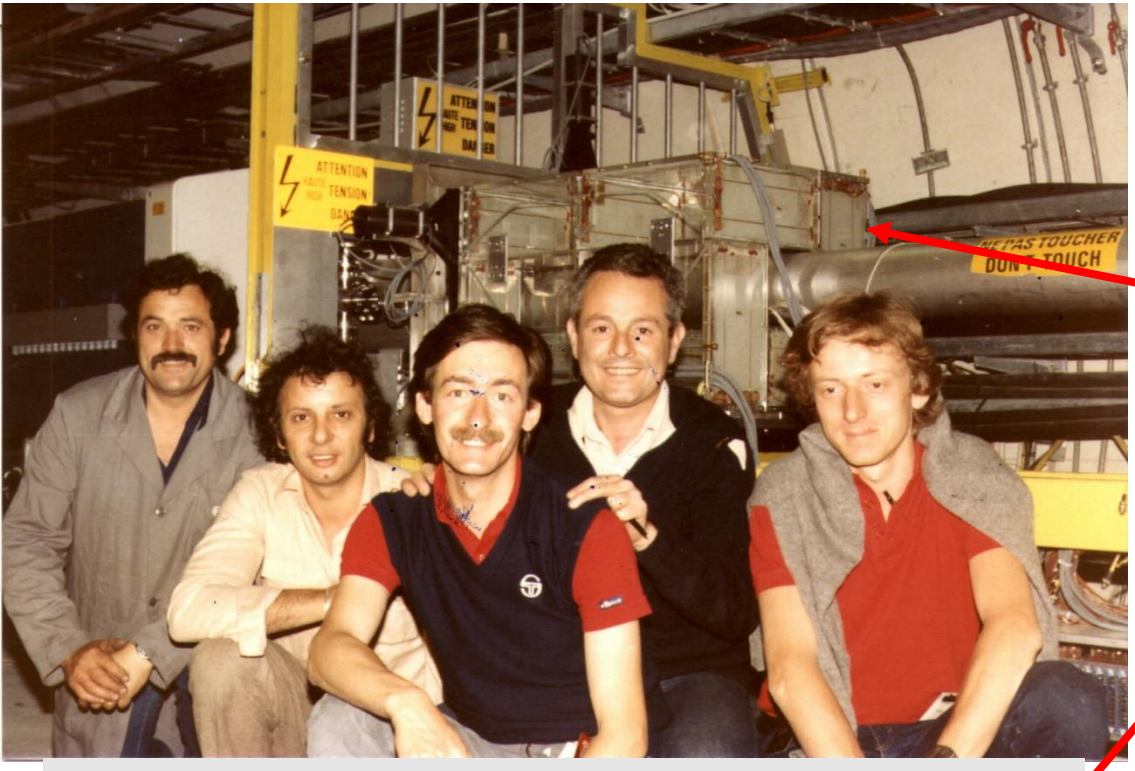
Bechini, Filippo, Favatone

Castaldi and the chamber survey





UA4
Installation completed



Favatone Bechini Filippo Piero Roberto

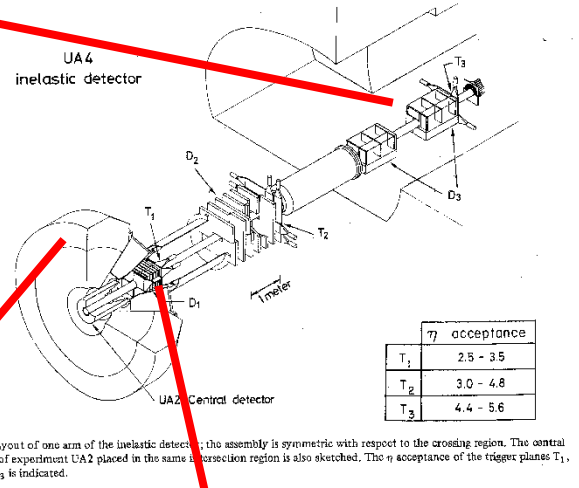
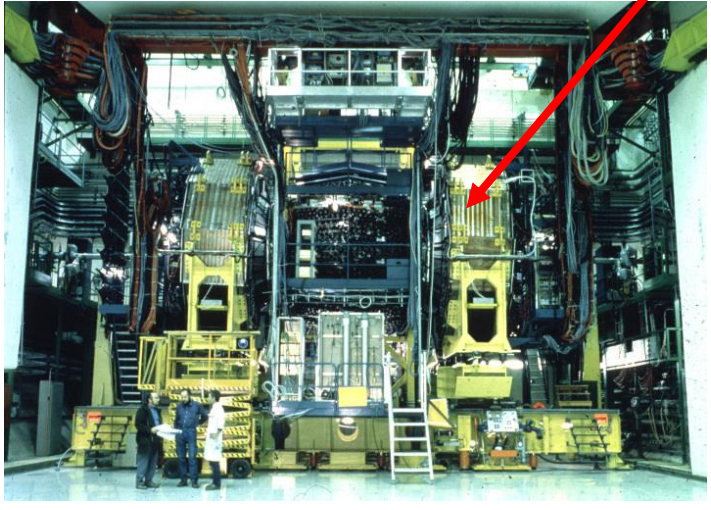
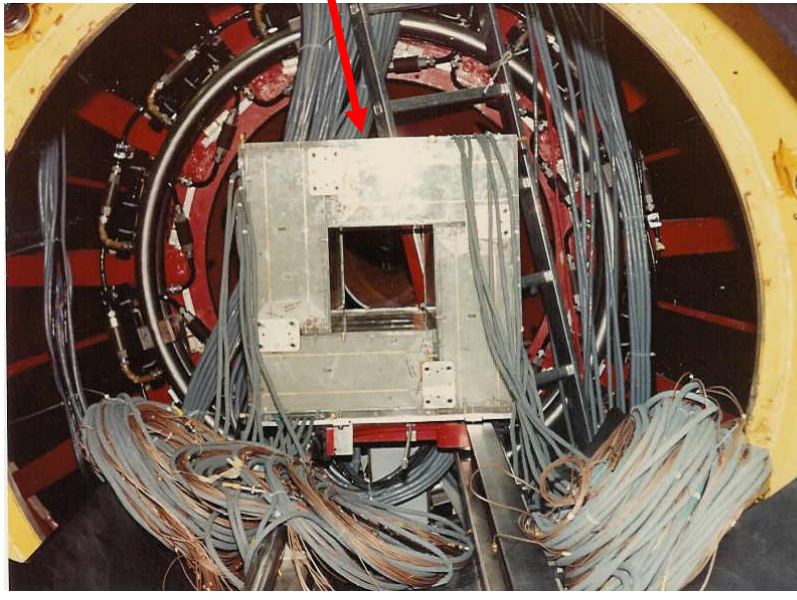


