Doubly Charmed Baryons in COMPASS

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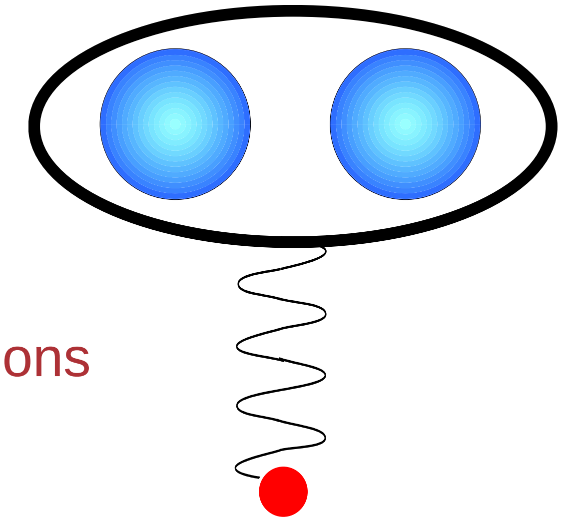
Workshop on Future Physics at COMPASS

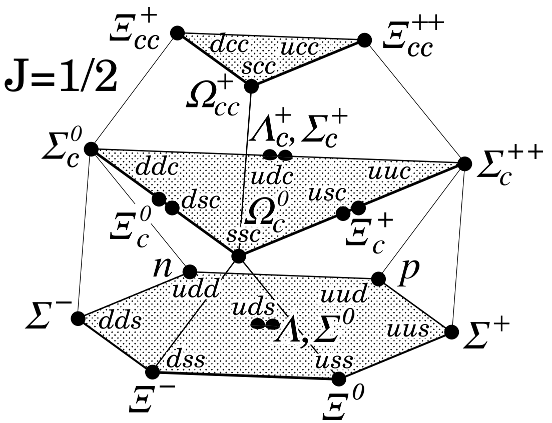
- Basics on CCQ
- Experimental Setup
- Trigger Scenario
- Simulations
- Rate Estimates
- Questions and Conclusions

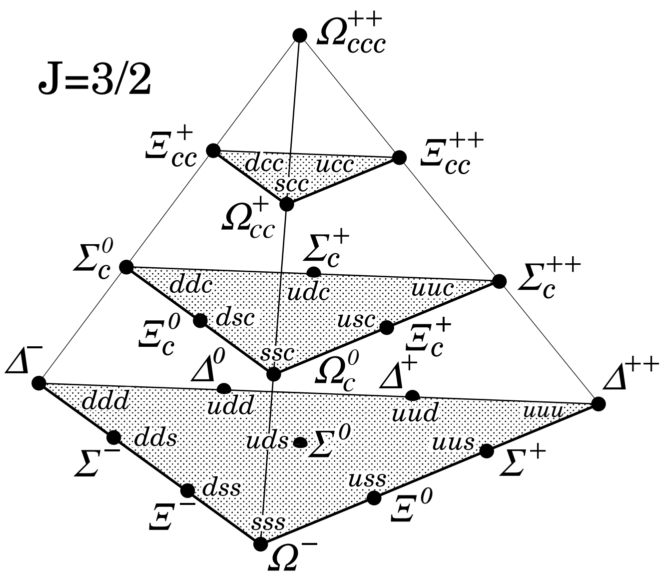


Simulations by Roland Kuhn

CCQ Basics

SU4 Baryon Multipletts





Masses and Lifetimes

	Likhoded	Tong	Ebert	Roncaglia	Körner	Itoh	Kaur
Ξ_{cc}	3.48	3.74	3.66	3.66	3.61	3.65	3.71
Ξ^*_{cc}	3.61	3.86	3.81	3.74	3.68	3.73	3.79
Ω_{cc}	3.59	3.76	3.76	3.74	3.71	3.75	3.89
Ω^*_{cc}	3.69	3.90	3.89	3.82	3.76	3.83	3.91

Masses in GeV

	Ξ^{++}_{cc}	Ξ^{+}_{cc}	Ω^{+}_{cc}
τ, ps	0.46 ± 0.05	0.16 ± 0.05	0.27 ± 0.06

Lifetimes in ps

Hadronic decay channels

$\Xi^+_{cc} \to$	$\Lambda^+_c K^- \pi^+$	(3%)	$\Omega^+_{cc} \to$	$\Omega^0_c \pi^+$	(5%)
	$D^+ \Lambda$	(2.5%)		$\Omega^0_c \pi^+ \pi^+ \pi^-$	(4%)
	$\Xi^+_c \pi^+ \pi^-$	(2%)		$\Xi^0_c K^- \pi^+ \pi^+$	(4%)
	$\Xi^0_c \pi^+$	(1.5%)		$\Xi^- D^+ \pi^+$	(2%)
	$D^+ K^- p$	(1%)		$\Xi^+_c K^- \pi^+$	(1.5%)
$\Xi^{++}_{cc} \to$	$D^0 \Lambda \pi^+ \pi^+$	(5%)	$\Omega^{++}_{ccc} \to$	$\Omega^+_{cc} \pi^+$	(5.5%)
	$\Lambda^+_c K^- \pi^+ \pi^+$	(5%)		$\Xi^+_{cc} K^- \pi^+ \pi^+$	(5%)
	$\Xi^0_c \pi^+ \pi^+$	(4.5%)		$\Xi^{++}_{cc} K^- \pi^+$	(2.5%)
	$D^+ \Lambda \pi^+$	(3%)			
	$\Xi^+_c \pi^+$	(1.5%)			

Measurements

SELEX (FNAL E781): $\Xi^+_{cc} \to \Lambda^+_c K^- \pi^+$, 15.9 events,
m=3519 MeV, $\tau < 33$ fs (90% CL)

