COMPASS experiment at CERN. Status and perspectives.

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On behalf of COMPASS Collaboration.

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“COMPASS” is ...

- … Common Muon and Proton Apparatus for Structure and Spectroscopy
- … Fixed target CERN experiment NA58 on SPS accelerator beams (μ,π,p)
- … collaboration of more then 200 physicists from institutes of 11 countries:

  Bielefeld, Bochum, Bonn (ISKP, PI), Burdwan and Calcutta, CERN, Dubna, Erlangen, Freiburg, Heidelberg, Helsinki, Lisbon, Mainz, Moscow (INR, LPI, MSU), Munich (LMU, TU), Nagoya, Prague, Protvino, Saclay, Tel Aviv, Torino (Univ., INFN), Trieste (Univ.,INFN), Warsaw (SINS, TU)

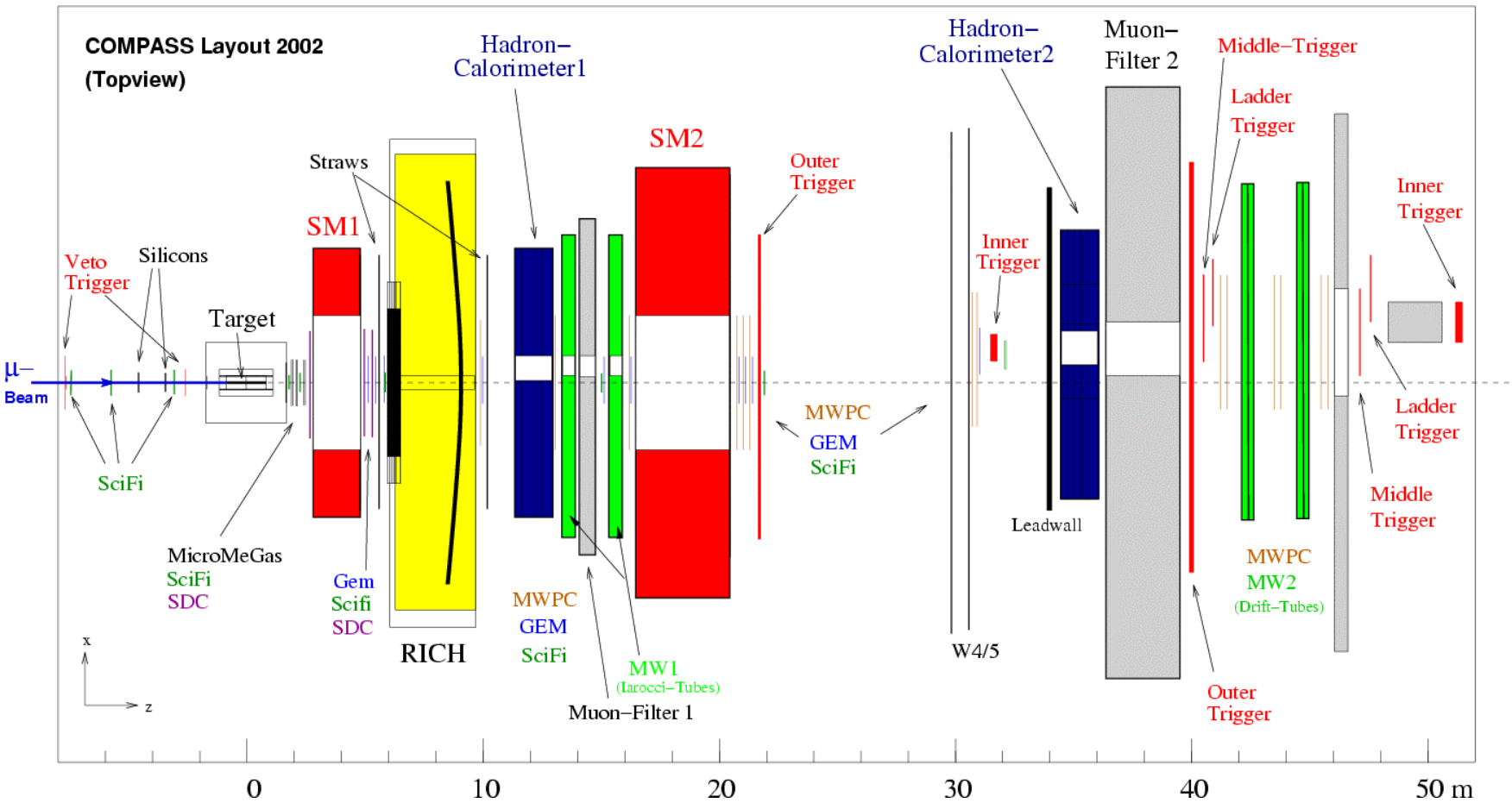

Jura
Geneva Lake
COMPASS

Physics program

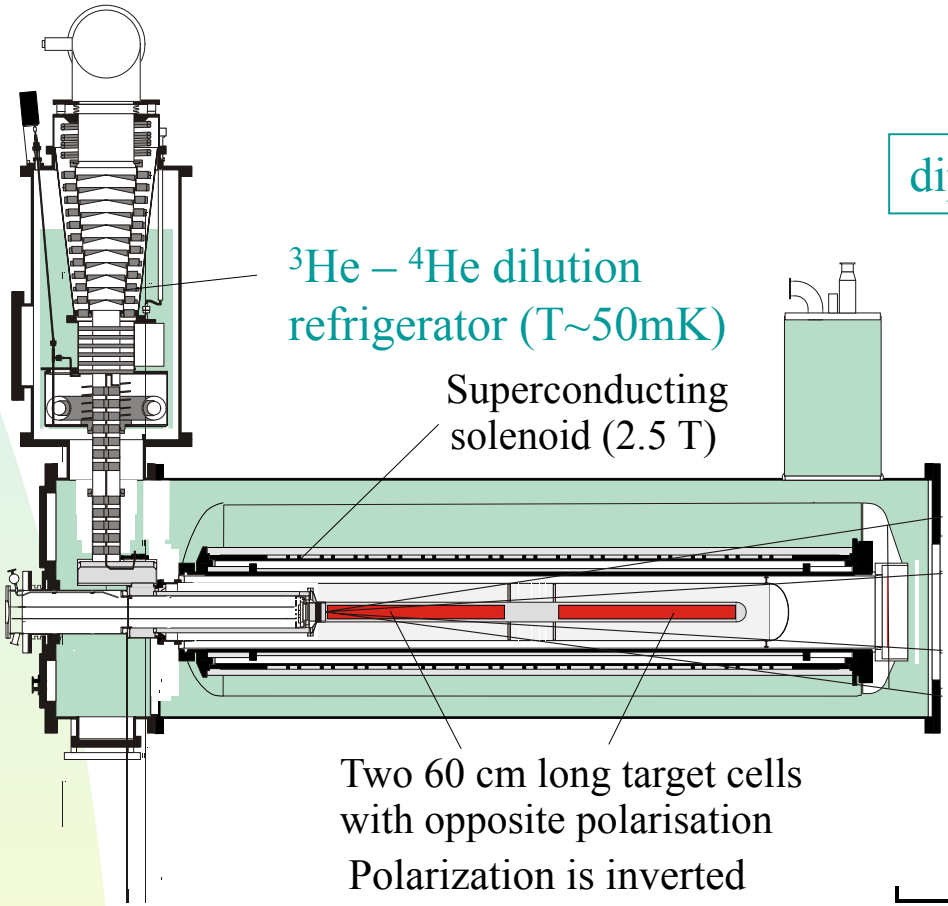
- With muon beam
(data taking has started in 2002)
  - Quark and gluon polarization in polarized nucleons
  - Polarization transfer in fragmentation
  - Transverse spin distribution

- With hadron beam(s)
(data taking will follow)
  - Polarizability of kaons and pions
  - Glueballs
  - Semi-leptonic decays of charmed hadrons
  - Double-charmed baryons spectroscopy

