# Refining of the analysis of the $\bar{n}p$ cross sections from OBELIX data


*Workshop on Hadron Spectroscopy*

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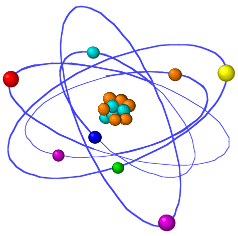
March 8 - 12, 1999

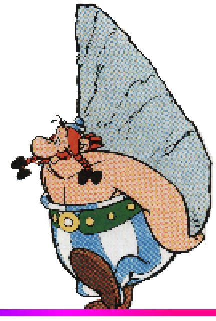
*Alessandro Feliciello / I.N.F.N. - Sezione di Torino*



# *Outlook*

- ★ $\bar{n}p$ annihilation cross section
- ★ $\bar{n}p$ total cross section
- ☛ Hint for the existence of a narrow quasi-nuclear state near the threshold

# $\bar{n}$ interaction
# *Why?*

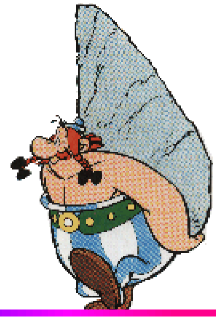


- scarce data on low-energy $\bar{n}p$ interaction
- complementary/alternative to $\bar{p}p$ interaction
- the initial $\bar{n}p$ state is a pure I = 1 state
- better energy and momentum resolution, compared to $\bar{p}d$ reaction, due to the absence of the spectator proton
- the percentage of *P*-wave in the initial state can be controlled by increasing the $\bar{n}$ momentum
- at least one prong in the final state (optimal for OBELIX)

**but**

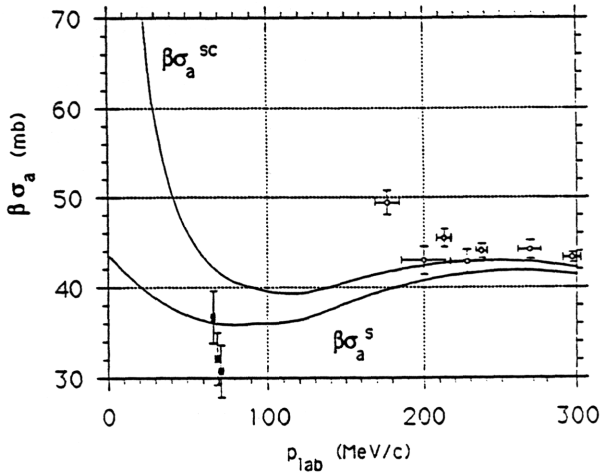
- technically difficult
- low production rate (~ 60 $10^{-6}$ $\bar{n}/\bar{p}$)

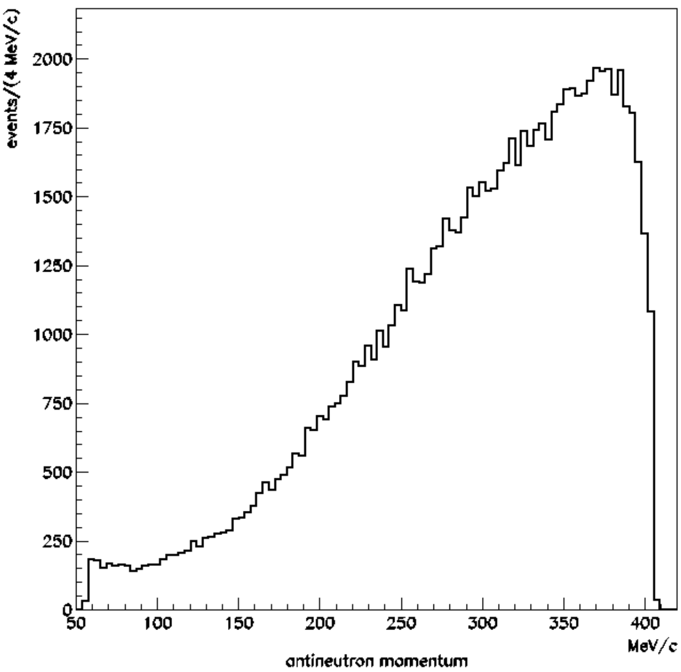
# $\bar{n}p$ cross section



Absence of Coulomb interaction:
no distortion on the σ trend
in the low momentum region

