DOUBLY CHARMED BARYONS IN COMPASS

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Abstract
The search for doubly charmed baryons has been a topic for COMPASS from the beginning. Requiring, however, a complete spectrometer and highest possible trigger rates, this measurement has been postponed. The scenario for such a measurement in the second phase of COMPASS is outlined here. First studies of triggering and simulation of the setup have been performed. New rate estimates based on recent measurements from SELEX at FNAL are presented.

1. INTRODUCTION

The COMPASS collaboration was founded in 1996 to perform a number of measurements in hadron physics ranging from polarized structure functions examined with deep-inelastic muon scattering to topics like light meson spectroscopy and the study of exotic hadrons [1]. After the first phase of the COMPASS experiment focusing on the contribution of gluons to the polarized structure function of the nucleon, a second phase is planned to address more topics with hadron beams. One of these topics, the search for doubly charmed baryons, is described in this report.

The quantum chromodynamics hadron spectrum includes doubly charmed baryons (DCBs): Ξ_{cc}^{+} (ccd), $\Xi_{cc}^{++}(ccu)$, and Ω_{cc}^{+} (ccs), as well as the triply charmed Ω_{ccc}^{++} (ccc). A 1996 DCB review [2] collected information on masses, lifetimes, internal structure, production cross sections, decay modes, branching ratios, yields, and experimental requirements for optimizing the signal and minimizing the backgrounds. DCB works published since then are given in Refs. [3, 4, 5, 6, 7, 8, 9, 10, 11]. The doubly and triply charmed baryons provide a new window for understanding the structure of all baryons. As pointed out by Bjorken [12], one should strive to study the triply charmed (ccc) baryon. Its excitation spectrum, including several narrow levels above the ground state, should be closer to the perturbative regime than is the case for the DCBs. The (ccq) studies are a valuable prelude to such (ccc) efforts.

Hadron structures with size scales much less than $1/\Lambda_{qcd}$ should be well described by perturbative QCD. The tightly bound colour antitriplet $(\mathrm{cc})_{\bar{3}}$ diquark in (ccq) may satisfy this condition. But the DCB radius may be large, if it is dominated by the low mass q orbiting the tightly bound (cc) pair. The study of such configurations and their weak decays can help to set constraints on models of quark–quark forces [13, 14]. Stong [15] emphasized how the QQq excitation spectra can be used to phenomenologically determine the QQ potential, to complement the approach taken for $Q\bar{Q}$ quarkonium interactions.

Savage and Wise [16] discussed the (ccq) excitation spectrum for the q degree of freedom (with the (cc) in its ground state) via the analogy to the spectrum of $\bar{Q}q$ mesons, where the (cc) pair plays the role of the heavy $\bar{Q}$ antiquark. Fleck and Richard [13] calculated excitation spectra and other properties of (ccq) baryons for a variety of potential and bag models, which describe successfully known hadrons. In contrast to heavy mesons, the descriptions of light quark (qqq) and singly charmed (cqq) baryons are less successful. We need to better understand how the proton and other baryons are built from quarks. The investigation of the (ccq) system should help put constraints on baryon models, including light quark (qqq) and singly charmed (cqq) baryons, since the (ccq) has a quark structure intermediate between (qqq) proton and $\bar{Q}q$ meson structures.

In the double-charm system, there have been many predictions for the masses of the J=1/2 states and the J=3/2 hyperfine excitations [10]. Most results are consistent with expectations of a ground state mean mass around 3.6 GeV/c^2. The (cc) colour antitriplet diquark has spin S=1. The spin of the third quark is either parallel (J=3/2) or anti-parallel (J=1/2) to the diquark. For (ccq), the J=1/2 states are expected to be lower than the J=3/2 states by around 80 MeV/c^2 [10, 11, 13, 17].

Bjorken [12] and also Fleck and Richard [13] suggest that internal W exchange diagrams in the Ξ_{cc}^+ decay could reduce its lifetime to around 100 fs, roughly half the lifetime of the Λ_c^+. Considering possible constructive interference between the W-exchange and two c-quark decay amplitudes, it is possible that this state should have an even shorter lifetime.

We describe qualitatively the perturbative production mechanism for DCBs. One must produce two c quarks (and associated antiquarks), and they must join to a tightly bound, small size anti-triplet pair. The pair then joins a light quark to produce the final (ccq). The two c-quarks may be produced (initial state) with a range of separations and relative momenta (up to say tens of GeV/c). In the final state, if they are tightly bound in a small size (cc) pair, they should have relative momentum lower than roughly 1 GeV/c. The overlap integral between initial and final states determines the probability for the (cc)-q fusion process. Such cross sections may be smaller by as much as 10^{-2}–10^{-3} compared to single-charm production. Aoki *et al.* [18] reported a low statistics measurement at $\sqrt{s} = 26$ GeV/c^2 for the ratio of double to single open charm pair production, of 10^{-2}. This $D\bar{D}D\bar{D}$ to $D\bar{D}$ cross section ratio was for all central and diffractive events. This high ratio is encouraging for (ccq) searches. Cross section guestimates are given in Ref. [2].