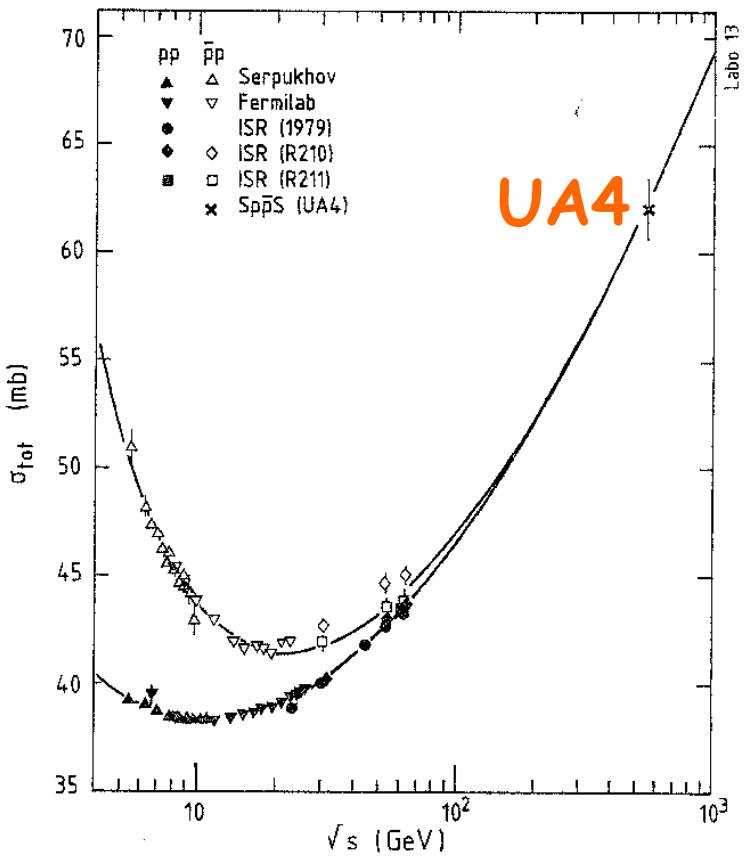
Fig. 1. Layout of one arm of the inelastic detector; the assembly is symmetric with respect to the crossing region. The central detector of experiment UA2 placed in the same intersection region is also sketched. The η acceptance of the trigger planes T_1, T_2 and T_3 is indicated.

