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international centre for theoretical physics

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Antinucleon-nucleon cross section near the threshold region

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Outlook

- ★ Physics motivations
- ★ Anomalies in the $\bar{N}N$ system, near threshold
  - ☛ $\bar{n}p$ total cross section
- ★ A possible measurement of $\bar{p}p$ elastic cross section at AD
  - ☛ the ELAPP project

Physics motivations

historical

- 60's: description of ordinary mesons (π, ρ, ...) spectrum (unsuccessful)

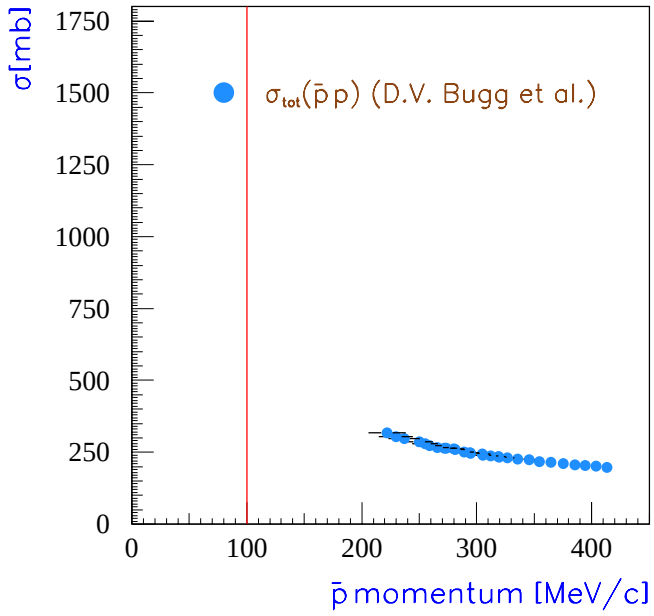
QCD

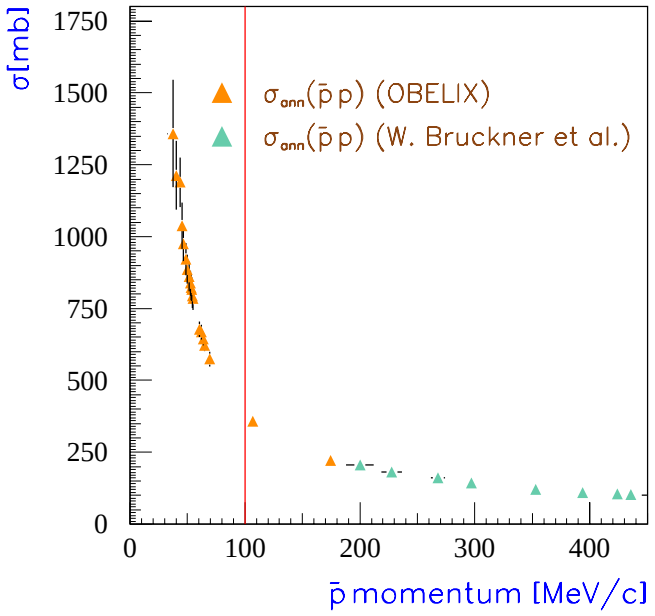
- 80's - 90s': search for multiquark configurations (exotics, glueballs, hybrids, non $q\bar{q}$ meson, ...)

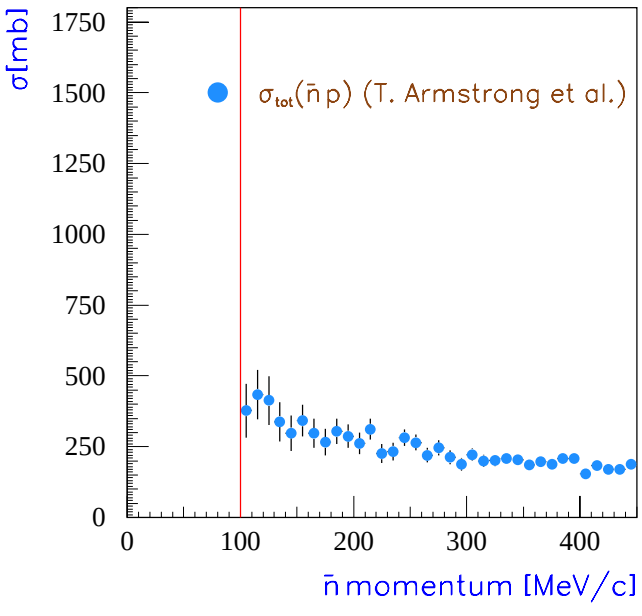
nuclear physics

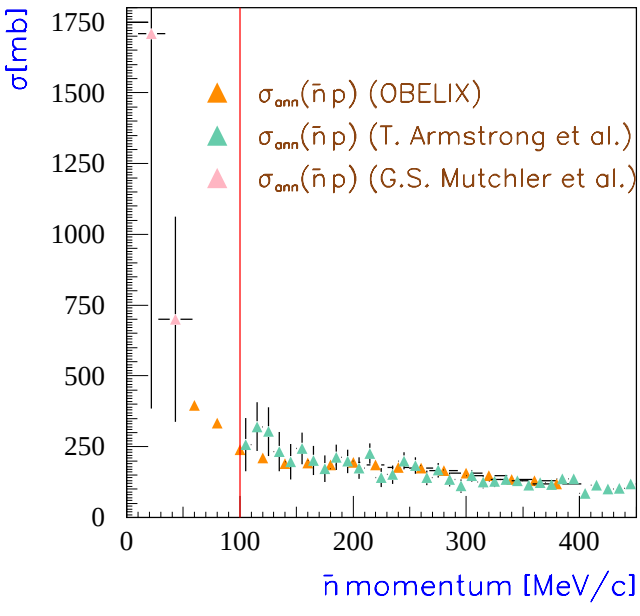
- understanding of nuclear forces:
  - G-parity rule ($\bar{p}p \leftrightarrow pp$ and $\bar{n}p \leftrightarrow np$)
  - several $\bar{N}N$ bound states or resonances ($\bar{N}N$ potential deeper than the NN one)
  - isospin dependence of the $\bar{N}N$ interaction (comparison of $\bar{p}p$ with $\bar{n}p$ or $\bar{p}n$ data)
  - dependence of annihilation strength on some channels (fit to the scattering and annihilation data)

