PROPOSAL No. 368

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PROPOSAL TO SEARCH FOR MASSIVE STATES DECAYING INTO MUON PAIRS AND PRODUCED BY HIGH ENERGY MUONS

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We propose a search for the production of heavy vector mesons, including the recently discovered ψ (3105) and ψ (3695), with masses in the range 3-10 GeV and decaying into muon pairs. This proposal uses the present E26 spectrometer with essentially no additional equipment required. The muon beam is used as a source of virtual photons which produce the heavy particles diffractively. A unique and clean signature is observed as follows:

1. The beam muon loses most of its energy but continues in the forward direction. The muon's remaining energy is measured in a tagging magnet which is the one presently used to calibrate the E26 spectrometer.

2. At least one other muon is detected in the spectrometer counter hodoscopes.

3. All three muons are visible in the present hadron chambers after emerging from the target. No other particles are visible. The target counters confirm that essentially no additional energy is released at the interaction vertex.

4. The muon pair is approximately coplanar with the incident muon ($\theta_{prod} \sim \frac{450\ MeV/c}{100\ GeV} \sim 4.5$ mrad).

Since the photon energy is known, the mass of the muon pair can be calculated by the assumption of diffractive production plus measurement of the muon angles only. However we plan also to measure the momentum of at least one of the muons in the spectrometer (+/-14%), so the reaction is actually overdetermined. We can improve the mass resolution further by assuming nothing else is produced, since for these heavy masses the momentum transfer to the nucleon is comparable to the multiple scattering in the target and small compared to 1/2 of the heavy particle mass.

Rates appear to be high, with several events/hour for a product of cross section times muon pair branching ratio equaling 1 nanbarn.

Advantage of using muons as a photon source

A number which has been quoted for the Fermilab breadband photon beam is 5 x 10^6 photons above 50 GeV for 5 X 10^{12} protons. Since for 10^6 muons incident on the target we get about 10^4 virtual photons above 75 GeV it is reasonable to ask why we use muons. The answer is:

1. The photon energy can be determined accurately with a crude measurement of the final muon energy. We expect to make a 20% measurement of the momentum of muons having energies between 20 and 70 GeV, giving us a photon energy of 130 to 80 GeV with a resolution on that energy which varies from 3% to 17.5%.

2. Very thick targets ($\sim$100 radiation lengths) can be used with muons. This gives a gain of a factor of 1000 over photon beams which cannot easily use targets thicker than 0.1 radiation length. Using this factor, the number of muon virtual photons exceeds the real photons above 50 GeV. If high energies are important we can take advantage of the relatively less steep decline with increasing photon energy. This advantage increases rapidly as the muon energy is increased. Really significant gains can be realized by increasing the muon energy from its present 150 GeV to 200 or 225 GeV.

Of course the existence of an ideally suited working muon spectrometer with good acceptance in the 3-10 GeV mass range is a powerful reason for using the muon beam also.

We propose a 100 hour test run to determine trigger rates and backgrounds as well as observe the newly discovered states while searching for new ones (or a rapidly rising continuum).

Virtual Photon Flux

We use an approximate formula for Γ_t, the number of effective transverse photons due to the Coulomb field of the incident muon:

$$\Gamma_t = \frac{\alpha}{4\pi^2} \frac{k}{q^2} \frac{E'}{E_0} \left[2 + \frac{4 E_0^2 E'^2 \sin^2\theta}{q^2 (\vec{P}-\vec{P}')^2} \right]$$

Integrating Γ_t over muon angles we arrive at an approximate formula which slightly underestimates the number of photons :

$$\frac{dN_\gamma}{dk} \sim \frac{\alpha}{2\pi} \frac{1}{k} \left(1 + \left(\frac{E'}{E_0}\right)^2 \right) \log \frac{q^2_{max}}{q^2_{min}}$$

where $q^2_{min} = m_\mu^2 \left(y + \frac{1}{y} - 2 \right) \qquad y = E'/E_0$

and q^2_{max} is determined either by the geometry ($q^2_{max} \simeq E_0 E' \theta^2_{max}$)
OR by a physical cutoff $q^2_{max} \sim .5\ (\mathrm{Gev}/c)^2$.

A plot of the fluxes obtained for 10^6 muons per pulse appears in the accompanying figure. Note that longitudinal photons have been ignored. Crude estimates reveal that they might contribute 20-30% of the transverse photons to the total cross section. This might be enhanced in special circumstances.