Experiment layout for muon physics



Polarized ^{6}LiD target

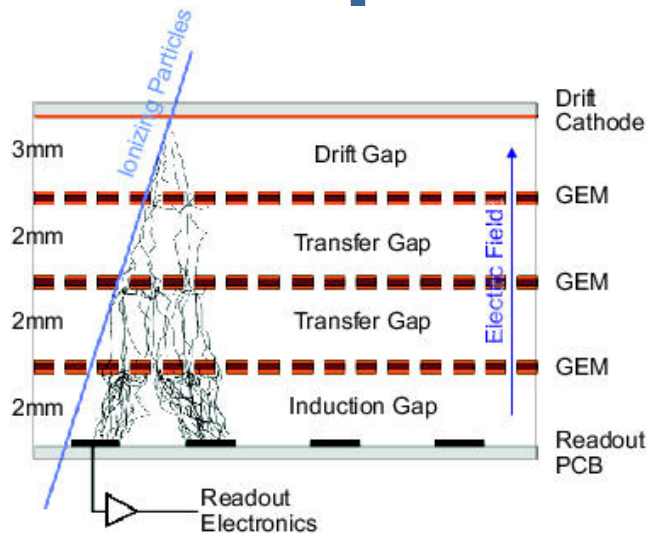


Detectors

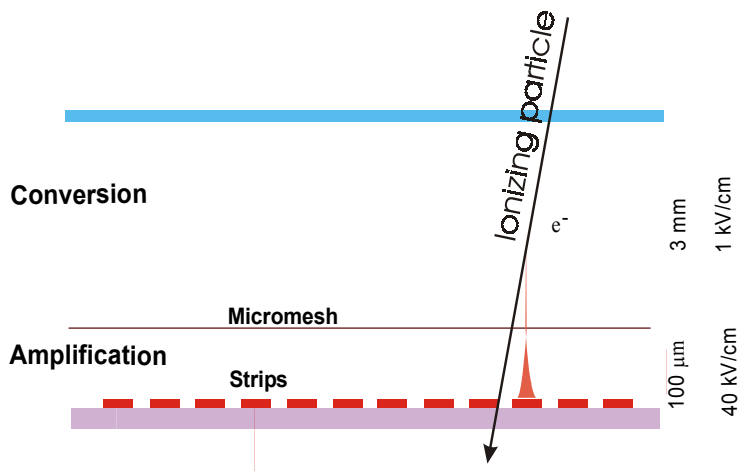
- Tracking detectors:
  - Scintillating Fibres
  - Silicon microstrips
  - MicroMegas
  - GEMs
  - Drift chambers
  - MWPCs
  - Drift tubes
  - Straws
- Calorimeters
  - 2 hadron calorimeters
  - electromagnetic calorimeter
- Ring Image Cherenkov detector

Detectors: new developments

GEM
(Gas Electron Multiplier)
- size 30x30 cm^2
- time resolution 12 ns
- space resolution 50 μm
- double side X-Y readout



MicroMegas
(MicroMesh Gaseous Structure)
- size 40x40 cm^2
- time resolution < 10 ns
- space resolution 70 μm



Calorimetry

Hadron Calorimeter 1 (500 ch)
sandwich: Fe + scintillator

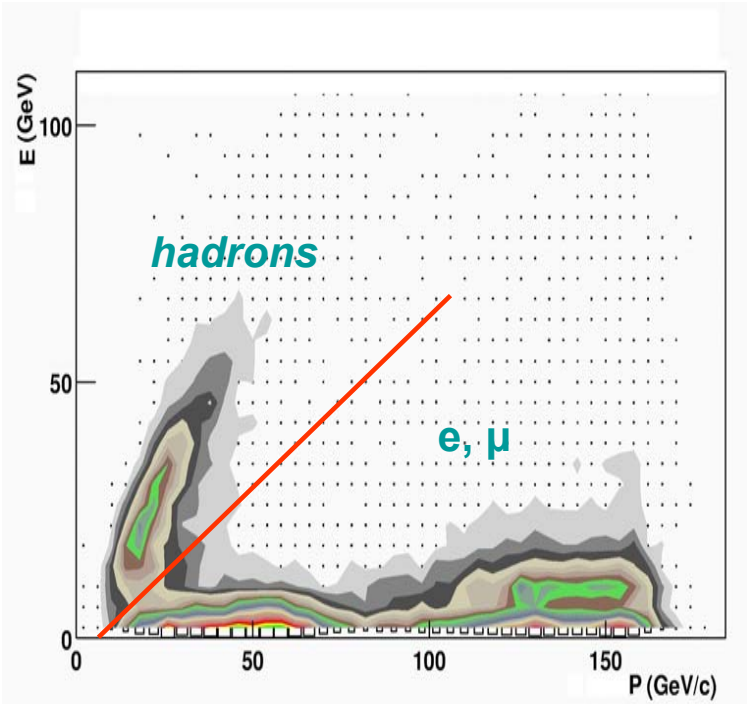
$$\pi: \frac{\sigma}{E} = \frac{59.4\%}{\sqrt{E}} \oplus 7.6\%$$

