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PROPOSAL FOR SPS BEAM DUMP EXPERIMENT IN OMEGA

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BEAM DUMP EXPERIMENT IN OMEGA

Birmingham - CERN - Neuchâtel - RHEL Collaboration

1. Summary

The main aim of this proposal is to search for the inclusive production of muons from the decays of charmed particles produced in association with a ψ/J particle. We propose to use π^- beams between 25 and 80 GeV/c (possibly 100 GeV/c). The $\psi \to \mu\mu$ is measured. A rapid increase in the yield of extra muons is expected with increasing momentum due to the opening of the $\psi D\bar{D}$ threshold and the experiment would constitute a sensitive test of the charm idea. The main merits of the experiment are the large acceptance of Ω, and the simplicity. We know of no other experiment which plans or is able to cover this momentum interval so that, even though similar muon experiments may be carried out at FNAL and Serpukhov (see Appendix 1), this one will supply complementary information in a very interesting region.

Two hadron absorbers will be used: the first between the target and the optical chambers and the second at the exit of the magnet. The main trigger requests are: interaction in target, ≥ 2 hits in proportional chamber after first absorber and in hodoscope after 2nd absorber; no halo muon. The typical ψ production rate will be 1000 per day. Production of other vector mesons and the $\mu\mu$ continuum can also be studied as well as related topics. Study of ψ production from antiprotons is envisaged for a later stage. A particularly simple Ω detector configuration is used. Pattern recognition is straightforward and fast. The FWHM- resolution on $\mu\mu$-invariant mass is of the order of 400 MeV/c^2.

2. Scope and Cross Section Estimates

Typical theoretical expectations for hadronic production of $D\bar{D}$, ψ, and $\psi D\bar{D}$... as computed by D. Sivers(1) are shown in fig. 1. "$D\bar{D}$" stands for associated production of charmed particles, baryons or mesons.

The results on ψ production at BNL, Serpukhov, NAL and CERN(Table 1)are well reproduced. 80 GeVπ's are expected to produce ψ's with a cross section of 80nb, of which 30nb is with accompanying charmed particles (Zweig mechanism). Production of charmed particles alone, without ψ, is estimated at 17μb.

If charmed particles decay semi-leptonically they are a source of prompt μ's final states. We shall observe, apart from background events:

- The Drell-Yan dimuon spectrum
- The ρ, ω, ϕ, ρ',...decaying into μ-pairs
- The ψ into μμ, as well as higher mass objects (6GeV/c^2 ?)
- Trimuons from ψ $D\bar{D}$...
  - $\bar{D} \rightarrow \mu$...
  - $\psi \rightarrow \mu\mu$
- Quadrimuons from ψ $D\bar{D}$...
  - $\bar{D} \rightarrow \mu$...
  - $D \rightarrow \mu$...
  - $\psi \rightarrow \mu\mu$
- A continuum of dimuons from $D\bar{D}$+...
  - $\bar{D} \rightarrow \mu^-$...
  - $D \rightarrow \mu^+$...

The latter subject is the least rewarding one: it looks difficult both to disentangle $D\bar{D}$ dimuons from the Drell-Yan continuum, and to interpret them. The most rewarding subject are the trimuons: background is expected to be low and decreasing with increasing energy, and the threshold effect due to the opening of charmed particle production channels should be easy to identify.

Other possible sources of multimuons are:

- Double ψ production → 4μ
- The double Dalitz decay of a pseudoscaler particle $\eta_c \rightarrow 4\mu$ (even $\eta \rightarrow 4\mu$).
- Heavy leptons.

3. Experimental Setup

The layout is shown in fig. 2.

The principal aim is to maximise the acceptance by compressing the setup longitudinally. The main components are:

- The beams, i.e. the S1 beam for π's up to 40 GeV/c and, at a later stage, $\bar{p}$'s of 40 GeV/c: and the H1 beam for π's and possibly p's of 60 and 80 GeV/c; with a beam telescope capable of handling the wanted intensity of 10^7/ burst $\simeq 10^7$/sec. The muon content is $\leq$ 1% in the telescope, and $\leq$ 5% over a $1m^2$ detector area, for the pion beams.
- A halo veto counter V1.
- The target box, made of 4 Cu (or Be) pieces each 5cm long, and sandwiched between 5 scintillators (S1 -S5) 1 cm thick, with pulse-height readout. Its triple function is:
    - a) to determine the interaction vertex to ± 2cm
    - b) to indicate roughly an interaction multiplicity, and
    - c) to include in the trigger signal, the requirement that a hadronic interaction has occurred (in order to avoid beam muon triggers).
- The first absorber which is of copper and has to reduce the hadron flux to a level tolerable for the spark chambers (see Appendix 2). Its total thickness is 135cm up to 40 GeV/c, and 165cm above. It ensures that $\leq$ .02 hadrons from a $\mu\mu$ event leak through, and $\leq$ .15 tracks per extra beam particle interacting within the 1.3 μsec memory of the spark chambers. These will therefore work with full efficiency, as the number of unwanted extra tracks will not exceed 2.5 (2 plus .5 halo muon), even at 10^7 particles per second.
- A large scintillation counter S6 to signal that prompt particles have penetrated the absorber, to serve as a strobe for the multiwire proportional chambers and to afford past-future protection for the MWPCs.
- Proportional chambers PC2, 3 and 4, all of which exist at Ω. PC2 is the most important; it has a memory time of 50 nsec and serves 2 purposes:

to identify those tracks which belong to the triggering event, and to complete the trigger signal, by imposing either ≥ 3 μ's, or 2 μ's with an opening angle bigger than 120 mrad in either the horizontal or the vertical plane. Such a cut will strongly favour ψ's over ρ's and the low mass continuum. This is discussed further in section 6.