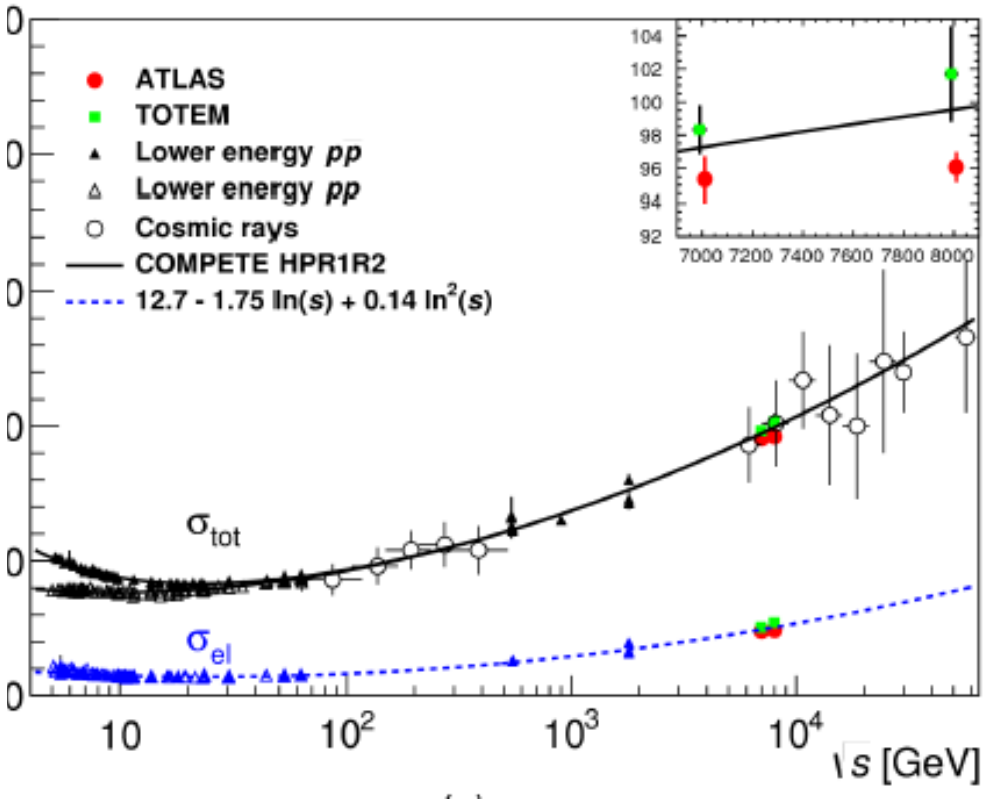
UA2





Also the P-P^{bar} σ_{tot} is rising with energy

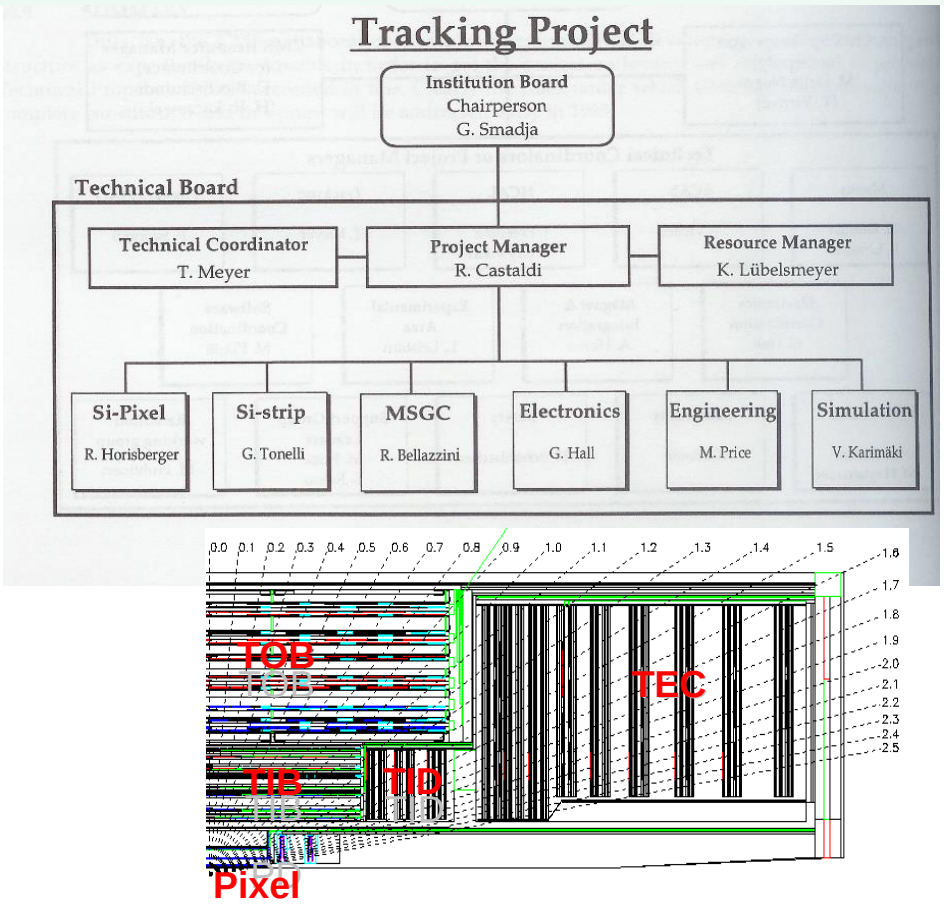


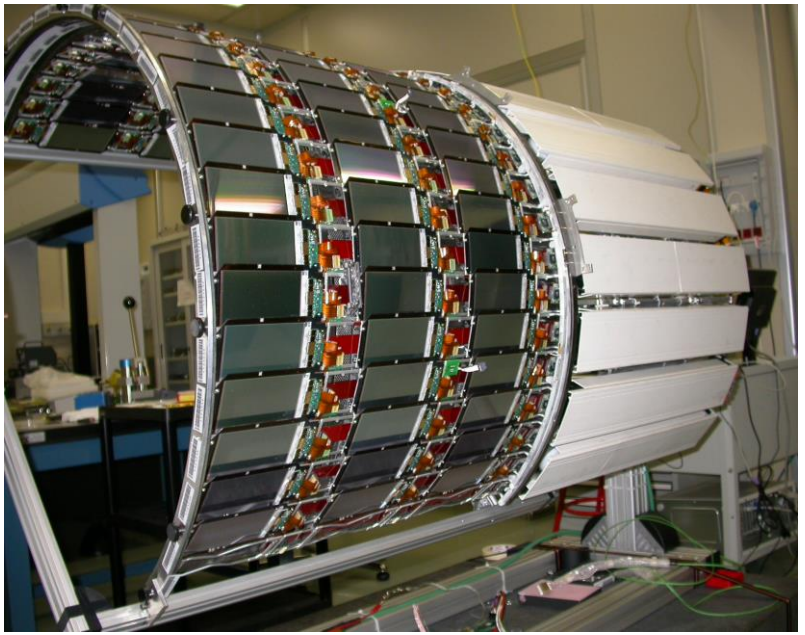


The rising P-P^{bar} σ_{tot} is approaching the P-P σ_{tot} values, as foreseen by the (revisited) Pomeranchuk teorem

1993: 20 years later the R209 proposal, the Pisa group proposes a very large modular Tracker with silicon & microstrip gas chamber modules for CMS. At December 2000 a full silicon Tracker was approuved and the construction began.