Experimental situation

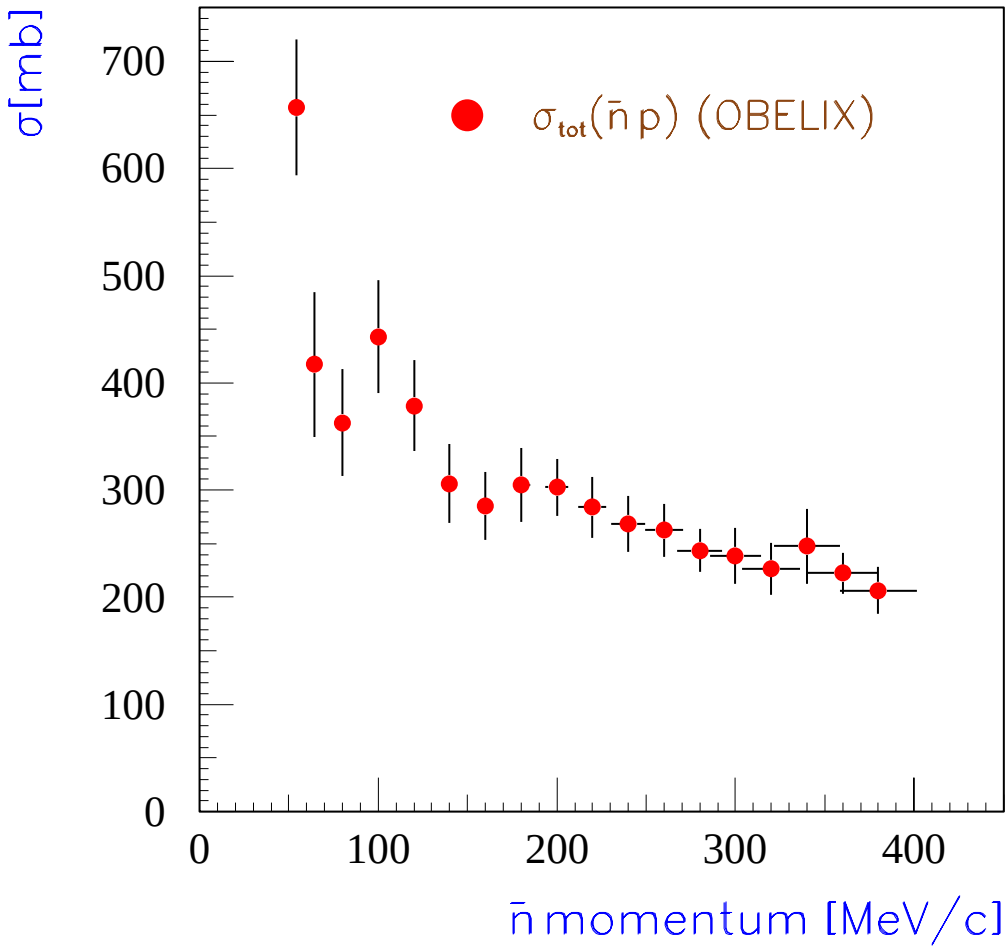






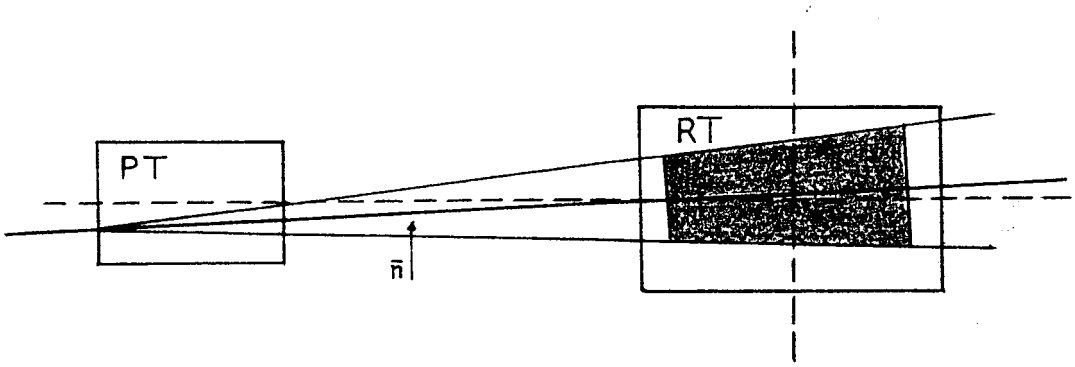


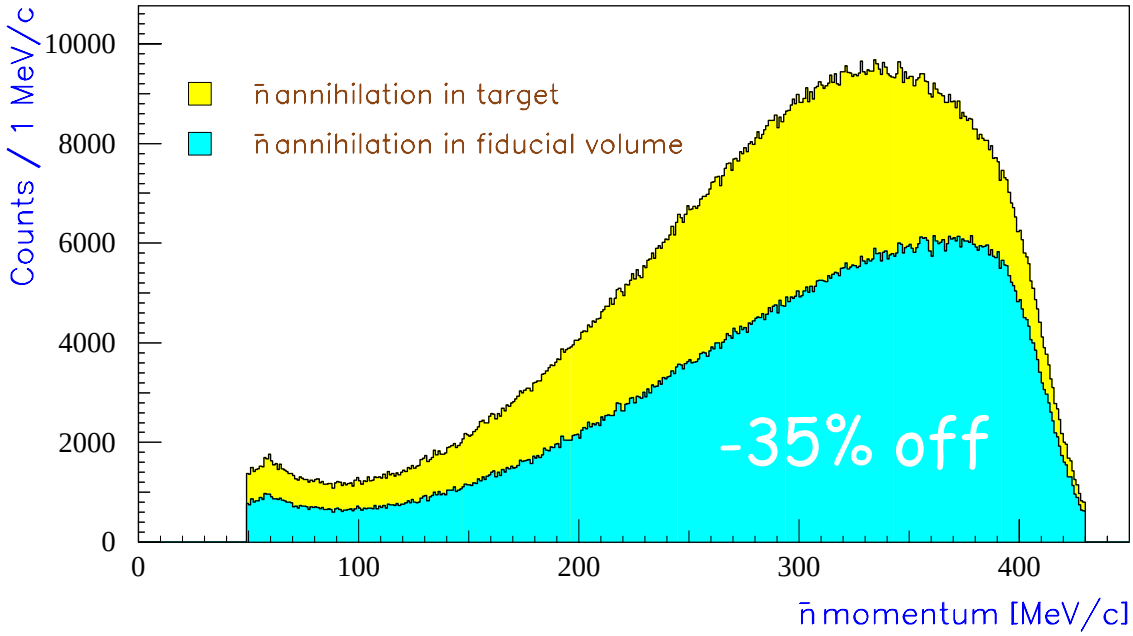
$\bar{n}p$ total cross section



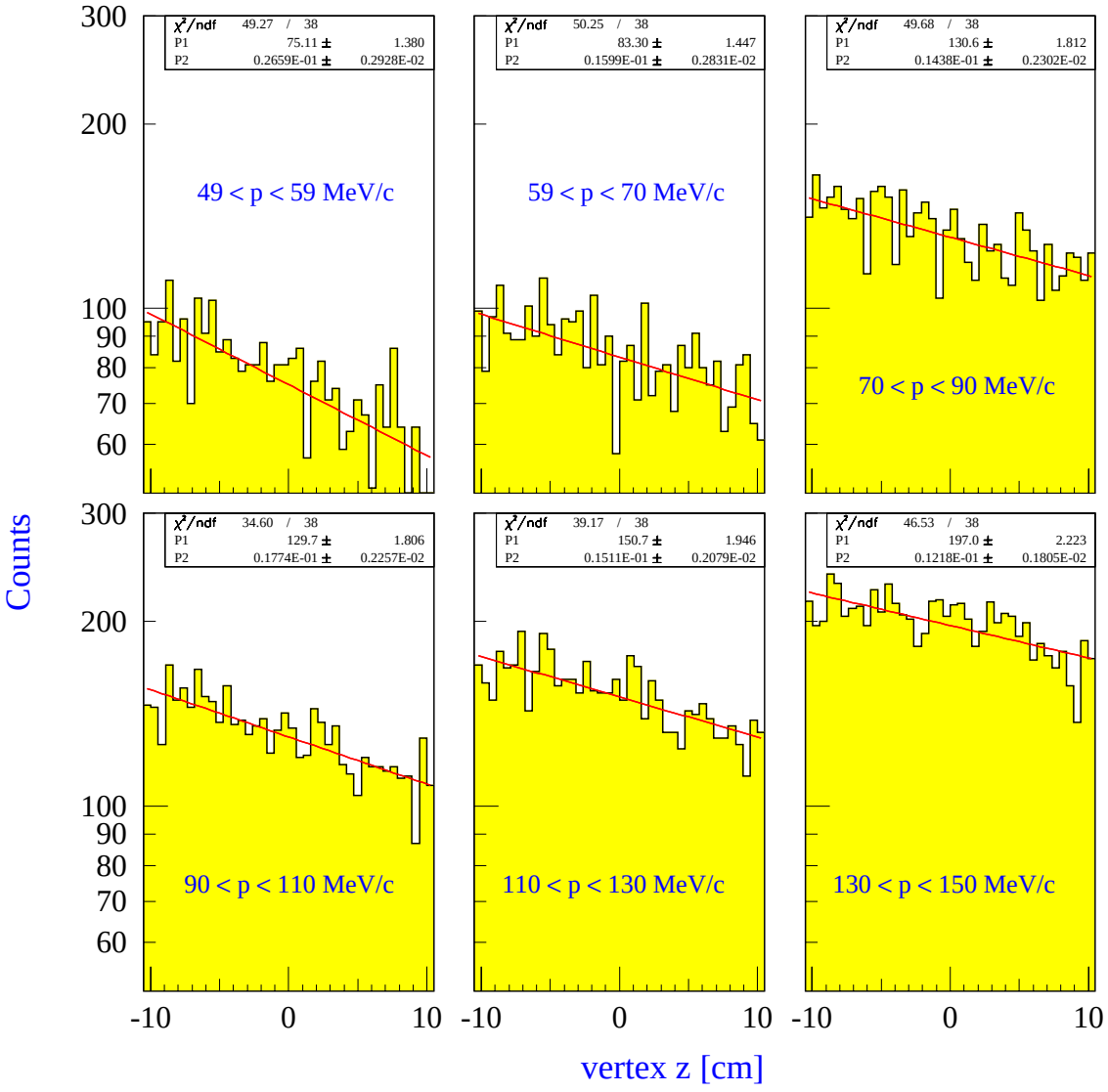
[*Phys. Lett.* **B** 475 (2000) 378]