- A veto counter V2 to veto beam muons.
- The return yokes of Ω (1.25m of iron) which act as a second absorber.
- A hodoscope H (600 x 380cm) having 60 elements 20cm wide, and 190cm long each, which is being prepared by the Birmingham group. The basic trigger requires ≥ 2 hits in this hodoscope but provision will exist to form matrix coincidences with the MWPCs (see section 6).

4. Event Analysis and Resolution

Tracks in the spark chambers are found and measured by the standard ROMEO programme. They are then extrapolated to the MWPC's, to the hodoscope H, and to the target box, in order to verify that a) their timing is correct, and b) their trajectories within the absorbers are consistent with multiple scattering and ionization loss only.

For a pion of $p \geq 3$ GeV/c, the probability of being validated as a muon in this manner is $\leq 10^{-3}$ (decay within one absorption length); the hadronic background among muon pairs is negligible.

To estimate the μμ mass resolution, we use the approximation

$$M_{\mu\mu} = \sqrt{P_{\mu 1} P_{\mu 2}}\ \theta \simeq \sqrt{P_{\mu 1} P_{\mu 2}}\ \frac{D}{L}$$

The μ momenta are measured in the optical chambers to

$$\frac{\Delta p_\mu}{p_\mu} \simeq \pm\ 0.3\%\ p_\mu \qquad (p_\mu \text{ in GeV/c})$$

and produce an uncertainty

$$\left[\frac{\Delta M_{\mu\mu}}{M_{\mu\mu}}\right]_{p_\mu} \cong \pm\ 0.1\% \times p_{\mu\mu}, \quad \text{i.e.}$$

$$\Delta M_\psi \cong \pm\ 45 \text{ MeV for a } \psi \text{ of } 15 \text{ GeV/c}$$

D represents the distance between the two μ's when they leave the first absorber, and L the distance between the end of the absorber and the interaction point. The uncertainty on the latter, of $\Delta L = \pm 2\text{cm}$, contributes

$$\left[\frac{\Delta M_{\mu\mu}}{M_{\mu\mu}}\right]_{\text{vertex}} \cong \pm\ \frac{2\text{cm}}{150\text{cm}} = \pm\ 1.3\%, \text{ or } \Delta M_\psi = \pm\ 40 \text{ MeV}.$$

We assume that the absorber causes an uncertainty in D due to multiple scattering, with an effect on $M_{\mu\mu}$ which reads

$$\left[\Delta M_{\mu\mu}\right]_{\text{coulomb}} \simeq 2\ \Delta P_T^{\text{coulomb}} = \sqrt{\frac{2\ L}{3\ L_{\text{rad}}}} \times 15 \text{ MeV/c}^2$$

or $$\Delta M_{\mu\mu} = \pm\ 125 \text{ MeV} \quad (L \simeq 150\text{cm},\ L_{\text{rad}} = 1.45\text{cm})$$

We infer a typical width of 400 MeV FWHM for the ψ. This is expected to be an upper limit since the correlation between lateral displacement and angle when the tracks have been extrapolated to the longitudinal position of the

5. Acceptance

The acceptance has been computed by a detailed Monte Carlo program, for the following reactions:

$$\pi p \to \bar{D}\,\psi\,C \qquad \text{at 40 GeV/c,}$$
$$\pi p \to \bar{D}\,\psi\,C\,\pi\pi \qquad \text{at 60 and 80 GeV/c,}$$

with $M = 3.1$, $\psi \to \mu\mu$; $M_D = 2$, $D \to \mu\nu\, K\pi\pi$, and $M_C = 2.5$, $C \to \mu\nu\Lambda$. (To compute an acceptance for ψ's at 25 GeV/c, we use there $M_D = 1.5$, $M_C = 2$). Phase space is used; all secondary particles peak at $X = 0$ and have rather wide p_T distributions. Two μ's were required to reach the hodoscope H, which meant roughly $\theta_\mu \leq 300$ mrad and $p_\mu \geq 4.4$ GeV/c. The third and fourth μ were required to traverse the sensitive volume of PC2 and at least two spark chambers, i.e. $\theta_\mu \leq 300$ mrad again, and $p_\mu \geq 2.2$ GeV/c. The results are shown in Table 2.

