

# Esperimento R420

## Split Field Magnet (SFM) detector

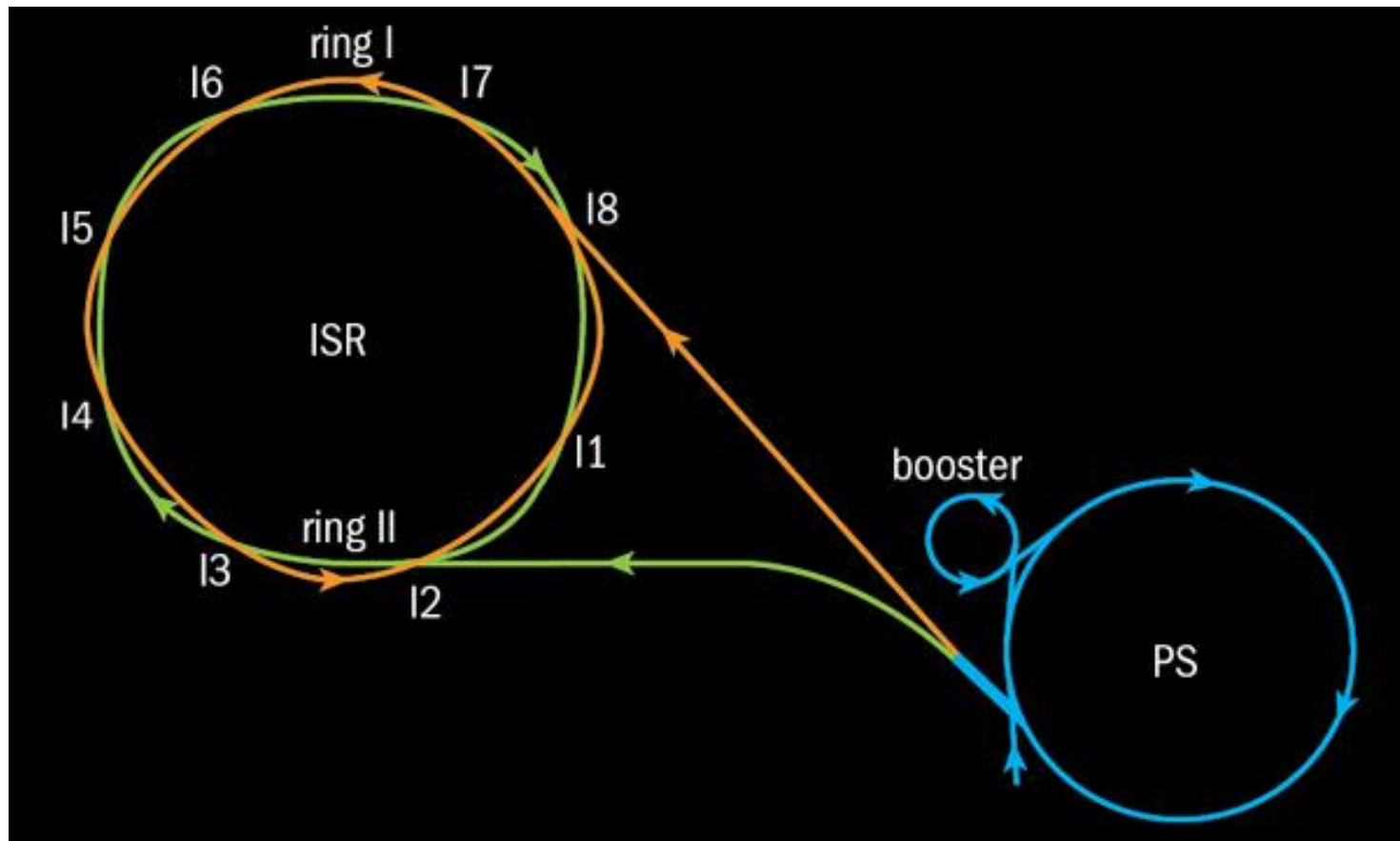
Fabrizio Fabbri  
Istituto Nazionale di Fisica Nucleare

“Volata” attraverso alcuni risultati degli esperimenti ai quali Franco ha partecipato... e anche qualche ricordo personale.

# Anelli di accumulazione ad intersezione ISR



SFM





ISR, primo collider di adroni (pp 1971 – pd, dd, p $\alpha$ ,  $\alpha\alpha$  1976)  
primo collider ppbar (1981)

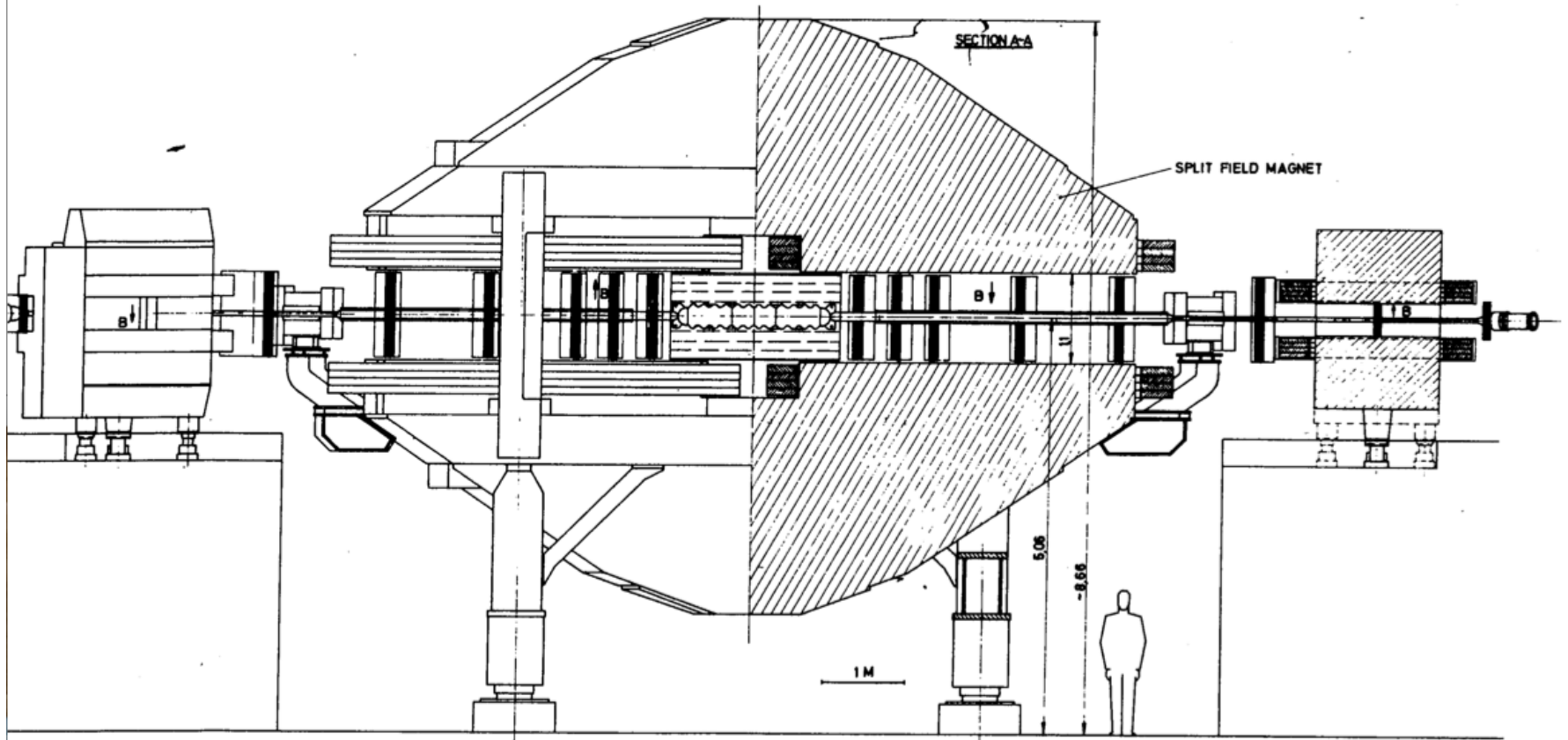
Primo acceleratore al mondo ad usare magneti superconduttori (Nov. 1980).

$$\sqrt{s} = 30, 44, 53, 62 \text{ GeV}$$

“ The many technological challenges that were met at the ISR, in the fields of vacuum technology and **stochastic cooling** for instance, paved the way for luminosity records to be broken “.

Luminosita` max.  $1.4 \times 10^{32} \text{ cm}^{-2} \text{ sec}^{-1}$  (pp)  
Record a collider adronico mantenuto fino al 2004 (Tevatron).

Fasci di alta qualita` per fisica mantenuti anche per 40-50 ore



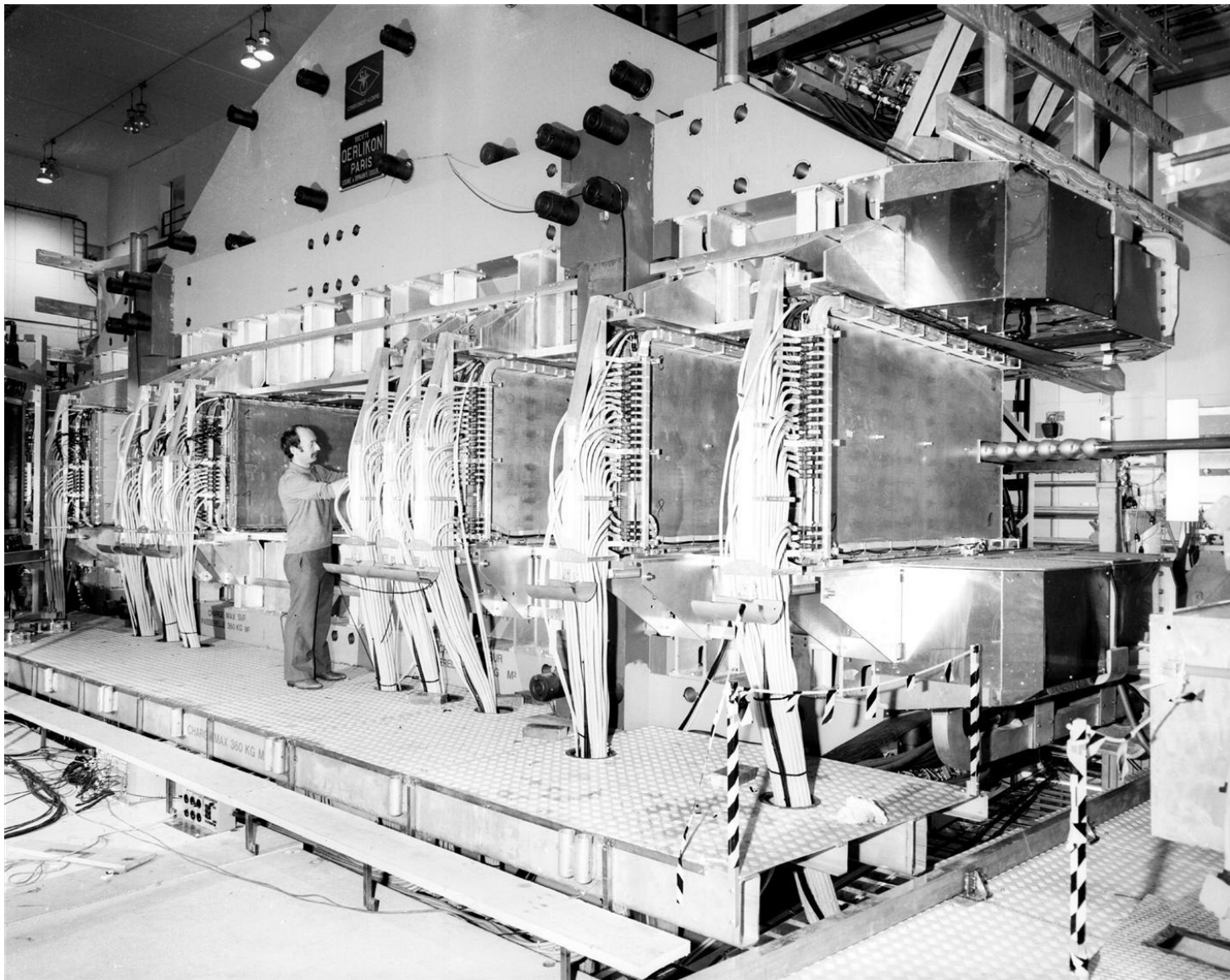
## SFM

Spettrometro con camere MWPC. Copertura in angolo solido circa  $4\pi$ .