VIRTUAL PHOTON FLUX

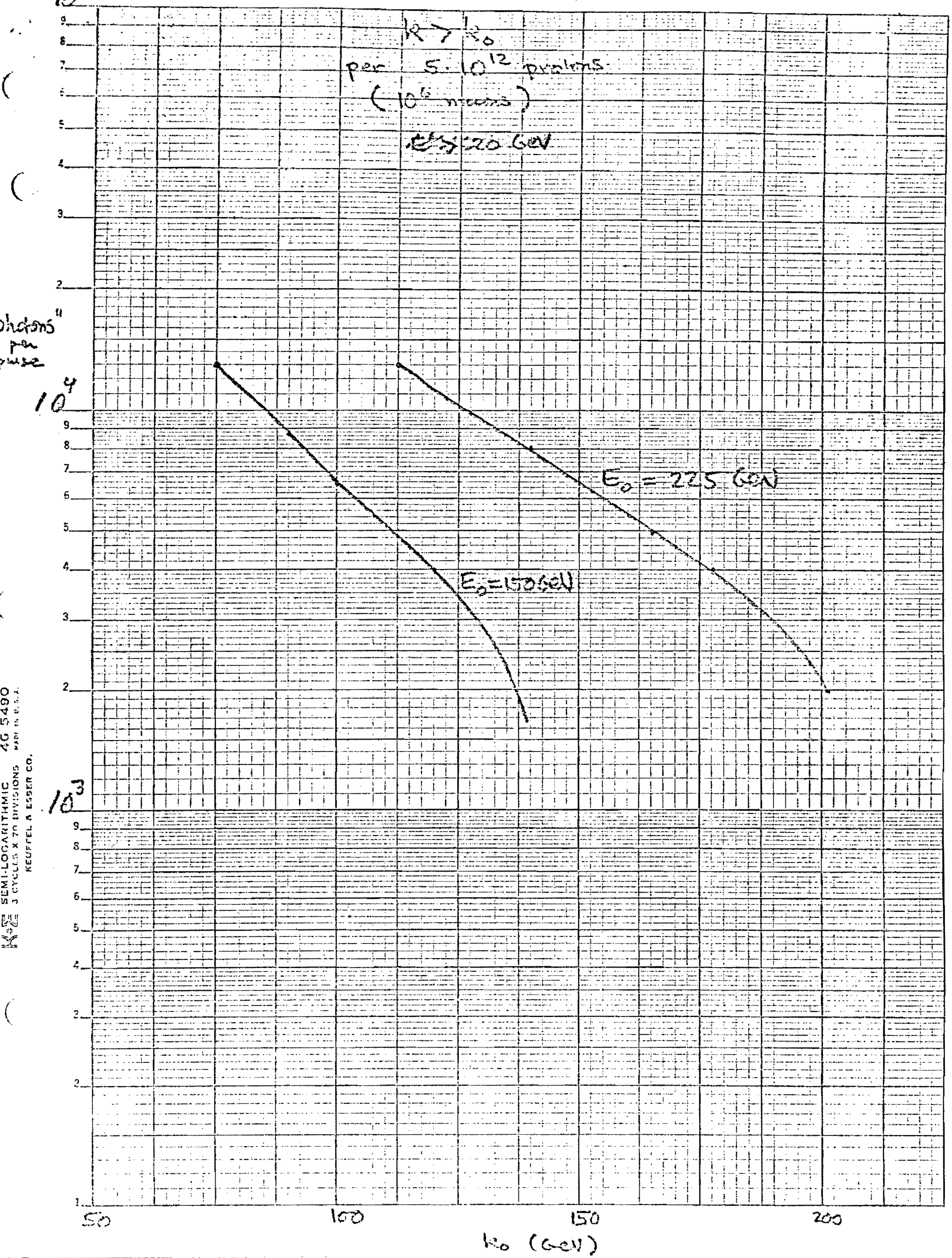


Table I N_γ/N_μ for specific cases

E_0=225 Gev

$\theta_\mu <$ 6 mrad.

k >	N_γ/N_μ
112.5 GeV	.013
180. GeV	.0018

E_0=150 GeV

k >	
75 GeV	.012
120 GeV	.0013

Sample Rate Calculation

Assume $N'_\gamma \sim .005\ N_\mu$

$N_\mu = 10^6$ /pulse

Target= 2 meters of iron=1.56×10^3 gms/cm^2

$\cong 10^{27}$ nucleons/cm^2

Virtual photons x target nucleons = 5×10^{30} /pulse

600 pulses/hour $\Rightarrow$

Rate(100% detection) = 3 events/nanobarn/hour

Cross section estimate: assume coupling to the photon is 1/10 as strong as the rho meson and that the total cross section for a V to interact with a nucleon is 1/3 that of the rho($\approx$ phi).