Experimental Setup

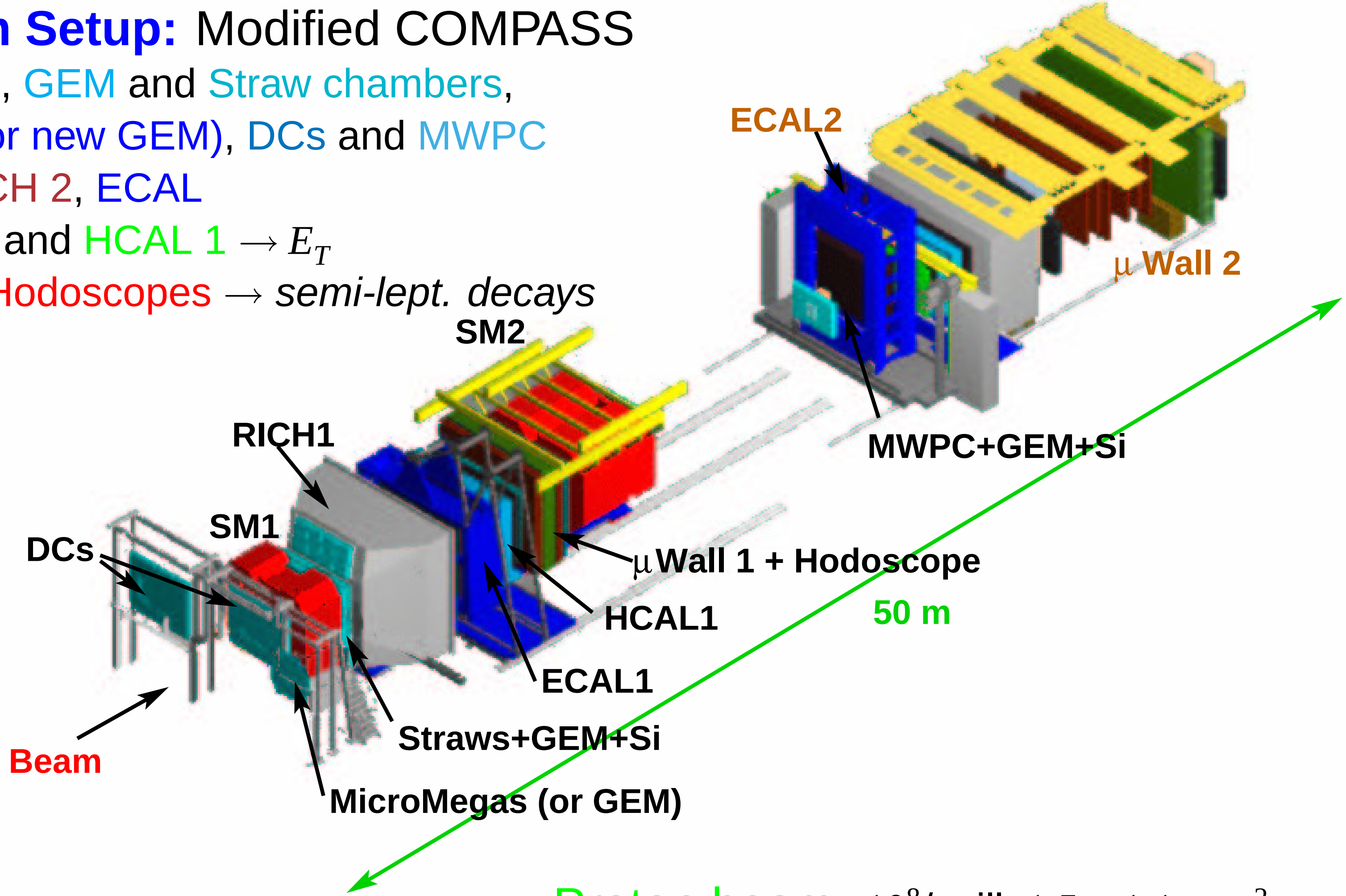
Double Charm Setup: Modified COMPASS

Tracking: Silicon, GEM and Straw chambers, Micromegas (or new GEM), DCs and MWPC

PID: RICH 1, RICH 2, ECAL

Trigger: ECAL 1 and HCAL 1 $\rightarrow E_T$

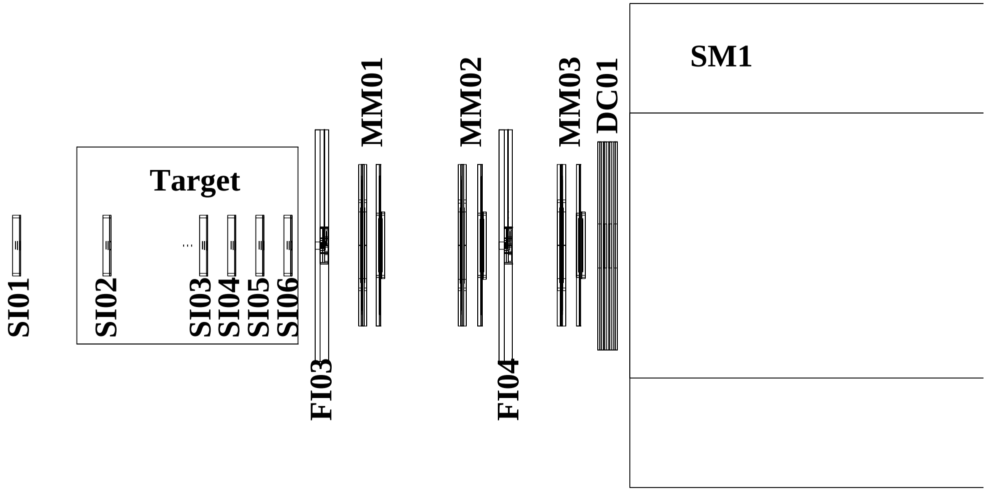
Muon Wall 1, Hodoscopes $\rightarrow$ *semi-lept. decays*



Proton beam: 10^8/spill, 1.5×1.1 mm^2, 280 GeV (beamline max.)