The probability to detect the $\psi \to \mu\mu$ (at $x \simeq 0$) increases from 10% at 25 GeV/c to 50% at 80 GeV/c. It is almost independent of p_T. One extra μ from charmed particle decays is seen with a probability of $\sim$ 50% - 65% (at 40-80 GeV/c: to be compared with a probability of $\sim 10^{-3}$ for a pion to simulate a μ, mainly via early decay). The probability to see a 4th μ is of the order of 5% to 10%. At 80 GeV/c, the acceptance for a ψ (6.0 GeV/c^2) $\to \mu\mu$ is 60% for $x \simeq 0$.

6. Trigger rate, event rate

The total μμ trigger rate can be estimated in various ways. In the Serpukhov experiment (Fig. 3) the total number of detected μμ pairs from pBe interactions is 500 times the number of ψ's. We double this figure to (over) compensate their reduced relative efficiency for low μμ masses, to get a probability of production of μμ pairs in pBe collisions of $5\ 10^{-5}$, and probably 10^{-4} in π^--nucleus collisions. With an interaction probability within the target box of 75%, and an unbiased trigger offering a detection probability of 65% or so, 500 μμ triggers per 10^7 π's of 60-80 GeV/c would result. Alternatively, we may use the ρ^o production cross section in $\pi^- p$ collisions of 2 mb per unit interval of c.m. rapidity(6). Multiplying this with the $\rho \rightarrow \mu\mu$ branching ratio, and folding with the acceptance, we get an effective cross section of 0.17μb at 80 GeV/c. We double this figure to include $\omega \rightarrow \mu\mu$, and multiply by 3 which is the ratio $(\rho/\omega + \text{continuum}) / (\rho/\omega)$ (see Fig. 3), to obtain finally 300 genuine μμ triggers per $10^7\ \pi^-$ at 80 GeV/c. The rate is smaller for incident protons, and for π's of lower momenta.

Such an unbiassed trigger may be useful to study the low mass regions, with a C absorber rather than the Cu absorber. To increase the luminosity for ψ production, we envisage two triggers:

A. The $\theta_{\mu\mu}$ cut described above allows to eliminate 80-90% of the low mass (ρ-like) μμ-events, and will reduce the trigger rate to $\leq$ 100 per $10^7\ \pi^-$ at 80 GeV/c, thereby reducing the acceptance for ψ's above 30 GeV/c. At 40 GeV/c, the trigger rate is reduced to < 30 per 10^7, with few ψ's lost (with a read out time of 13 msec, 40 triggers in a 1 sec burst lead to 50% dead time loss). Alternatively, a p_y-cut (p_T component in the horizontal plane) is being studied, which would use correlations between PC3 and PC4, analogous to the 1975 charm search trigger.

B. 3- and 4- μ events can be studied with maximum luminosity by requiring at least 3 particles in PC2.

Trigger A is satisfactory, at least at the lower momenta, provided we control the following main sources of background:

a) Accidental coincidences between beam μ's (10^5 for 10^7 π) and halo μ's ($5\ 10^5$). With a resolving time of 20nsec this would lead to 1000 coincidences, which we reduce (i) to 100 by the beam veto counter V2, (ii) to ∿ 10 by requiring a multiplicity of ≥ 3 in the last target scintillator, and (iii) to a few per burst by using fast anti-halo veto counters V1.

b) A π^- of 80 GeV impinging on copper will give rise to 1.3 10^{-3} μ's of ≥ 5 GeV/c via showering and π decays; including K decays may double this figure. The probability of producing two fast μ's this way is however smaller than the square of this figure, and likely to be reduced to nothing by the $\theta_{\mu\mu}$ cut. On the other hand, accidental coincidences between ∿ 2.5 10^4 single μ's produced by 10^7 π's with beam or halo μ's are again dangerous and can be made negligible only by a careful study of counters V1 and V2.

c) Noise in the hodoscope should be kept well below 10^4/sec per counter.

Trigger B is in principle safe; the only dangerous background comes from the halo muons which arrive within the memory plus gate width of PC2 and which may therefore simulate a multiplicity of 3 in a few percent of all dimuon events. This is bearable, and could be eliminated by correspondingly lengthening the pulse width of the veto counter V1.

Let us mention again that most of the background events should be identified as such and eliminated off-line by the procedure outlined in section 4.

The expected typical event rates for π^- interactions are the following:

- At 40 GeV/c, with σ (ψ + anything) = 30nb, 10^7 π/b, <u>10^4 burst/day</u> 75% interacting in the target, trigger A, branching ratio 7% for $\psi \to \mu\mu$, acceptance = 30%, deadtime loss and <u>security factor 1/3</u>, we expect <u>600 ψ/day</u>
- At 80 GeV/c, with σ (ψ + anything) = 85 nb, 5 10^6 π/b, trigger A, acceptance 50%, deadtime loss and security factor: 1/3; <u>1500 ψ/day</u>
- At 80 GeV/c, with σ ($\psi D\bar{D}$ + anything) = 35nb, 10^7 π/b, trigger B, acceptance for 3rd μ 65%, for 4th μ 12%, branching ratio B for D → μ..., and security factor ½: <u>1200 B trimuons/day</u> and <u>220 B^2 4 μ events/day</u> (or 120 $\mu\mu\mu$ and 2 4μ events for B = 10%).

