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Memorandum

To: P.G. Hansen, Chairman PSSC Committee

From: D. Garreta (Spokesman PS184)
G.A. Smith (Spokesman PS183)

Subj: Plans for 1985

The PS183/184 Collaborations have developed a plan for a joint venture in 1985. This plan involves further investigations of narrow charged pion/gamma-ray lines produced in $\bar{p}p$ interactions at rest utilizing the combined power of the two existing spectrometers. We wish to bring this plan to your attention, as some additional support will be required from CERN.

The stated goal of PS183 is to search for charged pion/gamma-ray lines in $\bar{p}p$ interactions at rest with unprecedented sensitivity ($\lesssim 10^{-4}$ per annihilation). This is clearly documented in our report which appears in the proceedings of the 1982 Erice meeting. In order to achieve these goals, an exposure of 5×10^{11} $\bar{p}$'s is required. To date, after three runs in December, 1983, April and August, 1984, the total integrated intensity has been ~ 3×10^{10} $\bar{p}$'s, or a factor of ~ 17 less than required.

The most demanding (statistically) feature of this experimentation is the gamma-ray search. This results from the fact that the gamma-ray converter, which is thin to maintain the high resolving power of the spectrometer is 5-10% efficient. To date we have accumulated ~ 2 million high quality gamma-rays, which gives a sensitivity ~ 2×10^{-3} per annihilation and falls far short of our goal. The spectrometer is working well and there appear to be no obvious shortcuts to higher yields without sacrificing resolution. Therefore, the only solution to this shortfall is to continue taking data in 1985, and later if necessary. For example, 550 hours of beam at $10^5\bar{p}$/sec will yield 2×10^{11} $\bar{p}$'s bringing us to one-half of our goal of 5×10^{11} $\bar{p}$'s. This is our intention, and we request your continued support in this regard.

This now brings us to the unique opportunities associated with a joint PS183/184 experiment. As you know, the PS183 Collaboration has reported [A. Angelopoulos et al, EP/84-47, April, 1983] evidence for a line at 200 MeV/c in the charged pion spectrum. The yield of this line in each of the positive and negative charge states is ~ 1.5×10^{-3} per annihilation, and its width is less than 6 MeV/c, consistent with experimental resolution. A preliminary interpretation by C. Dover suggests that it may be an isotensor meson with quantum numbers $J^{PC}(I^G) = 1^{+-}(2^-)$. The isospin selection results primarily from the narrow width, which heretofore would have been considered surprising for such models. However, it now appears that such a width can be justified in terms of both quantum number conservation and quark rearrangement considerations. Hence, the width may hold special meaning for a proper theoretical understanding of the underlying physics.

Given the potential importance of this discovery, we feel that an independent measurement is required to confirm this effect and measure its width. This is based on the assumption that a second detector with entirely different systematics should observe the effect, if it is real. Fortunately, there exists a well-understood, high resolution spectrometer in the South Hall which is capable of confirming the existence and measuring the width of the line down to 1 MeV/c (factor of six improvement). This is the SPESII spectrometer of the PS184 Collaboration, which in its present position is just but a few meters away from the PS183 target. It appears that with very little cost SPESII can be positioned to view the target. This could be done in a parasitic mode as the PS183 Collaboration continues its search for gamma-ray lines. Furthermore, it is unlikely PS183 will ever achieve the 1 MeV/c resolution of SPESII. Therefore, once SPESII has completed its search for the 200 MeV/c line, it could turn to a general search of the pion spectrum in regions below and above 200 MeV/c. This would be a unique opportunity to find ultra-narrow lines with unprecedented sensitivity ($\sim 10^{-4}$ per annihilation). Again, this would be done in a parasitic mode with PS183.

In summary, 575 hours of beam (including start-up and calibrations - 25 hrs.) to PS183/184 in 1985 would provide: (a) a gamma-ray search with sensitivity $\lesssim 10^{-4}$ per annihilation as requested by PS183 at Erice; (b) confirmation by SPESII of the 200 MeV/c charged pion line seen earlier by PS183; and (c) a search by SPESII for ultra-narrow ($\sim$ 1 MeV/c) lines with high sensitivity. As items (b) and (c) are carried out parasitically by the PS184 Collaboration, no additional antiprotons are required for these activities. The following sections to this memorandum provide you with further technical justification for these claims.