The transmission technique

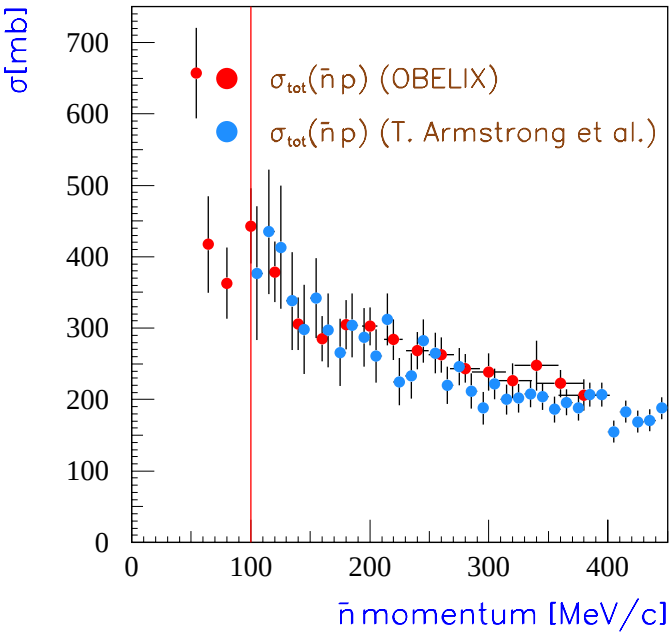


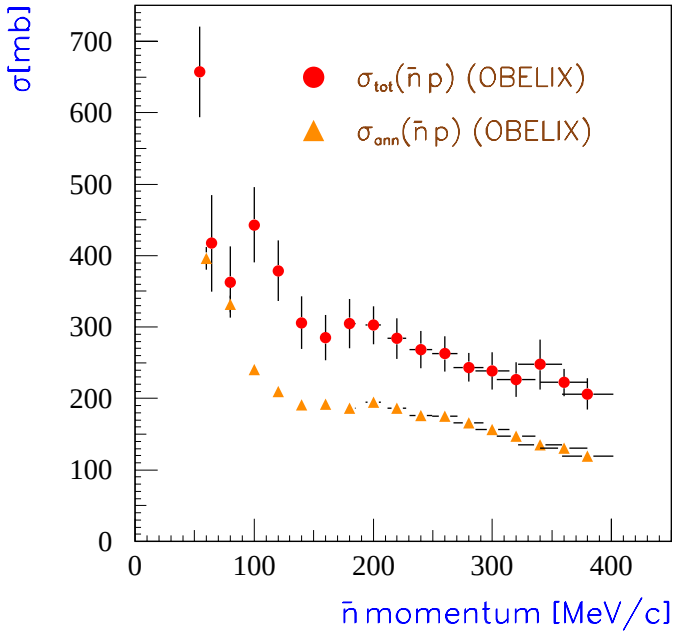


The transmission technique

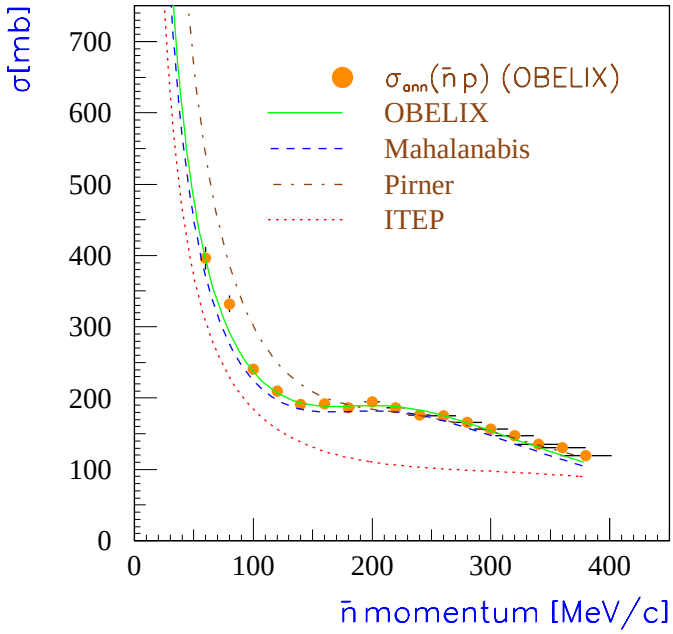


Comparisons



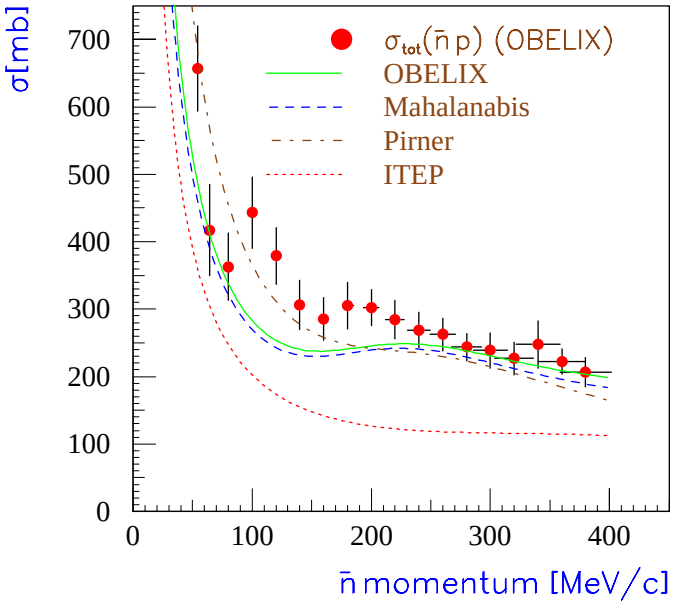


Effective range expansion

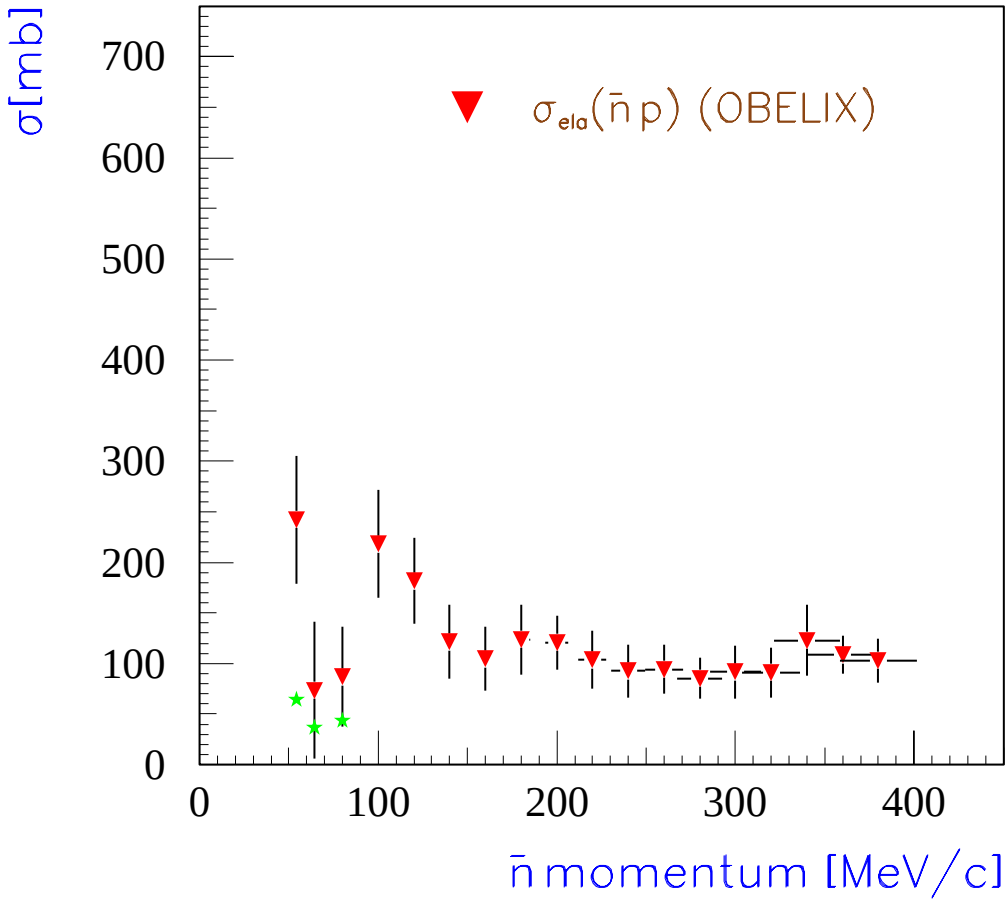


