Charm particles studies in emulsion: Review of phase 1

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1 Introduction

We report what has been done in CHORUS so far concerning charm production in the emulsions. The interests are reminded here.

Analysis of single charm production in DIS of ν_μ allows to:

- Improve the knowledge of the single charm production cross section close to threshold (sensitive to m_c).
- Improve the precision on the weighted semileptonic branching ratio B_c (combined with $B_c \times V_{cd}^2$ from counter experiments it reduces the error on V_{cd}^2).
- Monitor the kink finding efficiency of the scanning methods used to find τ.

Double kink muon tracks are the sign of a $D_s^+ \to \tau^+ \to \mu^+$. Their study allows to:

- Measure the diffractive production of D_s^{+*} and D_s^+
- Measure $B(D_s \to \tau)$.
- Get a limit on the ν_τ mass.

The analysis of events with 2 charm particles gives the opportunity to make the best measurement of $c\overline{c}$ production in ν interactions. Finally we remind that Chorus is not in a good position to improve the limit on $D^0 \to \overline{D^0}$.

Only the muonic decays were searched for extensively in phase 1 and it obviously reduces the aims that can be fulfilled. The work done on muonic decays is reported.

2 Charm particle production in DIS CC with muonic decay

2.1 Counter reconstruction for Data

In phase 1 the dimuon events underwent the same reconstruction as the events of the τ search stream : in particular muon identification given by IQ(JTTR2+40) which is set by TTMUON described in [4, 5].

Advantages:
-the scanning load can be maintained at a low level by searching for decays along the muon tracks only.
-the knowledge of the muon scanning efficiency coming from the large statistic of 1μ events is applicable to the charm events.

Disavdantages:
-it depends on the complete counter detector and not only on a subpart, so the error is more difficult to control.
-the criteria for identification might be too restrictive for the sake of a good separation between 0μ, 1μ and multi μ events.
-the algorithm requires a matching between the identified muon and a track from the reconstructed vertex, which adds several sources of inefficiencies.

2.2 Counter reconstruction efficiency from Monte-Carlo study

The performance of the reconstruction programs (choral 2.13.22) has been studied using dimuon charm events simulated with JETTA (calling LEPTO and JETSET routines), and fully simulated in the detector with EFICASS.

Some 98%[8, 5] of the events simulated in the emulsion have a vertex reconstructed in the correct emulsion stack. It is comparable to the results obtained for CC [4, 6] events. 41% of the events are identified as dimuon events (2% have more muons), 35% of them being opposite signs [5] . More details are given in Table 1 on the primary and secondary muon

reconstruction.

	$\sharp\mu^-$ from ν_μ	$\sharp\mu^+$ from charm
Total	1318 (100%)	1318 (100%)
Associated to reconstructed μ	1148 (87%)	665 (50%)
Sign correct or unknown	1136 (86%)	642 (49%)
multiple attribution	11 (0.8%)	16 (1.2%)

Table 1: identification efficiency of the μ^- and the μ^+ in MC events, by choral 2.13.22

2.3 Dimuon data scanning

The scanning (VERSION 05) of some 415 dimuon events of 1994 was done on the basis of predictions from choral 2.9.04. In that version, only long tracks in the spectrometer were identified as muons.

The events which had not been found in emulsion using the first predictions, were searched for again (VERSION 25) using predictions from choral 2.13.22 together with newly reconstructed events.
Collection of decay topologies was done by manual check. The data flow is presented in Table 2. The first control plots of kinematical quantities of the candidates seem to be comparable to Monte-Carlo expectations, expect for the flight length distribution of the 1995 candidates which is shorter than expected.

2.4 Scanning efficiencies from Monte-Carlo study

Nagoya scanned 58% of the modules of 1994 and 48% of the modules of 1995 [14]. Before being sent to the scanning the predicted tracks can be subject to the cuts presented in Table 3.

The efficiency of TT $\rightarrow$ CS location is determined by the fraction of predicted muons belonging to a 1080x810μm^2 and 15mrad window wrt the

	1994 VERSION 05	1994 VERSION 25	1995
Choral version	2.9.3 → 2.12.4	2.13.18 → 2.13.21	?
Nev (2μ) predicted	415	2028	4819
Nev ($>2\mu$)predicted	9	50	122
Stacks considered	1→3	1→4	1→4
Selection criteria	all dimuons	opp. sign dimuons	opp. sign dimuons
Nev located	84	234	546
Decay search method	FU all scan back tr. FD all vertex tr.	FU μ^+	FU μ^+
Nev for decay search	47	148	312
Number decay topologies	14	32 (22 new wrt 05)	35

Table 2: Data reduction of dimuon events during scanning at Nagoya (FU and FD mean follow up and follow down respectively)

true muon at CS. It is multiplied to the experimental efficiency for CS → SS matching of 0.89 before being put in the Table 4 as "$\varepsilon_{bulk_{loc}}$".
The decay finding efficiencies of $c-2\mu$ events were determined in [5] for the Pt and Impact parameter automatic approach and in [9] for a purely kinematical approach. Note that the results concern 2 different samples of reconstructed and located events, they are summarised in Table 5.