Brodsky and Vogt [19] suggested that there may be significant intrinsic charm (IC) $c\bar{c}$ components in hadron wave functions, and therefore also $cc\bar{c}\bar{c}$ components. The double intrinsic charm component can lead to (ccq) production, as the (cc) pairs pre-exist in the incident hadron. Intrinsic charm (ccq) production, with its expected high X_f distribution, would therefore be especially attractive. When a double charm IC state is freed in a soft collision, the charm quarks should also have approximately the same velocity as the valence quark. Thus, coalescence into a (ccq) state is likely. Cross section guestimates are given in Ref. [2].

The semi-leptonic and non-leptonic branching ratios of (ccq) baryons were estimated by Bjorken [12] in 1986. He uses a statistical approach to assign probabilities to different decay modes. He first considers the most significant particles in a decay, those that carry baryon or strangeness number. Pions are then added according to a Poisson distribution. The Bjorken method and other approaches for charm baryon decay modes are described by Klein [20]. For the Ξ_{cc}^{++}, Bjorken [12] estimated the $\Lambda_c^+\pi^+K^-\pi^+$ final state to have 5% branching ratio; while for the Ξ_{cc}^+, he estimated the $\Lambda_c^+\pi^+K^-$ final state to have 3% branching ratio. One expects [2] that roughly 80% of the (ccq) decays are hadronic, with as many as one-third of these leading to final states with all charged hadrons.

Recently the SELEX experiment at Fermilab has reported the first observation of the doubly charmed baryon Ξ_{cc}^+ in the channel to $\Lambda_c K^-\pi^+$ [21]. Evidence for other states was found as well. The forward production seems to be strongly enhanced in baryon beams. Effectively, a large fraction of their observed Λ_c are daughters of doubly charm baryons [22]. This requires new mechanisms of charm- or even di-charm generation. Therefore much larger yields of doubly charmed baryons could be expected at the high-rate COMPASS experiment.

2. EXPERIMENTAL SETUP

To measure doubly charmed baryons with the COMPASS spectrometer several modifications have to be made and some detector systems have either to be built from scratch or upgraded. This section outlines the hardware requirements for a DCB measurement.

It is foreseen to run the double charm measurement with a proton beam of 280 GeV (the maximum of the present beamline setup) and an intensity of up to 10^8 during the 5-s SPS spill every 16.8 s.

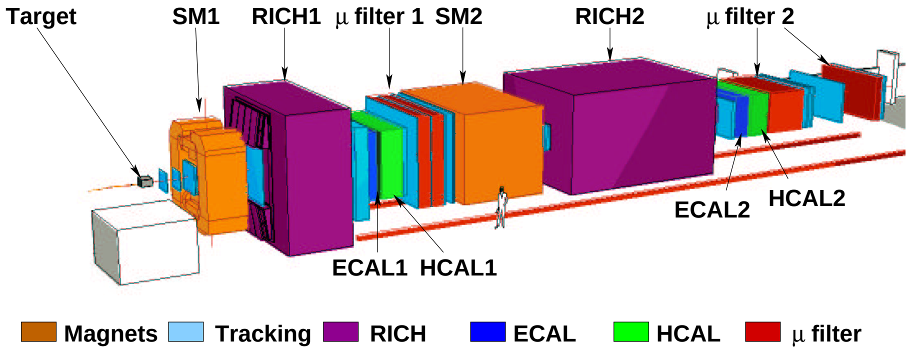


Fig. 1: General setup of the COMPASS spectrometer.

2.1 Spectrometer

COMPASS uses a double magnetic spectrometer with tracking, electromagnetic and hadronic calorimetry and particle identification in each section: the first stage detects low-momentum particles with large angles (± 180 mrad). High-momentum particles are analysed in the second part (± 25 mrad) using a large lever arm and a higher magnetic field than in the first stage. In this way an angular resolution down to 10 μrad (for small scattering angles) and a transverse resolution down to 7 μm can be achieved. A schematic view of the spectrometer is given in Fig. 1. For the double charm setup the gap of the first spectrometer magnet should be reduced from the present 1.72 m to 0.82 m, which is possible by removing some of the modular yoke pieces. This provides a higher field for the higher beam energy and also a smaller stray field in the tracking zones.