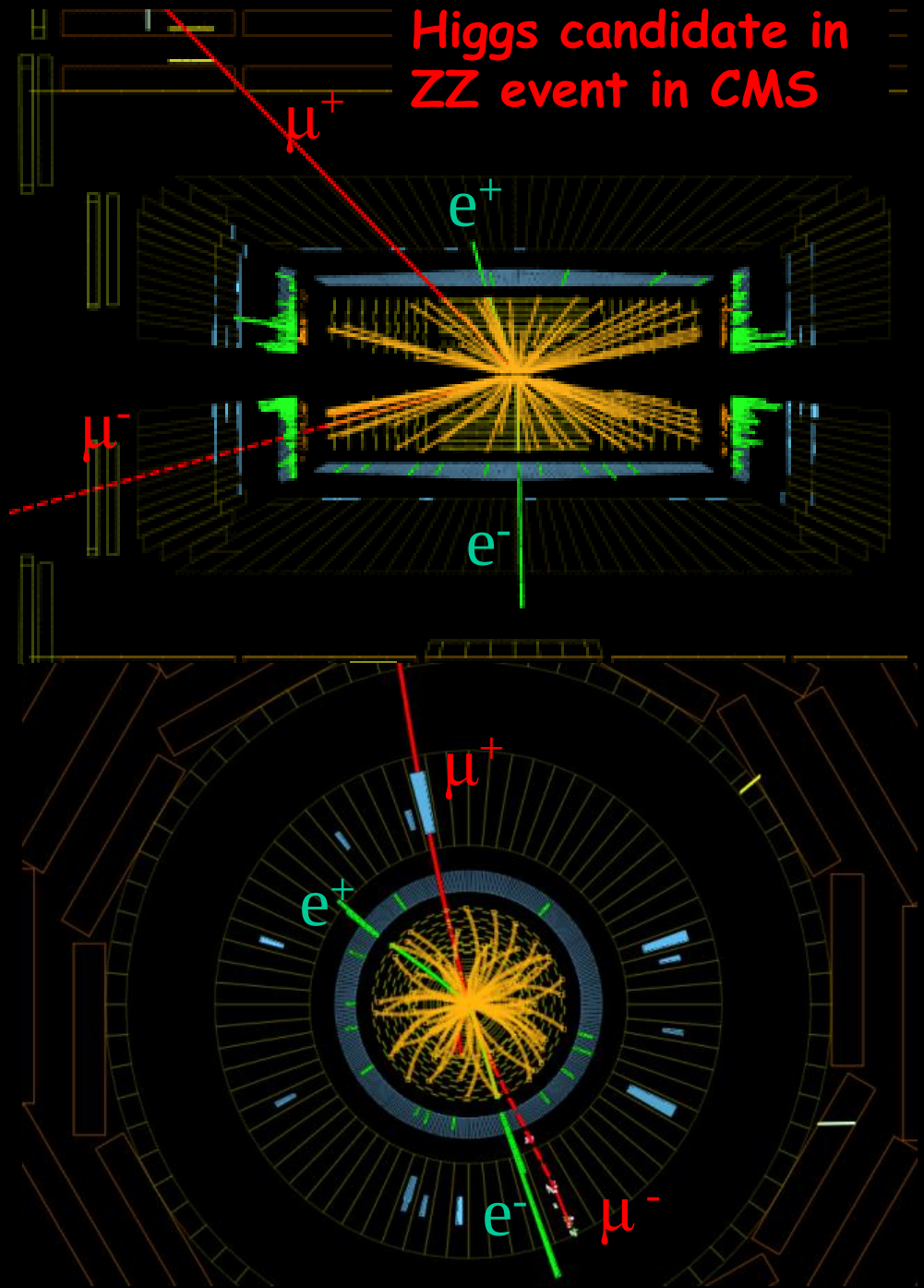
The inner part of the CMS Tracker in construction at San Piero a Grado (Pisa)