2.5 Expected number of events

The expected number of single charm dimuon events coming from a follow up of the μ^+ is estimated here. Note that we will multiplicate efficiencies obtained by separate analysis, taking care of different cuts, the global efficiency quoted here will therefore be rough.
The expected number of events is:

$$(N_c^{\mu^-\mu^+})_{CC} = \frac{\sigma(c)}{\sigma(CC)} \times B(c \to \mu) \times \varepsilon_{observed} \times N^{CC} = 120 EVENTS$$

Where

$$\varepsilon_{observed} = \varepsilon_{det} \times \varepsilon_{vtx} \times \varepsilon_{rec\mu^-\mu^+} \times \varepsilon_{beforescan} \times \varepsilon_{fidcut} \times \varepsilon_{bulk_{loc}}(\mu^+) \times \varepsilon_{decay} = 0.075$$

Cut	Applied on	ε	Reference
fraction in Nagoya (1)	events	58%	[10]
$\theta \leq 400mrad(2)$	$\mu^- or \mu^+$	98%	[5, 10]
$\theta_{X7} \geq 50mrad$(3a)	$\mu^- or \mu^+$	100%	[5]
$\theta_{X7} \geq 50mrad$(3b)	μ^-	94%	[5]
$\theta_{X7} \geq 50mrad$(3c)	μ^+	92%	[5]
$\theta_{X7} \geq 50mrad$(3d)	$\mu^- and \mu^+$	86%	[5]

Table 3: Efficiency of the cuts applied just before scanning

Cut	Applied on	ε	reference
Fiducial cut (4)	events	84%	[10]
$\varepsilon_{bulk_{loc}}(5)$	μ^-	50%	[9]
$\varepsilon_{bulk_{loc}}(6)$	μ^+	38%	[9]

Table 4: Efficiency of the cuts applied during scanning

For the decay finding efficiency we supposed a manual scanning with only 2 sources of inefficiency from very short decays (2 % loss) and muon mismatch (12% and 19% lost for charged and neutral charms respectively) and a ratio of charged versus neutral charms equal to unity like in [5]. ε_{decay} is then equal to 83%. ε_{det} is taken to be 92%, the reconstruction efficiencies come from section 2.2 and all the others come from cuts (2), (3a), (4), and (6) mentionned in section 2.4.

$\frac{\sigma(c)}{\sigma(CC)}$ and $B(c \to \mu)$ are taken to be 5×10^{-2} and 10×10^{-2} respectively. and N^{CC} is taken to be 3.2×10^5 for 1994-1995.

For Nagoya in particular it means 70 events expected for 1994 - 1995, to be compared to 67 decay topologies observed.

(Note that for the talk an additional P_t cut was considered for ε_{decay} which was not applied to data, it has been removed here)

Bias in the samples			
	AB [9]	MC [5]	
Reconstruction criteria Cuts for bulk location	spec $\mu^-\mu^+$ from TTMUON (5) (6)	all $\mu^-\mu^+$ from TTMUON (2) (3a)	
Decay finding $\eta_{kink} = \eta_{P_{t-kink}} \cdot \eta_{loc} \cdot \eta_{\mu} \cdot f(...)$			
	AB [9]	MC [5]	
	charged	charged	neutrals
$\eta_{P_{t-kink}}$	71%	62%	65%
η_{loc}	69%	68%	86%
η_{μ}	96%	88%	81%
$f(...)$	$80\%(long) + 12\%(short)$	100%	100 %
η_{kink}	44%	37%	45%

Table 5: Decay finding efficiency for charm dimuon events

2.6 Experimental check of the kink finding efficiency of automatic search

The 10 single prong decays of 1994 that were found by following the μ^+ have been submitted to the impact method and the video image automatic analysis that was applied for VERSION 25 of the scanning. The expected and observed efficiency of the impact parameter method for charm is 0.74 and 0.80 respectively. The observed efficiency of the video image analysis on the other hand is 0.4 and some losses are not understood pointing to a possible misevaluation of that contribution to ε_{kink} .

