EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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Memorandum

To : The members of the EEC

From : W.Bartl*, G.Neuhofer*, F.Niebergall**, M.Regler, W.Schmidt-Parzefall, K.R.Schubert**, M.Steuer*, M.Vivargent*** and K.Winter

Subject : Request for machine time to perform a K^o regeneration experiment with the setup of S74.

Data taking for the experiments S74, i.e. $K^o \to \pi e \nu$ and $K^o \to \pi^+\pi^-\pi^o$ will be terminated in January 1971. The apparatus of these experiments as shown in fig.1 and the m_7 beam are both very well suited to perform an additional experiment which we want to describe here. The time requested for this experiment is two weeks, and we would like to run during the South Hall period following the January/February period. Short tests have already been undertaken, and more extensive tests could follow in January.

Coherent regeneration of K^o_S states out of K^o_L states in solid matter is a well known phenomenon [1]. Together with the phenomenon of CP violation in K^o_L decays it leads to interference patterns in the time distribution of many decay modes, e.g. in the $\pi^+\pi^-$ mode [2]. A most remarkable decay time pattern can be reached from the interference between K^o_S states produced in a charge exchange process and K^o_S states regenerated in a block of matter behind the charge exchange target as shown in fig.2 . The charge exchange process $K^+p \to K^o\pi^+p$ and its detection in the cylindrical spark chambers (CCH in fig.1) permit to know the production point and the state ($\psi = \frac{1}{\sqrt{2}}(S+L)$) of

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the neutral kaon. After passage through the regenerator between life times τ_1 and τ_2, the state at $\tau_3 \geq \tau_2$ transforms into

$$\psi(\tau_3) = \frac{e^{-N\ell\sigma_T}}{\sqrt{2}} \left[S\, e^{(i\delta - \frac{1}{2})(\tau_3-\tau_2)/\tau_S} \left(\varrho + e^{(i\delta-\frac{1}{2})\tau_2/\tau_S} \right) + L \left(1 + \varrho e^{(i\delta - \frac{1}{2})\tau_2/\tau_S} \right) \right],$$

where the term with σ_T describes the absorption, $\delta = (m_L - m_S)\tau_S$, τ_S is the K_S mean life and ϱ the regeneration amplitude.

The $\pi^+\pi^-$ intensity integrated over all $\tau_3 \geq \tau_2$ can be written as

$$N = N(\tau_2) \propto \varepsilon(\tau_2) \left[e^{-\tau_2/\tau_S} + |\varrho|^2 + 2|\varrho| e^{-\tau_2/2\tau_S} \cos(\Delta m \cdot \tau_2 - \varphi_\varrho) \right]$$

where $\varepsilon(\tau_2)$ is the production point dependent acceptance of the detector, see fig.3 , and CP violating $\pi^+\pi^-$ decays from the K_L component have been neglected.

W.A.W.Melhop et al [3] used this pattern with about 300 events to determine the sign of the mass difference $\Delta m = m_L - m_S$. We estimate to reach about 3000 events and we propose as one of our aims to constrain the values of τ_S and Δm to their world averages and to determine only $|\varrho|$ and φ_ϱ. We would run at a K^0 momentum of about 2.0 GeV/c with a copper regenerator.

The CERN group of J.C.Chollet et al [4] has measured the CP violating parameter $\eta_{00} = A(K_L \to \pi^0\pi^0) / A(K_S \to \pi^0\pi^0)$ relative to ϱ_{Cu} at this momentum, and a determination of $|\varrho|$ with $\pm 7\%$ or better would be desirable.

The hydrogen target of our setup has an effective length of 43 cm, thus giving $N(\tau_2)$ in a life time range of $\Delta\tau \approx 4.5$ from one fixed regenerator position. We propose to take the majority of the data with a 13 cm thick regenerator, positioning its exit face 35 cm behind the target, and with a thin anticounter immediately behind the regenerator. The Monte Carlo calculated acceptance $\varepsilon(\tau_2)$ at these conditions is also shown in fig.3 . In order to reach results which are highly independent of Monte Carlo calculations we want to run about 30% of the time without regenerator but with anticounter to maintain the $\tau_3 \geq \tau_2$ condition. The time dependance

$$N_{free}(\tau_2) \propto \varepsilon(\tau_2)\, e^{-\tau_2/\tau_S}$$

contains exactly the same acceptance as the one with regenerator.