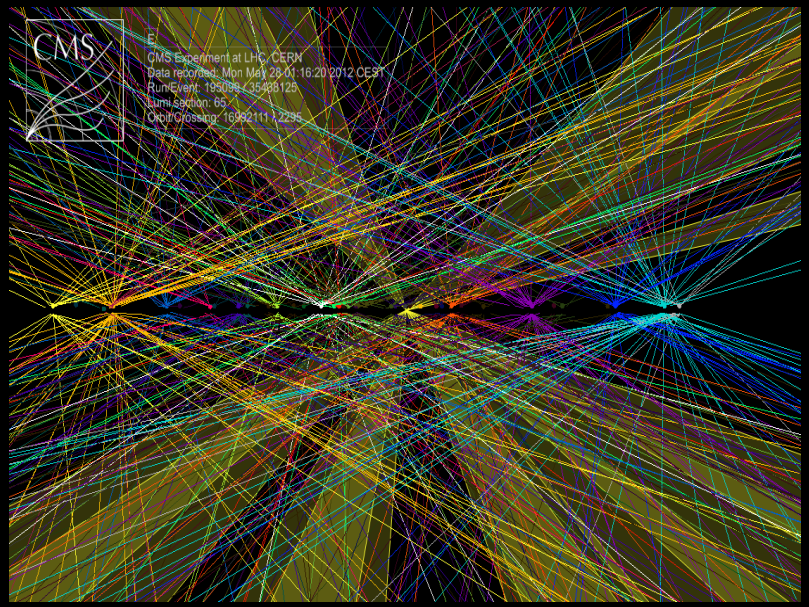


CMS, today

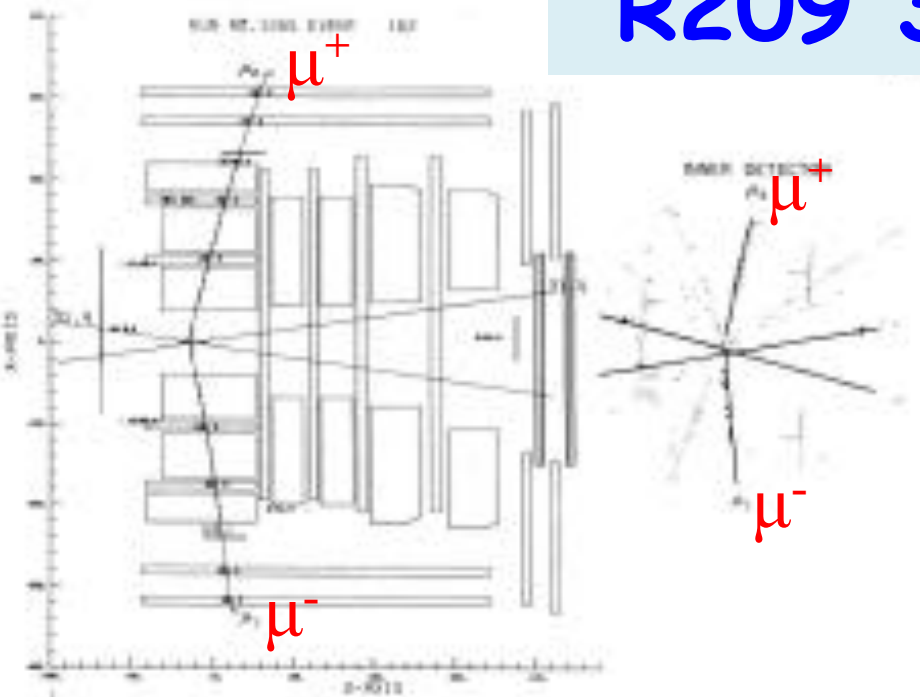
Higgs candidate in ZZ event in CMS

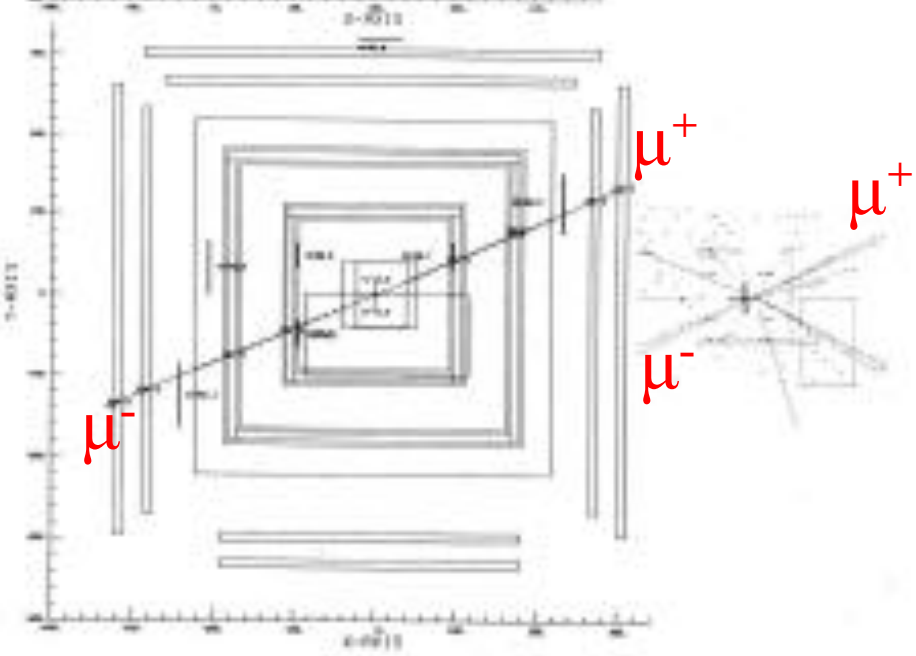


Minimum bias events at 13 TeV (pileup <n>≈27) in CMS tracker

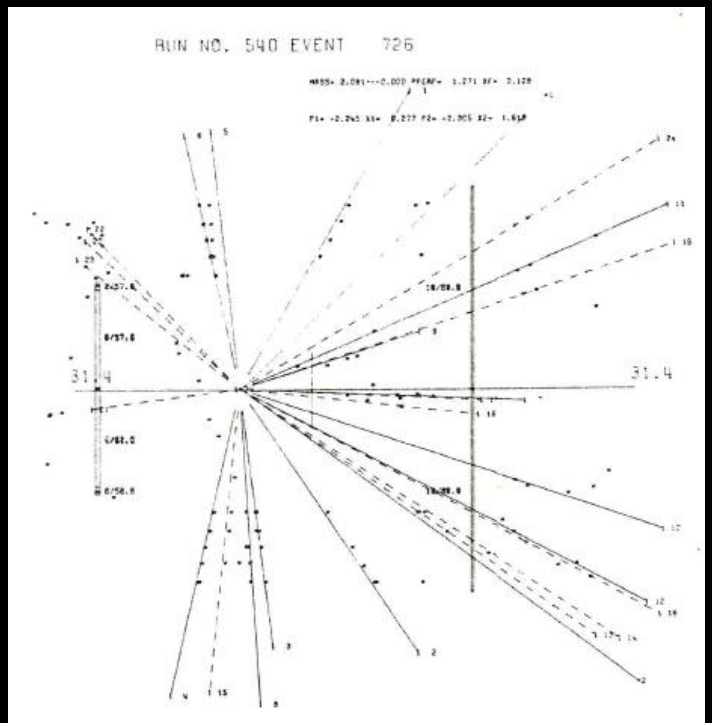


R209 37 years ago





μ-pair event reconstructed in the R209 spectrometer with an exploded view of the Pisa vertex-tracking central detector



Minimum bias event (<n>≈ 12) reconstructed in the Pisa vertex-tracking detector

Conclusions

A lot of New Physics have been discovered during my adventure in H.E.P. and I hope that much more "New Physics" has to come for the fun of next generation of "Fisici a Pisa"