The 8 single prong (very)long decays and 2 single prong nuclear interactions of 1995 have been submitted to the Parent Track Search. The observed efficiency of PTS is 0.6. The losses are due to background tracks (2), parent track angle cut (1) and impact parameter cut(1).

The 5 three prong long decays of 1995 have also been submitted to PTS, and the observed efficiency is 0.4. The loss is due to the existence of a daughter track with a small angle wrt the parent track.

3 Diffractive production of D_s^+ and decay into τ

3.1 Monte-Carlo study

The diffractive production of D_s^+ and D_s^{+*} was simulated as an elastic process (nucleon not transformed into another baryon) with the following inputs: Vector Meson Dominance model, polarization effects from photoproduction (for the D_s^{+*}), and exponential fall of the momentum transfer to the nucleon. Weighting the obtained differential cross section with the CHORUS expected beam spectrum, and doing the same for CC gives the result presented in Table 6. It is to be compared with the measurement of $(2,9 \pm 1) \times 10^{-3}$ [11]

number(D_s^{+*}/CC)	$2,1 \times 10^{-3}$
number(D_s^+/CC)	$1,1 \times 10^{-3}$
number diff/CC	$3,1 \times 10^{-3}$

Table 6: ratio, given by the simulation, of the number of D_s^{+*} and D_s^+ produced diffractively to the number of CC events

3.2 expected number of events

The detector finding efficiency is 65% for a selection based on TKSL bank (CCSELE package [12]) or TTRL bank (DTCAL routine [4]) for muon identification, and with a veto on hadronic energy. The expected number of events in 4 years of running is then 15, for 7.2×10^5 CC, and a scanning efficiency of 60%, taking the experimental cross section for D_s^+ diffractive production. It implies some 1.5 events for 1994 in Nagoya modules.

3.3 observation in Nagoya

Out of 350 data events preselected for 1994 data, 111 events were located in the bulk. All tracks available were used to find the vertex by eye and search for the presence of a double kink on the μ^+.

The event 4692 of run 1673 of stack 1 has a double kink along the μ^+ trajectory. The other events don't show any decay. The topology was confirmed by several analysis: grain by grain measurement, video image analysis and eye scan of different experienced people.
The kinematics of the event is compatible with the diffractive production of a D_s^{+*}:

- $E_{\mu^-} = 18.6$ GeV
- $E_{\mu^+} = 1.8$ GeV
- $E_{em} = 0.8$ GeV
- $\theta_1 = (39.5 \pm 4)$ mrad
- $\theta_2 = (87.3 \pm 1.6)$ mrad
- $FL_1 = 68\mu$m
- $FL_2 = 147\mu$m

The good angular accuracy of both kinks was obtained by swelling the emulsion, attaining a shrinking factor of 0.94. The conversion point of the γ giving electromagnetic activity in the calorimeter is being searched for in stack 3.

4 Associated charm production

CHORUS is in a good position to make the best direct measurement of $c\overline{c}$ production in ν_μ interactions [13]. The only sample of events where a partial search has been performed is the dimuon sample. Let us re-evaluate the number of $c\overline{c}$ expected to be observed in the dimuon sample with our present knowledge of efficiencies.

Taking $\varepsilon_{rec}(2\mu) = 0.98 \times 0.35$ and $\varepsilon_{scan} = 0.41$ (combination of cuts (2) (3a) (4) (5)) we find for the CC interactions:

$(N_{c\overline{c}}^{\mu^-\mu^-})_{CC} < 5.3 \times 10^{-6} N^{CC}$
$(N_{c\overline{c}}^{\mu^-\mu^+})_{CC} < 5.3 \times 10^{-6} N^{CC}$

With $\frac{\sigma(NC)}{\sigma(CC)} = \frac{1}{3}$ and $B(c \to \mu) = 0.1$ and guessing $\frac{\varepsilon_{rec}(2secondary\mu)}{\varepsilon_{rec}(2\mu)} = \frac{0.25}{0.35}$ we find, for the NC interactions:

$(N_{c\overline{c}}^{\mu^-\mu^+})_{NC} < 1.3 \times 10^{-7} N^{CC}$

(Note that for the talk, some slightly more optimistic values were presented)

Both muons (and all primary vertex tracks) were followed by manual scan for 5 plates for a reduced statistics of events: the 47 events of scanning VERSION 05. None of them present a decay on 2 different tracks. However an interesting event was found, Run 1941 Event 2928, with a μ^- attached to the primary vertex, and a μ^- attached to a 2 prong decay. The possibility of second very long charm decay is not excluded yet.

References

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