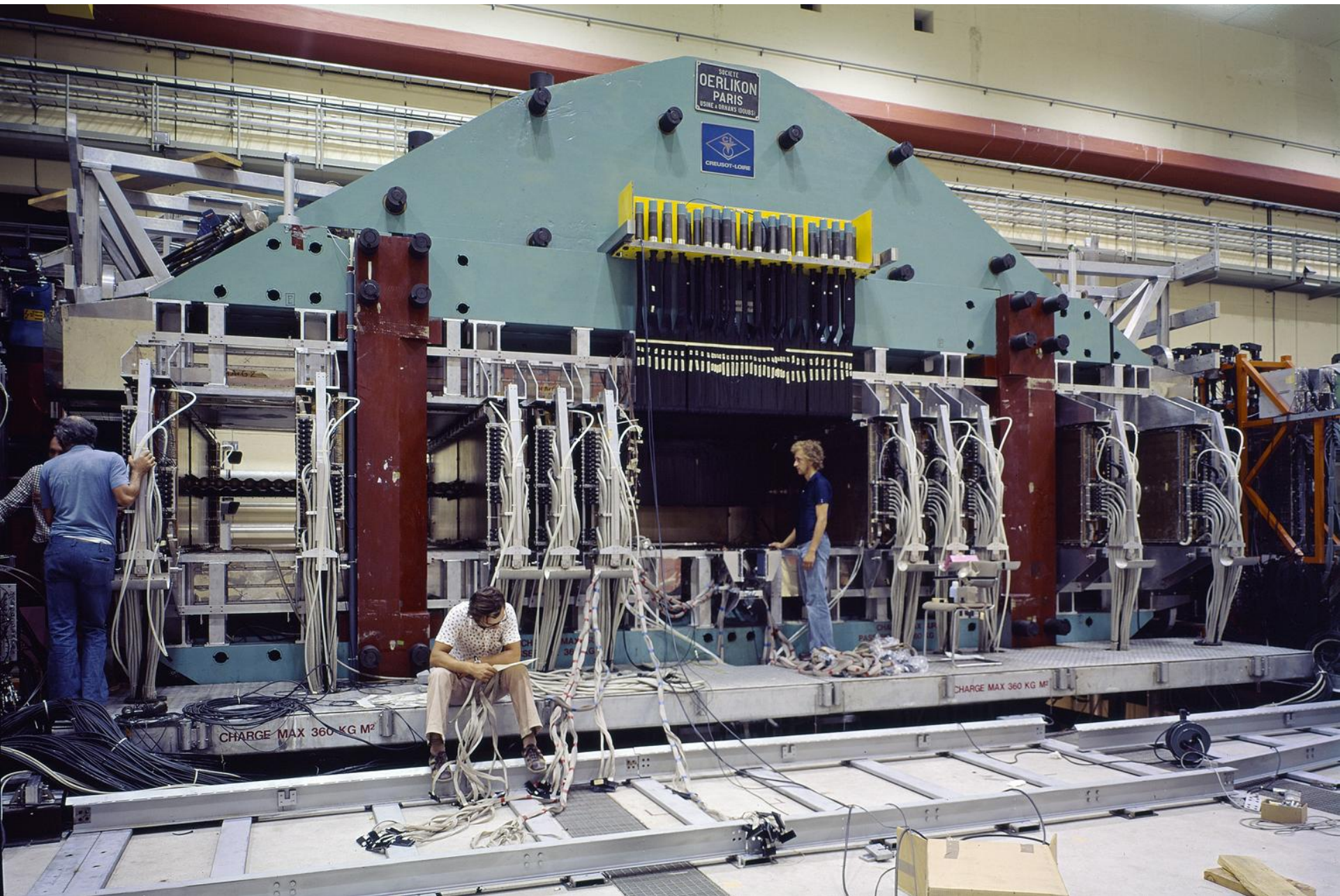
Campo magnetico "splittato" (non omogeneo, Sigh!).

Cherenkov a diversi angoli per identificazione di particelle.

Sistema di tempo di volo (scintillatori plastici)