7. Preparation of apparatus and software

All the apparatus referred to above either exists or is in preparation. The target arrangement will be built at Neuchâtel, and the correlation logic and hodoscope at the Rutherford Laboratory under the guidance of the Birmingham group.

We expect to be ready by August 1976. The copper (8t) for the absorber can be obtained on loan. We plan to design the absorber in such a way that it can be installed or removed in one day.

A modified version of the present ROMEO programme will be prepared at Birmingham with assistance from CERN. Since the tracks will be measured in the optical chambers the pattern recognition part of the existing program will require no modification.

8. Further possibilities

Several additional studies can be made in this experiment, or will be obtained as by-products. Some of them will come out of the data of the main experiment

- search for doubly charged $\mu^+\mu^+$ or $\mu^-\mu^-$ resonances
- search for ρ', $\rho'' \to \mu\mu$
- the relative yield of ψ's compared to the continuum for incident π^+ and π^- might clarify the production mechanism in terms of the quark annihilation picture.

Other subjects would require modifications in the setup:

- ρ, ϕ and ψ production as a function of the size of the target nucleus. In the single step Glauber model$^{(3)}$, the ψ:ρ ratio increases by roughly a factor of 3 when going from Be to Pb, and varies by 5% in Pb per 1mb total ψN cross section. Anyway, a crucial test of this model would be offered.
- a study of the $\mu\mu$ continuum including the threshold region. μ pairs from $C\bar{D}$ or $D\bar{D}$ are expected to show up around $M_{\mu\mu}$ = 500 to 1000 MeV, and can possibly be disentangled from the Drell-Yan continuum by studying the excitation function in the 20 - 40 GeV/c beam momentum range.
- in order to obtain satisfactory resolution on ρ/ω and ϕ and on the continuum, it would be necessary to replace the copper absorber by BeO and C. The beam intensity would then have to be reduced to $\leq 10^6$ per burst to avoid saturating the optical chambers. For a Be target $\Delta M\mu\mu$ would then be ∿ ± 30 MeV and for a Cu target ∿ ± 60 Mev.
- at 80 GeV/c, measurement of the production of single muons in a W target of variable density. For compact W, a 20 GeV/c π^+ has a probability of 10^{-4} to decay within one absorption length into a μ of 16 ± 4 GeV/c. The situation is therefore favourable for $.2 \leq x \leq 1$ and $0 \leq p_T \leq 2$ GeV/c.
- $e^\pm$ beam dump: 10^7 $e^\pm$ of 80 GeV hit 1 L_{rad} of Pb, followed by 1 L_{abs} of Be where photons interact. Several hundred ψ's/day, and many fewer ρ/ω and ϕ are expected. A rather light absorber can be used. Replacing the Be target by more Pb will again allow, with much reduced statistics, some conclusion about vector meson interactions in nuclei.

- The feasibility of $\bar{p}$"p" → $\mu\mu$ in the RF beam has to be studied.
- $K^{\pm} \to \pi^{\pm}\mu\mu$ can be studied in the RF beam with the same layout after removing target and absorber.

The desirability of carrying out these further experiments would have to be judged on the basis of the state of knowledge at the time of the experiment.

9. Beam and Computer Time Request

As mentioned earlier we plan to be ready to receive the first beam in the West Hall. We request 12 days in each of the S1 and E1/H1 beams including 3 days setting up in each beam. A total of $\sim 4 \times 10^6$ triggers should include $> 10^4$ ψs.

We envisage a second phase of the experiment after the analysis of the first part, with a similar time request, where we should plan to use the RF beam in a separated mode ($\bar{p}$).

We estimate that the Omega apparatus could be restored to its normal form (absorbers removed and all chambers replaced) in about two days so we do not consider the experiment unduly disruptive to the Omega running.

The computer time needed is estimated to be 150 CDC 7600 equivalent hours. We plan to divide the computing between the Rutherford Laboratory, Neuchâtel and CERN.

Appendix 1

The following second generation beam dump proposals have been recently submitted at FNAL:

No. 433 (J.K. Walker et al., FNAL - Northern Illinois).
10^{10} p or π/ burst on steel dump followed by 1 dipole and 3 toroid magnets, proportional chambers, 3π sr. acceptance in c.m.

No. 436 (R.K. Adair et al., Yale _ BNL - FNAL)
400 GeV p on steel and earth, followed by counter hodoscopes.

No. 439 (D. Garelick et al., Northeastern)
10^9 400 GeV p on magnetised iron, drift chambers, ± 100 mrad lab acceptance.

No. 443 (.J.E. Pilcher et al., Chicago - Princeton)
10^7 p, π^+, π^- on the H_2 and D_2 target, followed by Chicago Cyclotron spectrometer.