Regenerator and anticounter are the only necessary modifications to the setup of S74. Also the existing reconstruction programs can be widely used, an important exception being the cinematical fit routine. K^o_S states from production may scatter elastically at copper nuclei, and K^o_L states may transform into K^o_S by diffractive regeneration. Therefore, the fit has to determine θ_x and θ_y , the horizontal and vertical scattering angle of the kaon in the regenerator central plane. The number of constraints is thus reduced to 3 for two pion decays with momentum analysis for both pions and to 2 for decays with one momentum measurement. The angular resolution of the apparatus is on average 15 mrad, whereas the angular distribution of single nuclear scattering has a width of about 30 mrad. Separation of the diffractive events from the transmission events should thus be possible. The time dependence $N_{diff}(\tau_2)$ of the diffractive events has been calculated including all multiple scattering and interference effects. The influence of diffractive events with $\theta<15$ mrad on the precision of $|\rho|$ and φ_ρ is weak.

References

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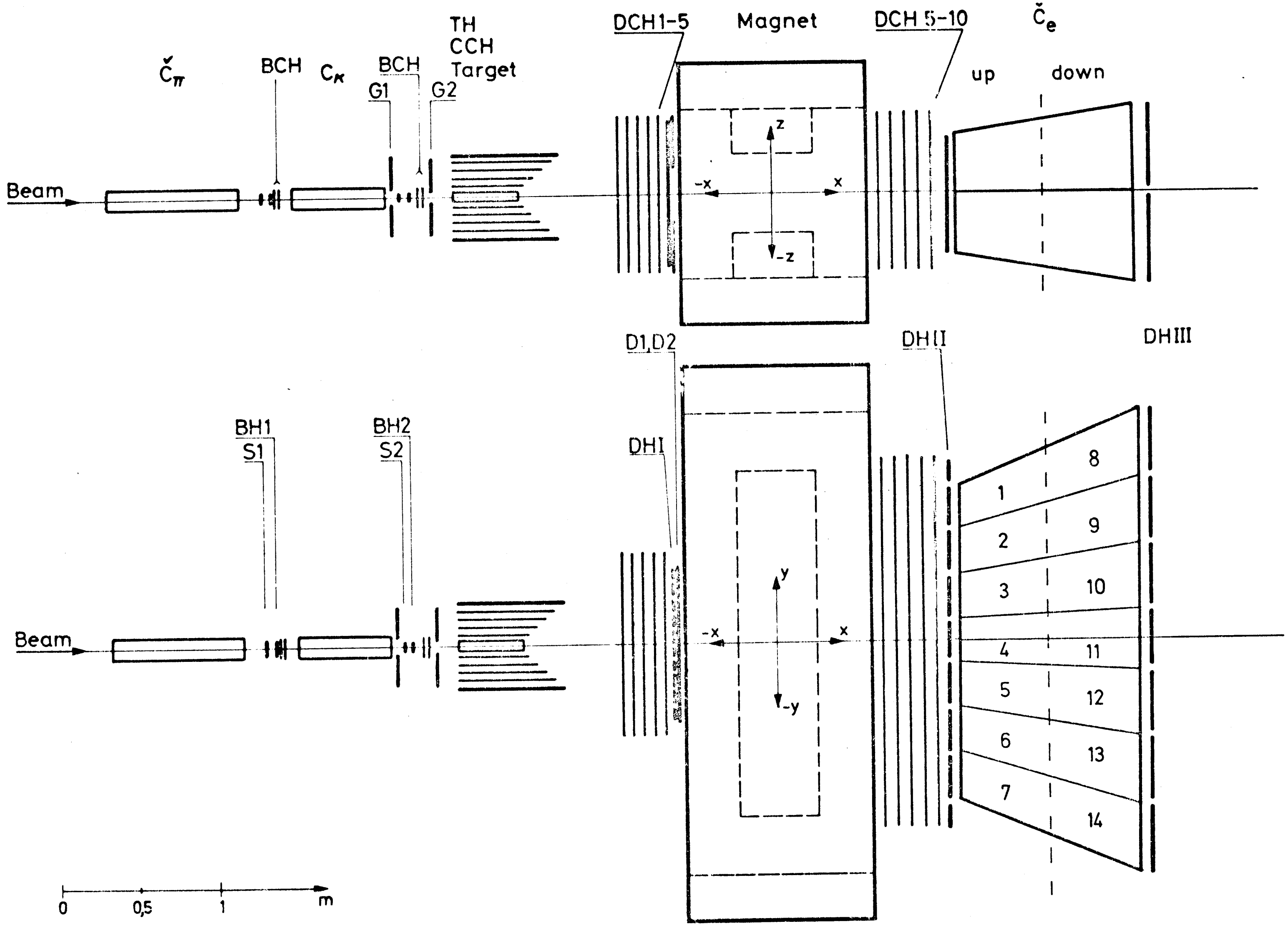
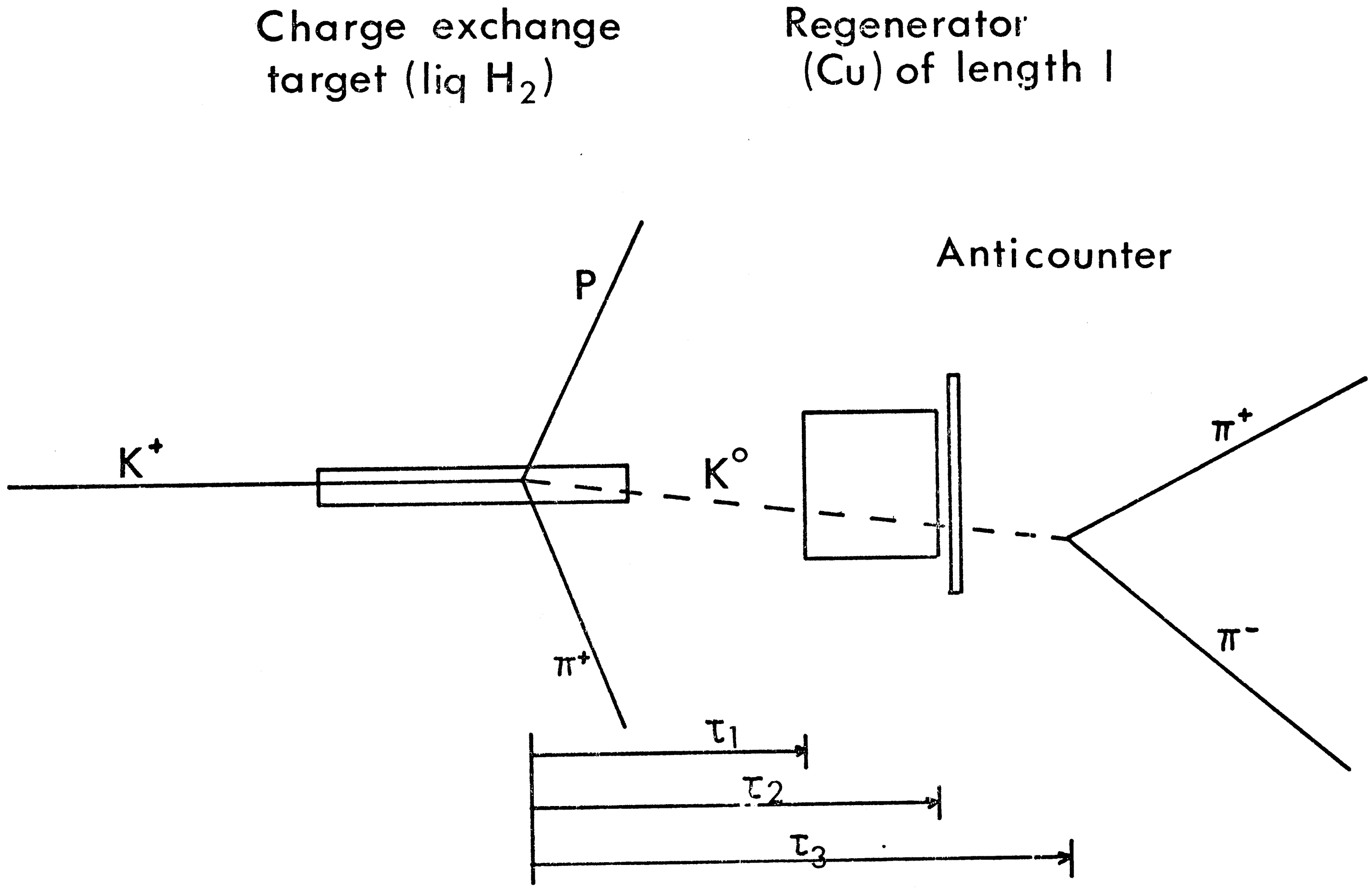
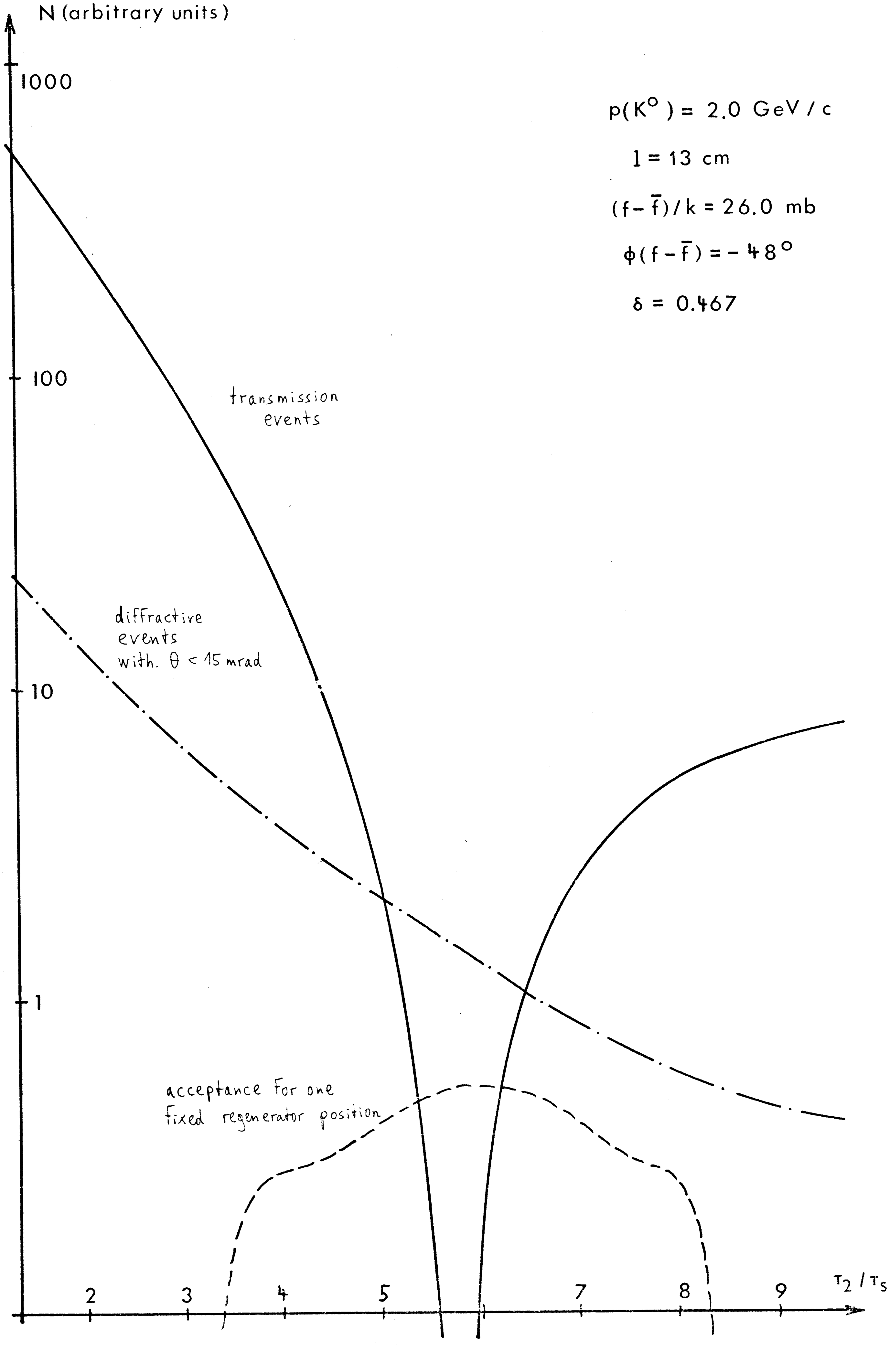


FIG.1 Plane view of the apparatus.



Charge exchange target (liq H_2)
Regenerator (Cu) of length l
Anticounter
P
K^+
K°
π^+
π^+
π^-
τ_1
τ_2
τ_3

Fig. 2



N (arbitrary units)
1000
100
10
1
p(K°) = 2.0 GeV/c
l = 13 cm
(f − f̄)/k = 26.0 mb
φ(f − f̄) = − 48°
δ = 0.467
transmission events
diffractive events with θ < 15 mrad
acceptance for one fixed regenerator position
2
3
4
5
7
8
9
τ2 / τs

Fig. 3