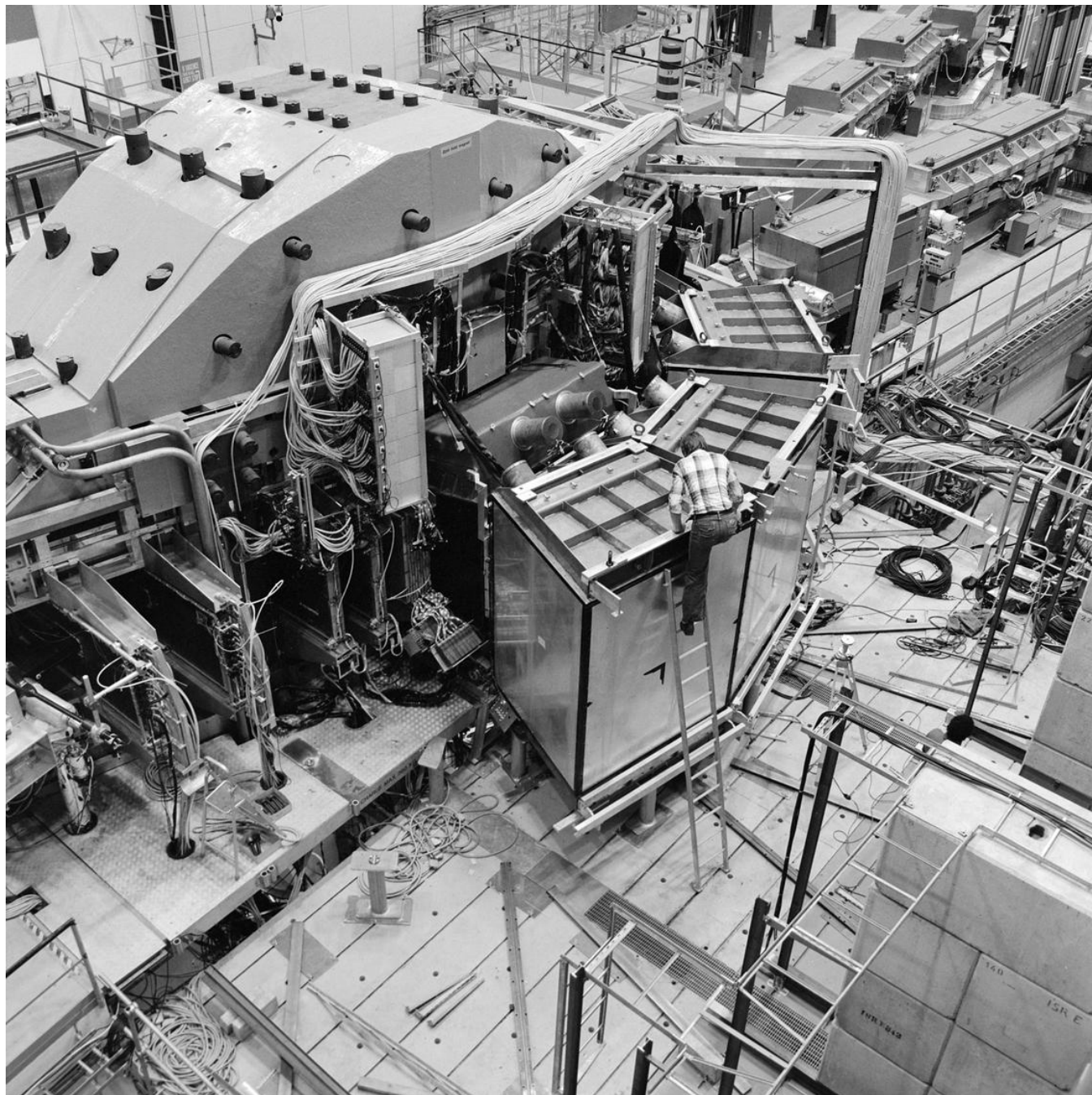


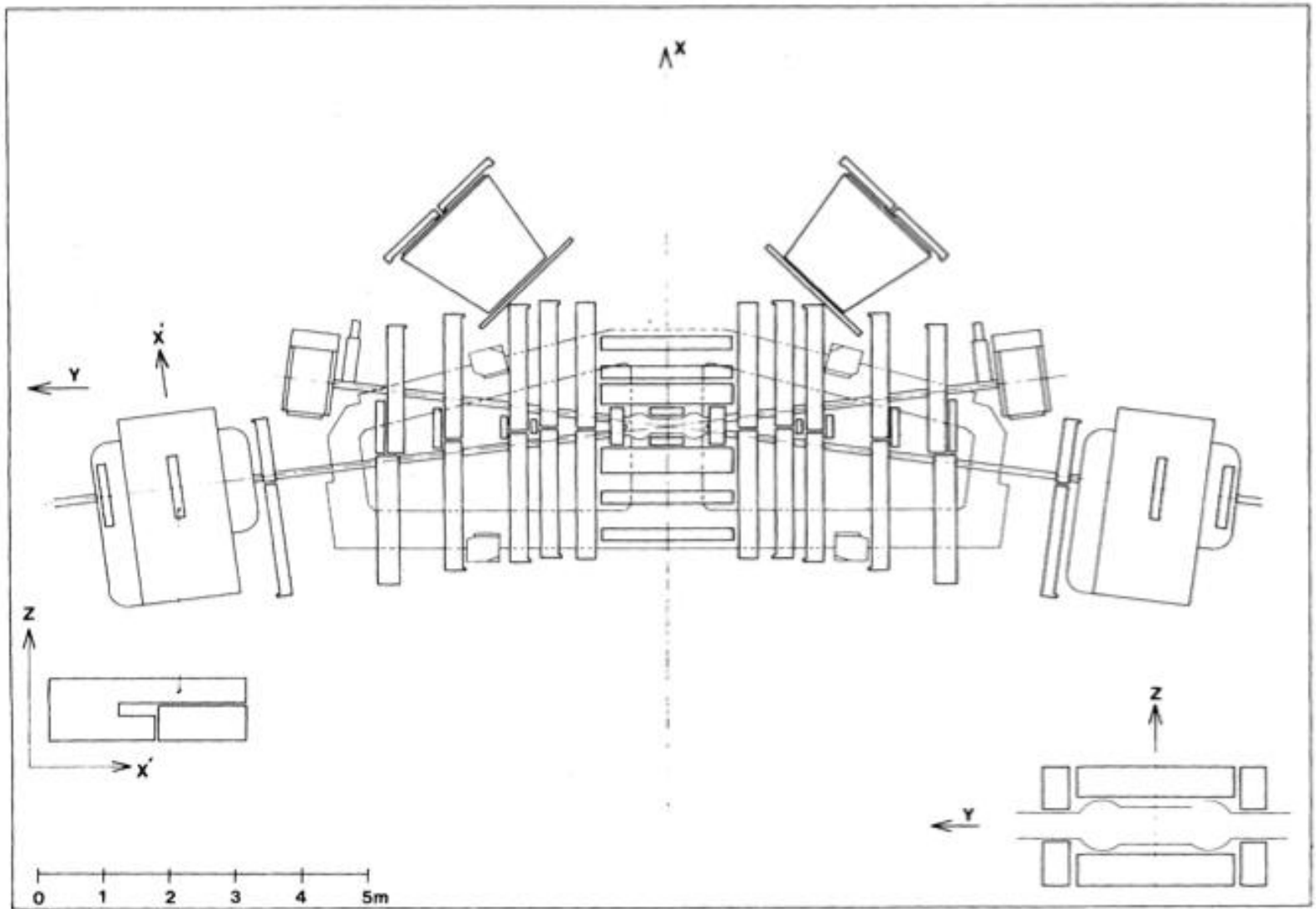
MWPCs

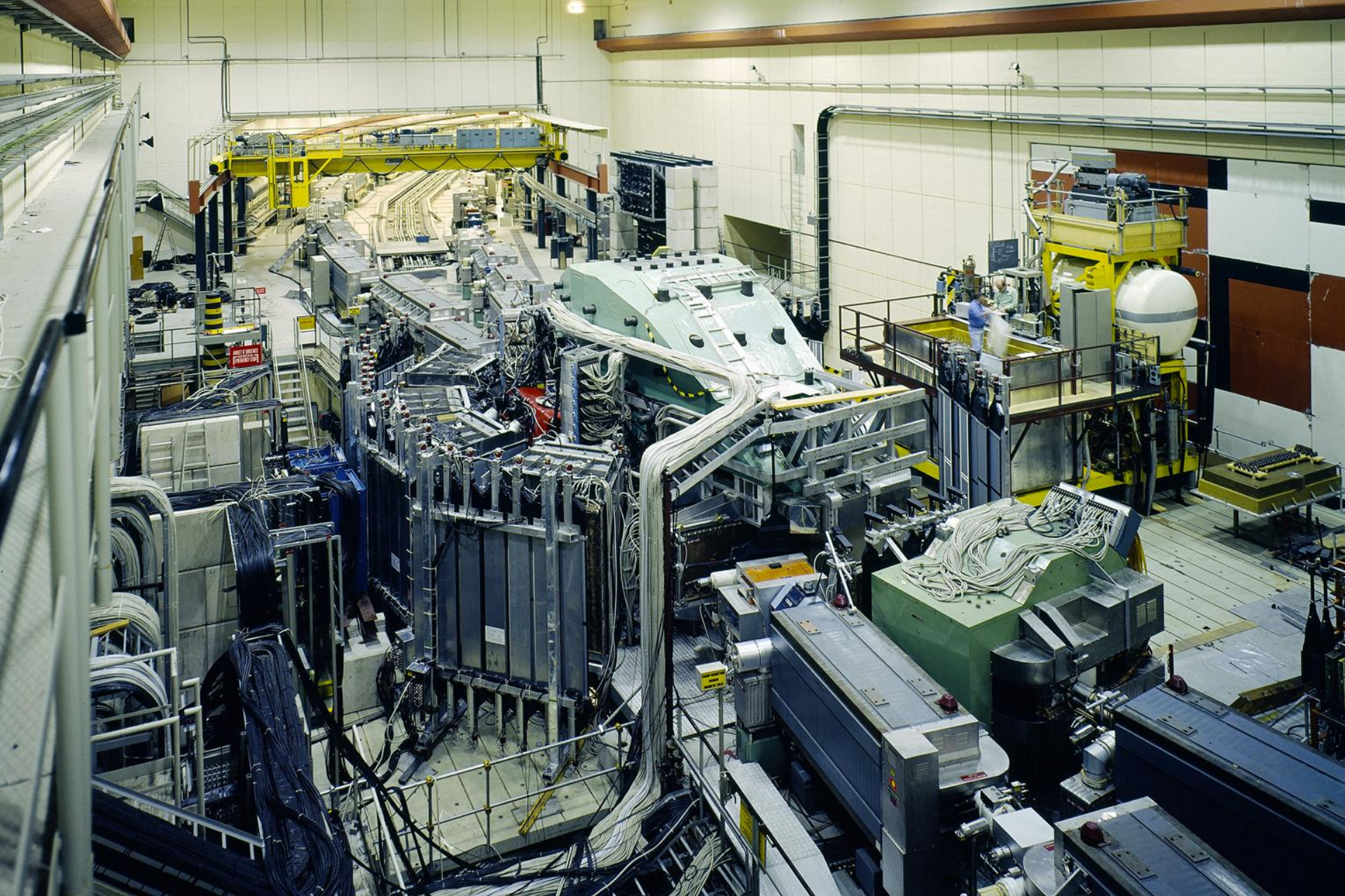




Cherenkov







TOF system (scintillatori plastici)

Esperimento R420 (approvato ufficialmente nel maggio del 1980)

Motivazione: “Studio della fisica di tipo  $In s$  nelle interazioni  $ppbar$  alle energie degli ISR”

Goal: confronto diretto con interazioni  $pp$  alle stesse energie, per evidenziare eventuali differenze non triviali e per inserire “punti” intermedi in energia fra misure di esperimenti a bersaglio fisso ed esperimenti al collider  $SppS$ , attesi di lì a poco.

I fasci di antiprotoni in realtà circolarono negli ISR solo nel 1981, stesso anno nel quale furono iniettati anche nell'SPS, per cui alcuni risultati uscirono quasi contemporaneamente.

Collaborazione: ABCDHW (Ames, Bologna, CERN, Dortmund, Heidelberg, Warsaw)

Gruppo di Bologna:

Giacomelli, Rimondi, Fabbri (da subito, gennaio 1980)

Campanini, Deninno, Dallavalle (il nostro laureando D.O.C.) poco dopo

Siroli, Cuffiani

Poli

Inizio della collaborazione NON completamente indolore per noi.

Inesperienza sul detector, e alcune “ingenuita`” iniziali, nostre.

Italiani noi, tedeschi “tosti” loro.

Ottimo rapporto fin da subito con P.G.Innocenti (CERN) e col gruppo di AMES, entrati poco prima di noi nella collaborazione.

## Nostre responsabilita` iniziali in R420:

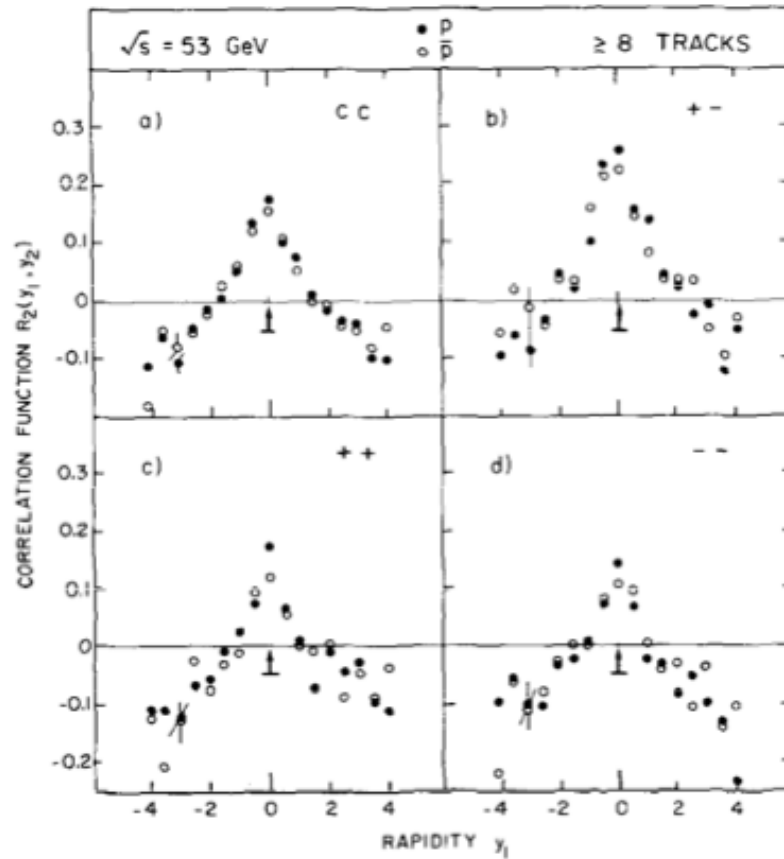
1. Run e Data quality check ppbar (MB e urto elastico)
2. Studi su eventi di Minimum Bias trigger in pp e ppbar.  
Ricostruzione eventi (install. programmi su CDC 7600 e VAX).  
Analisi.
3. Misura e confronto diretto urto elastico pp e ppbar.  
Adattare programma di ricostruzione SFM per ppbar a basso t.  
Ricostruzione eventi e analisi.

Successivamente (estesa la nostra collaborazione a R416, R418, R419)



# Primi risultati con antiprotoni

## COMPARISON OF SHORT-RANGE RAPIDITY CORRELATIONS IN $\bar{p}p$ AND $pp$ INTERACTIONS AT $\sqrt{s} = 53$ GeV



We find clear evidence for strong short-range correlations in  $ppbar$  interactions, which are equal to those found in  $pp$  interactions.

The correlation coefficients for  $pp$  interactions are essentially energy independent.



# COMPARISON OF INCLUSIVE DISTRIBUTIONS IN $pp$ AND $\bar{p}p$ INTERACTIONS AT $\sqrt{s} = 53$ GeV

Volume 132B, number 4,5,6

PHYSICS LETTERS

1 December 1983

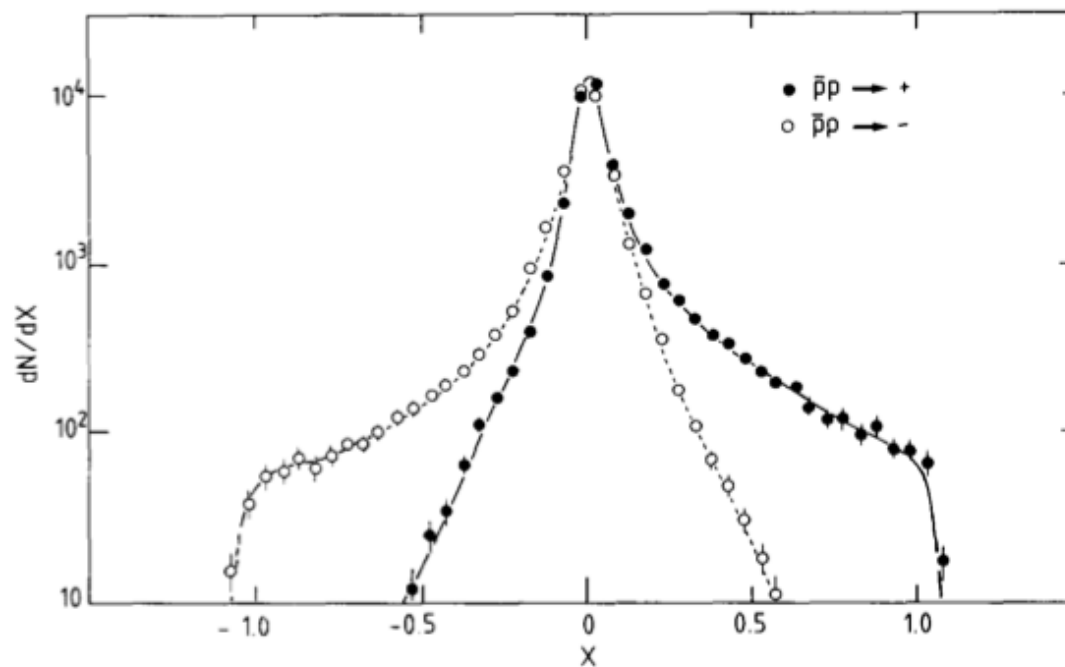


Fig. 3.  $x$ -distributions of positive and negative particles produced in  $\bar{p}p$  interactions at  $\sqrt{s} = 53$  GeV. Only raw data with elastic events removed are presented. The slight differences between leading particles for  $x > 0$  and  $x < 0$  is due to the acceptance. The lines are only meant to guide the eye.