1. Expected Data Rates and Sensitivities in the SPESII and PS183 Spectrometers

We show in Figure 1 the full layout of the two spectrometers in combination. For logistical reasons, SPESII would be positioned to view the target at 90°, as does the PS183 spectrometer in its existing location. To assist in understanding the data rates which we expect and for purposes of comparison, we list in Table 1 the specifications of the two spectrometers. We define the following rates (per annihilation), assuming for purposes of illustration a line at 200 MeV/c with a width Γ = 6 MeV/c:

$$\underset{(\pm\,\Gamma/2)}{\text{Signal Rate}} = R_s = \frac{2}{3} \times \lambda \times \frac{\Delta\Omega(200)}{4\pi} \times t \quad ; \qquad (1)$$

$$\underset{(\pm\,\Gamma/2)}{\text{Bkg. Rate}} = R_b = \frac{dn_\pi}{dk}(200) \times (\Delta k{=}6) \times \frac{\Delta\Omega(200)}{4\pi} \times t \quad ; \qquad (2)$$

and

$$\text{Total Rate} = R = \int_{k_{min}}^{k_{max}} \frac{dn_\pi(k)}{dk} \times \frac{\Delta\Omega(k)}{4\pi} dk \times t \quad ; \qquad (3)$$

where

λ = average yield per annihilation of line decaying into π^+ or π^-;

$\frac{\Delta\Omega(k)}{4\pi}$ = momentum-dependent solid angle subtended by spectrometer;

t = average efficiency for identifying π^+ or π^- in spectrometer (decay survival x reconstruction efficiency);

and $n_\pi(k)$ = momentum-dependent yield of π^+ or π^- per annihilation .

These yields have been calculated for both spectrometers and appear in Table 2. We assume a yield of 1.5×10^{-3} per annihilation for the signal. We also show the expected total integrated rates assuming a flux of $10^5\bar{p}$ per second.

We have assumed practical and achievable run conditions for the purpose of calculating our sensitivities. Specifically, a 25 hour exposure with $10^5\bar{p}$/sec ($0.9\times10^{10}\bar{p}$) will result in the sensitivities given in Table 3. For the purpose of these calculations, we have assumed beam utilization efficiency is 75%.

The capability of SPESII is illustrated in Table 4, where we compare sensitivities between SPESII and PS183 for assumed widths of 6,1 MeV/c and yields 1.5×10^{-3},3×10^{-4}. These results show the power of SPESII, particularly for weak, narrow lines.

The physical arrangement described in this memorandum could next be turned to a coincidence measurement in which lines emitted sequentially could be studied. The sensitivity of such a measurement depends on the widths and strengths of the lines in question. If our 1985 studies are successful, this could constitute a program for 1986.

2. Experimental Program

We plan to make the following measurements. Both spectrometers will be recording data at all times.

		Time	Sensitivity
1)	Calibrate SPESII on the $K^+_{\mu 2}$ peak (including initial startup and testing of both spectrometers):	25 hrs.	88σ [a]
2)	Confirmation of the 200 MeV/c structure and measurement of its width with SPESII:	25 hrs. (+) 25 hrs. (-)	18σ [b] 18σ [b]
3)	Scan of 150-400 MeV/c region with SPESII (10 settings @ 25 hrs for each charge):	500 hrs.	8.8σ [c]
	Total	575 hrs.	

[a] Assuming yield of 3×10^{-3} per annihilation and $\Gamma < 1$ MeV/c.

[b] See Table 3: assumes $\Gamma = 6$ MeV/c; sensitivity will increase if Γ is less.

[c] See Table 4: sensitivity is for each of 20 settings; assumes $\Gamma = 1$ MeV/c and yield $= 3\times10^{-4}$ per ann.