The tracking system is built up from a set of **L**arge **A**ngle **T**rackers (**LAT**) covering the outer region with lowest track density and **S**mall **A**ngle **T**rackers (**SAT**) for the inner regions. So-called *tracking stations* are distributed all over the spectrometer and consist of three different detector types staggered, each smaller one having finer granularity and rate capability and covering with some overlap a central hole in the next larger one. For the innermost part, directly in the beam, silicon detectors [23] and scintillating fibres are used. The LAT are small cell size drift chambers, straw chambers [24] and further downstream MWPC and large cell size drift chambers. The very important inner trackers between the beam region and the LAT consist of Micromegas [25] before the first magnet and GEM detectors [26] after that.

The compatibility of the tracking system with the high-intensity hadron beam, however, still has to be proven. In particular the inner trackers may run at a higher risk of discharges, which could make a partial revision of the setup necessary.

Particle identification is first of all given by RICH 1. A second RICH is currently under planning and should be able to cover the high momentum part of the spectrum passing through the second magnet. It is foreseen to have a fast readout which could make particle identification at the second trigger level possible. In addition two upgraded Cherenkov counters of CEDAR type will provide particle identification in the beamline to be able to obtain clean cross section measurements.

Further downstream electromagnetic and hadronic calorimeters provide the energy measurement needed to form a first level trigger based on transverse energy. Thereafter two muon filters allow muons from semi-leptonic charm decays to be identified. In addition to the existing muon walls the first muon filter has to be augmented by a muon hodoscope for triggering. Only a small fraction of muons from semi-leptonic decays would reach the present muon hodoscopes put far downstream for DIS measurements.

2.2 Target setup

The target setup as described in the present simulation is shown in Fig. 2. Beam definition is provided as in the present setup by scintillating fibres and silicon microstrips. The beam impinges on a segmented target of in total 2% of a nuclear interaction length. It is foreseen to use different materials for the thin target plates to study the A-dependence of charm production. The segmentation allows charm hadrons to decay mostly outside the target material to allow a cleaner vertex separation.

After the target a silicon microstrip telescope is needed to allow precise vertex determination. A clear separation of primary production vertex and secondary decay vertex is the cleanest signature for a weak charm decay. As a minimum setup, 16 microstrip planes arranged in four projections are foreseen. Depending on resolution, acceptance and possible stray fields a fifth station might be needed. A further consideration is the possibility to fully reconstruct semi-leptonic decays by using a densely packed decay detector right after the target as shown in Fig. 3. In the order of 16 planes are spaced within 2 cm along the beam and have a pitch of 10–15 μm. This setup would allow one to see a fraction of charm tracks (mostly D-mesons) still in the detector before their decay. Both resolution and the benefit of a charm decay detector still have to be studied carefully in simulations.

After the target a scintillating fibre detector will be used to obtain the track multiplicity at the trigger level and provide precise timing for all vertex tracks.

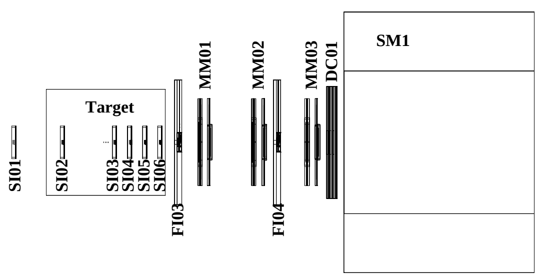


Fig. 2: Target region as used in the simulation.

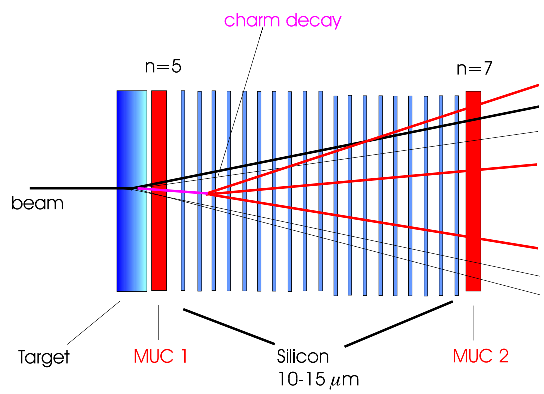


Fig. 3: Charm decay detector. 16–20 planes are spaced by 2 mm and have a pitch of 10–15 μm.

In COMPASS no precision vertex detector is present yet. The design of this detector has to fulfil a number of strict requirements:

- The detector has to stand fluences up to 5×10^{14} particles/cm^2.
- The spatial resolution in beam direction should be better than 100 μm to provide sufficient resolving power for charm decay vertices.
- Finally, at the very high particle rates foreseen, a good timing resolution is needed to recognize interaction pileup and disentangle multiple beam tracks.

It is foreseen to make use of the Lazarus effect [27] by operating silicon detectors at cryogenic temperatures so that they can survive larger fluences.

During the process of detector optimization we have to investigate the design of a monolithic target-vertex-cryostat, determine the best pitch size, and determine the effects of a larger lever arm vs. acceptance and mechanical design.

Finally the readout has to run at a speed of up to 100 kHz. ADCs are needed to obtain better space resolution, a good timing of the signal, and discrimination of secondary interactions.