# Distribuzioni in rapidita` e Pt

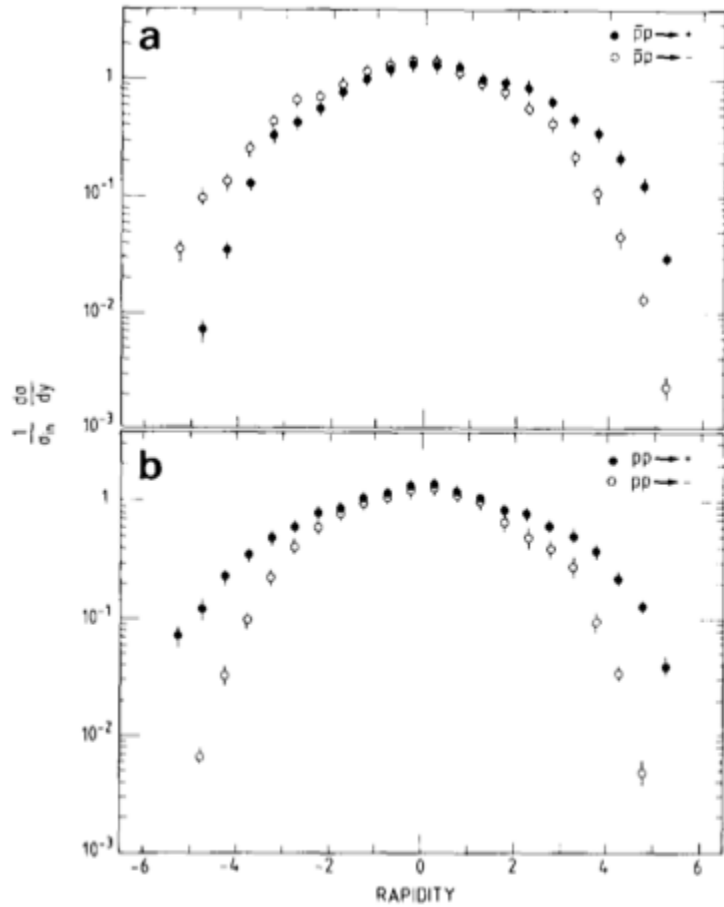
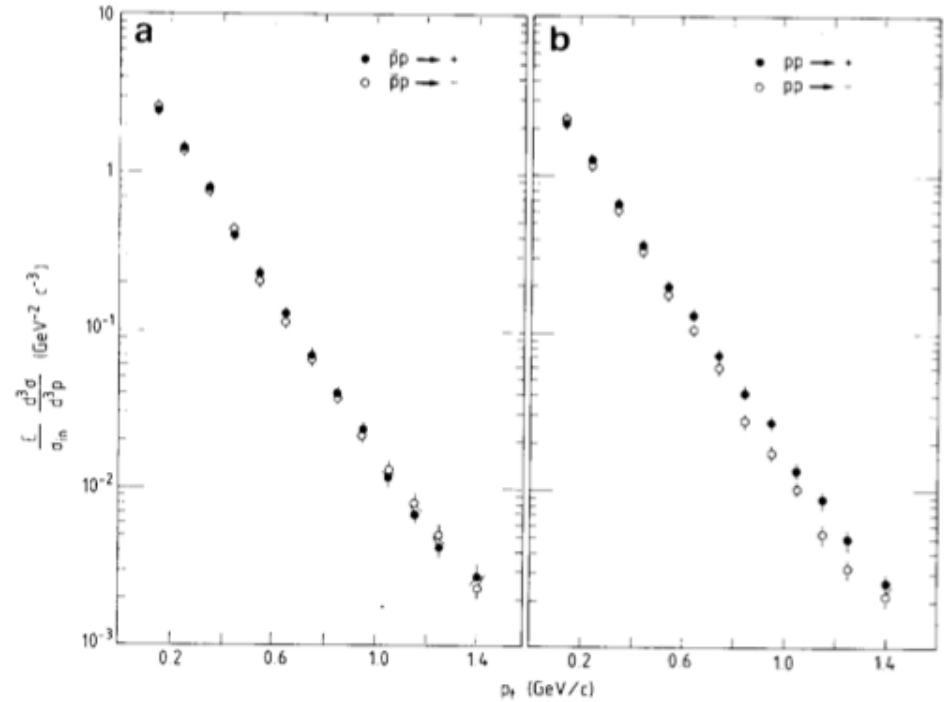
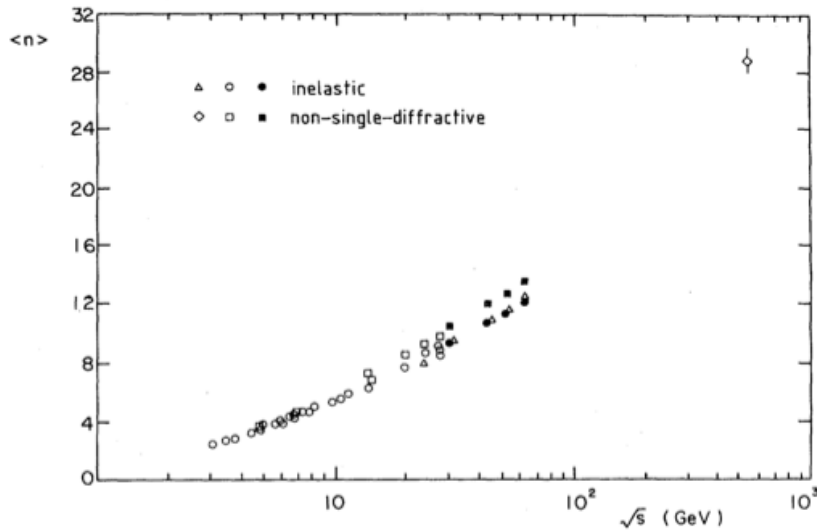


Fig. 2. Rapidity distributions for positive and negative particles produced inclusively in (a)  $\bar{p}p$  and (b)  $pp$  interactions at  $\sqrt{s} = 53$  GeV.



We find all the typical features of In s physics. The comparison of the spectra from  $pp$  and  $p\bar{p}$  collisions at the same energy does not show any appreciable difference apart from the obvious differences due to electric charge and baryon number.

# Charged Multiplicity distributions



(i) The energy dependence of the mean charged multiplicity may be described by an expression of the form

$$\langle n \rangle = A + B \ln s + C \ln^2 s .$$

A simple  $\ln s$  dependence is excluded by the data.

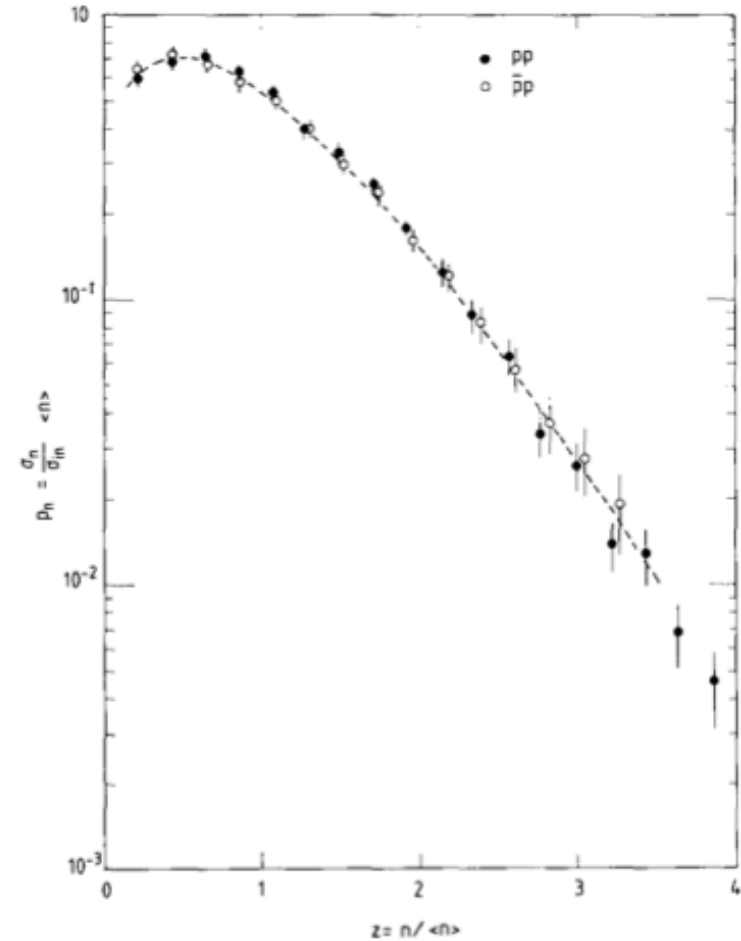


Fig. 4. The observed charged multiplicity distributions in pp and  $\bar{p}p$  collisions for  $|\eta| < 1.3$  expressed in the KNO scaling form. The dashed line is a fit to the experimental data at  $\sqrt{s} = 540$  GeV.

## A MEASUREMENT OF $\bar{p}p$ AND $pp$ ELASTIC SCATTERING AT ISR ENERGIES

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*A. Breakstone et al. /  $\bar{p}p$  and  $pp$  scattering*

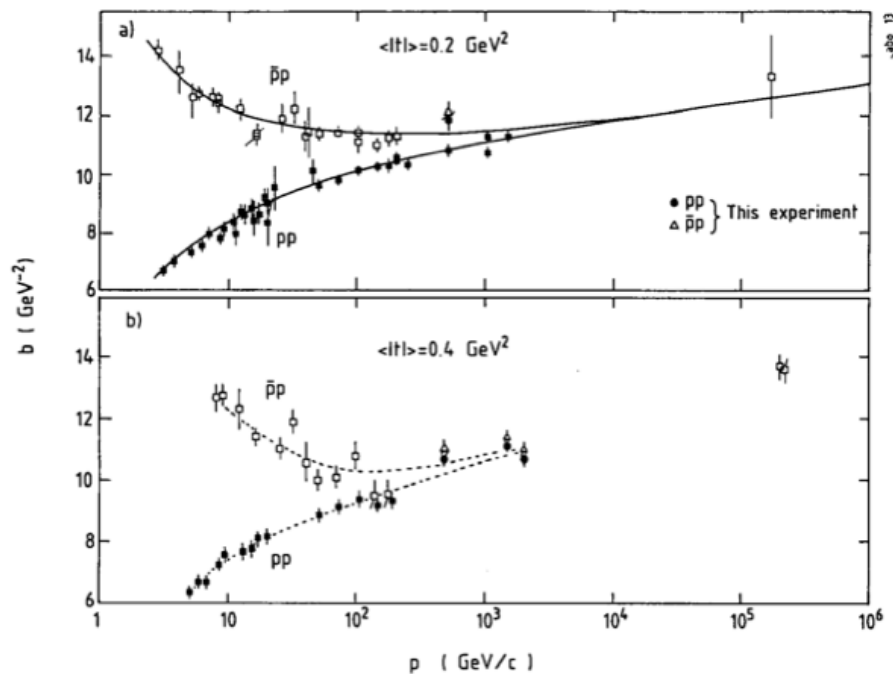


Fig. 2. Compilation of local slopes at  $-t = 0.2$  and  $0.4 \text{ GeV}^2$  as functions of equivalent laboratory beam momentum. The solid lines in fig. 2a are the fits of ref. [14], the dashed lines in fig. 2b are included only to show the trend of the data.