Then $\sigma_{\gamma \to V}$ = (1/10)x(1/10) 15 microbarns ($\sigma_{\gamma \to \rho} \cong 15 \mu b$)

$1/10 \approx 1/3^2$

= 150 nanobarns.

If the branshing ratio into muon pairs is .01*,we get 450 events for 100 hours of rumning. Our sensitivity is therefore between 10 and 100 times lower,depending on the backgrounds,detection efficiency,etc. Ie $\approx$ $B\sigma < 0.1$ nb would be the type of limit which could be set.

* for ψ(3105) it is .05, for ψ(3695) it is unknown, but $\neq 0$.

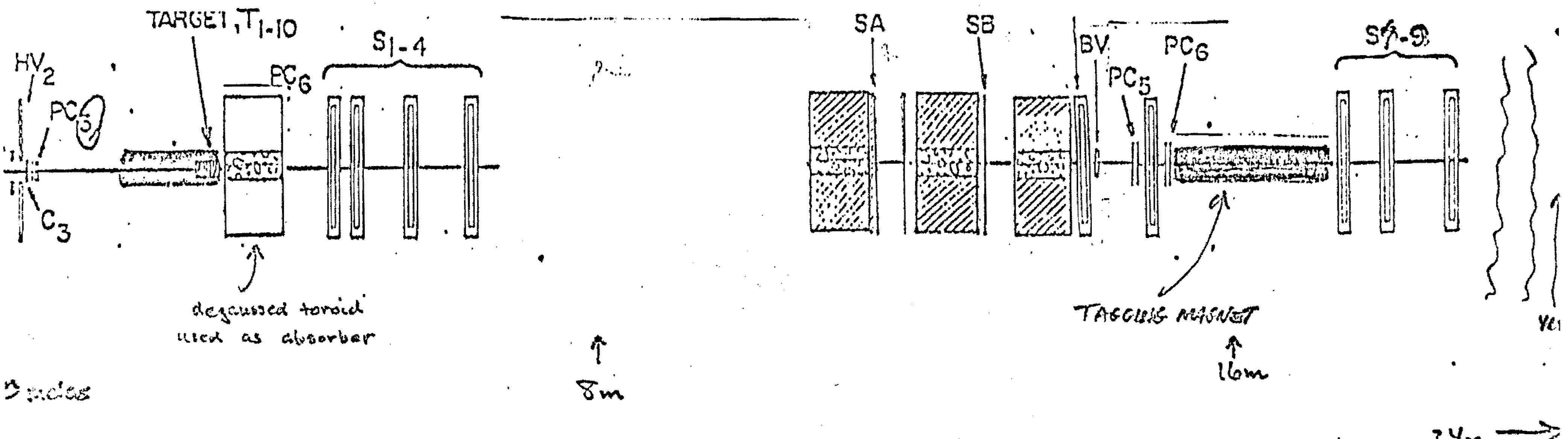
Backgrounds Expected From Electromagnetically Produced Tridents

The numbers below apply to 10^6 muons at 200 GeV incident for 100 hours on a 2 meter iron target. Only the incoherent tridents are considered, the coherent tridents are smaller in this mass range.