No. 444 (J.E. Pilcher et. al., Chicago - Princeton)
10^7 225 GeV p, π^+, π^- on C target, followed by Chicago cyclotron spectrometer (high intensity run).

No. 436 has no magnet and aims at a comparison of single μ and μ pairs production. To our knowledge, No. 439 and No. 444 have been accepted, No. 433 and No. 443 have been deferred; the Serpukhov experiment (Denisov et al.) is being set up in a π beam.

Appendix 2: Hadron shower development

We use data on hadron showers in Fe, a. for protons of 19.2 GeV/c (A. Citron et al.(4)) and b. for π^- of 150 GeV/c (K. Anderson et al.(5)). Fig. 4 shows the track density vs. absorber thickness, integrated over the lateral distribution up to a radius of ∿ 50cm. We interpolate between these curves to fix our absorber thickness, in units of L_{abs}, for non correlated beam particles. Showers required by the trigger logics to originate in the target box are somewhat shorter; we use the dashed curves of Fig. 4 which correspond to interactions which take place at $X = 0$, the origin of the absorber. When folded with an exponential distribution of primary interactions, they reproduce the measured shower curves.

"Grey" nuclei like Fe have a slightly longer (by ∿ 15%) absorption length for pions than for protons. We have not fully considered this effect, nor the (opposite) effect of the magnetic field which slightly shortens the showers.

References:

1. D. Sivers, private communication.
2. Yu. M. Antipov et al., Serpukhov preprint 75-125 (1975).
3. K.S. Kölbig, B. Margolis, Nucl. Phys. B6, 85 (1968).
4. A. Citron et al., N.I.M. 32, 48 (1965).
5. K. Anderson et al., NAL Proposal 331, Appendix.
6. D. Fong et al., Phys. Letters 60R, 124 (1975).
7. K.J. Anderson et al., Phys. Rev. Letters 36, 237 (1976).

Table 1. Summary of ψ production from hadrons, adapted from (2).

Incident particle + target	P_{inc}	Variable	Range	σ form	Parameter	Ref.
p + Be	30	$p_\perp^2$	$0 < p_\perp^2 < 1.6$	$e^{-bp_\perp^2}$	$b = 1.6$	S.C.C. Ting+
p + Be	70	$p_\perp^2$	$0 < p_\perp^2 < 1.6$	$e^{-bp_\perp^2}$	$b = 1.8 \pm 0.3$	Yu. M. Antipov et al.(2)
		$p_\perp^2$	$0 < p_\perp^2 < 1.0$	$e^{-bp_\perp^2}$	$b = 1.7 \pm 0.4$	
		x	$0.3 < x < 0.8$	e^{-ax}	$a = 6.0 \pm 1.2$	
		y^*	$0.4 < y^* < 1.1$	e^{-cy^*}	$c = 3.8 \pm 0.8$	
π^+ + Be	150	x	$0.2 < x < 0.6$	$e^{-\alpha x}$	$\alpha \simeq 0$	
		P_T^2	$0 < P_1{}^2 < 4$	$e^{-bP_T^2}$	$b \simeq 1$	
p + Be	150	x	$0.1 < x < 0.7$	e^{-ax}	$a = 5$	K.J. Anderson et al. 7)
		P_T^2	$0 < P_T^2 < 4$	$e^{-bP_T^2}$	$b \simeq 1$	
π^- + Fe	200	x'	$x' \geqslant 0.5$	$e^{-a'x'}$	$a' = 6.2 \pm 0.8$	G.J. Blanar et al.+
		$p_\perp$	$0.3 < p_\perp < 2$	$e^{-b'p_\perp}$	$b' = 1.6 \pm 0.2$	
		$p_\perp^2$	$0.1 < p_\perp^2 < 4$	$e^{-bp_\perp^2}$	$b = 0.81 \pm 0.14$	
p + Fe	240	x'	$x' \geqslant 0.4$	$e^{-a'x'}$	$a' = 9.7 \pm 1.6$	
		$p_\perp$	$0.3 < p_\perp < 2$	$e^{-b'p_\perp}$	$b' = 2.2 \pm 0.5$	
		$p_\perp^2$	$0.1 < p_\perp^2 < 4$	$e^{-bp_\perp^2}$	$b = 1.1 \pm 0.3$	
n + Be	~250	x'	$x' > 0.25$	$e^{-a'x'}$	$a' = 10$	B. Knapp, W. Lee et al.+
		$p_\perp^2$	$0 < p_\perp^2 < 2.5$	$e^{-bp_\perp^2}$	$b = 1.5$	

1. $x' = p_\parallel / p_{beam}$, $x = p_\parallel^* / p_{max}^*$;

   (*) denotes the value in c.m. frame.

2. The momentum is in GeV/c,

   the slope b' is in $(GeV/c)^{-1}$ and the slope

   b is in $(GeV/c)^{-2}$.

\+ Papers presented at Stanford Symposium, August 1975.