annihilation

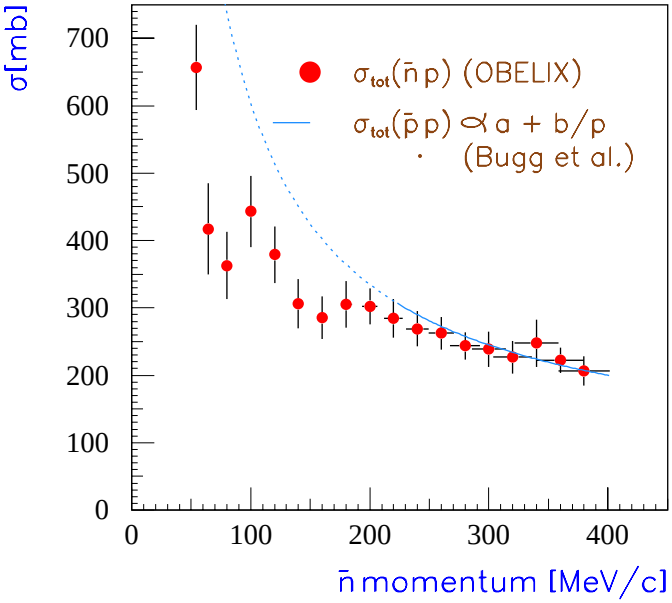
total



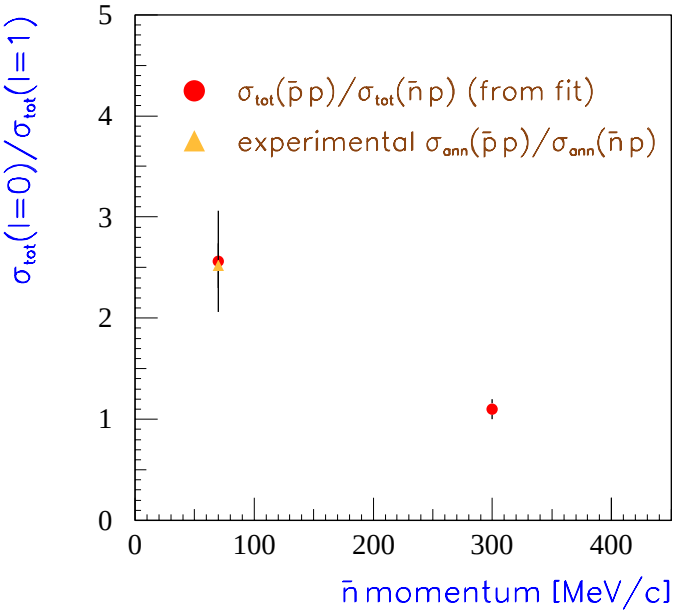
$\bar{n}p$ elastic cross section



Isospin dependence

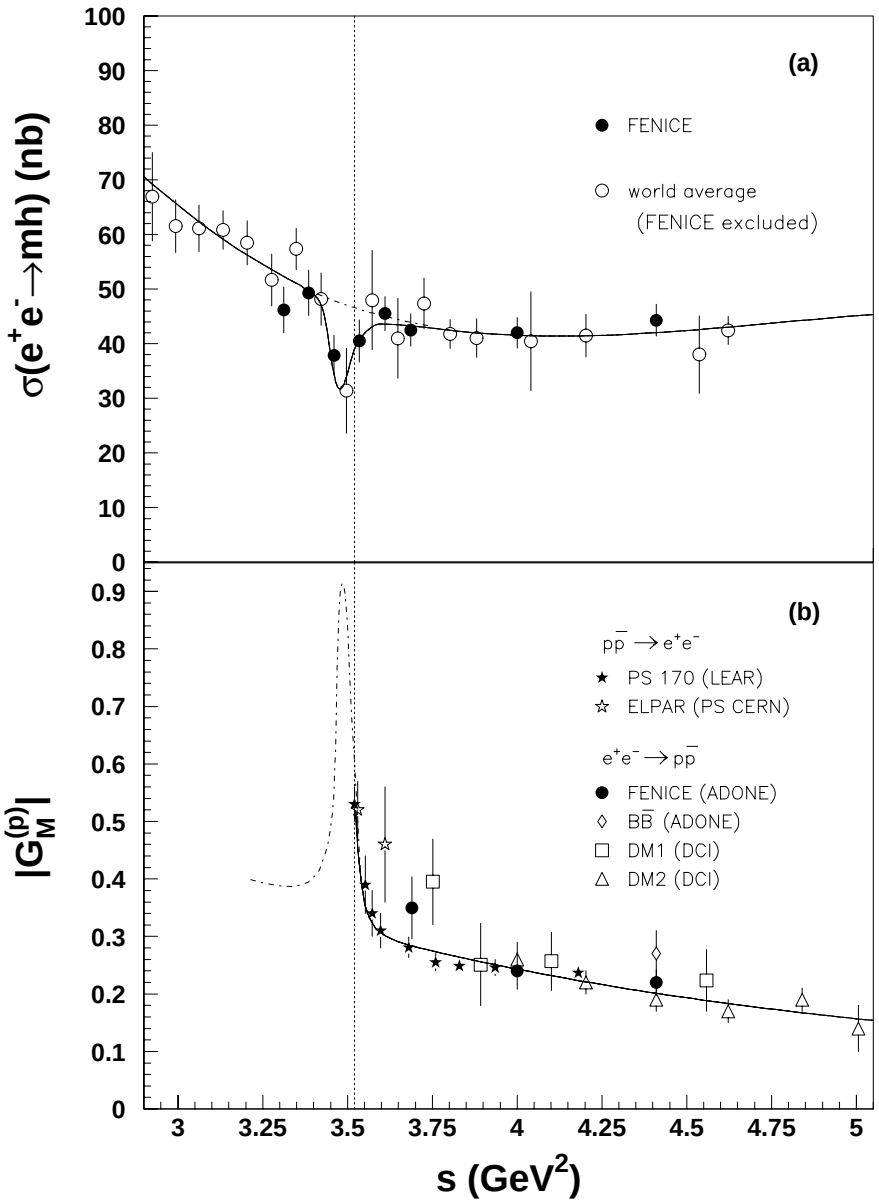


$$R_{tot} = \frac{\sigma_{tot}(\bar{p}p)}{\sigma_{tot}(\bar{n}p)} = \frac{\sigma^0_{tot} + \sigma^1_{tot}}{2\sigma^1_{tot}}$$