3. TRIGGER SCENARIO

One of the most important problems to solve is to reduce the vast number of inelastic interactions to the interesting ones showing signatures for charm hadron decays. This is discussed in this section.

The starting point are 2×10^6 interactions per SPS spill. The first-level trigger has to reduce this to a rate of not more than 100 kHz, i.e. by at least a factor 4. Owing to the constraints of the readout system of existing detectors per event, 1 μs is available for the trigger decision at this level.

Three types of triggers can be envisaged at this trigger level, of which a combination should be able to reach the desired rejection level at a reasonable efficiency:

- Requiring simple charged track multiplicities bigger than 4 is a safe cut, in particular when searching for double charm. This removes a large part of the diffractive inelastic reactions and all elastic ones.
- A large transverse energy detectable by the calorimeters can indicate charm decays.
- A rather high fraction (up to 17%) of D-mesons decay semi-leptonically, mostly producing a muon. This can be selected by the muon filters of the spectrometer.

These trigger types shall be discussed in the following.

The rate coming from the first level trigger is still far too high to be written to mass storage. Therefore a second and/or third trigger level is required. The features exploited at these further levels are described below:

- Hit multiplicity, suppression of secondary interactions and a possible multiplicity jump in the vertex detector can already be performed in an intelligent detector frontend.
- Track prototypes can be formed within a super ROB, a particularly powerful readout buffer computer which reads the entire vertex detector. With these track angles, track multiplicity and possibly high track impacts can be investigated.
- Vertex reconstruction needs the power of a third-level trigger farm with many CPUs or high power co-processor cards for the super ROB. Here vertices can be searched, and separated production and decay vertices can be identified.
- Finally, particle identification can be performed from the information of the RICH detectors, and secondary vertices of hyperons and strange mesons can be tagged.

The final rate should be in the order of 10–20 000 triggers per spill.

3.1 Transverse energy

The high charm quark mass of around 1.5 GeV opens up a large number of decay channels. At the same time the Q value of the decay is large and therefore also the transverse momenta of the decay products. Enriching events with high p_T tracks will therefore also enhance charm decays. Experiments E791 and E831 already used this type of cut successfully. Typical values are 3–5 GeV reducing the number of triggers by a factor of 3–5 at efficiencies between 70 and 55%. The simulation of doubly charmed baryons shows an even higher transverse energy due to the two charm quarks and rather long decay chains. Figures 4 and 5 illustrate this trigger.

3.2 Multiplicities and muon trigger

Owing to the large Q value of the double charm decay and the long decay chains, the charged track multiplicity is very high. For example, looking at the decay $\Xi_{cc}^+ \rightarrow \Lambda_c \mathrm{K}^- \pi^+$ with some associated D mesons, basically no events with less than 10 charged tracks are seen. A simple cut of at least four tracks would already cut down the events by half with 100% charm efficiency. Higher reduction factors at still very high double charm efficiencies can be reached. Technically this trigger would be implemented by means of a fast scintillating fibre detector at the end of the vertex region. Multiplicities of double-charm events and minimum-bias events are compared in Figs. 6 a) and b).

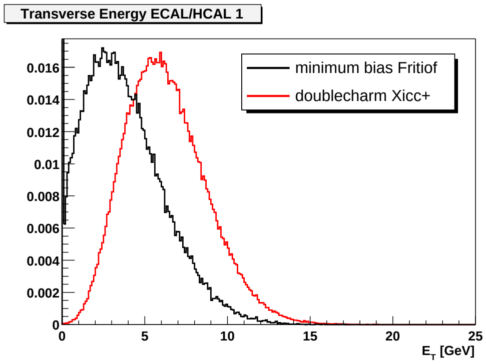


Fig. 4: Distribution of transverse energy of minimum-bias events and double charm events.

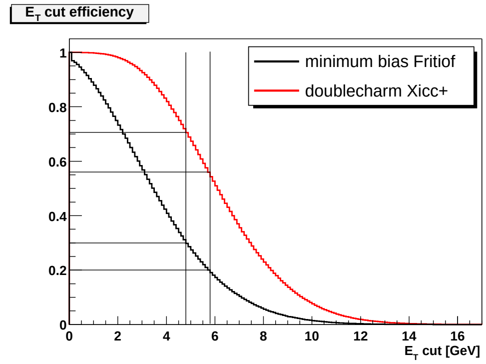
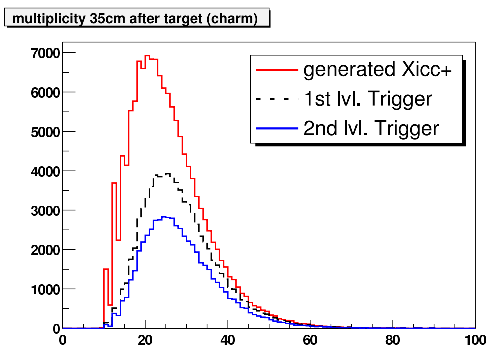
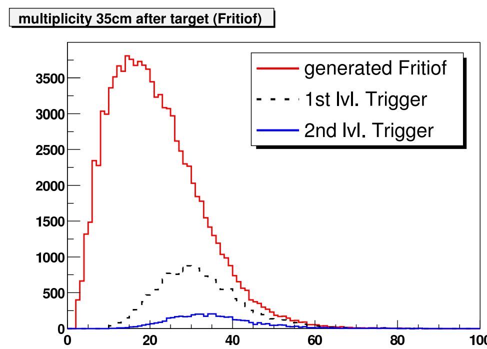