Table 2: Computed Acceptances

Beam Momentum (GeV/c)	25	40	60	80
	$\pi p \to \psi\bar{D}C$		$\pi p \to \psi\bar{D}C\pi\pi$	
	$(\psi \to \mu\mu,\ \bar{D} \to \mu^-\nu\ K\pi\pi,\ C \to \mu^+\nu\ \Lambda)$			
Trigger ($\geq 2\mu$ in H and PC2)	.14	.54	.63	.77
Trigger and $\psi \to \mu\mu$ detected ($\langle x_\psi \rangle = 0$), with or without $\theta_{\mu\mu}$ cut	.11	.31	.38	.50
*Trigger and 3μ seen, among which the ψ	.015	.16	.21	.32
*Trigger and 4μ seen	0	.02	.03	.06
Reaction	$\pi p \to \psi$ + anything			
Trigger and $\psi \to \mu\mu$ detected, for $x_\psi = 0.8$, no $\theta_{\mu\mu}$ cut	.50	.70	.81	.85
with $\theta_{\mu\mu}$ cut	.35	.42	.40	.20

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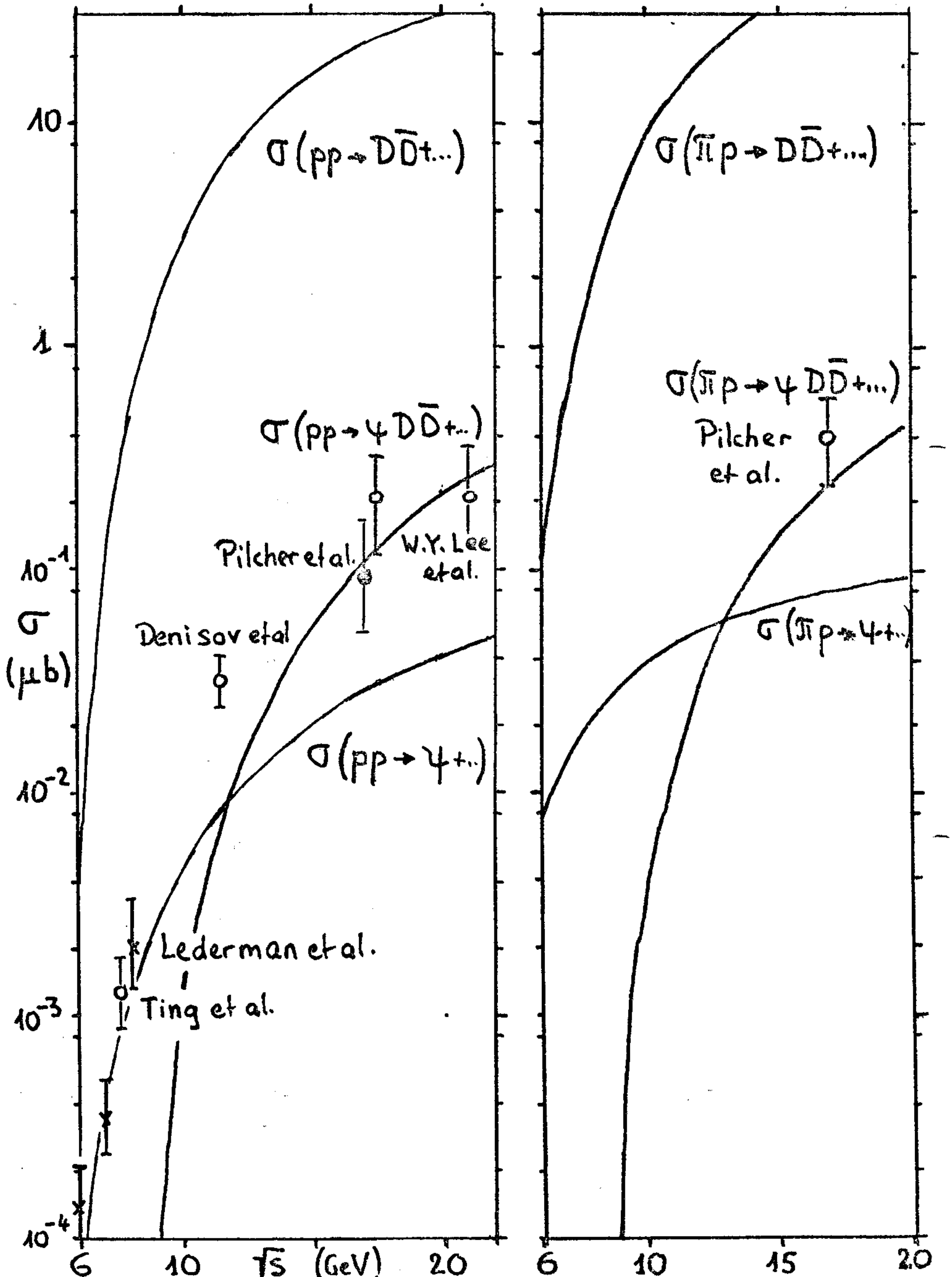
* The acceptances for the 3rd and 4th μ depend strongly on the assumed $\bar{D}$ and C decay modes.

The p_T dependence of the acceptance is almost negligible up to $p_T = 3$ GeV/c.