FENICE experiment (ADONE/LNF)

$\sigma(e^+e^-) \rightarrow$ hadrons

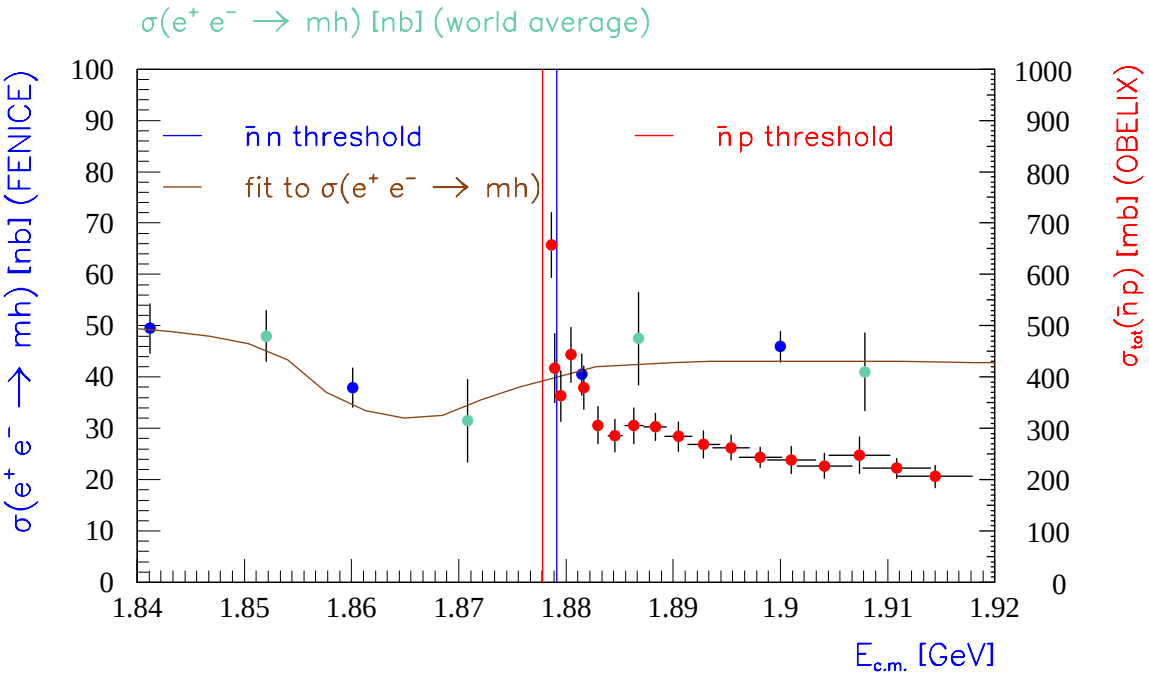


[*Nucl. Phys.* **B** 517 (1998) 3]

$M_x = (1.87 \pm 0.01)$ GeV

$\Gamma_x = (10 \pm 5)$ MeV

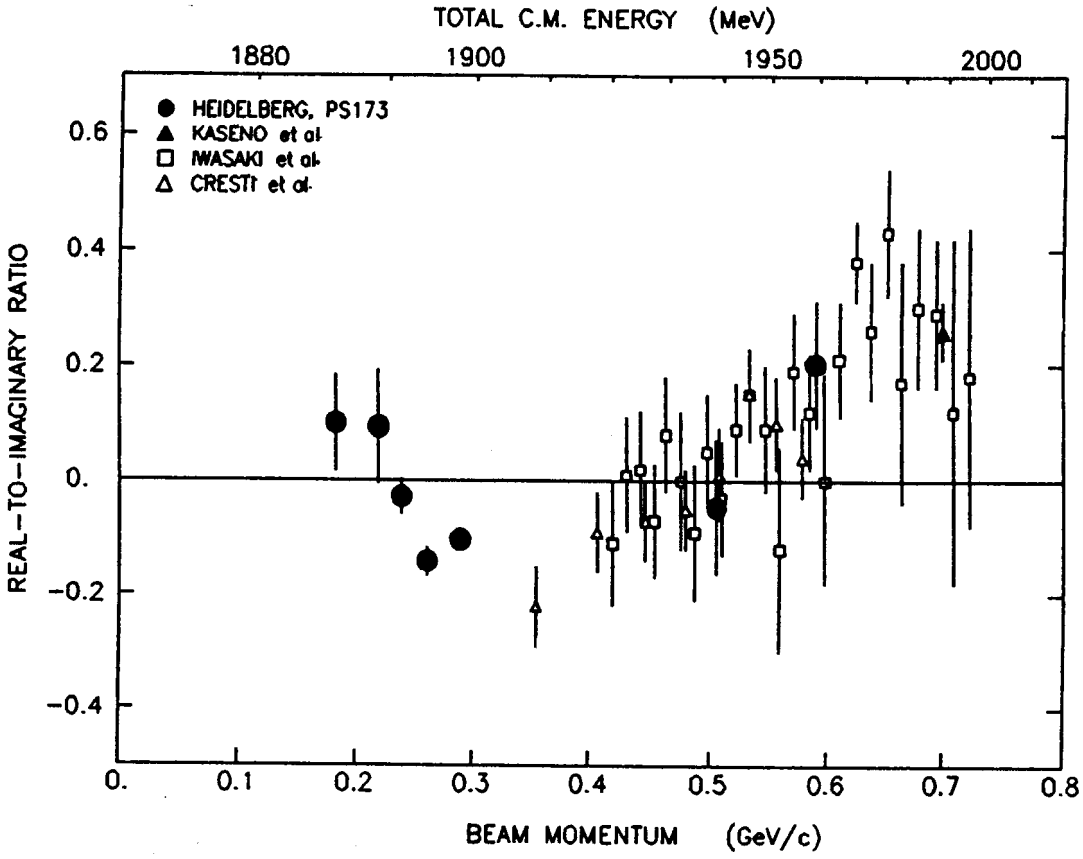
The threshold region



other anomalies:

- ρ parameter
- old hints from DM2 experiment (still unpublished!)
- new results from FOCUS experiment

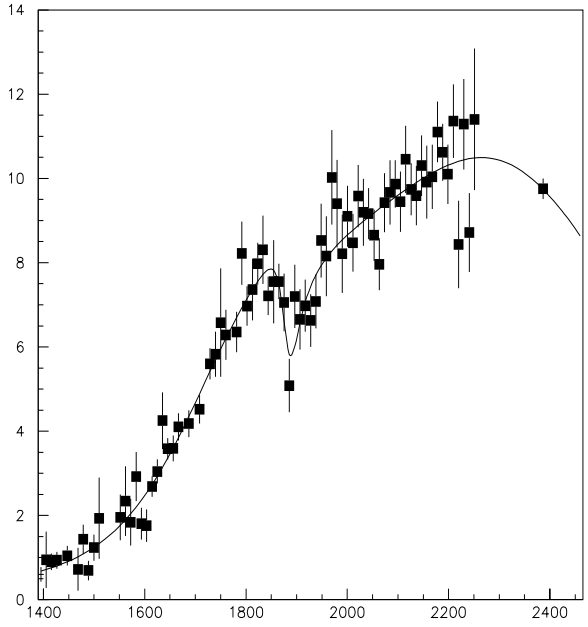
The ρ parameter



[W. Brückner et al., Phys. Lett. **B158** (1985) 180]

Photoproduction experiments

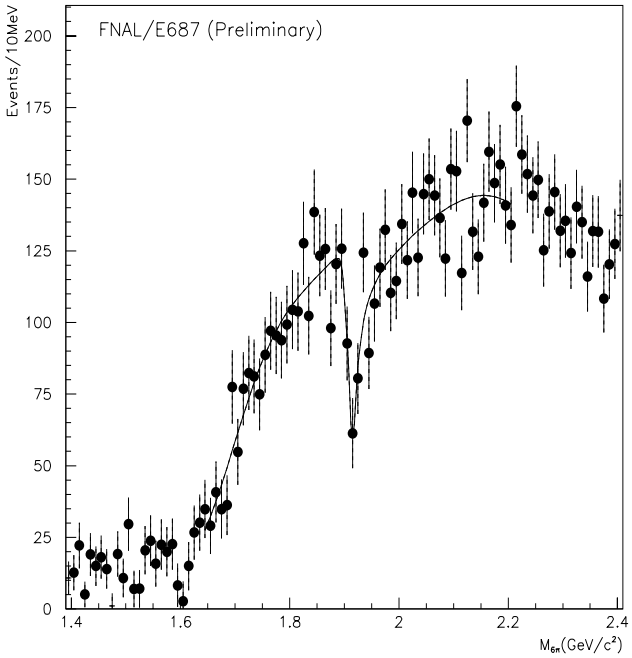
$\sigma(nb)/20\,MeV$



$\sqrt{s}\,(MeV)$

$e^+e^- \rightarrow 3\pi^+ 3\pi^-$

DM2 data



FNAL E687

$3\pi^+ 3\pi^-$ inv. mass distribution in high energy photoproduction

A. Feliciello

Which origin for such anomalies?

- threshold of the $\bar{p}p \to \bar{n}n$ channel ($p_{\bar{p}}^{lab}$ = 98 MeV/c)
- s-wave dominance, in the frame of coupled channel approach
- quasi-nuclear bound states near threshold

measurement of $\sigma_{ela}(\bar{p}p)$
at low momentum

measurement of $d\sigma/d\Omega$
(relative importance of s- and p-wave contributions)
essential to discriminate among different hypotheses

Is it possible to perform such a measurement at a machine like AD???
(the unique source of $\bar{p}$ in world today)

Experimental problems

❶ simultaneous detection of:

- ☛ $\bar{p}$ - large dE/dx
  - secondary particle emission
- ☛ p - very low energy (0 ÷ 5 MeV)

❷ no trigger possible,
due to the AD beam structure:

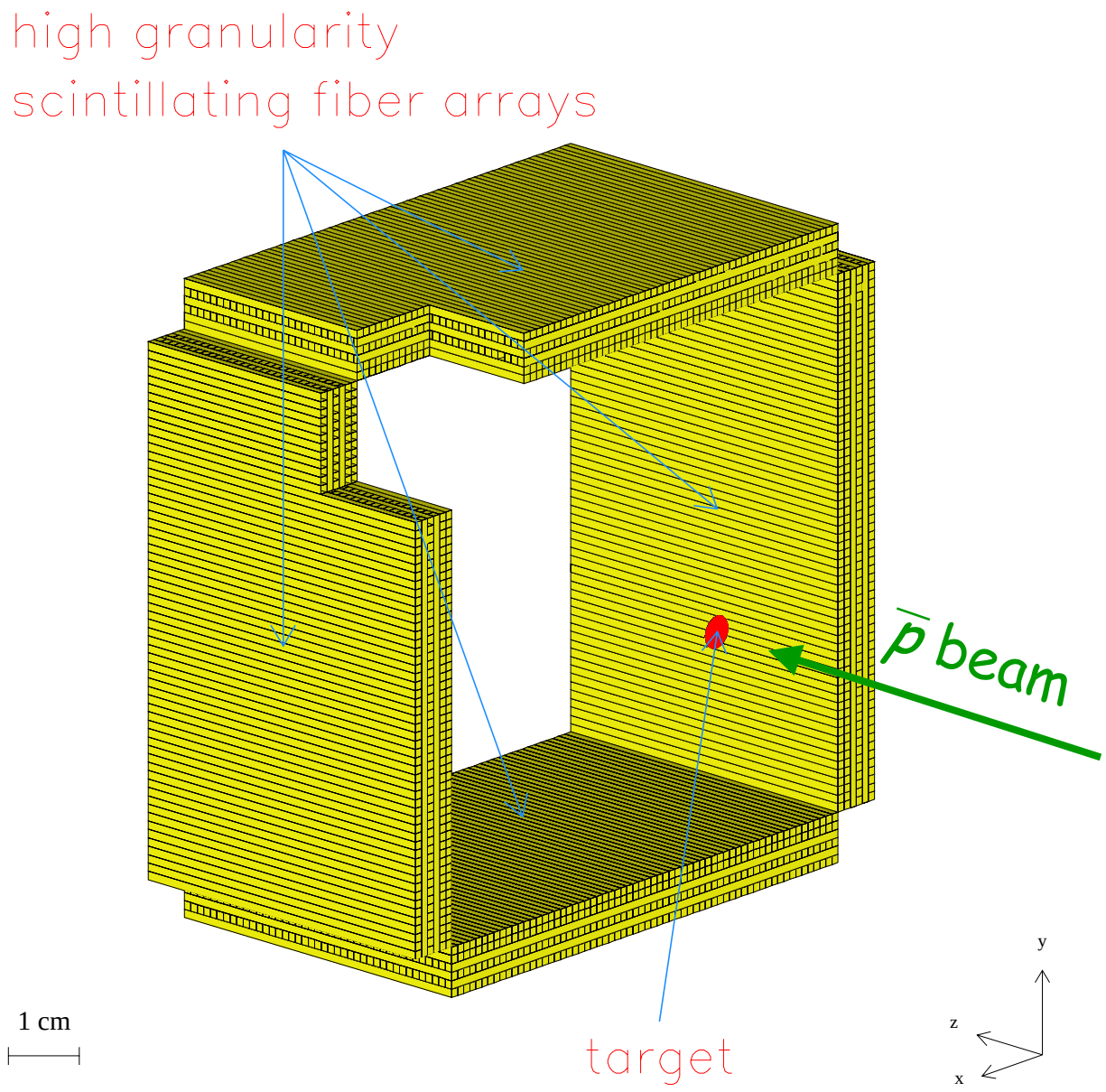
burst
- intensity: $10^6 \div 10^7$
- duration: ≤ 1 μs
- frequency: ~ 10^{-2} Hz