Target Setup

Target Region

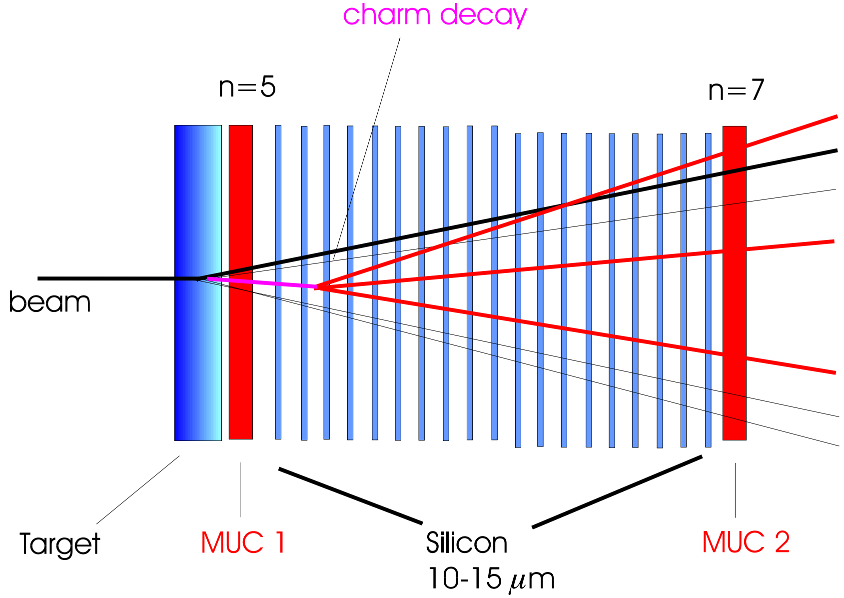


- Silicon/SciFi for beam definition
- Segmented target, 2% λ_{int}
- Silicon vertex telescope

→ study resolution

- SciFi for track multiplicity trigger and timing

Charm Decay Detector



- Charm decay within detector array (mostly D's)
- Trigger on multiplicity jump, charm track (2nd level)

→ cf. secondary vertex trigger

- More difficult

Vertex Detector

Detector requirements

- Fluences up to 5×10^{14} ptc/cm^2
- Resolution $\sim 100\mu$m
- Good timing resolution (~ 2 ns)

Detector optimisation

- Monolithic target-vertex-cryostat
- Pitch size (25 μm vs 50 μm)
- Lever arm vs. acceptance

Readout and triggering

- Readout speed up to 100 kHz
- ADC for resolution, timing, sec. interactions
- 2nd/3rd level trigger information

Trigger Scenario

Starting point: 2×10^6 int. per spill

First Level Trigger

- Simple track multiplicities > 4

$\longrightarrow$ SciFi for fast counting

$\longrightarrow$ factor 2 $\varepsilon = 100\%$

- Transverse energy E_T cut 3-5 GeV

$\longrightarrow$ ECAL1/HCAL1 sufficient

$\longrightarrow$ factor 3–5, $\varepsilon = 70 - 55\%$

- Muon trigger from semi.lept. D decays

$\longrightarrow$ MF1 hodoscopes similar to DIS MF2

$\longrightarrow$ factor 30, $\varepsilon = 10\%$

- Envisage OR of $N \times E_T(med) \times \mu$ and $N \times E_T(hi)$

Total reduction: factor 4–10 at $\varepsilon \sim 60\%$

Next step: 2×10^5 triggers per spill

Second/Third Level Trigger

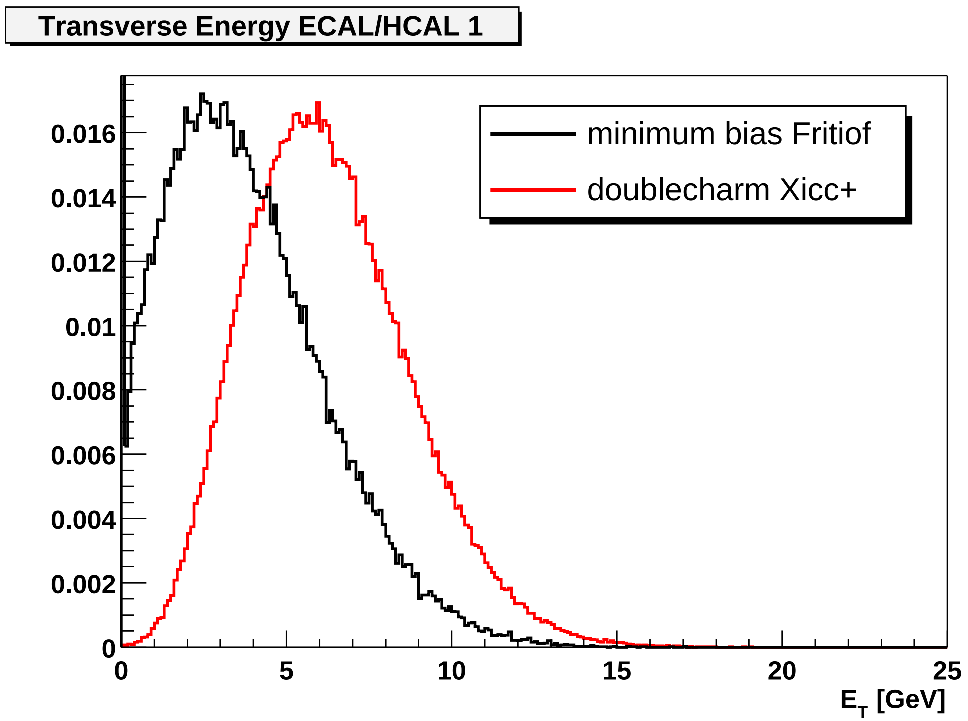
- Detector: Frontend
  - Hit multiplicity
  - Suppression of sec. interactions
  - Decay detector: mult. jump
- Tracks: Super ROB / 2nd level
  - Track angles
  - Track multiplicity
  - High impact tracks
- Vertex: Super ROB / 3rd level farm
  - Secondary vertex
  - Vertex separation
- PID: 3rd level farm
  - RICH reconstruction
  - Secondary tags (K^0, Λ, Ξ etc.)