Fig. 1: D. Sivers' predictions for ψ and charm production in pp and πp collisions.



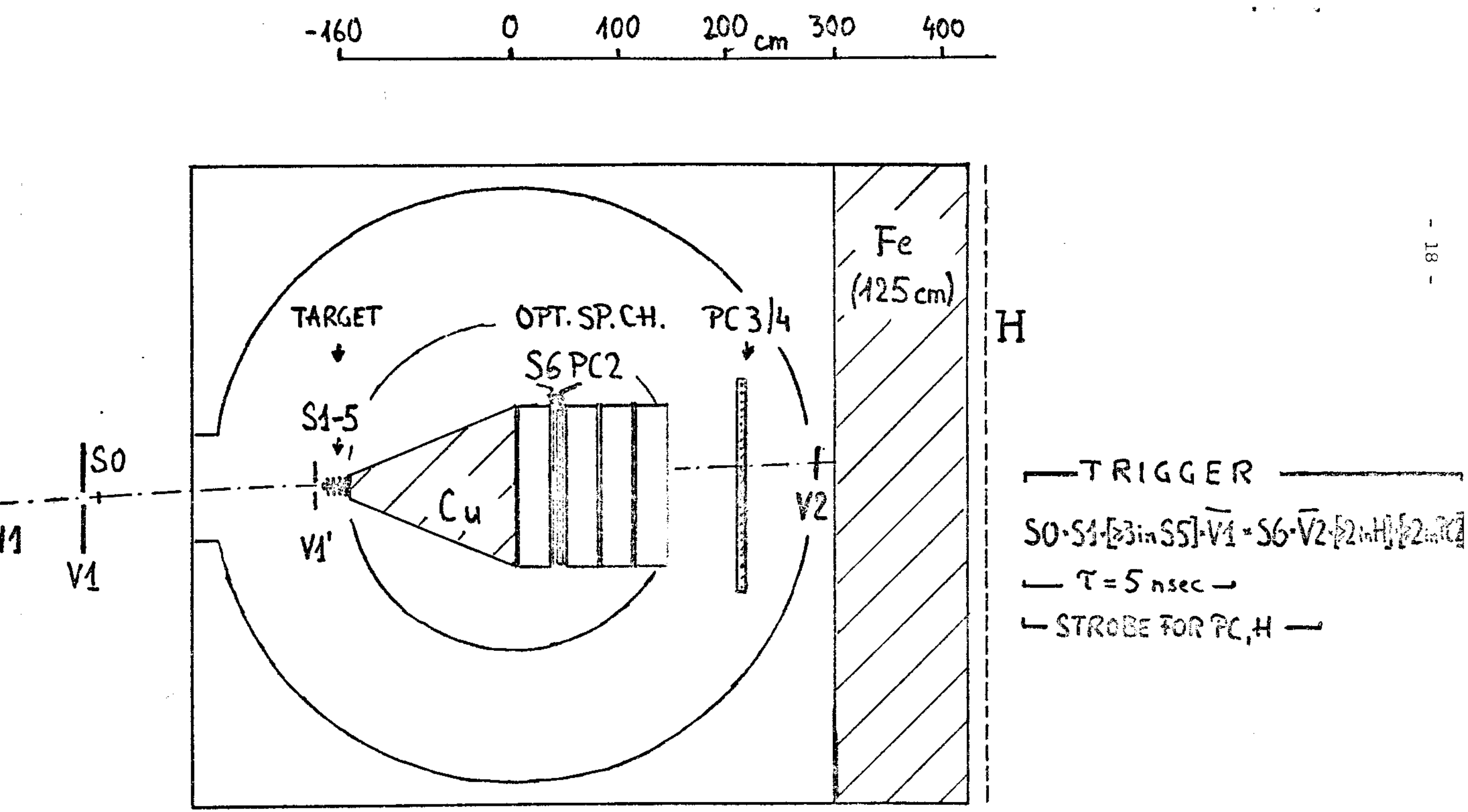


Fig. 2. Experimental layout.