❸ the detector must be operated in vacuum

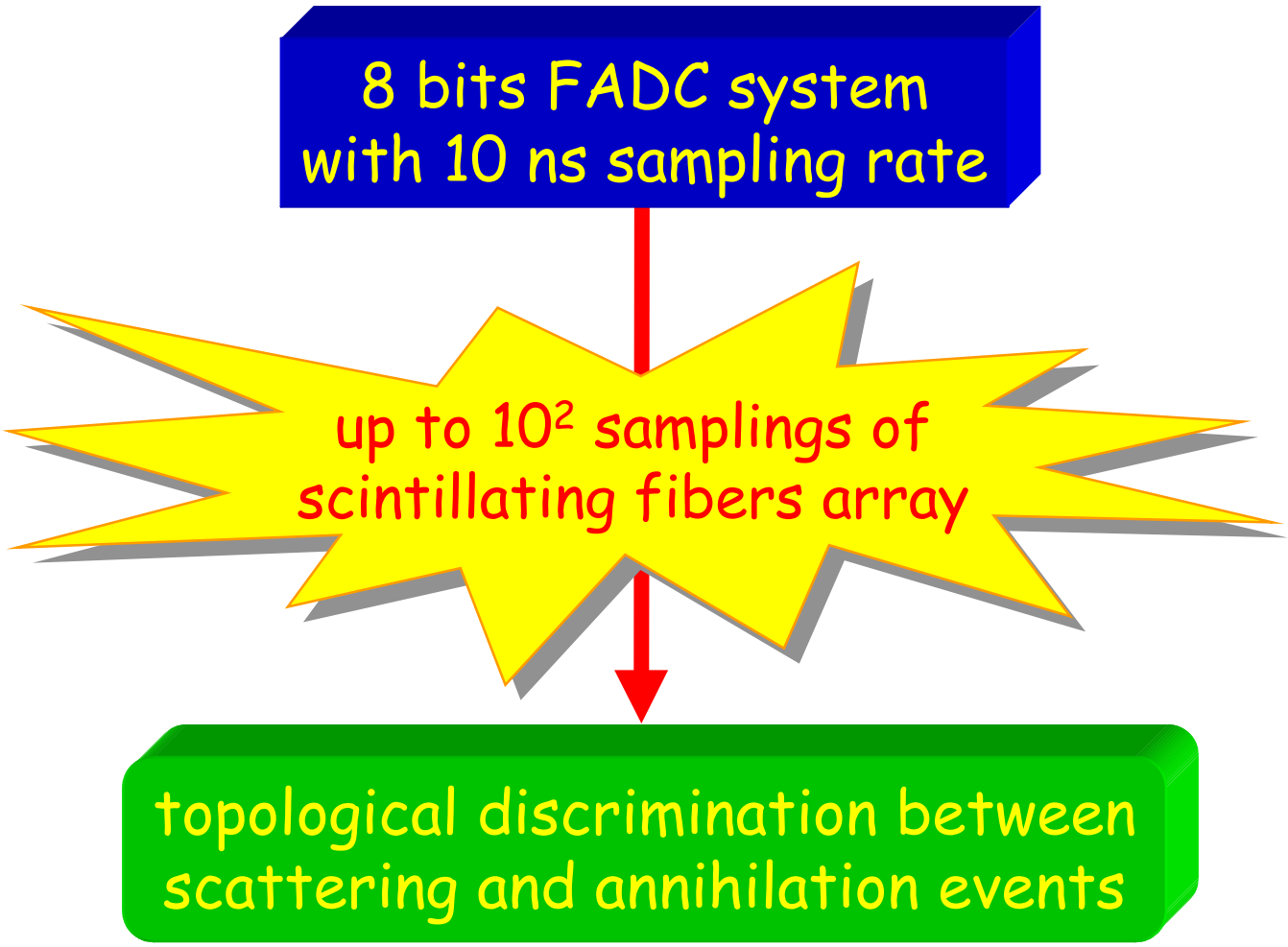
❹ very thin CH_2 target needed (1 ÷ 10 μm)
- difficult to produce
- difficult to sustain in place

❺ fixed beam energy

The ELAPP project



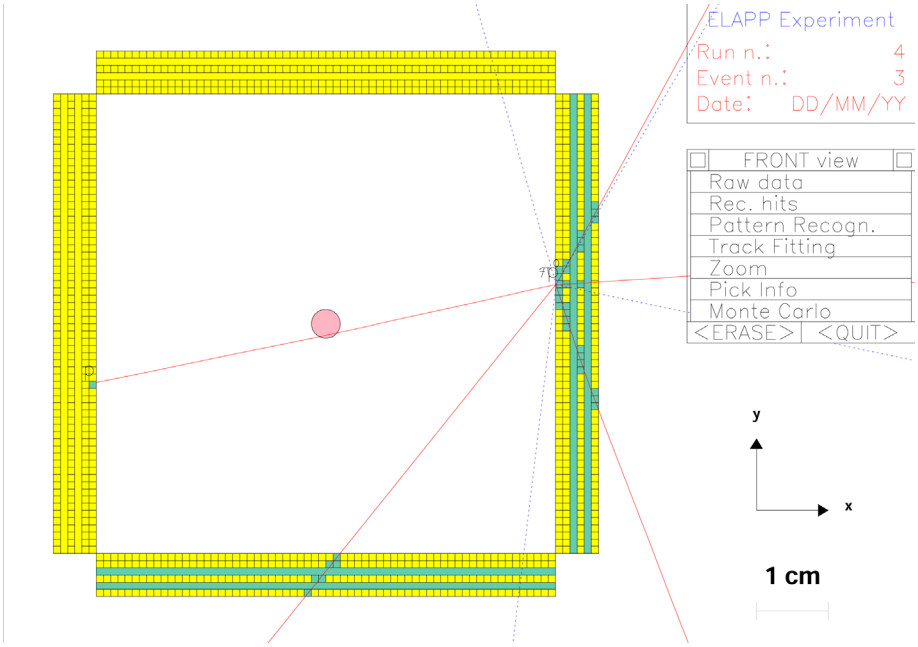
Measurement strategy

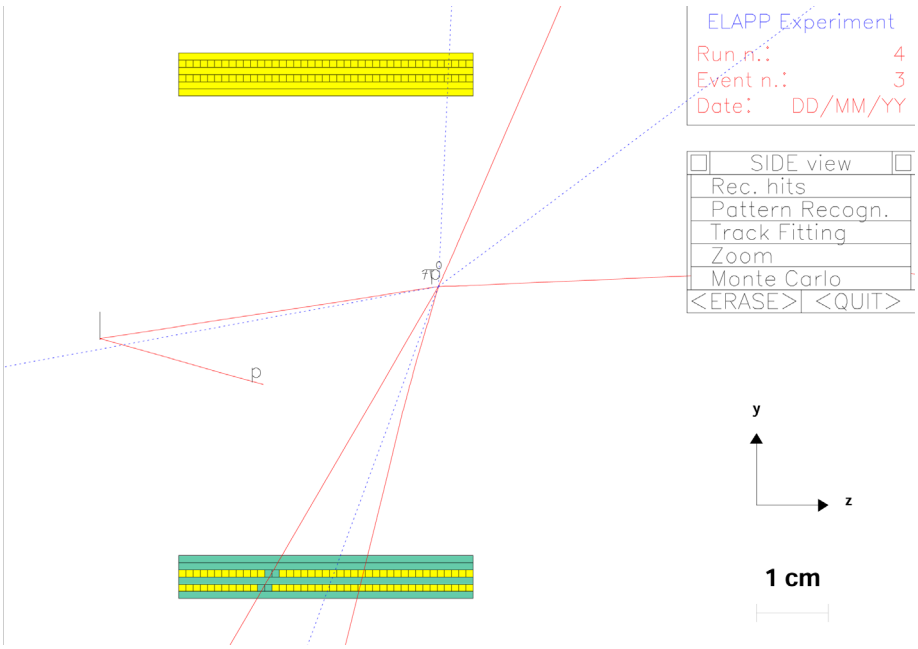


provided that:

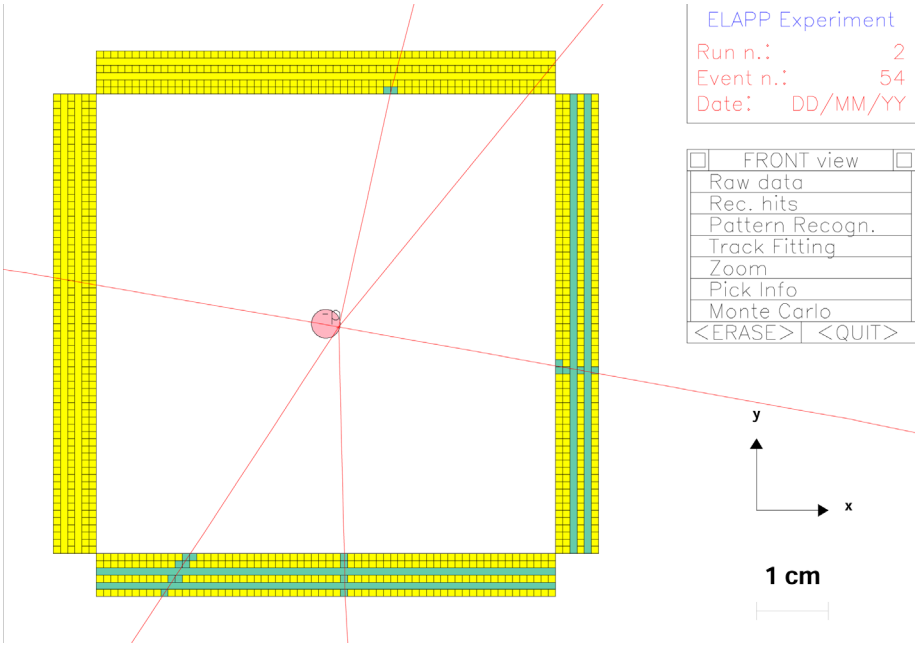
- no more than 30 ÷ 40 interactions/spill
- no (few) particles from spurious events
  - $\bar{p}$ annihilation from beam halo
  - $\bar{p}$ annihilation in structures surrounding the apparatus

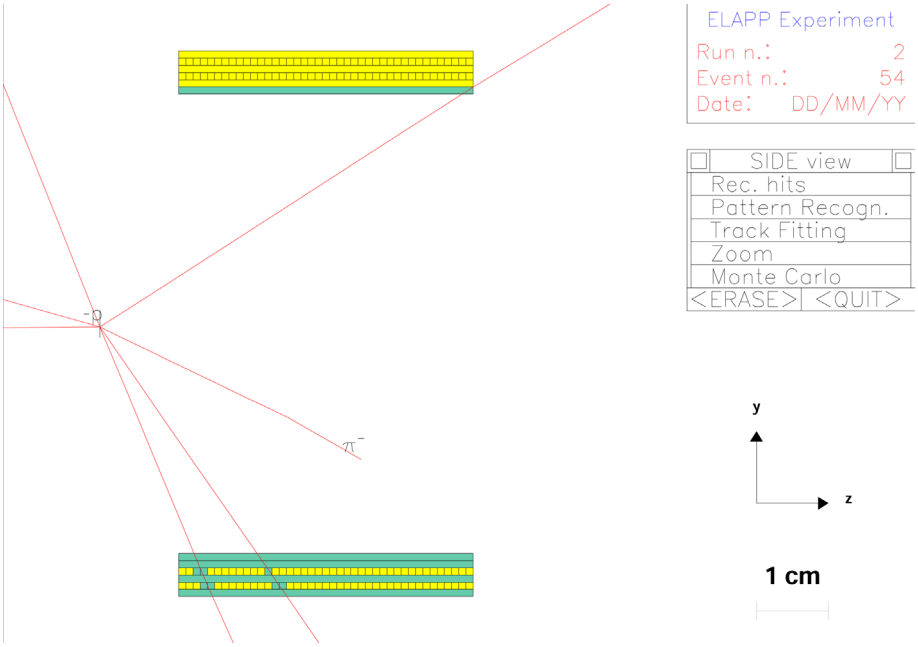
The typical event





The "anti" typical event





Expected event rates
(rough estimation)

$$N_{int} = (N_{\bar{p}} \cdot x)\rho\left(\frac{2}{14} \cdot 500 + \frac{1}{14} \cdot 2600\right) \cdot 10^{-27} \cdot N_A$$

$\sigma_T(\bar{p}p)$ = 500 mb
$\sigma_T(\bar{p}^{12}C)$ = 2600 mb
ρ = 1.1 g/cm^3

$$N_{int} \approx 15 \cdot (N_{\bar{p}} \cdot x)\rho$$

$N_{\bar{p}}$ expressed in units of 10^6
x expressed in μm

$$N_{ela} = (N_{\bar{p}} \cdot x)\rho\left(\frac{2}{14} \cdot 150\right) \cdot 10^{-27} \cdot N_A \cdot \Delta\Omega \cdot \varepsilon_r$$

$\sigma_E(\bar{p}p)$ = 150 mb
$\Delta\Omega \sim 0.7 \cdot 4\pi$
$\varepsilon_r \sim 50\%$

$$N_{ela} \approx 0.5 \cdot (N_{\bar{p}} \cdot x)\rho$$

$N_{\bar{p}}$ expressed in units of 10^6
x expressed in μm

$$N_{ela/int} \approx 3 \cdot 10^{-2}$$

40 int./burst → 1 elastic scatt./burst

$1.5 \cdot 10^3$ elastic scatt./day

Requirements for the beam

- Variable energy: 50 ÷ 100 MeV/c...
  but also 100 ÷ 200 MeV/c
  - ➨ no measurements in this region
  - ➨ easier *p* detection

- good focus: Ø ≤ 2 mm
  no halo at r ≈ 3 cm

- all possible sources of background (degrader, collimator, beam dump) far away from the detector (≥ 4m)

CERN/SPSC 2001/002 – SPSC/P320
December 14, 2000

Proposal to the SPSC

Measurement of the ELastic Anti Proton Proton Cross Section at AD

The ELAPP Collaboration

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Conclusions

✔ $\sigma_{tot}(\bar{n}p)$ measured for the first time:

❶ down to 50 MeV/c

❷ with high statistics

✔ evident anomalous behaviour of $\sigma_{tot}(\bar{n}p)$ ($\rightarrow \sigma_{ela}(\bar{n}p)$) near threshold

indication for a structure below 100 MeV/c in the elastic channel???

☛ possibility of looking at this effect in the elastic ($\bar{p}p$) channel, never measured (but where???)