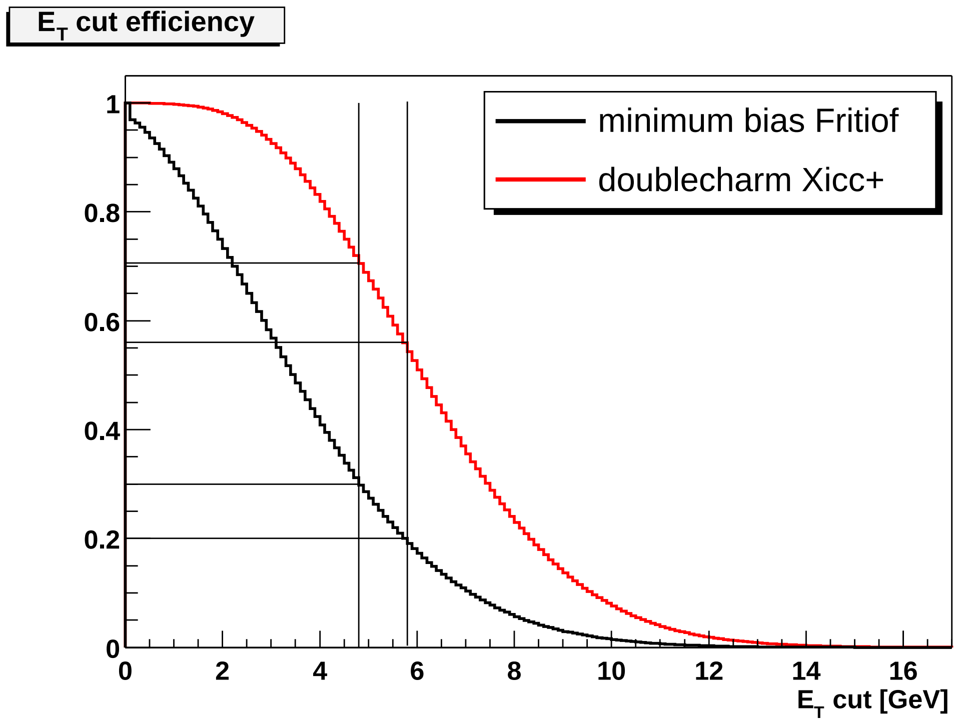
Transverse Energy

- High charm mass $\rightarrow$ high Q-value, high p_T tracks
- Simulation of charm shows many tracks with high p_T

$\rightarrow$ transverse energy from long decay chains

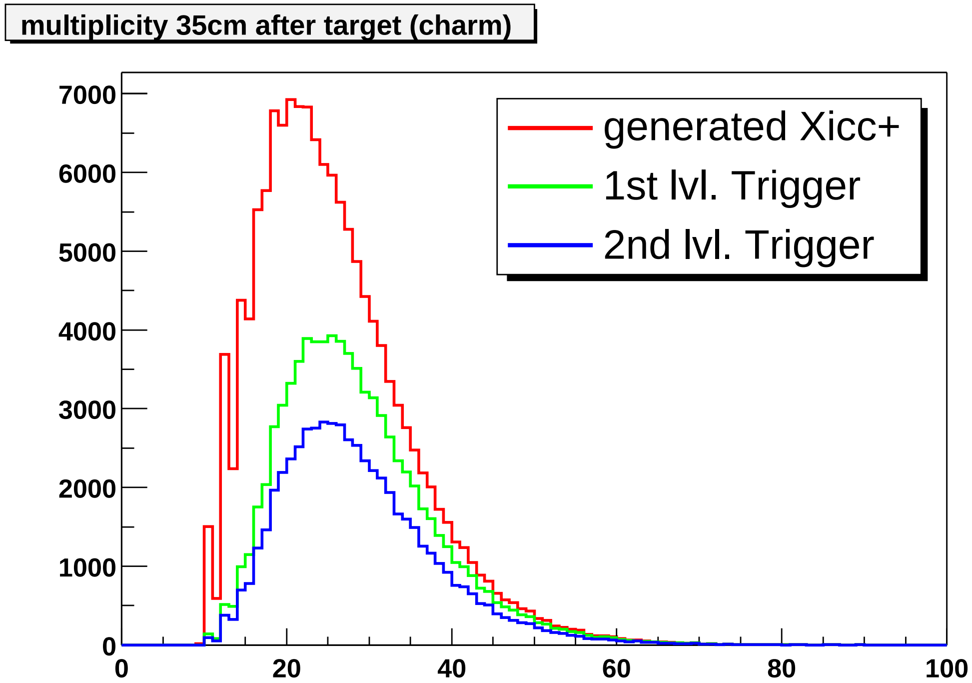
- Used e.g. by E791 (rather soft) and E831 at FNAL

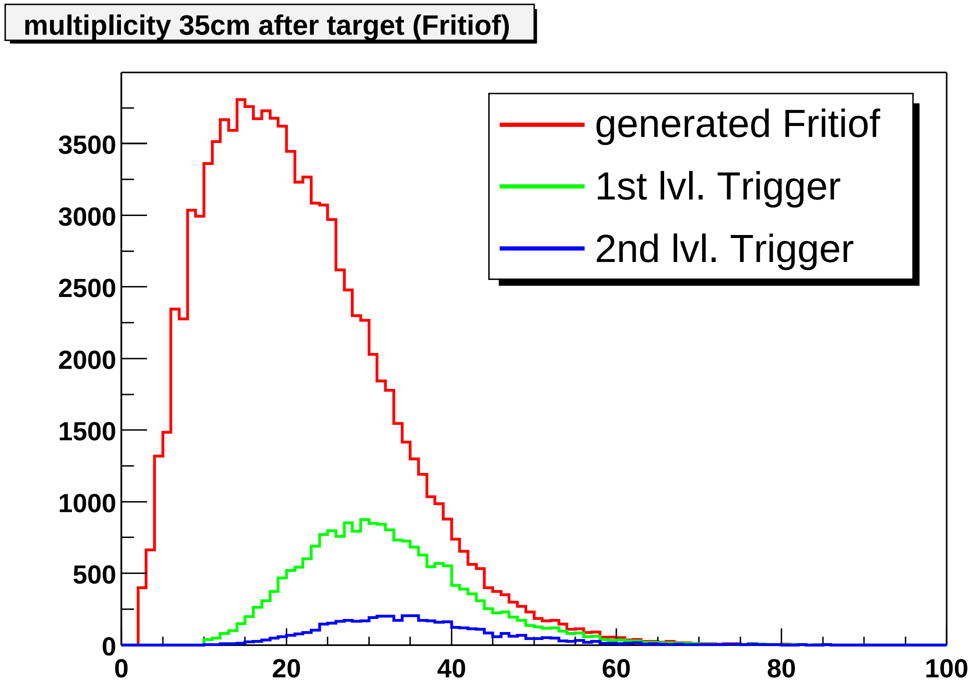




Multiplicities and Muon Trigger

Multiplicity cut as high as 10!