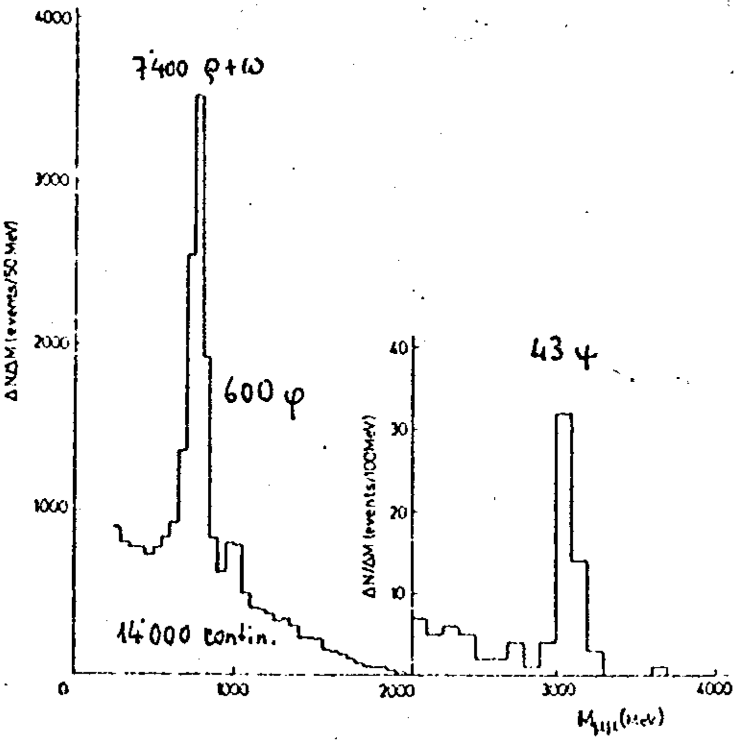


Fig. 3: Dimuon mass spectrum measured with carbon absorber. From (2)

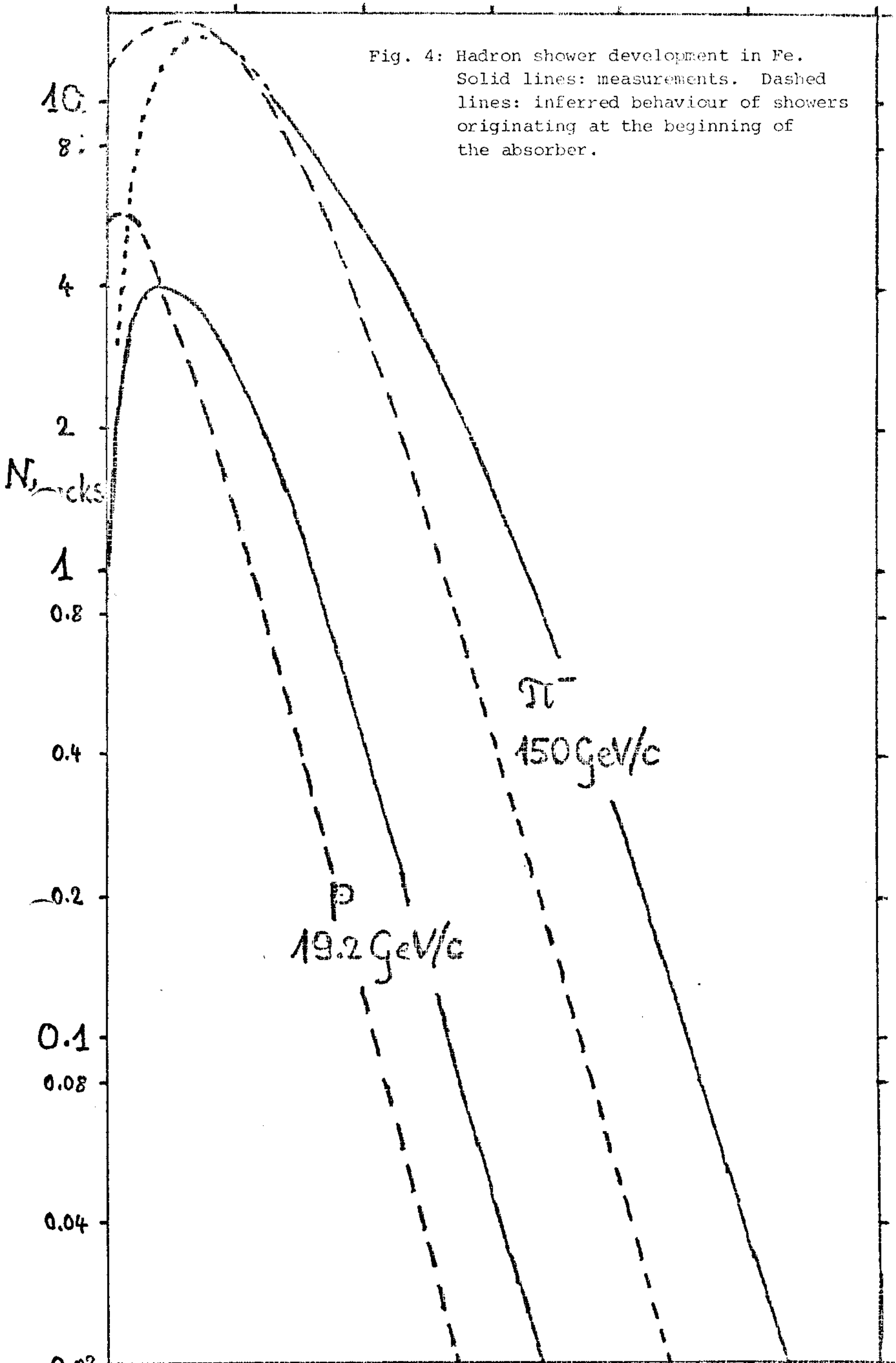


Fig. 4: Hadron shower development in Fe. Solid lines: measurements. Dashed lines: inferred behaviour of showers originating at the beginning of the absorber.