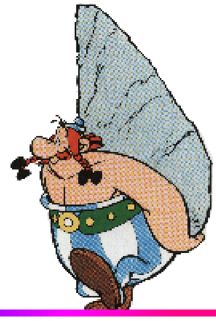
$\beta\sigma_{ann}(\bar{p}p)$



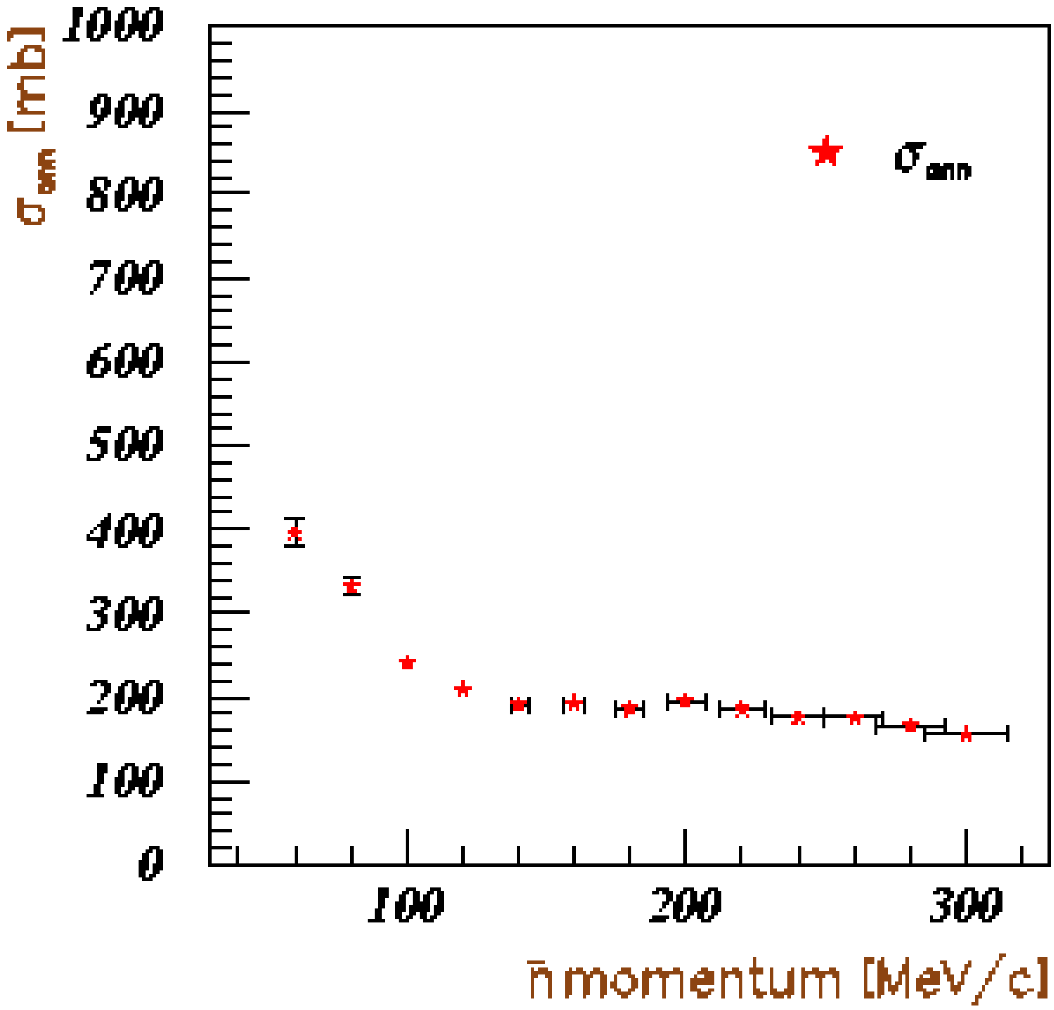



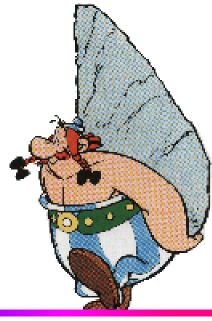

Capability of reconstructing the momentum of **each** interacting $\bar{n}$

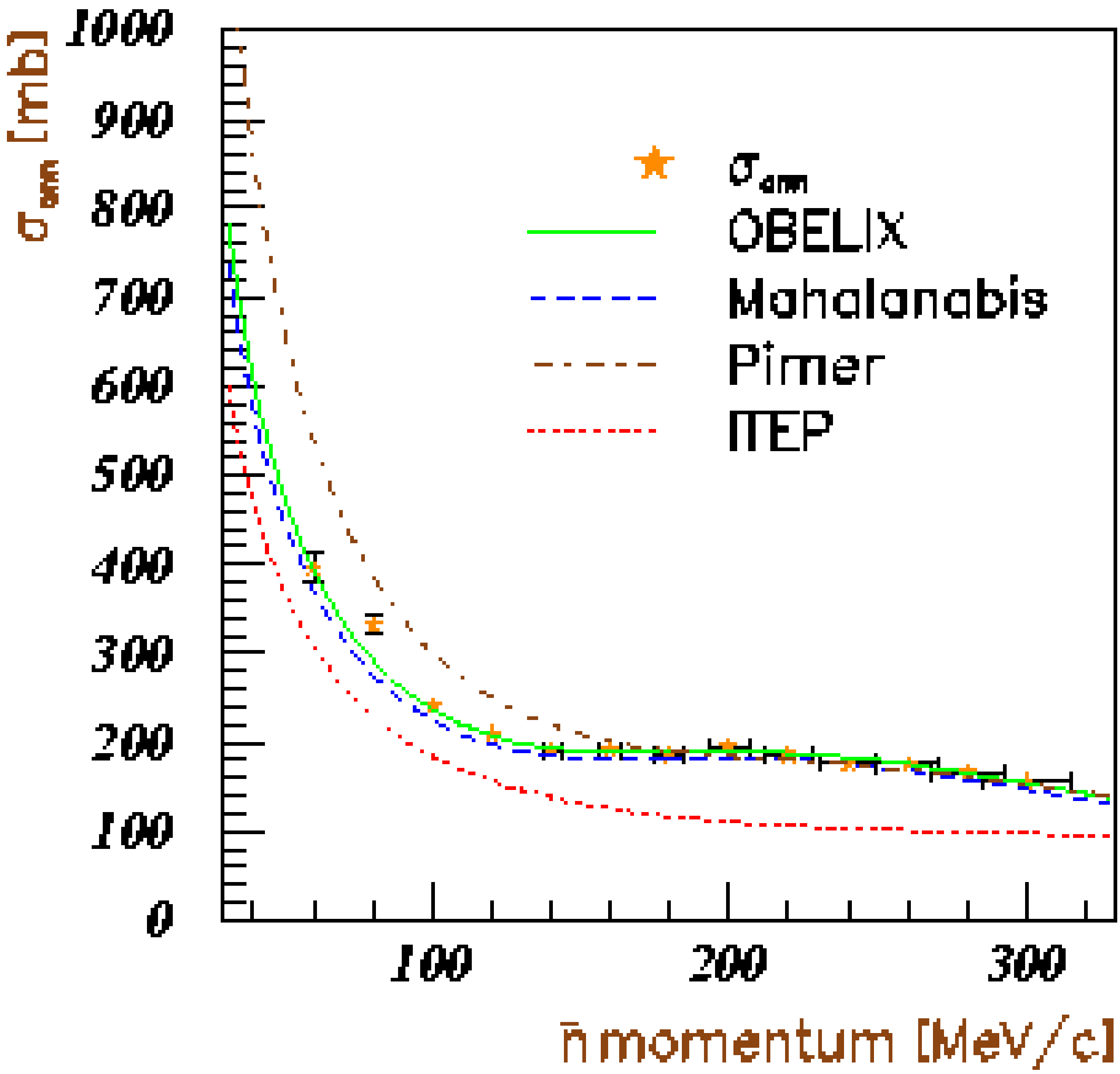
# $\bar{n}p$ annihilation cross section



$$\sigma^{i}_{ann} = \frac{1}{\rho N_A \Delta z}\,\frac{1}{\varepsilon\varepsilon_{trig}}\,\frac{N^{i}_{ann}(1-\gamma^{i})}{N^{i}_{\bar{n}}}$$