- Trigger on muon from semileptonic D decays BR($D^0 \rightarrow \mu X$)=7%, BR($D^+ \rightarrow \mu X$)=10%,
- Strong reduction from σ_{tot} (1/30)
- p_T cut possible

Online Filter Schemes

Filtering on EVBs:

12–16 dual CPU PCs

- At 40 kHz: 2-3 ms/evt

$\longrightarrow$ little room for complicated tasks

Filter Farm:

Server blades, $\sim$300 CPUs

- Topical reconstruction:
- - Secondary vertizes
- - Decay tags
- - RICH reconstruction

Frontend Preprocessing:

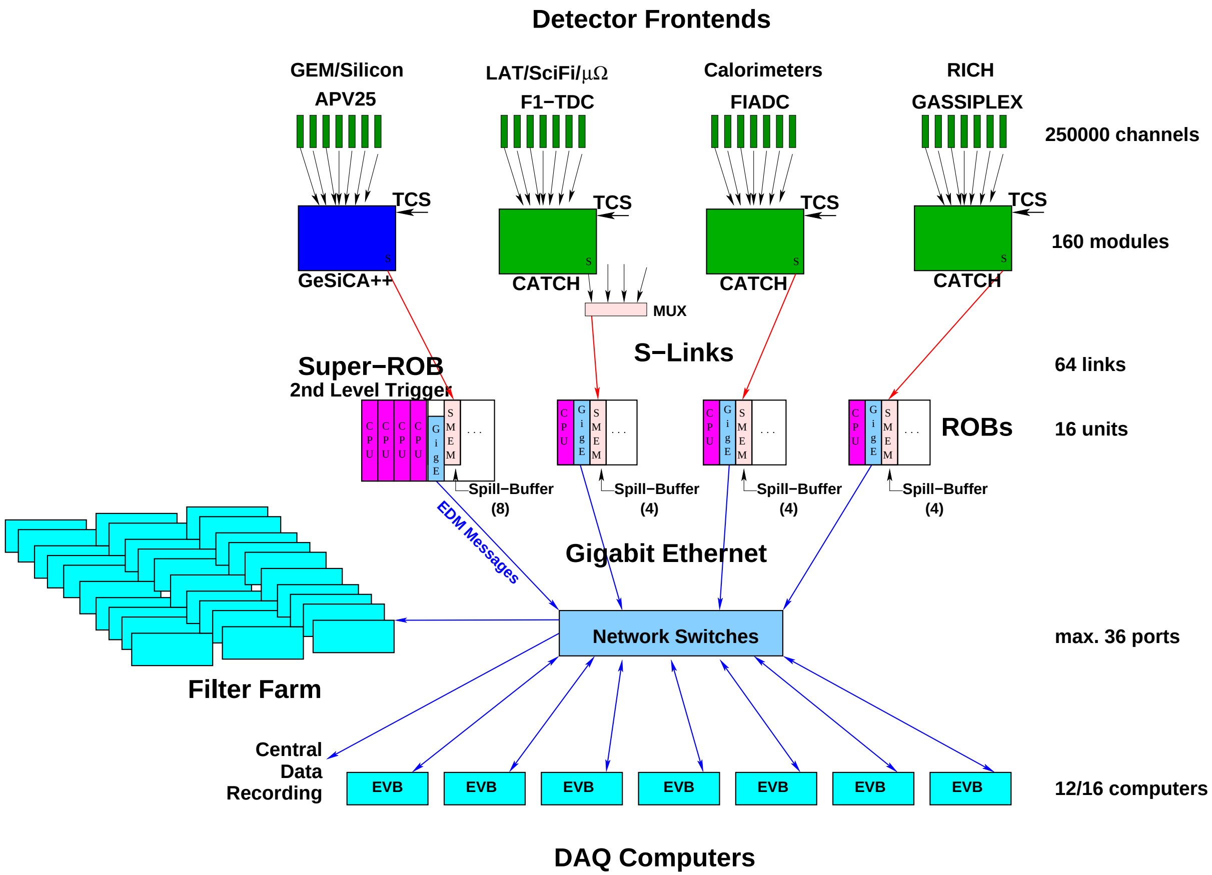
SGADC++, GeSiCA++

- Clusters
- Timing cuts
- Hit multiplicities
- Secondary interaction (second threshold)

Super ROB / 2nd level:

Quad-CPU, DSP coprocessors

- Track multiplicities
- High impact tracks
- DATE EDM

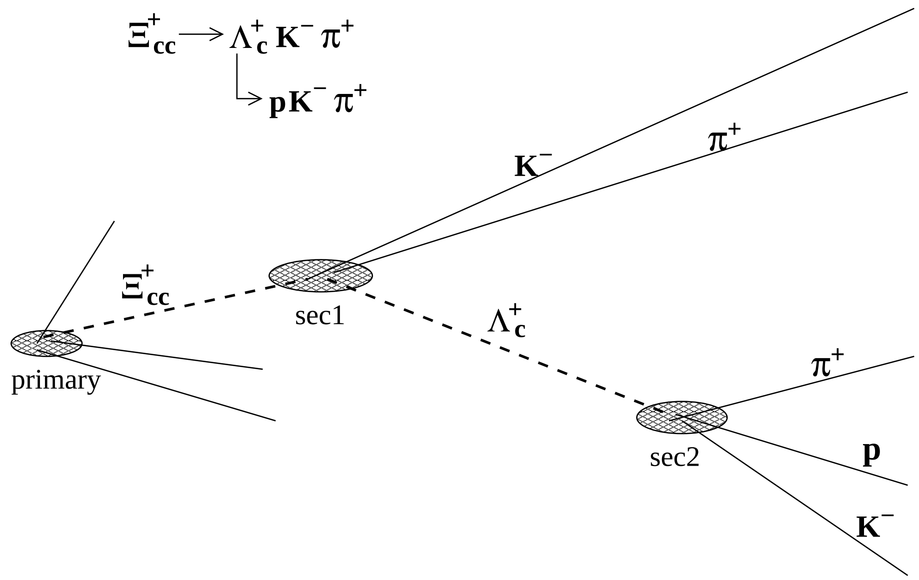


Simulations

Based on SELEX Channel:

$$\Xi_{cc}^{+} \rightarrow \Lambda_c^{+} K^{-} \pi^{+}$$

with associated $\bar{D}^0$ and D^-



Production parameters:

$$\sigma \sim (1 - x_F)^3$$

$$\sigma \sim exp(-1.2 p_t^2)$$

COMGEANT Setup:

- Downstream part as for DIS
- SM1 field map for 132 cm

$\longrightarrow$ go to 82 cm when available

- Target setup as shown

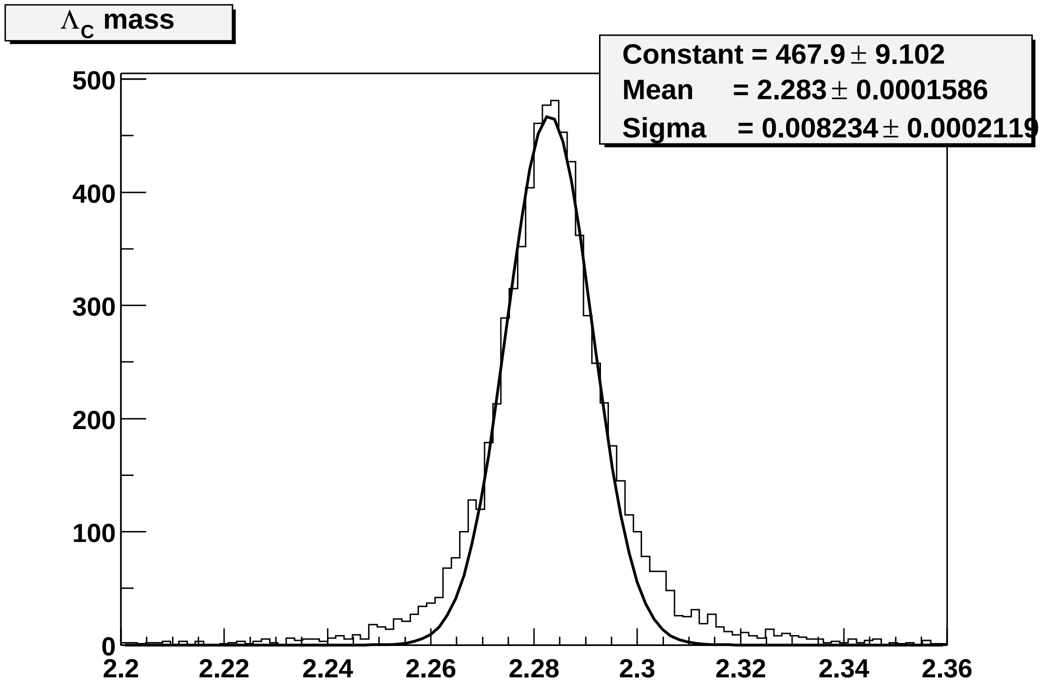
$\longrightarrow$ room for optimisation

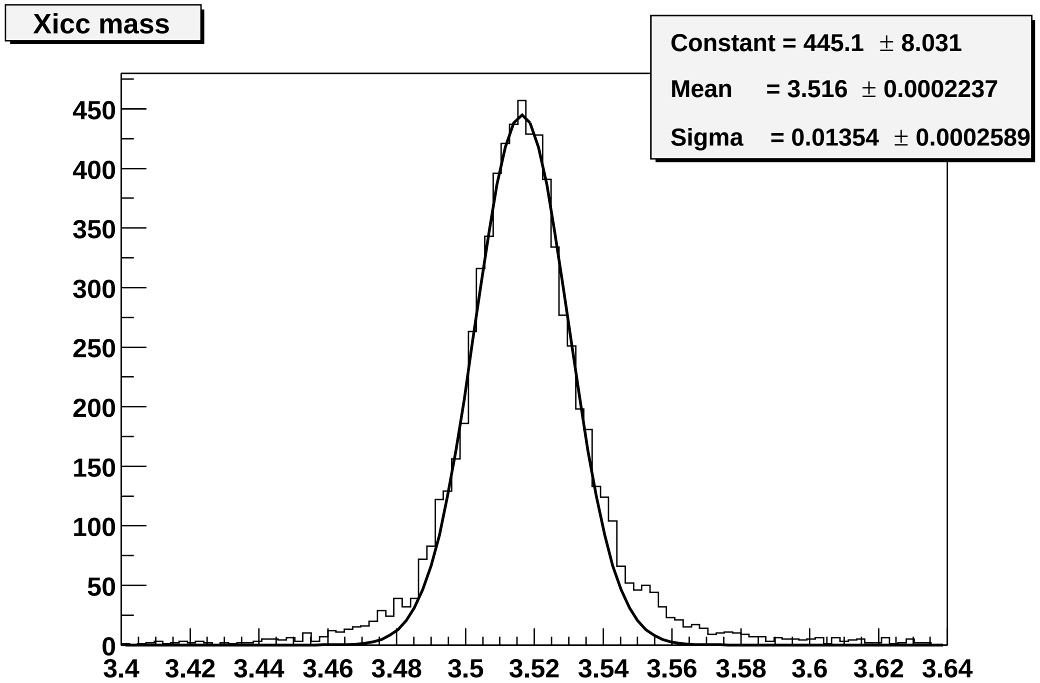
Assumptions and Cuts:

- SELEX lifetime $\tau(\Xi_{cc}^{+}) \sim 25$ fs
- Main GEANT cuts at 100 MeV
- No RICH simulation, only thresholds, but PID for all K's and proton
- Require any secondary vertex outside target