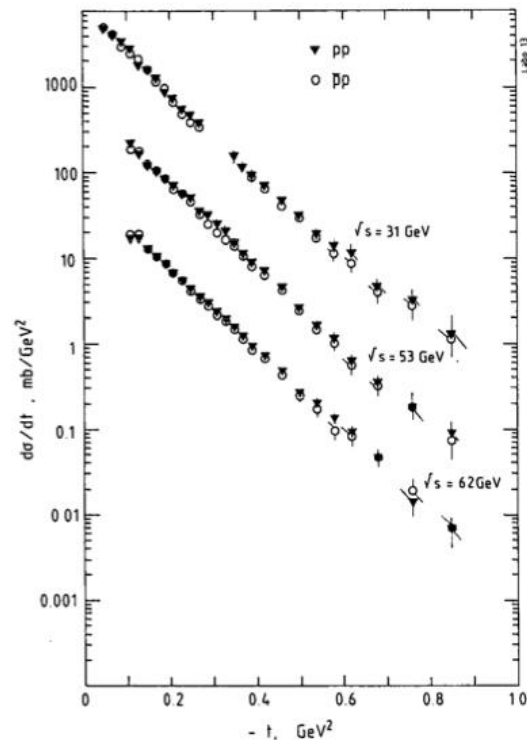
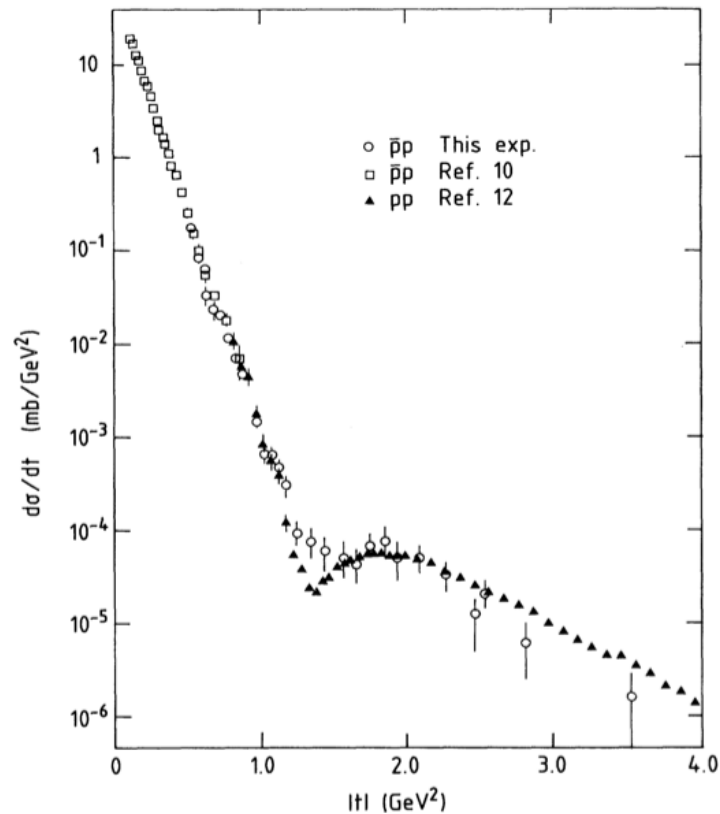
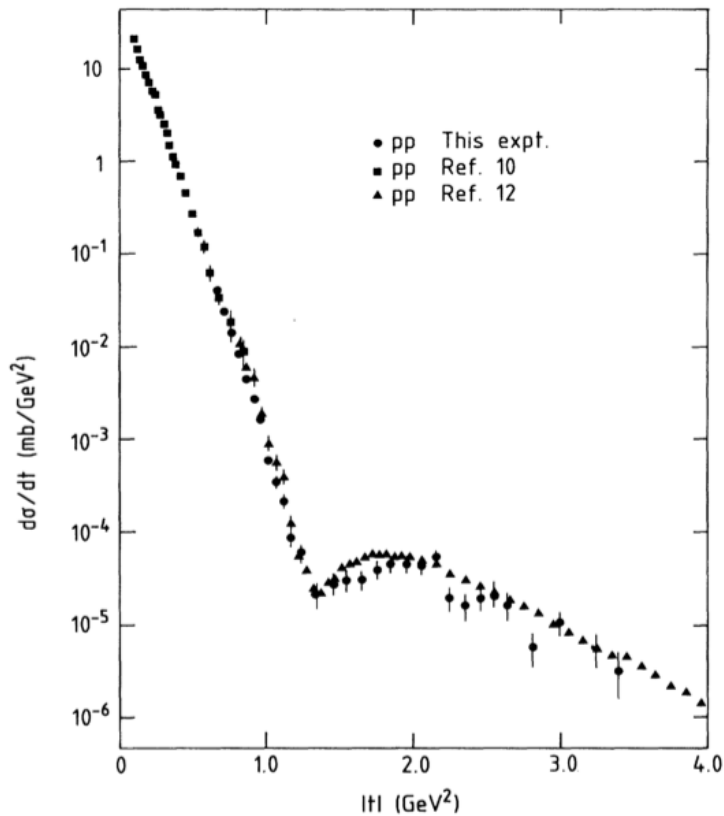


Fig. 1. Elastic differential cross sections at  $\sqrt{s} = 31, 53$  and  $62 \text{ GeV}$ . Only  $t$ -dependent errors are shown. The systematic scale error is estimated at 10% for  $pp$  data and 15% for  $\bar{p}p$  data. The 31 (53)  $\text{GeV}$  data have been scaled by a factor of 100 (10) for clarity.

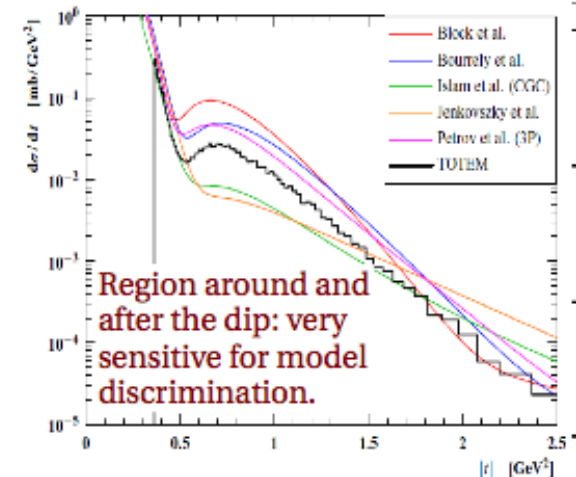
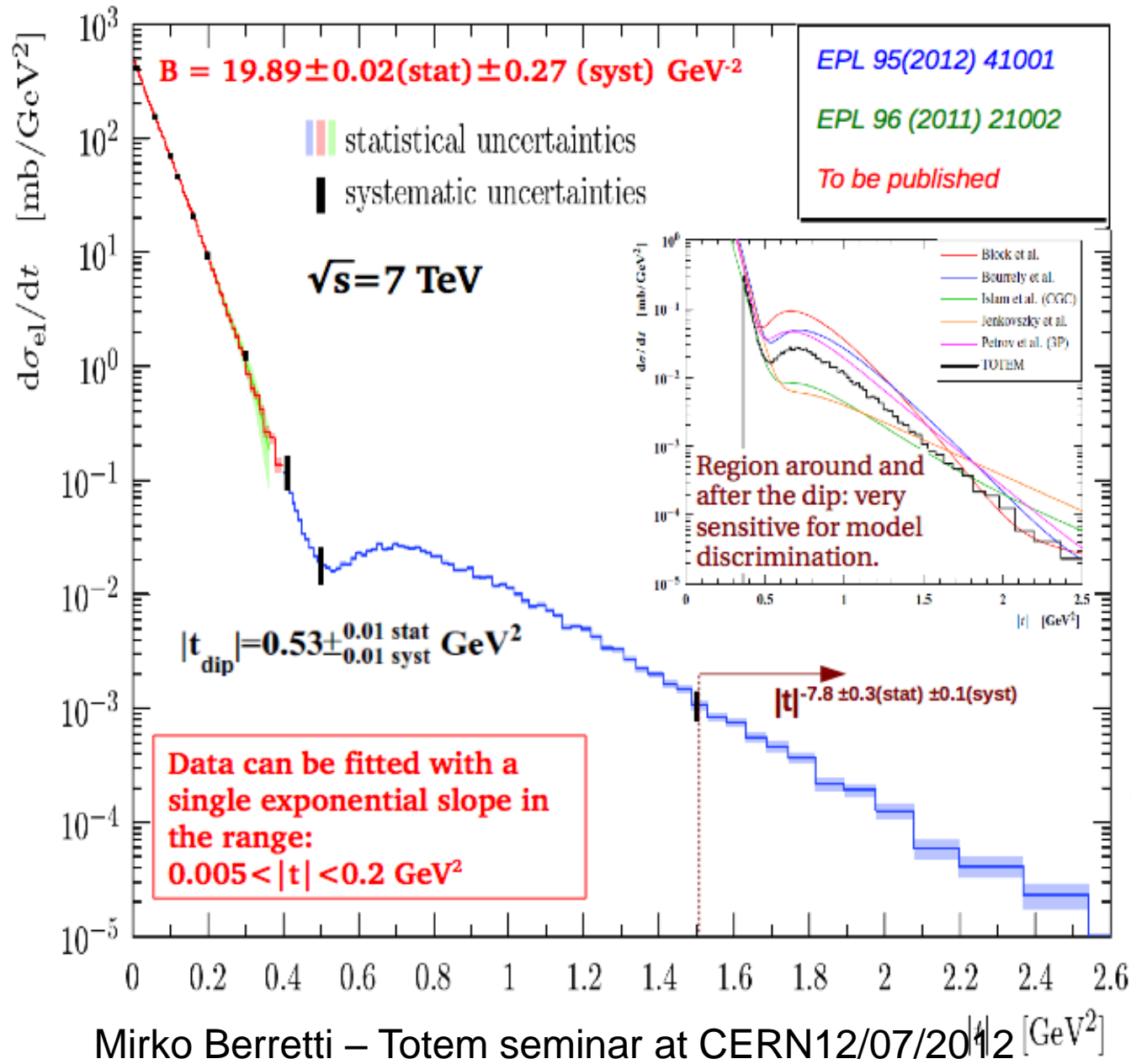
“We report the results of a measurement of the differential cross sections for  $p\bar{p}$  and  $pp$  elastic scattering at  $\sqrt{s} = 31, 53$ , and  $62 \text{ GeV}$  in the region  $0.05 < |t| < 0.85 \text{ GeV}^2$ . These data, together with the results of the measurements of the  $p\bar{p}$  and  $pp$  total cross sections, determine most of the forward elastic scattering parameters in the ISR energy range.”