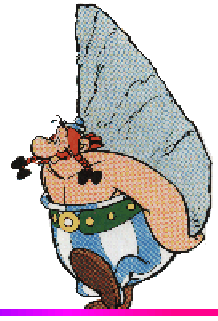






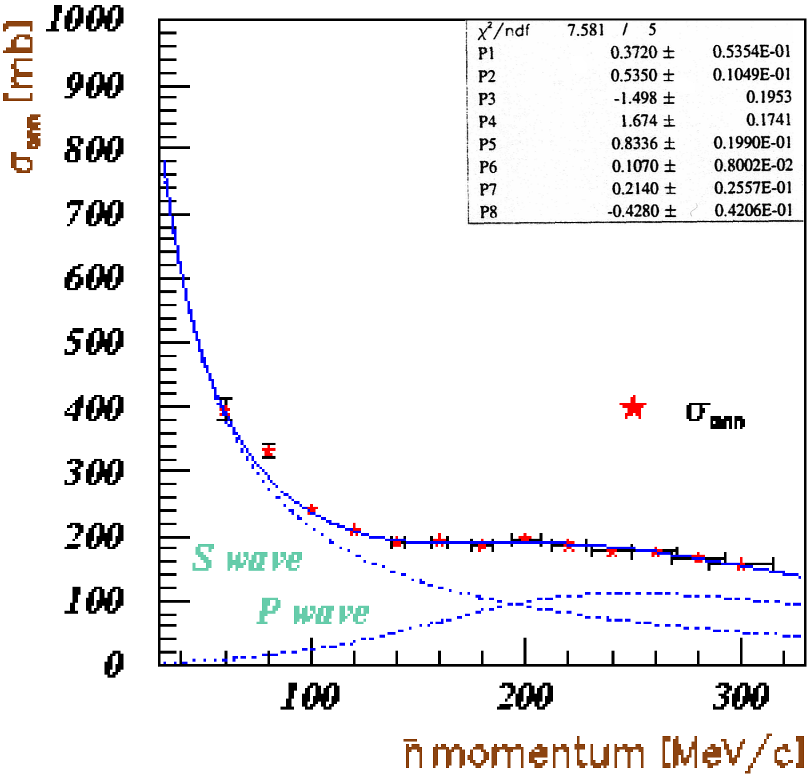
σ_ann [mb]
1000
900
800
700
600
500
400
300
200
100
0
100
200
300
σ_ann
OBELIX
Mahalanabis
Pirner
ITEP
n̄ momentum [MeV/c]

# *Effective range expansion*



$$\sigma_{ann} = \frac{4\pi}{k^2}\sum_l (2l+1)(Im f_l - |f_l|^2)$$

$$f_l = \frac{1}{\cot\delta_l - i}$$



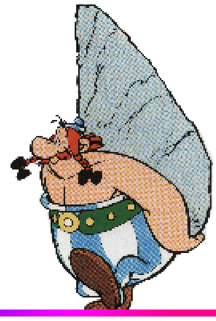

$$k\cot\delta_0 = \frac{1}{a_1} + \frac{1}{2} r_1 k^2$$

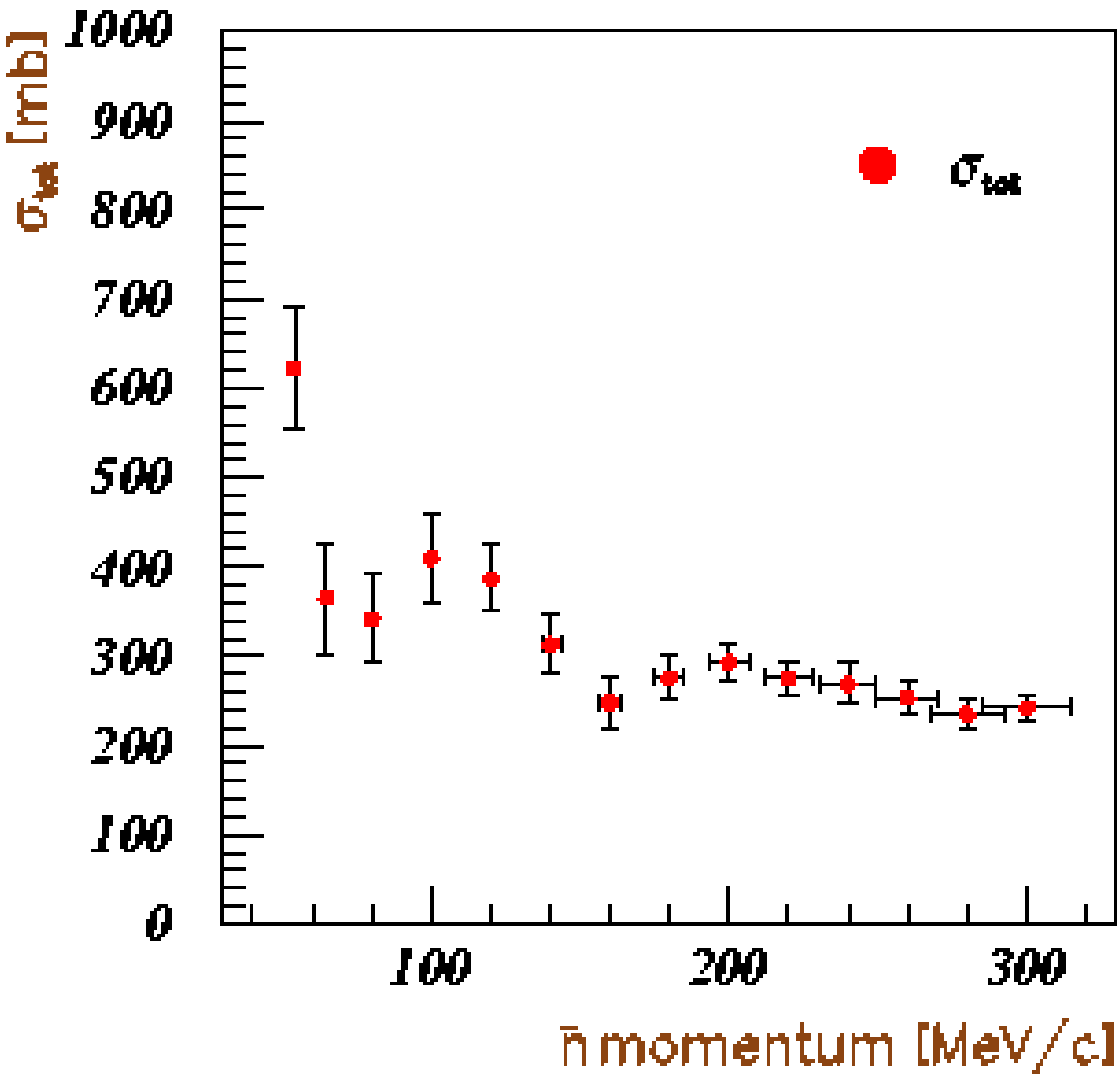
$$k^3\cot\delta_1 = \frac{1}{b_1} - \frac{3}{2}\frac{1}{R_1} k^2$$