Acceptance and Resolution

Geometrical acceptance and tracking capability: 5%

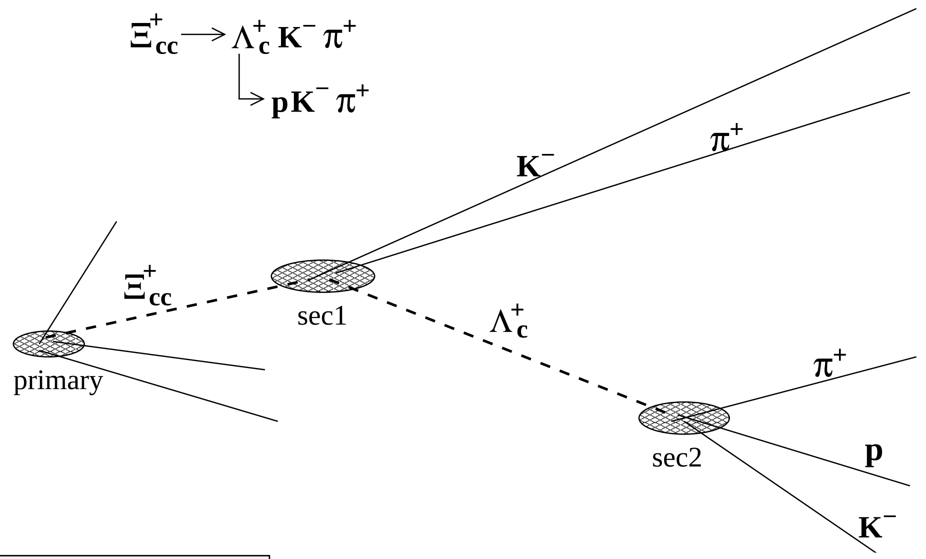


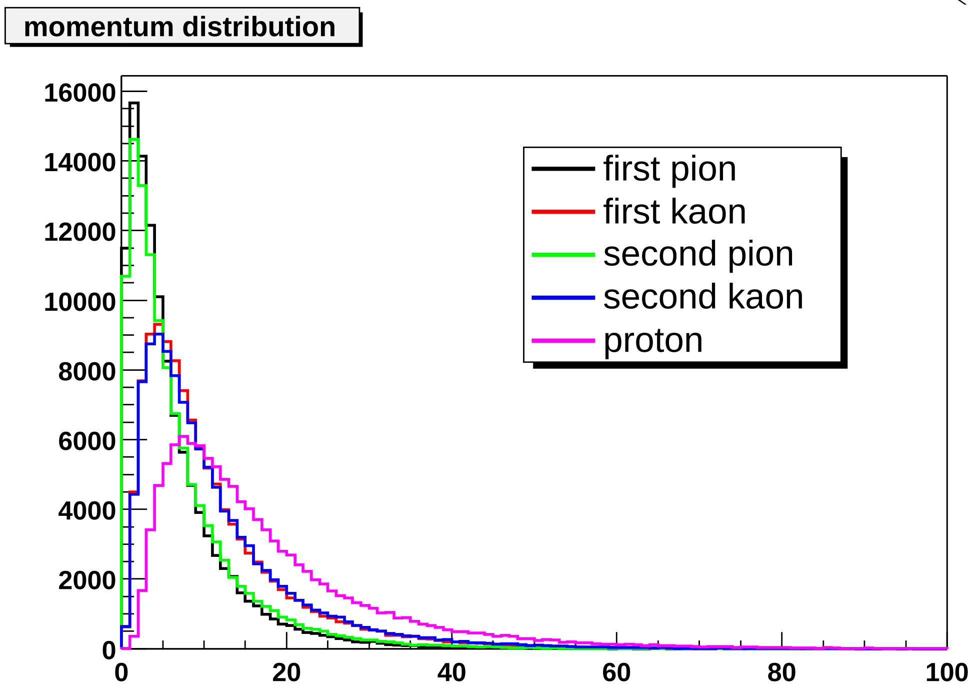


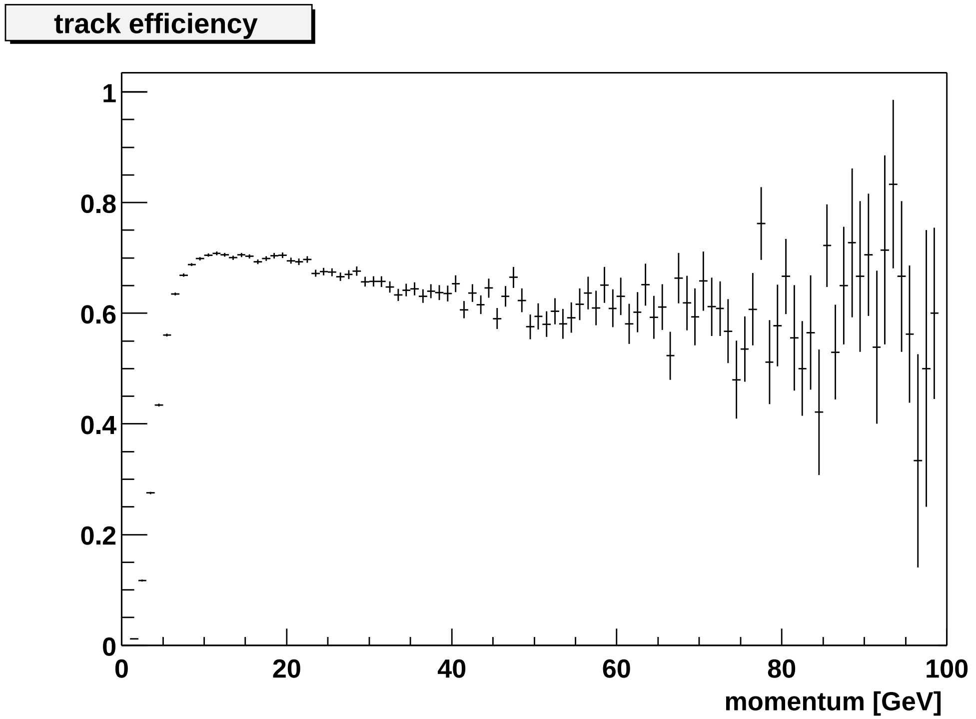
$\sigma(\Lambda_c) = 8$ MeV

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

Momenta and track efficiencies

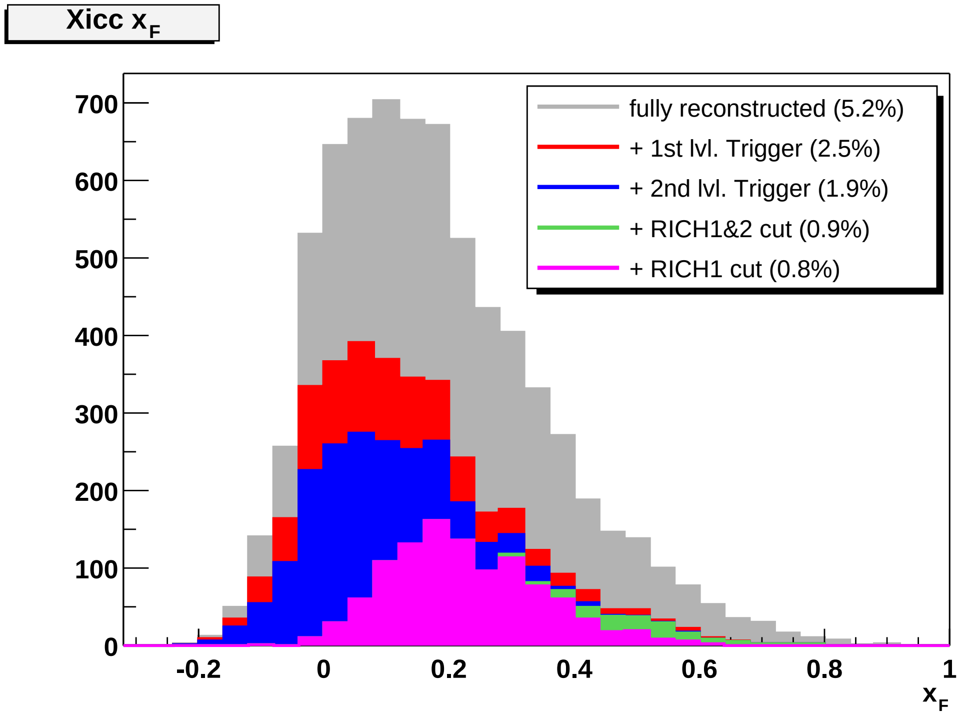


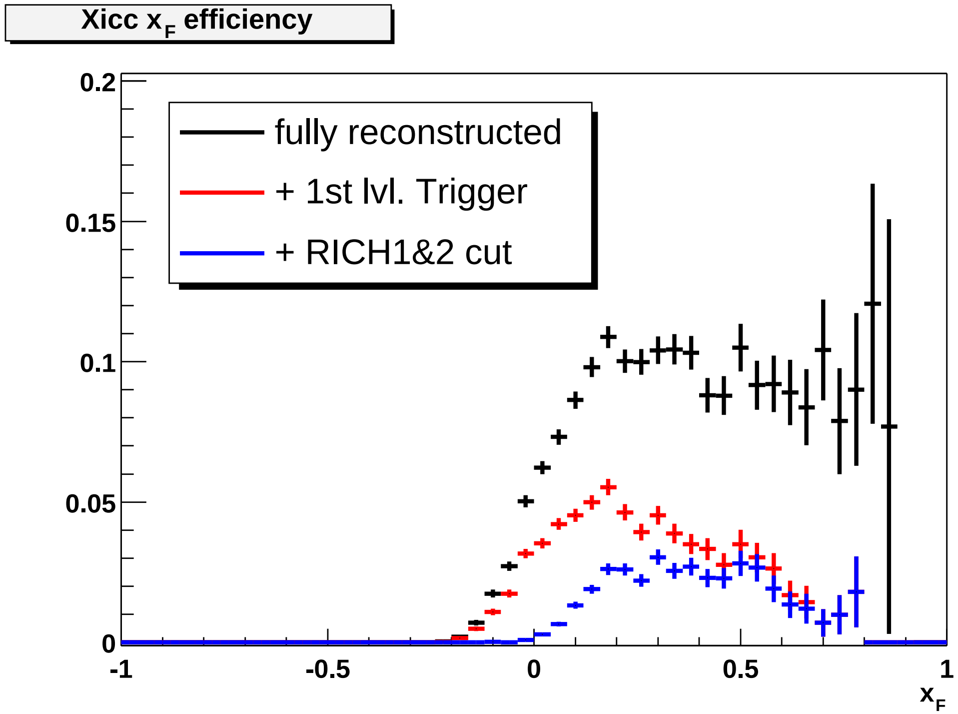




Trigger Efficiencies

Muon trigger:	$\mu > 2$ GeV	Charm/Fritiof : 29.5% / 11.7%
Multiplicity trigger:	more than 10 charged tracks	100% / 85%
1st level trigger:	*Multiplicity* $\wedge ((E_T > 5.8\text{GeV}) \vee (E_T > 5.8\text{GeV} \wedge \mu))$	57.7% / 20%
2nd level trigger:	Some vertex activity	41.5% / 4.6%





Rate Estimates

Beam rate: 10^8/spill

Target: 2% λ_{int}
- 10^{12} interactions in 100 d
- Luminosity $\int \mathscr{L} = 250$ pb^{-1}

Based on SELEX:
- From 1600 Λ_c get 50 CCQ
- Considering cuts and BR: 50% of Λ_c from CCQ

$\longrightarrow$ assume: $\sigma(CCQ) \sim\ 1\ \mu$b
$\longrightarrow$ produce: 250 Mio.

Simulation and BR:
- Detectable channels for CCQ and daughters: $10\% \times 20\% = 2\%$
- Acceptance $\times$ Trigger = 0.8%