Fig. 5: E_T-cut efficiency. Shown are curves for minimum-bias and double charm. Intersections for a background reduction to 20% and 30% are drawn.



a) Multiplicities from double charm



b) Multiplicities from minimum-bias

Fig. 6: Multiplicities for all generated events, events passing a first-level trigger consisting of a multiplicity cut plus a minimum transverse energy and events requiring a reconstructible secondary vertex are compared.

Another clean signature is the production of muons in semi-leptonic decays of charm mesons. The branching ratios are

$$BR(D^0 \to \mu X) = 7\% \,, \quad \text{and} \quad BR(D^+ \to \mu X) = 10\%$$

whereas background from pion and kaon decays is small due to their much longer lifetimes compared to the charm mesons. Therefore a reduction factor of 30 from σ_{tot} can be reached at an efficiency which is basically equivalent to the semi-leptonic branching ratio. In addition, background can be further reduced by requiring a minimum transverse momentum of the muon.

3.3 Online filter

Coming to an acceptable data rate requires online filtering of the events. In the present COMPASS DAQ system with its 12 (to max. 16) eventbuilder computers (with 2 processors each) there is little room for complicated tasks, since at 40 kHz only 2–3 ms are available to process one event. Therefore other, additional or alternative ways of filtering and data processing have to be implemented. The various possible options will be briefly discussed here.

A very resource-efficient first approach is to improve the frontend electronics of detectors relevant to further trigger decisions with more processing power by means of fast Field Programmable Gate Array (FPGA) chips. This allows the preprocessing of data at an early stage saving CPU power on the actual filtering stage for mostly physics-oriented data treatment. Possible tasks for frontend preprocessing are:

- correlation and cut on the signal time,
- data reduction by forming clusters from adjacent channels including time cuts and amplitude weighting,
- determination of hit multiplicities,
- rejection of secondary interactions by means of a second threshold for too large signals.

As a second-level trigger a special readout buffer computer (Super-ROB) could be developed for the vertex detector. A large part of physically relevant data arrives at this single computer and equipping it with extra CPU power (4–8 CPUs) and, in addition, with powerful DSP or FPGA co-processor cards can yield a high selectivity based on simple criteria. It is mainly the forming of track prototypes that can be performed here from which selections on

- track multiplicities,
- track angles (partly correlated to transverse momenta),
- a preliminary interaction vertex and
- high track impact parameters

can be derived easily. This can be nicely embedded in the COMPASS DAQ system by also making this special machine the event distribution manager which directs the data flow from ROB computers to eventbuilders (Fig. 7). A large fraction of events would be simply flagged by the EDM after processing on the Super ROB to be discarded on all other ROBs.

The final filtering of events can be done in a dedicated filter farm consisting of densely packed CPUs, either as flat rack servers or better server blades with CPUs with low power consumption in racks with high integration and built-in network, power and cooling infrastructure. These systems can attack complicated filtering tasks like

- secondary vertex reconstruction,
- tagging of daughter decays (hyperons, K^0_s, D mesons),
- reconstruction of RICH rings.

In a system with 300–600 CPUs processing time of up to 25–50 ms per event is available.

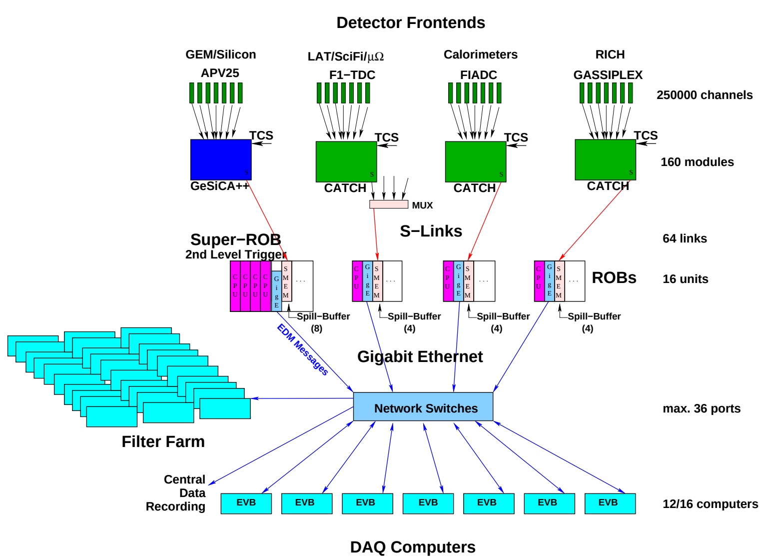


Fig. 7: Improved DAQ system for the second phase of COMPASS.