3. Technical Considerations

It is important that the optics of SPESII not be degraded for this experiment as a result of wedding it to PS183. In this regard, the front face of the SPESII quadrupole must be ~ 40 cm from the interaction point. This can be arranged without any significant changes to the PS183 target and surrounding detectors. Second, the dispersion of SPESII at the target is 6 mm per 1×10^{-3} $\Delta p/p$ in the direction of the beam. The PS183 vertex resolution is presently 5 mm FWHM in this direction, contributing 0.8×10^{-3} to $\Delta p/p$. This is negligible, compared to the overall 5×10^{-3} resolution of SPESII, including effects of Coulomb scattering as the particle enters SPESII. The vertical coordinate need not be well measured at all, and energy loss along the third direction traversed by the particle as it enters SPESII is small and easily corrected.

Pion decay in the SPESII spectrometer accounts for a 50% loss of particles as noted previously. Because of the narrow angular acceptance of this spectrometer, a negligible number of such decays are reconstructed. The present PS183 algorithm does not exclude such events; however due to the short flight path this is only a 20% contamination. It is likely the algorithm can be improved to eliminate pion decays entirely.

The electronic and data collection systems of the two experiments require some change. The experiment pre-trigger (the arrival of a $\bar{p}$ in the S1, S2 counters) will be sent to both experiments. Thereafter, each spectrometer will look for activity in its own counter-chamber detection system. Each side will then record data on tape using its own computer.

4. Support from CERN

We will require the following support form CERN:

a) Engineering help in relation to the physical move of SPESII;
b) Additional barraque space (~ 15 m^2) in the vicinity of the PS183/184 detectors;
c) An additional 40,000FS from the EP Electronics Pool;
d) 100,000FS of computing.

The purpose of this memorandum has been to inform you of our plans for 1985 and emphasize the important physics we think we can accomplish operating efficiently around a common target. We hope you concur with our enthusiasm and request your support in helping us carry out this program.

Table 1 - Specifications of SPESII and PS183 Spectrometers

		SPESII	PS183 (per π^+ or π^-)
1)	$\frac{\Delta\Omega}{4\pi}(200)$	2.4×10^{-3}	7×10^{-3}
2)	t(200)	0.5x0.9=0.45	0.8x0.9=0.72
3)	$\int_{k_{min}}^{k_{max}} \frac{dn_\pi}{dk} \times \frac{\Delta\Omega}{4\pi}(k)dk$	2.34×10^{-4}	103×10^{-4}
4)	$\frac{dn_\pi}{dk}(200)\times(\Delta k=6)$	2.26×10^{-2}	2.26×10^{-2}
5)	Momentum resolution at 200 MeV/c (Γ)	1 MeV/c	6 MeV/c

Table 2 - Calculated Signal, Background and Total Rates in SPESII and PS183 Spectrometers (π^+ or π^-; Γ = 6 MeV/c; signal yield = 1.5×10^{-3} per ann.)

	SPESII (per $\bar{p}$)	PS183 (per $\bar{p}$)
R_s	1.08×10^{-6}	5.06×10^{-6}
R_b	24.4×10^{-6}	114×10^{-6}
R	105×10^{-6}	7416×10^{-6}
Total π^+ or π^- per sec @ $10^5\bar{p}$/sec	10.5	742 a)

a) This value exceeds the maximum data acquisition rate of the system, which is 165 π^+ or π^- per second.

Table 3 - Yields and Sensitivities Resulting from a 25 Hour Run (π^+ or π^-; Γ = 6 MeV/c; signal yield = 1.5×10^{-3} per ann.)

	SPESII	PS183
1) Signal [a]	0.73×10^4	0.76×10^4 [c]
2) Background [b]	16.5×10^4	17.1×10^4 [c]
3) Sensitivity=1)/$\sqrt{2)}$	18 σ	18 σ

[a] R_s*0.9×10^{10}*0.75

[b] R_b*0.9×10^{10}*0.75

[c] These values have been scaled by the ratio 165/742 (see Table 2, footnote a).