### Measurement of $\bar{p}p$ and $pp$ Elastic Scattering in the Dip Region at $\sqrt{s} = 53$ GeV

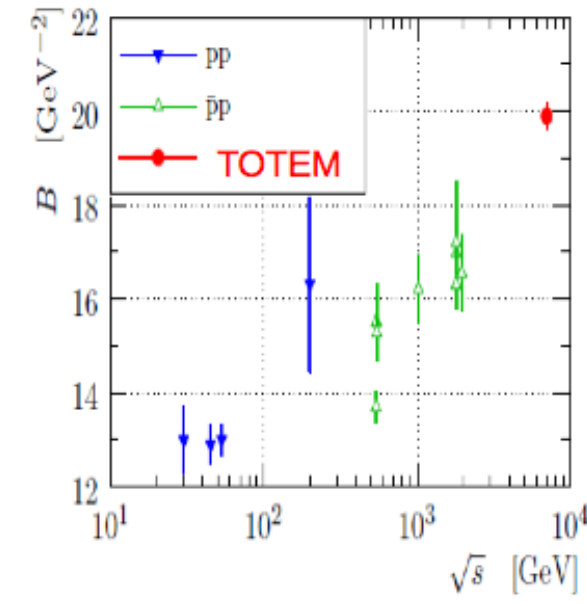


Prima evidenza di assenza di dip in  $ppbar$  (assieme a UA4)

# Elastic scattering results: $5 \cdot 10^{-3} < |t| < 2.5 \text{ GeV}^2$



- $0.36 < |t| < 2.5 \text{ GeV}^2$
- $0.02 < |t| < 0.33 \text{ GeV}^2$
- $5 \cdot 10^{-3} < |t| < 0.4 \text{ GeV}^2$



- Shrinkage of the forward peak:**
- minimum moves to lower  $|t|$  with increasing CM energy
  - exponential slope grows with the CM energy

Si e` detto, all'inizio trattamento un po` "rude" per noi.

Nel giro di poco tempo, pero`, ci siamo guadagnati piena fiducia e rispetto.

Non solo. Penso che il nostro atteggiamento sempre e comunque amichevole talvolta anche "giocosu", tipico italiano, abbia pure un po` scalfitto la dura corazza Teutonica.

Sono riusciti a mandare giu` perfino questo (1982), senza rappresaglie !





Meeting della collaborazione ABCDHW a Dortmund (1982 ?)



Memorabili le sfide di “scatto” Campanini-Nakada sul parcheggio del Bld 14 prima di andare a pranzo alla cantina del CERN.



La partenza bruciante di Campanini, ahime`, di solito era rovinata dalla perdita di una scarpa...

Con malcelata soddisfazione di Tatsuya...



## Successivamente

1. Analisi alla Bose-Einstein (all'epoca non molto comune) pp e p $\bar{p}$
2. Studio dati raccolti con Double Pomeron Exchange trigger
3. ( $\langle pt \rangle$  e particle source size) vs multiplicity in pp
4. Analisi dettagliata molteplicità carica in rapidity bins in MB pp
5. Misura sezioni d'urto invarianti di distribuzioni inclusive ( $y, x_F, pt$ ) su tutto lo spazio delle fasi in pp

Coinvolgimento in analisi eventi ad alto Pt, con particella trigger identificata a diversi angoli (gluon jet tagging)

BOSE-EINSTEIN CORRELATIONS IN  $pp$  AND  $\bar{p}p$  INTERACTIONS  
AT  $\sqrt{s} \approx 63$  GeV

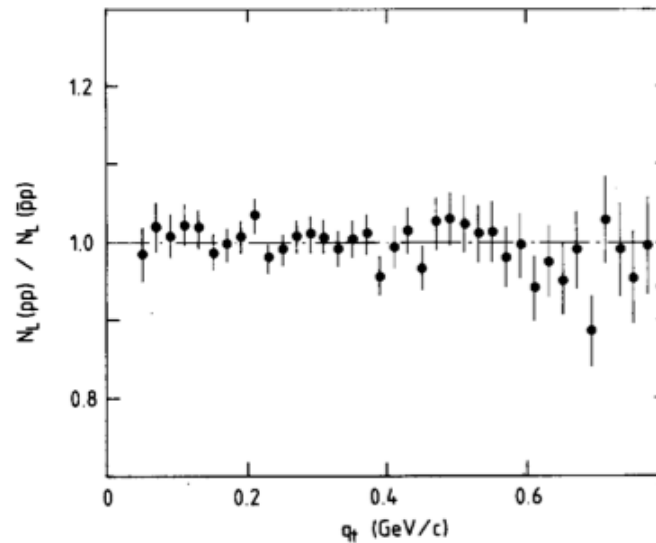
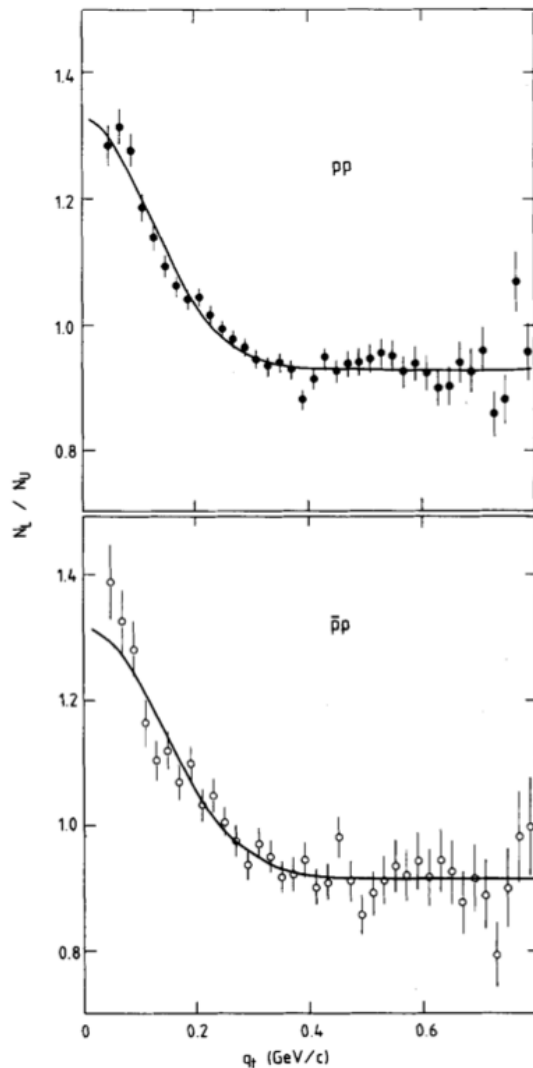
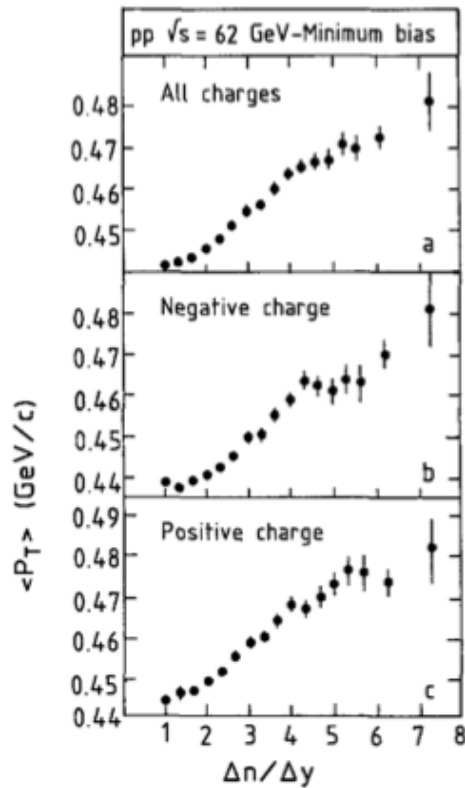


Fig. 2. The ratio  $N_L^{pp} / N_L^{\bar{p}p}$  for like pairs of the  $pp$  sample relative to the  $\bar{p}p$  sample plotted versus  $q_T$ .

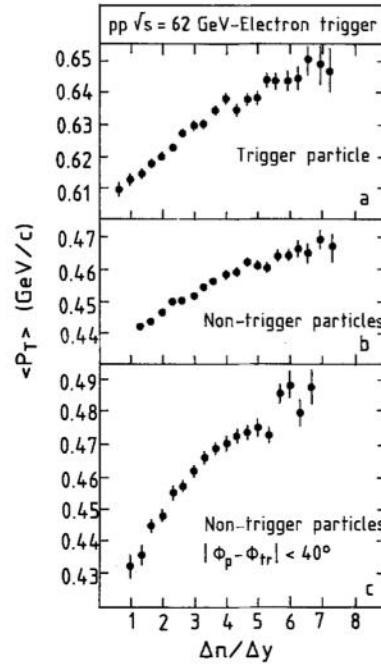
Our data show the existence of Bose-Einstein interference effects in  $pp$  and  $p\bar{p}$  interactions at ISR energies. The interference is only partial, in the sense that the chaoticity parameter is about 0.44 (and not unity).

The radius of the pion emitting region is about 1.1 fm, which is somewhat smaller than the values found at lower energies. We find that the chaoticity parameter and the radius of the pion source are equal in  $pp$  and  $p\bar{p}$  interactions.

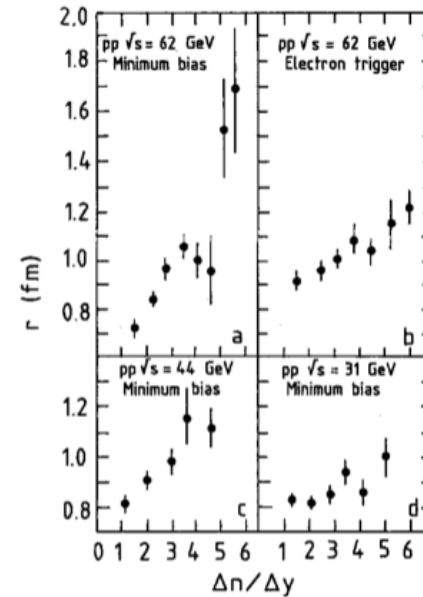
# Multiplicity Dependence of the Average Transverse Momentum and of the Particle Source Size in $p-p$ Interactions at $\sqrt{s}=62, 44$ and $31$ GeV



**Fig. 1.** **a** The average transverse momentum of charged particles, with  $0.15 \leq p_T \leq 2.5$  GeV/c, produced in the central region of rapidity ( $|y| < 1.5$ ) plotted versus charged particle density  $\rho$ , at  $\sqrt{s}=62$  GeV. **b** Same as in **a** for negative particles only. **c** Same as in **a** for positive particles only



**Fig. 3a-c.** Electron trigger data;  $\sqrt{s}=62$  GeV: **a** The average transverse momentum of the triggering particle with  $0.4 < p_T < 1$  GeV/c, as a function of  $\rho = \Delta n / \Delta y$ . **b** The average transverse momentum of all the non-trigger particles having  $0.15 \leq p_T \leq 2.5$  GeV/c as a function of  $\rho$ . **c** The average transverse momentum for non-trigger particles, with  $0.15 \leq p_T \leq 2.5$  GeV/c, lying in a  $\phi$  interval of  $\pm 40^\circ$  around the trigger track