An alternative approach can be the implementation of a more homogeneous system of networked compute nodes which in a first layer address directly buffered detector data and then pass on data to further levels [28]. This approach in its full reach can even accomplish a readout system without dedicated hardware trigger signals that samples data at a constant frequency and performs data reduction, feature extraction and filtering in parallel as the data is transported and combined. This, however, also puts strong requirements on the frontends which actively have to perform hit-detection and data reduction before transferring any data. Although this might not be fully realizable in COMPASS, the compute node network can be a cost-effective alternative to an expensive CPU farm.

4. SIMULATIONS

In preparation for the COMPASS Future Workshop in September 2002 a number of simulation studies were performed. Their results are summarized here. Further studies to address a number of open questions are under way.

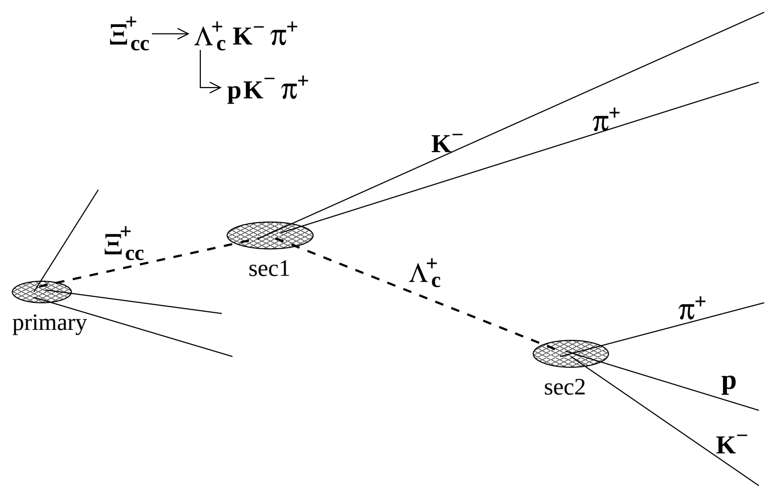


Fig. 8: Schematic decay chain of the Ξ^+_{cc} in the SELEX channel.

The first set of simulations of doubly charmed baryons in COMPASS was based on the decay channel $\Xi^+_{cc} \rightarrow \Lambda_c K^- \pi^+$ (Fig. 8) observed by SELEX at FNAL [21]. Together with the baryon two anti-D- mesons are generated. The production parameters are assumed to follow

$$\sigma \sim (1 - x_F)^3$$
$$\sigma \sim \exp(-1.2 p_T^2) \ .$$

The remaining energy is given to the Fritiof event generator to add further light hadrons.

For the detector simulation COMGEANT, a Monte Carlo program based on GEANT 3.14 is used. The detector geometry used here is from the first spectrometer magnet SM1 onwards identical to the present DIS setup. The target area before this magnet was already shown in Fig. 2 but there is further room for optimization. Currently only fieldmaps for magnet gaps of 1.72 m and 1.32 m are available. However, a more favourable gap of 82 cm should be studied in the near future.

The following assumptions and cuts are implied in this simulation study.

- The doubly charmed baryon was simulated with a lifetime of 25 fs corresponding to a value as favoured by the SELEX observations.
- The main cuts in GEANT were set to 100 MeV for faster processing.
- There was no detailed simulation of the RICH, only momentum thresholds for the various particles were applied. Positive identification of all kaons and protons was required.

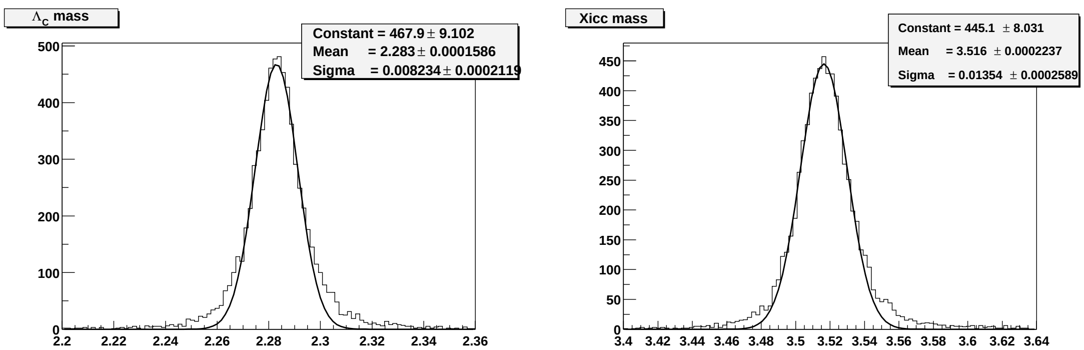
- Any secondary charm vertex was required to be outside the target material to be reconstructible.