Table 4 - Comparison of SPESII,PS183 Sensitivities as a Function of Width, Yield of Line Detected (π^+ or π^-)

Γ(MeV/c)	Yield(per ann.)	SPESII	PS183
6	3×10^{-4}	3.6 σ	3.6 σ
1	1.5×10^{-3}	44 σ	18 σ
1	3×10^{-4}	8.8 σ	3.6 σ

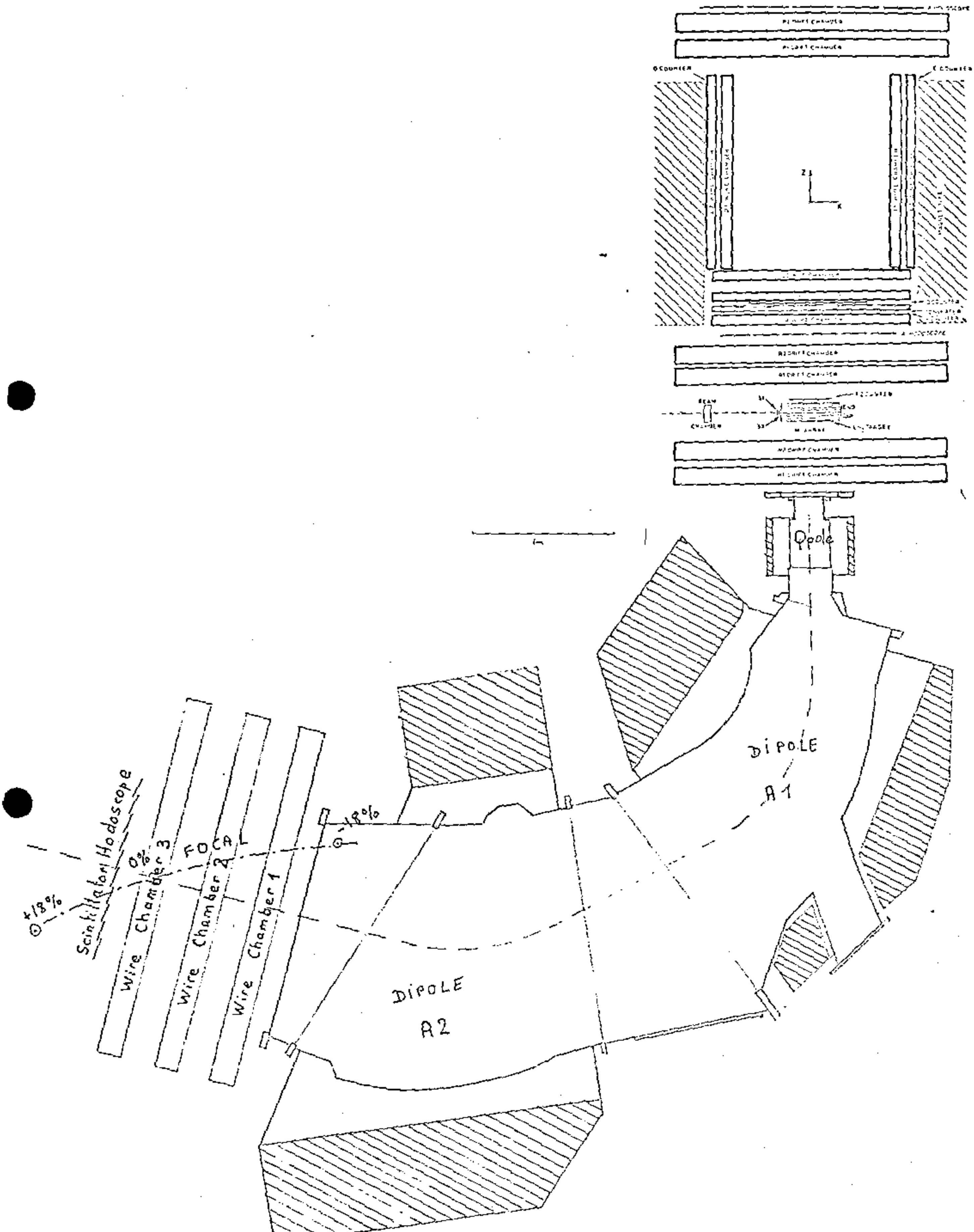
Qpole
DIPOLE
A1
DIPOLE
A2
Wire Chamber 1
Wire Chamber 2
Wire Chamber 3
Scintillator Hodoscope
FOCAL
0%
+18%
-18%

FIGURE I