**$\chi^2 = 7.58 / 5 = 1.52$**

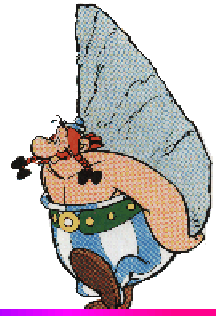
**C.L. ~ 20%**

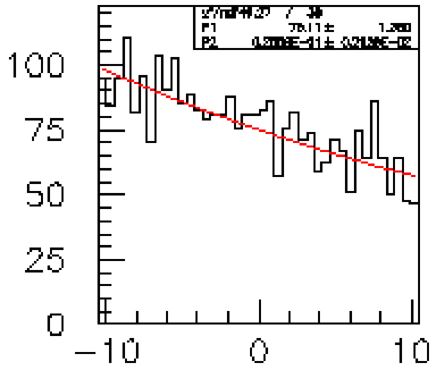
# $\bar{n}p$ total cross section



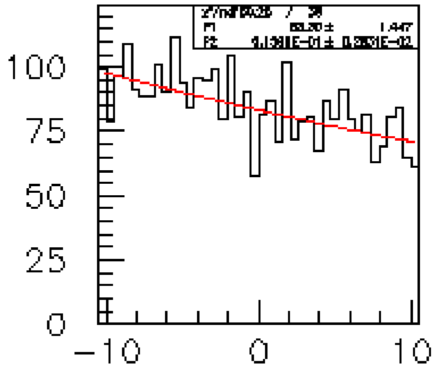


# *Transmission method*

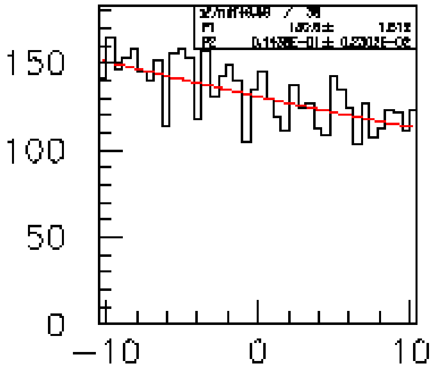




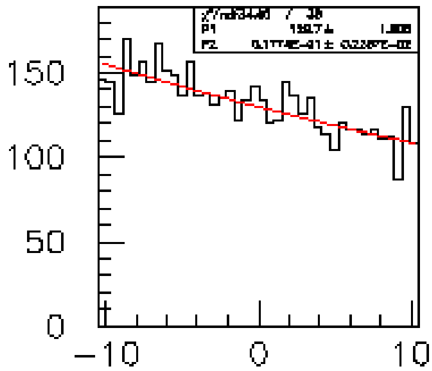

50 < p < 60



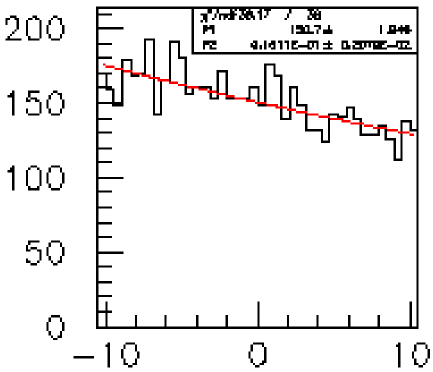

60 < p < 70



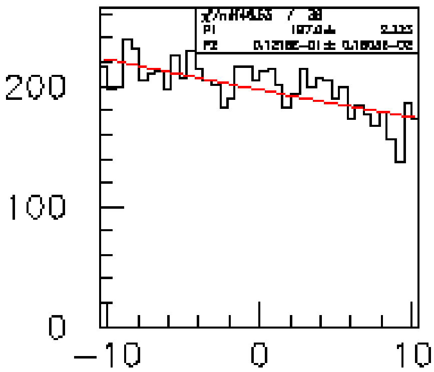

70 < p < 90



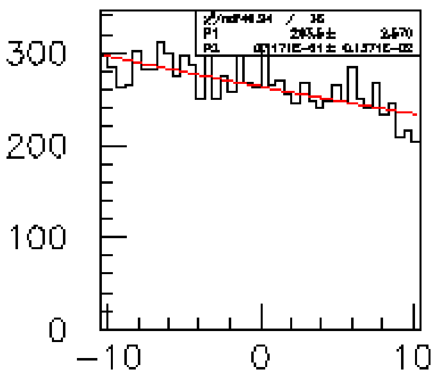