**Fig. 5a-d.** Radius of the particle emitting source as a function of  $\rho$ : **a** Minimum bias trigger at  $\sqrt{s}=62$  GeV. **b** Electron trigger at  $\sqrt{s}=62$  GeV. **c** Minimum bias trigger at  $\sqrt{s}=44$  GeV. **d** Minimum bias trigger at  $\sqrt{s}=31$  GeV

# Production of the $f^0$ Meson in the Double Pomeron Exchange Reaction $pp \rightarrow pp\pi^+\pi^-$ at $\sqrt{s} = 62$ GeV

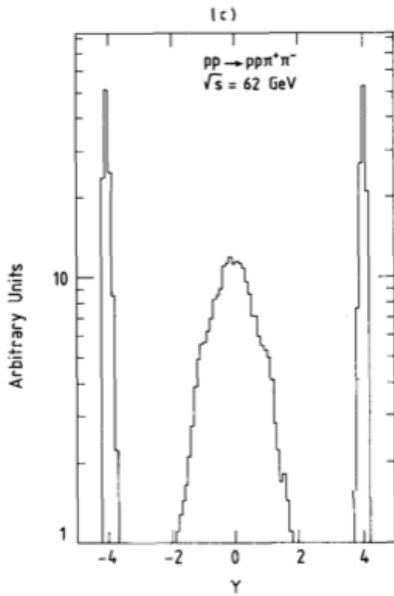
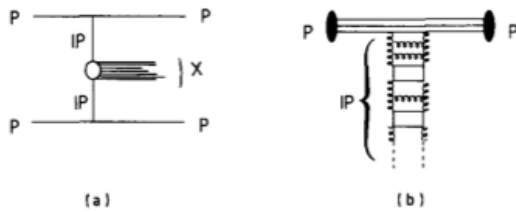
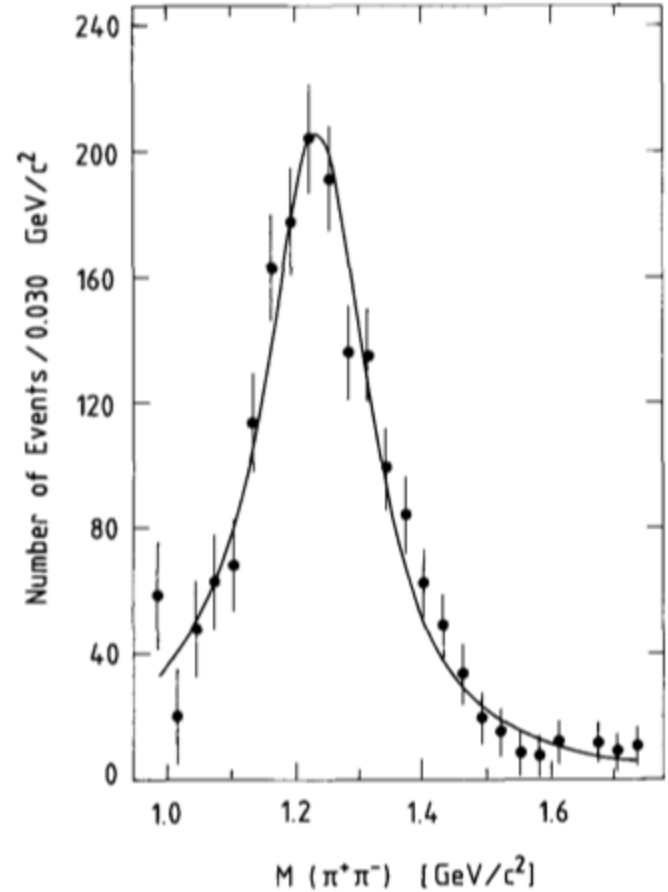


Fig. 1. a Double Pomeron Exchange in  $pp \rightarrow pp\pi^+\pi^-$ . b Example of gluon ladders and quark loops which may sum to produce a Pomeron trajectory. c Rapidity distribution of particles from 4-C fits to the reaction  $pp \rightarrow pp\pi^+\pi^-$  at  $\sqrt{s} = 62$  GeV. (Uncorrected)



With an integrated luminosity of  $50\text{nb}^{-1}$  a cross section  $\sigma(pp \rightarrow pp f^0)$  of  $(8 \pm 1 \pm 3)\mu\text{b}$  was determined.

Primo di una serie di lavori sulla ricerca di stati "esotici" per l'epoca (glueballs)

**Charged Multiplicity Distributions in Rapidity Bins  
for pp Collisions at  $\sqrt{s} = 31, 44$  and  $62$  GeV.**

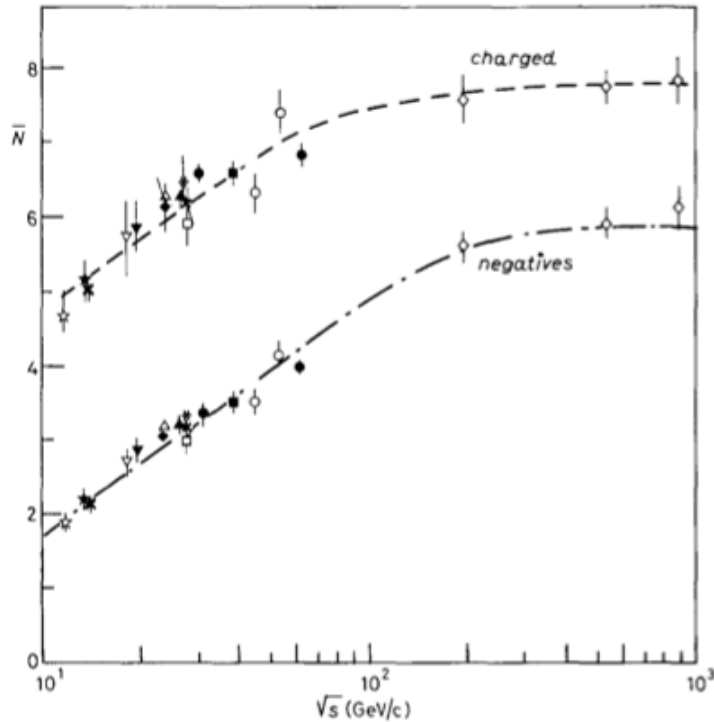


Fig. 14. - Compilation of the average number of clans in the whole phase space vs. c.m. energy. The lines are only meant to guide the eye. Symbols are the same as in fig. 6.

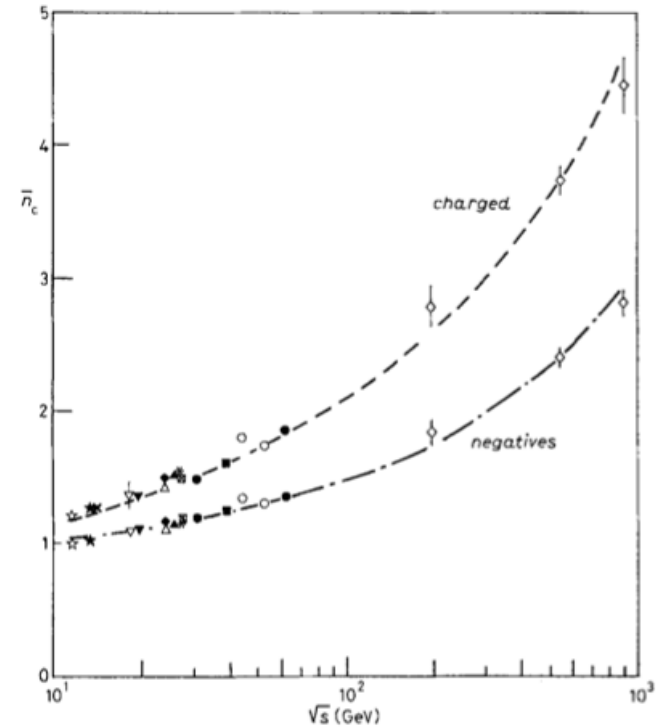
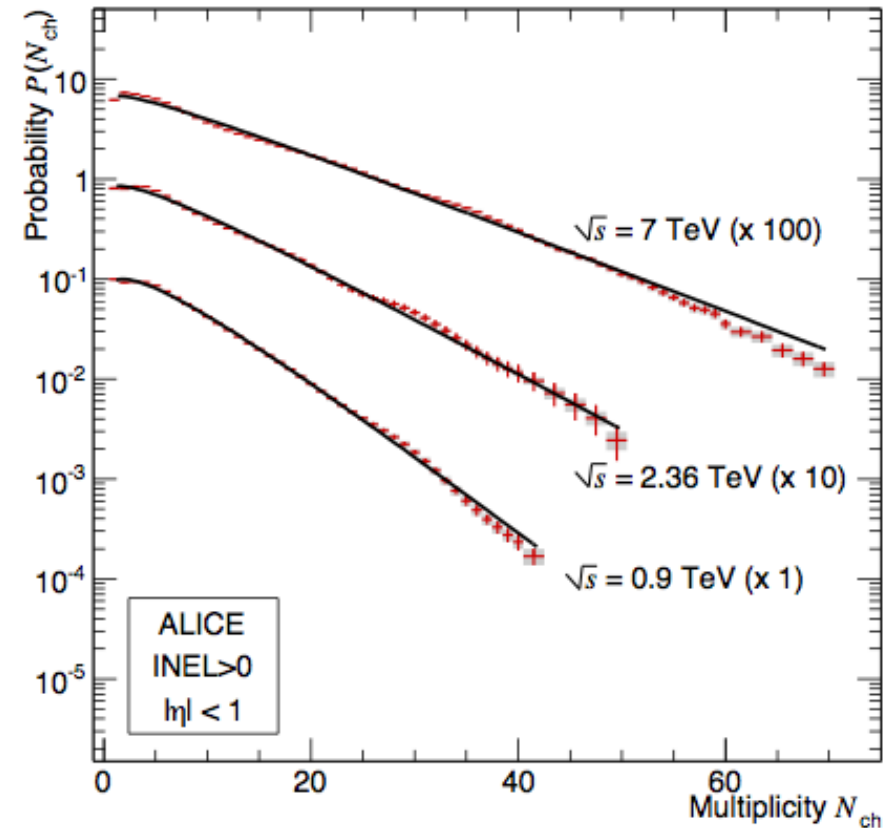
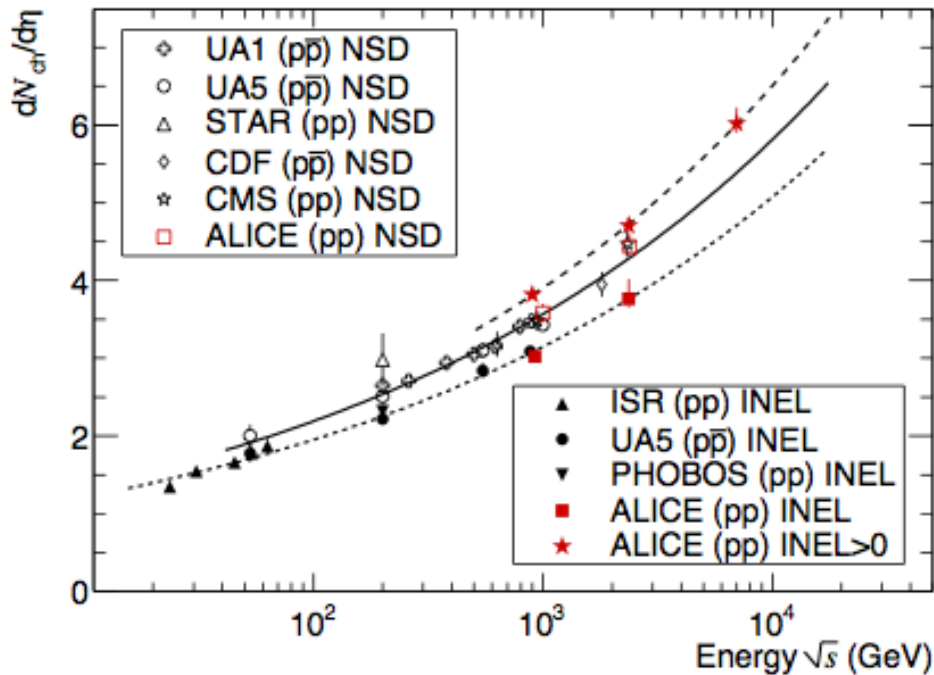


Fig. 15. - Compilation of the average number of particles (charged and negatives) per clan in the whole phase space vs. c.m. energy. The lines are only meant to guide the eye. Symbols are the same as in fig. 6.