$M_{\mu\mu}$ (GeV)	3	4	5	6	8	10
Events in interval	560	160	50	18	3	.4

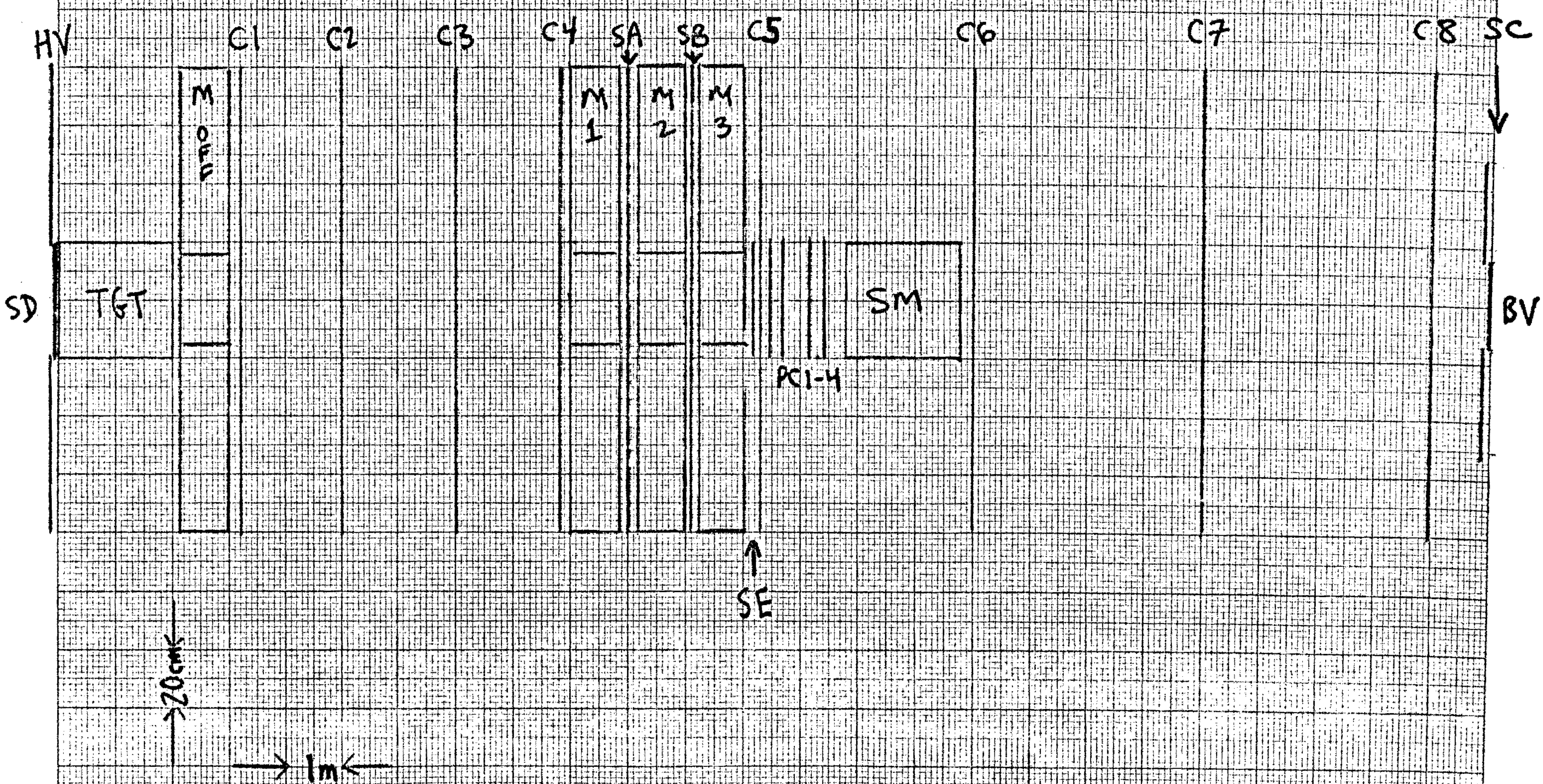
Reference is CERN/SPSC/74-78 SPSC P.18 1 July 1974 "Proposed Experiments and Equipment for a Programme of Muon Physics at the S.P.S."

LAYOUT OF PROPOSED EXPERIMENT



K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM. 46 1512
KEUFFEL & ESSER CO. MADE IN U.S.A.

PROPOSED ARRANGEMENT



PROPOSED TRIGGER IS

(BEAM)·(mu1)·(mu2)

WHERE

a) (BEAM) INCLUDES SD * $\overline{HV}$

b) (mu1) = SA * SB

c) (mu2) = SE * SC * $\overline{BV}$

MASS RESOLUTION AND DETECTION EFFICIENCY

Preliminary monte carlo studies indicate a detection efficiency in the range 50% to 75% for ψ particles with momentum above 60 GeV/c. The corresponding mass resolution is in the range 10-20%.

TYPICAL NUMBERS FROM A RUN OF 200 GeV INCIDENT μ's WITH A SLIGHTLY LONGER GEOMETRY ARE:

M_J	EVENTS tossed	Accepted EVENTS	Efficiency
3.1	12,800	8330	65%
5.0	11,200	6132	55%
7.0	9,600	3838	40%

SAMPLE MOMENTUM RESOLUTION OF SMALL TOROID

RUN 568
CALIBRATION WITH SMALL MAGNET.
EVENTS VS. 1000. / E PRIME