The following sections illustrate the results of these simulations.

4.1 Acceptance and resolution

The overall geometrical acceptance and tracking capability of the simulated setup was found to be 5%. Detector efficiencies were not yet applied, but the present reconstruction program CORAL was used.

The mass resolution for the reconstructed Λ_c was found to be 8 MeV whereas the resolution of Ξ_{cc} turned out to be 13 MeV as shown in Fig. 9.



a) $\sigma(\Lambda_c) = 8$ MeV

b) $\sigma(\Xi_{cc}) = 13$ MeV

Fig. 9: Mass resolutions of Λ_c and $\Xi_c c$ after reconstruction.

4.2 Momenta and track efficiencies

Figure 10 summarizes the distribution of momenta of the various particles simulated in the Ξ_{cc} events. It is notable that only very few particles reach momenta above 40 GeV/c. This underlines the importance of the first spectrometer magnet. Presently a relatively poor average momentum resolution of 2% in this region is found, indicating that a reduced gap of SM1 leading to a higher field would be beneficial. Figure 11 shows that for particles above 5 GeV/c a reasonable tracking efficiency above 80% can be reached with the present setup.

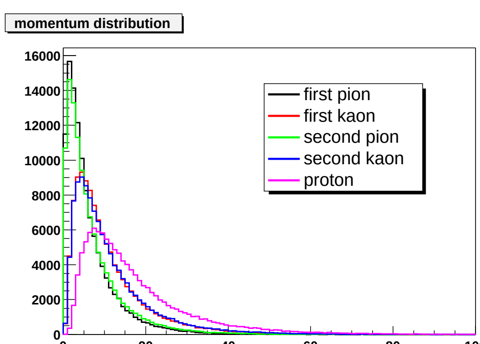


Fig. 10: Distribution of momenta of particles arising form the Ξ_{cc} decay.

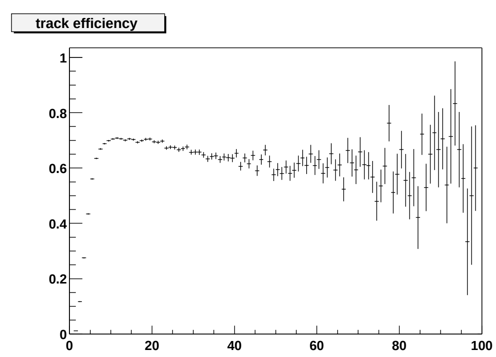


Fig. 11: Tracking efficiency vs. momentum for the present setup.

4.3 Trigger efficiencies

Finally, it was also possible to derive estimates for trigger efficiencies from the simulations in a simplified way. Note, however, that in the following exclusive double charm events are only compared to events generated by Fritiof as a kind of minimum-bias hadronic background. A large part of the total cross section constituted by elastic and diffractive scattering events are not treated here. They should be strongly suppressed by a hard multiplicity cut.

Trigger type	Ratio Charm/Fritiof
Muon trigger ($p(\mu) > 2$ GeV/c)	29.5% / 11.7%
Multiplicity trigger	100% / 85%
(more than 10 charged tracks)	
1st level trigger	57.7% / 20 %
(*Multiplicity* $\wedge$ (($E_T > 5.8$ GeV) $\vee$ ($E_T > 3$ GeV $\wedge$ μ)))	
2nd level trigger	41.5% / 4.6%
(some vertex activity)	

These values show that in comparison to the relatively hard spectrum of products from Fritiof, the discussed trigger scenario would work, i.e. provide a sufficient reduction at the first trigger level and good selectivity at the second.

In addition Fig. 12 shows the absolute x_F-acceptance of reconstruction and triggers and Fig. 13 the efficiency distribution normalized to all generated events. Here also the effect of RICH cuts was included. These cuts are based simply on acceptance and momentum cuts according to the operating thresholds of the employed RICH detectors. It turns out that the second RICH detector does not contribute a lot, mostly due to the fact that the fraction of tracks with momenta above 40 GeV/c is rather low. Nevertheless, the high-momentum part is of particular interest for the highly forward produced subsample which is of biggest relevance in the comparison with the SELEX results. In any case RICH cuts in the end would clean up the data substantially and reduce ambiguous interpretations.

The figures show as well that a reasonable reconstruction efficiency is reached already at $x_F > -0.1$.