90 < p < 110



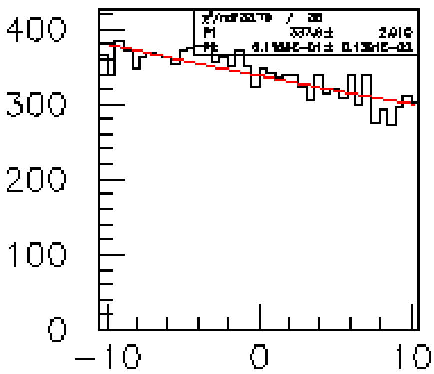

110 < p < 130



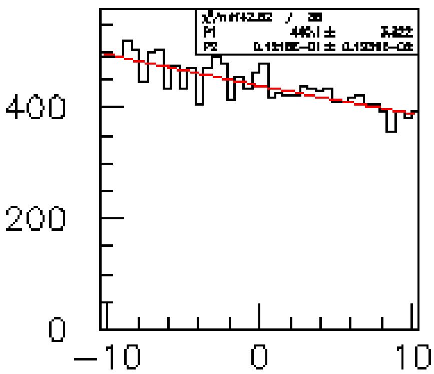

130 < p < 150



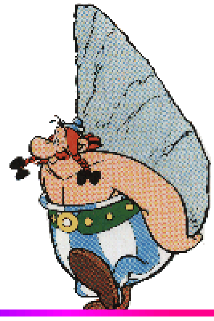

150 < p < 170

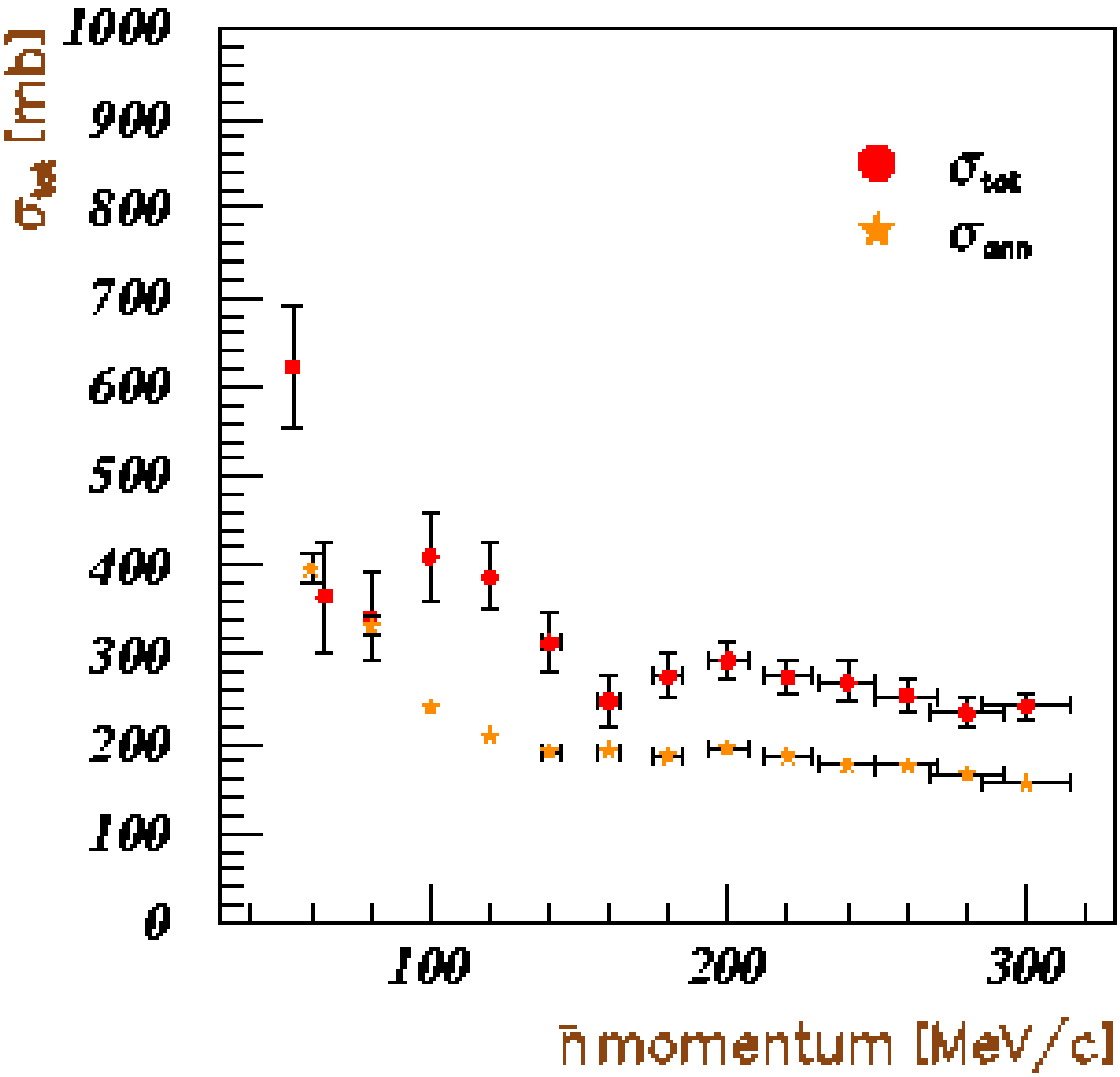



170 < p < 190

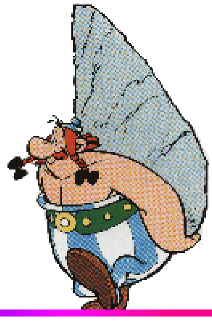


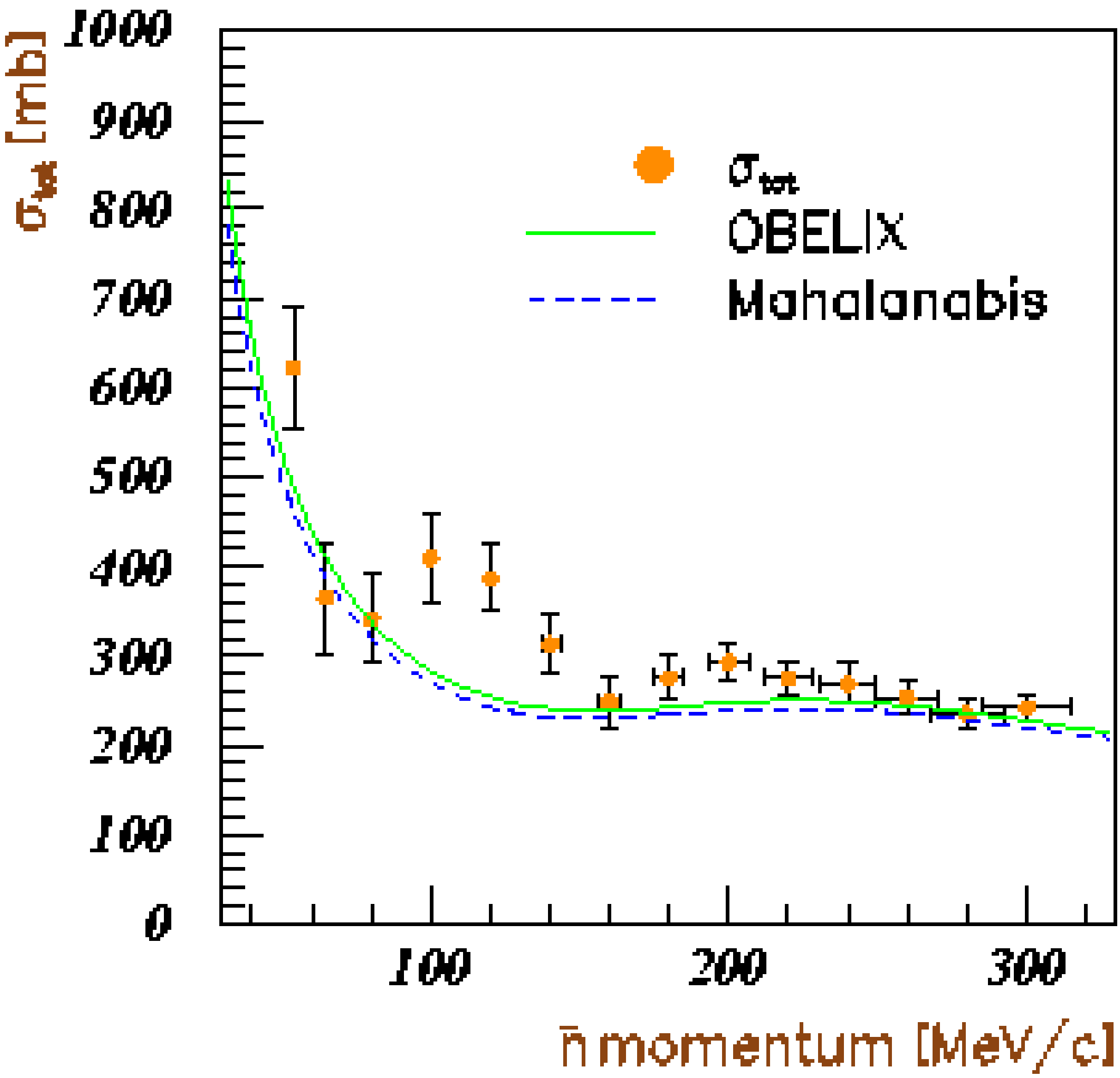

190 < p < 210





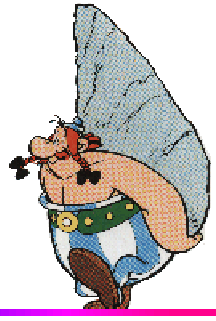
σ_tot [mb]
1000
900
800
700
600
500
400
300
200
100
0
100
200
300
σ_tot
σ_ann
n̄ momentum [MeV/c]