“The interpretation of the negative binomial fits in terms of a cascade process yields a fixed number of clans (about 7.5) and an increase of the clan size with energy. In this picture the clans cannot be resonances, as was thought in the old cluster model”

# ALICE - 2010



“The unfolded distributions at 0.9 TeV and 2.36 TeV are described well by the Negative Binomial Distribution (NBD). At 7 TeV, the NBD fit slightly underestimates the data at low multiplicities ( $N_{ch} < 5$ ) and slightly overestimates the data at high multiplicities ( $N_{ch} > 55$ )”



Collaborazione iniziata nel 1980 e chiusa ufficialmente nel 1993.

39 pubblicazioni (circa l'80% pubblicate entro il 1988)

Numero medio di cit./art. = 34.4

Con un certo orgoglio...

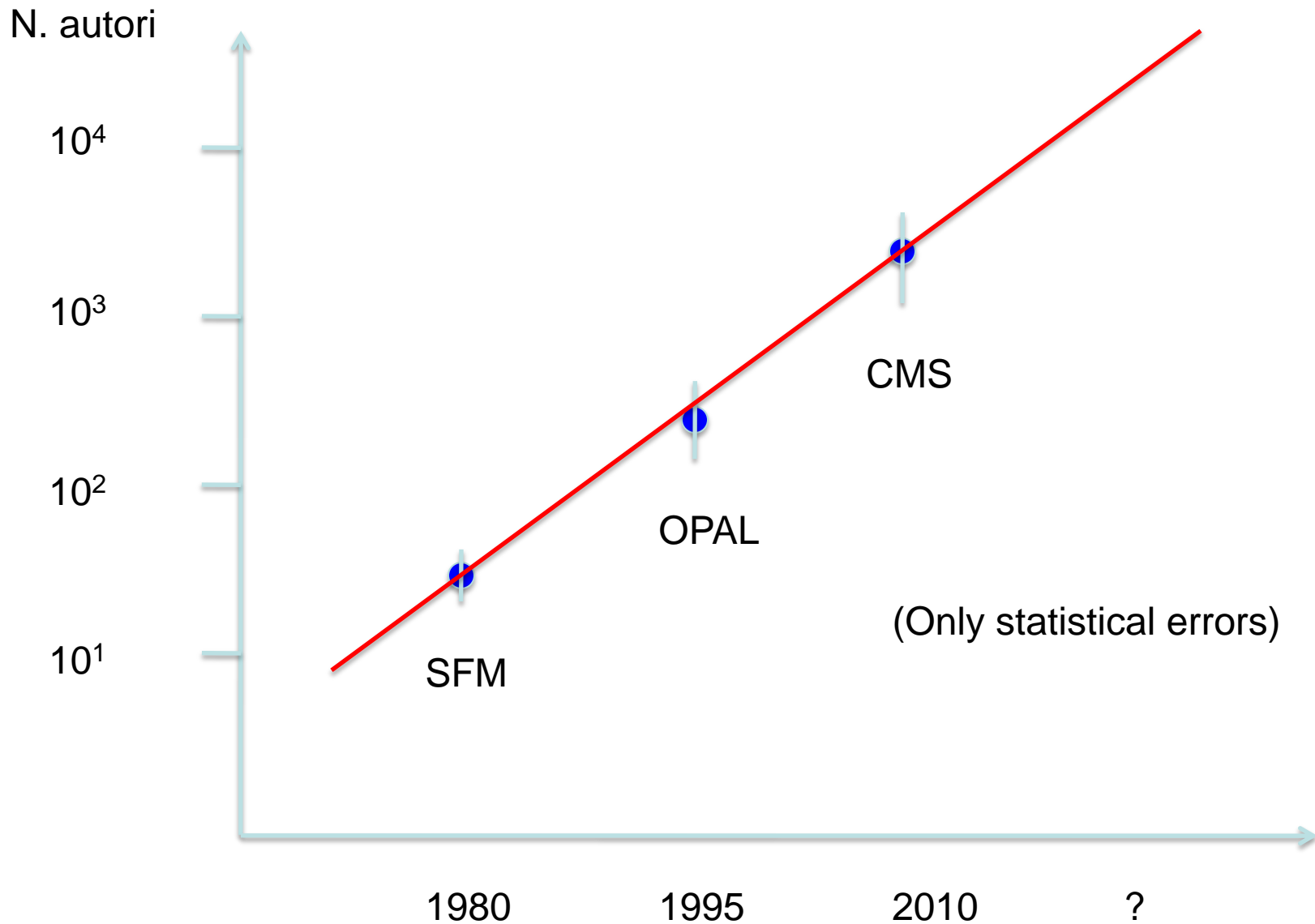
Sui 39 lavori pubblicati, le analisi fatte prevalentemente dai bolognesi hanno il seguente ranking per quanto riguarda le citazioni:

- |  |   |
|--|---|
| 3° Elastic scattering small t            | ( 1° Multiplicity distributions in pp ) |
| 6° $\langle pt \rangle$ e raggio vs mult | ( 2° Elastic scattering high t )        |
| 8° BE pp, ppbar                          |   |
| 9° Inclusive pp,ppbar                    |   |
| 15° short range corr.                    |   |
| 17° $f^0$ in double pomeron              |   |
| 19° nch in Y bins                        |   |

## Eredita` lasciata al Gruppo 1 di Bologna

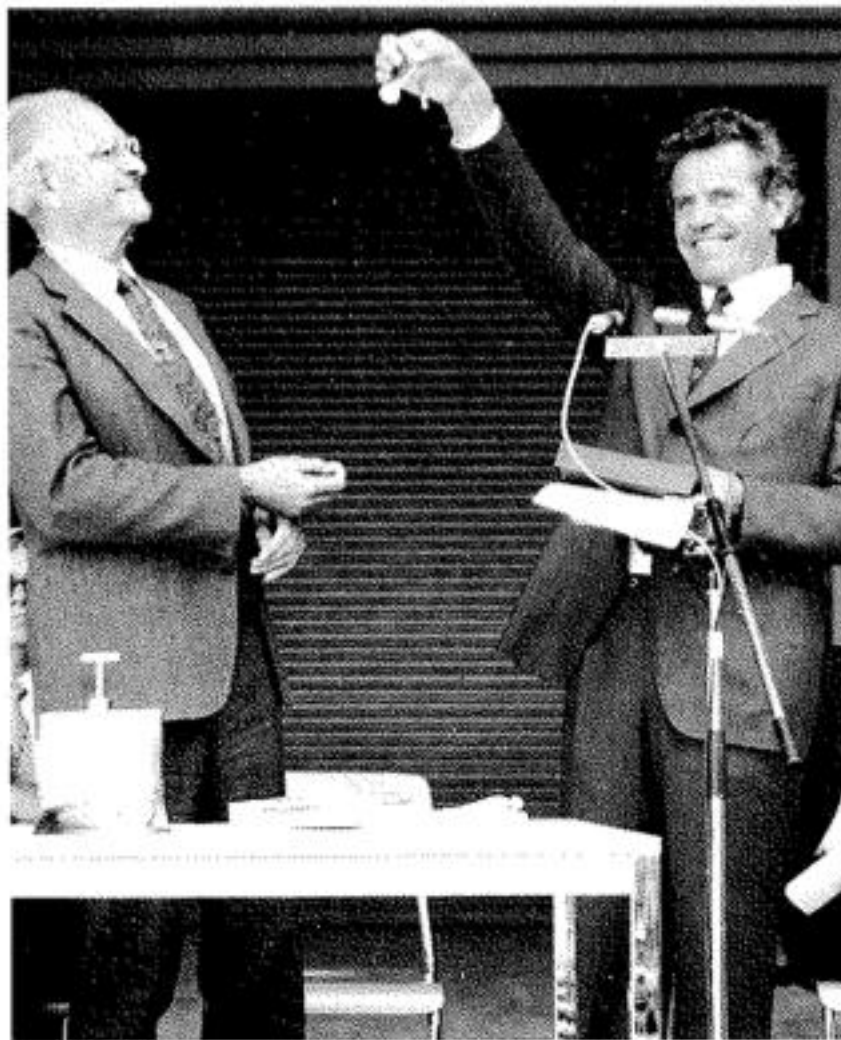
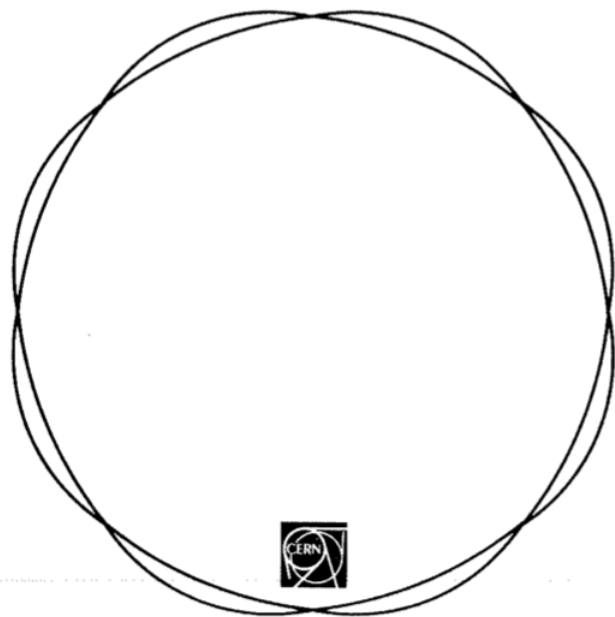
Ricercatori senior e alcuni giovani in SFM formano il nucleo del gruppo in OPAL (1985)

Ricercatori senior e giovani in OPAL formano il nucleo del gruppo in CMS (1995)



Nel 2030 una collaborazione di HEP potra` diventare provincia e avere la targa !

**CLOSURE CEREMONY  
OF  
THE  
INTERSECTING  
STORAGE  
RINGS  
26.6.1984**





Richard Feynman era presente ai seminari che si svolsero in Auditorium per la cerimonia di chiusura degli ISR.

Giorgio Bellettini, Chairman inflessibile sul rispetto dei tempi.

“May I refuse a question to Prof. Feynman ?”

**Grazie per l'attenzione**