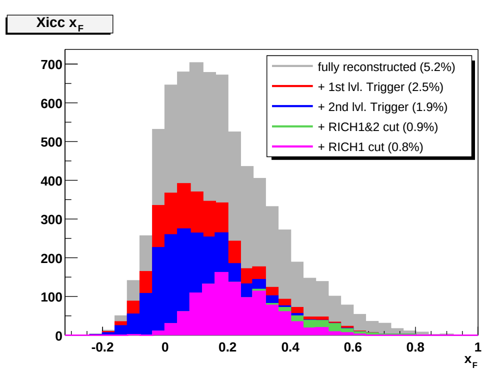


Fig. 12: Accepted events vs. x_F for the various steps in the triggering process. In addition the effect of RICH cuts based on simple acceptance and momentum thresholds are shown.

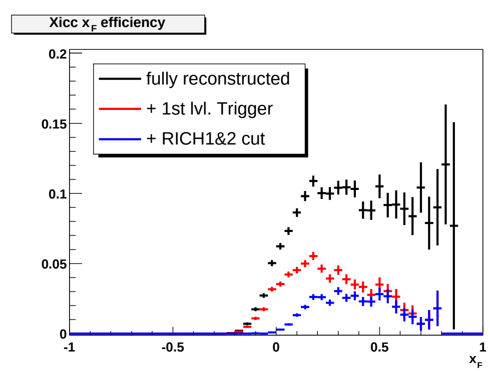


Fig. 13: Reconstruction and trigger efficiencies normalized to all simulated events.

5. RATE ESTIMATES

Rate estimates can be obtained from the conducted simulations. Further input are the nominal beam rate of up to 10^8 protons per spill and the assumed target with a thickness of 2% of an interaction length.

This leads to a total of 10^{12} interactions in a run of 100 effective days which corresponds to an integrated luminosity of $\int \mathcal{L} = 25$ pb^{-1}, based on a total cross section of 40 mb per nucleon.

The SELEX observations [22, 29] point to an unexpectedly large fraction of double charm production: From roughly 1600 reconstructed Λ_c they obtain about 50 doubly charmed baryons. If one then takes into account all cuts and branching ratios of the observed channels one comes to the conclusion that about half of all Λ_c in fact come from doubly charmed baryons. Assuming therefore a double charm production cross section in the order of the singly charmed baryon production cross section of about 2 μb (cf. results from WA89 [30] at a similar energy to COMPASS), this would mean for COMPASS that 50 million doubly charmed baryons would be produced.

Taking into account now the results of the simulation (acceptance $\times$ reconstruction $\times$ trigger $\times$ RICH = 0.8% as from Fig. 12) and estimates for branching ratios ($BR(CCQ) \times BR(CQQ) = 30\% \times 20\% = 6\%$) and assuming an additional factor for the overall detection and vertexing efficiency of 40 to 70%, one arrives at 10 000 to 17 000 reconstructed doubly charmed baryons. Here $BR(CCQ)$ already includes an estimated sum of all measurable CCQ channels, not only the simulated channel $\Xi_{cc}^+ \rightarrow \Lambda_c \mathrm{K}^- \pi^+$, and $BR(CQQ)$ denotes the fraction of reconstructible daughter baryon decays. This result is quite remarkable aside from the simple numbers in the sense that this would bring the highly interesting field of CCQ spectroscopy into reach.

But even a more conservative cross section estimate along the lines of $\sigma(CCQ) \sim \sigma_{tot} \times (10^{-3})^2$, i.e. a factor 10^{-3} down from charm production giving in the order of 10 nb would still correspond to 250 000 produced or 100 to 170 reconstructed doubly charmed baryons. This number nevertheless would constitute a solid observation.

6. CONCLUSIONS

In this report the hardware requirements for the measurement of doubly charmed baryons in COMPASS were outlined and the results of first simulations were presented. It was shown that sufficient suppression factors for the first trigger level could be reached by a combination of multiplicity and transverse energy cuts enhanced by identifying muons from semi-leptonic decays. Based on these results, rate estimates for a COMPASS measurement were obtained. With the exciting SELEX observations in view, doubly charmed baryons could be produced so abundantly that CCQ-spectroscopy would be in reach for COMPASS.

Simultaneously to the search for doubly charmed baryons valuable high-statistics data on singly charmed baryons can be obtained. Here one has to choose between a single charm measurement with double charm as bonus or a strict orientation of setup and triggers toward double charm. This choice is essentially determined by data rates and the desired selectivity.

However, there is still a lot of work to be done. An optimized setup has to be found for the vertex detector, the spectrometer layout and the trigger detectors. In particular there is substantial design work needed for the vertex detector. Further simulation studies of trigger efficiencies and reduction factors are needed. It would be interesting to obtain a better handle on the rejection of minimum-bias events from real hadron beam data. Then the best filter algorithm has to be found and coded. Further question marks lie in lifetimes, cross sections and production mechanisms of doubly charmed baryons.

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