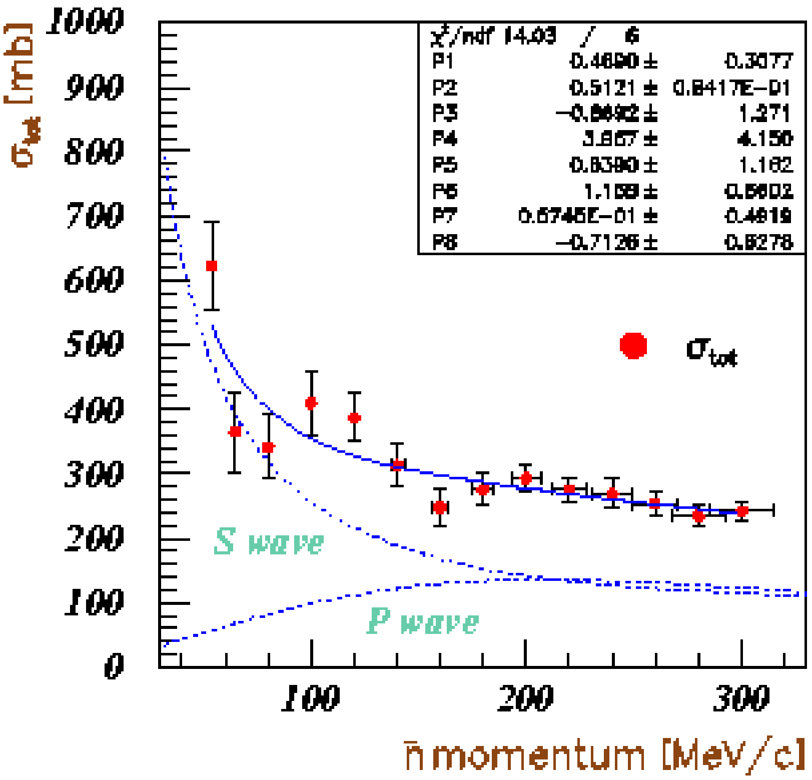

$\chi^2 = 38.06 / 6 = 6.34$

# *Effective range expansion*



$$\sigma_{tot} = \frac{4\pi}{k^2} \sum_l (2l+1) Im f_l$$

$$f_l = \frac{1}{\cot\delta_l - i}$$

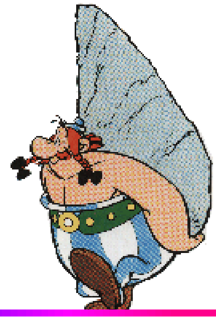


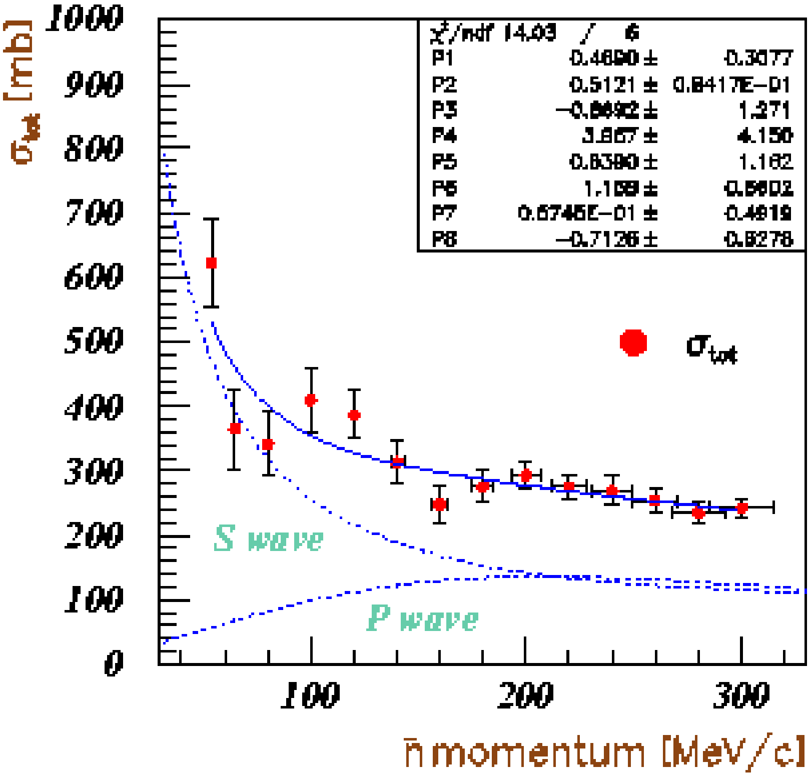

$$k\cot\delta_0 = \frac{1}{a_1} + \frac{1}{2} r_1 k^2$$

$$k^3 \cot\delta_1 = \frac{1}{b_1} - \frac{3}{2}\frac{1}{R_1} k^2$$

**$\chi^2 = 14.03 / 6 = 2.34$**

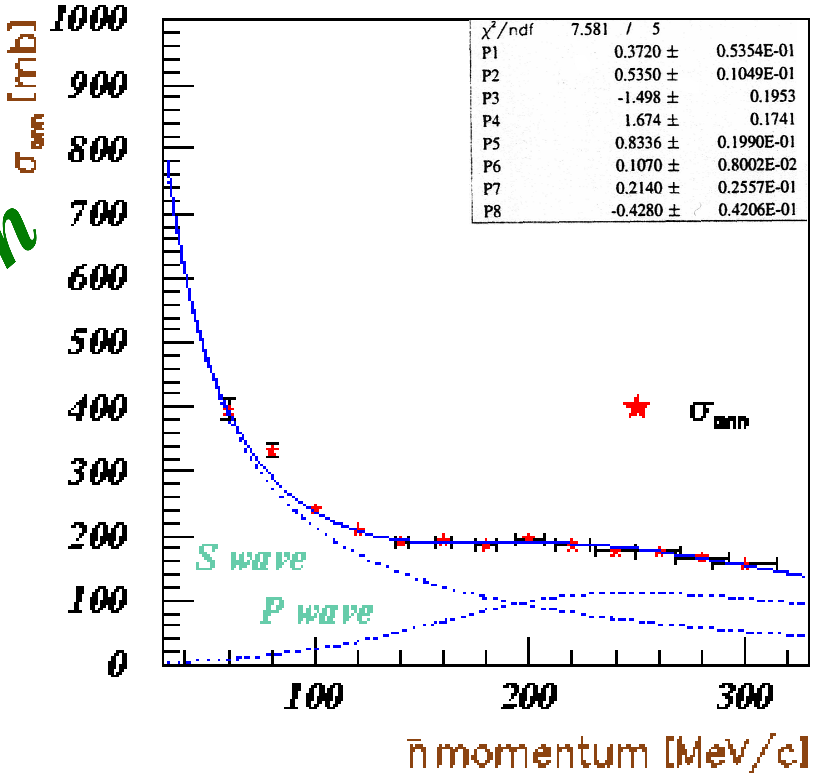