- Reconstruction $\times$ vertex separation = 20–40 %

$\longrightarrow$ detect: 8000–16000

This scenario would allow CCQ spectroscopy

Pessimistic estimate:

- $\sigma(CCQ) \sim \sigma_{tot} \times (10^{-3})^2$
- i.e. factor 1000 down from σ_c

$\longrightarrow$ assume: $\sigma(CCQ) \sim\ 10$ nb
$\longrightarrow$ produce: 2.5 Mio.
$\longrightarrow$ detect: 80-160

Open Questions

- Optimized setup: vertex detector, spectrometer, trigger detectors
- Design work needed

- Studies of trigger eff., reduction factors:

$\longrightarrow$ rejection of minimum bias from data
- More simulation studies
- Best filter algorithm

- Cross section and production mechanism
- Double charm or single charm plus double charm bonus?

Conclusions

Charm physics in COMPASS

- Hardware requirements
  - Good vertex detector
  - ECAL1/HCAL1 for E_T trigger
  - Muon hodoscope in first spectrometer
  - RICH 2 helps
- Trigger requirements
  - First level trigger is achievable:

  $\longrightarrow$ Multiplicity, E_T, muons
  - Filter farm and maybe second level (Super ROB) needed
- Double charm in particular:
  - Even higher E_T and multiplicities
  - Momenta in average lower
  - Cross sections and lifetimes are still a question mark