**C.L. ~ 5%**

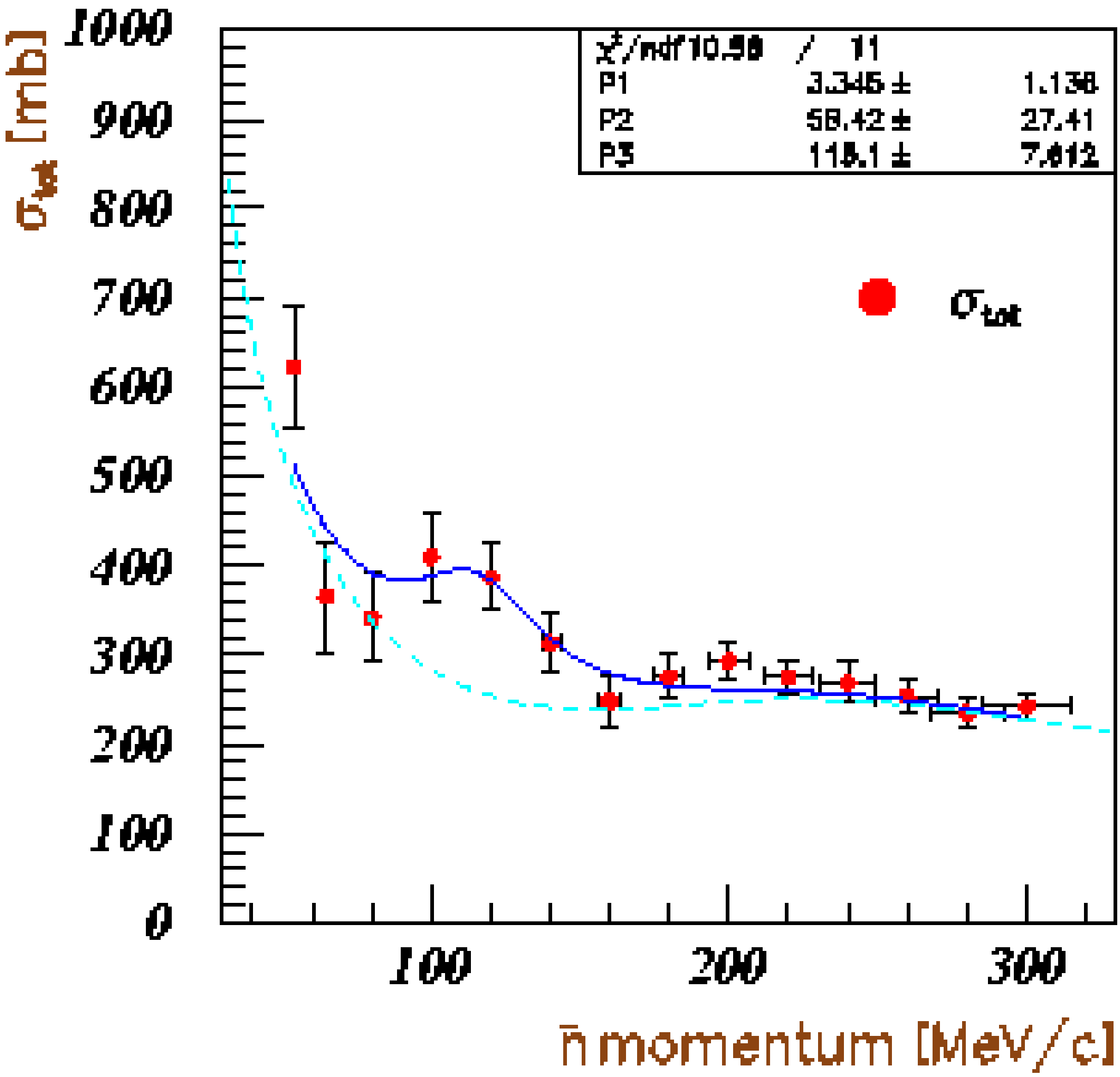





*total*

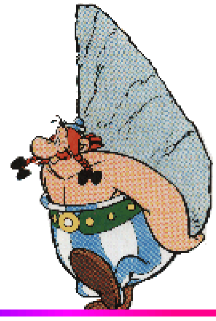
*annihilation*

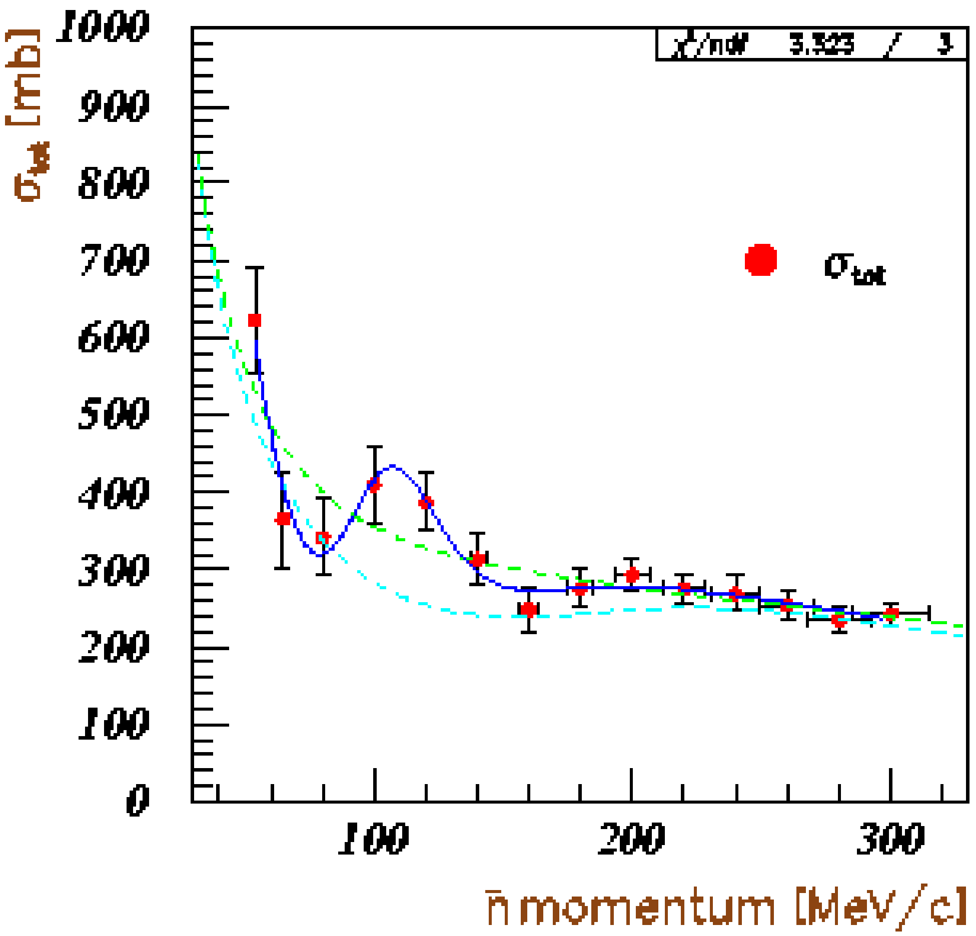




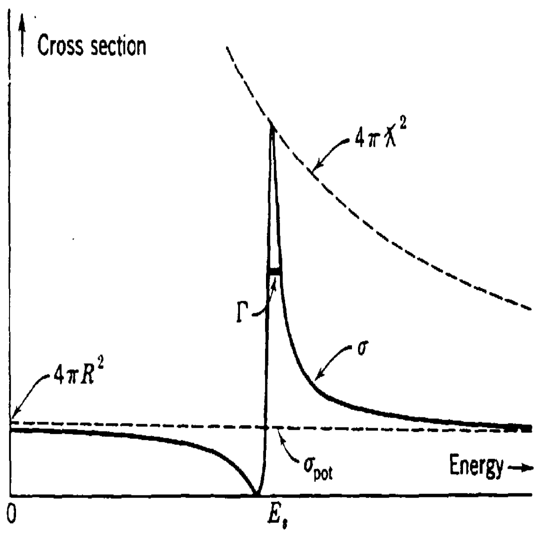

**$M_X \sim 1885$ MeV**

**$\Gamma_X \sim 9$ MeV**





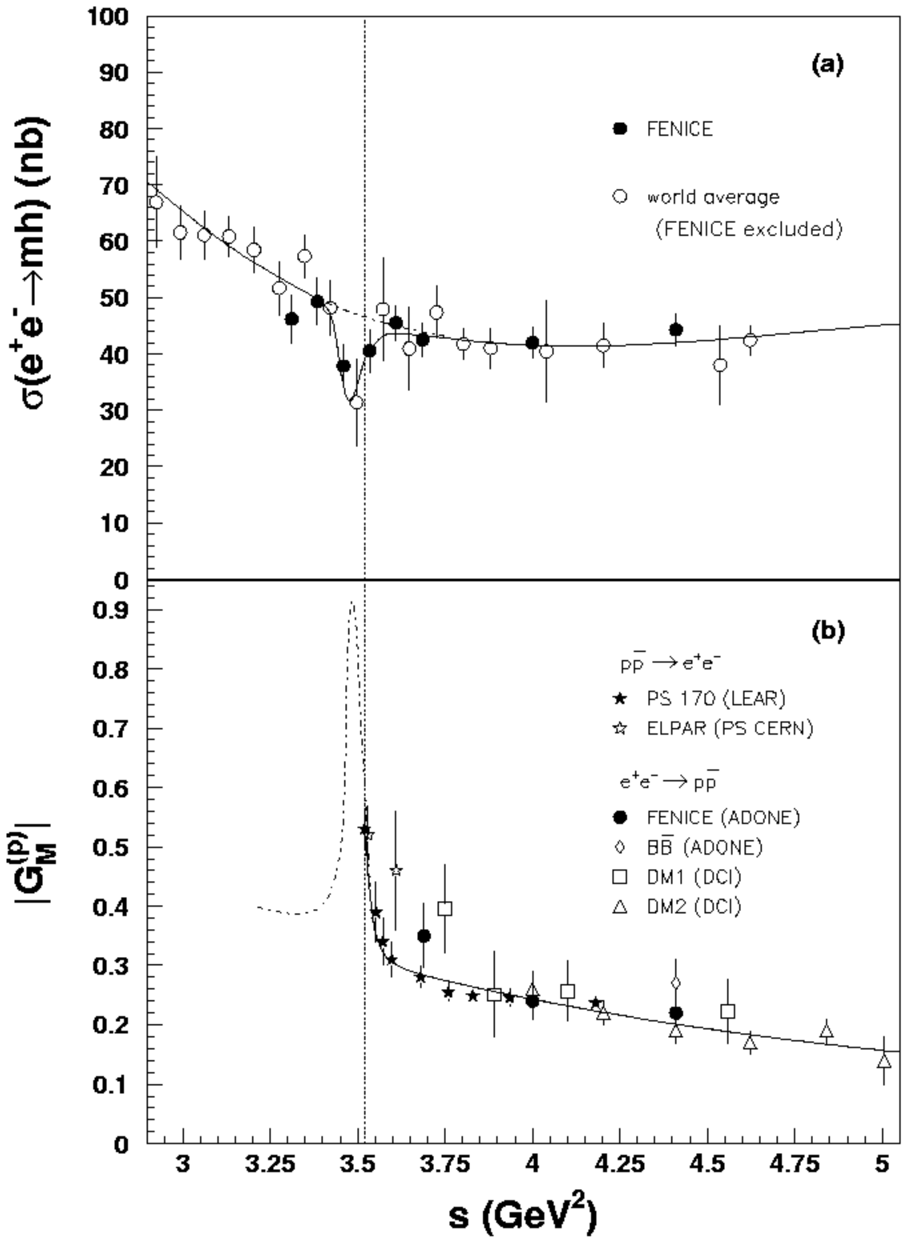
σtot [mb]
1000
900
800
700
600
500
400
300
200
100
0
100
200
300
n̄ momentum [MeV/c]
σtot

Cross section
Γ
σ
Energy
0

*FENICE experiment*

# $e^+e^- \rightarrow$ *hadrons*

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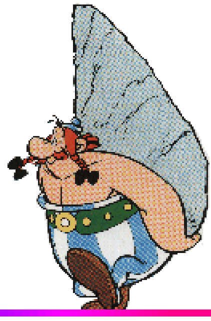
$$M_x = (1.87 \pm 0.01)\ \text{GeV}$$
$$\Gamma_x = (10 \pm 5)\ \text{MeV}$$

# Conclusions



- $\bar{n}p$ $\sigma_{tot}$ and $\sigma_{ann}$ measured for the first time:
  - ❶ down to 50 MeV/*c*
  - ❷ with high statistics
- confirmation of the abnormally large *P*-wave contribution in some low-energy $\overline{N}N$ interactions
- indication of a narrow (quasi-nuclear ?) state

(as usual, much more work needed)