Hadron Calorimeter 2 (200 ch)
sandwich: Fe + scintillator

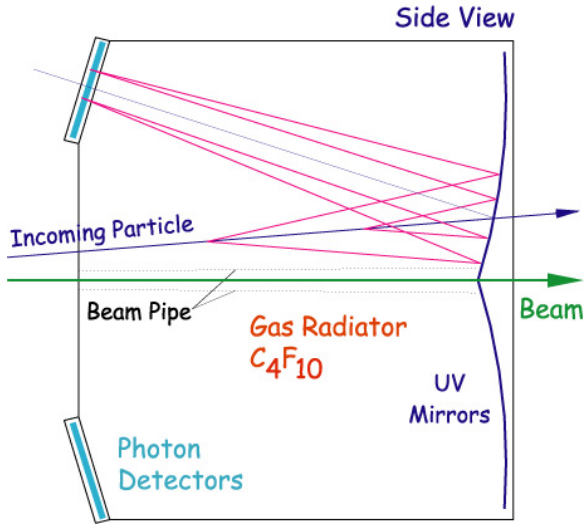
$$\pi: \frac{\sigma}{E} = \frac{65\%}{\sqrt{E}} \oplus 4\%$$

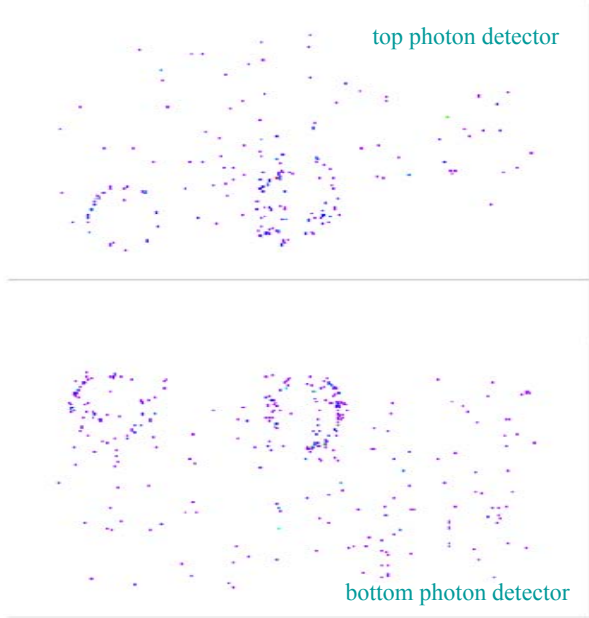
Electromagnetic Calorimeter 1
(~ 1000 ch of GAMS detector)

$$\frac{\sigma}{E} = \frac{5.8\%}{\sqrt{E}} \oplus 2.3\%$$

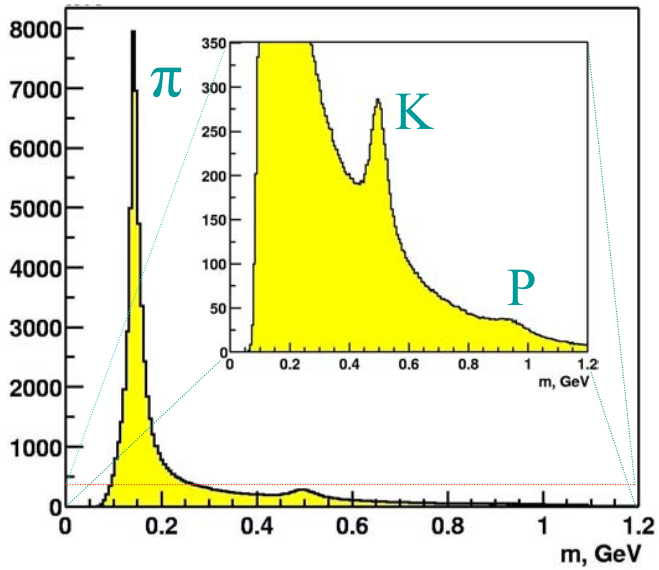


RICH



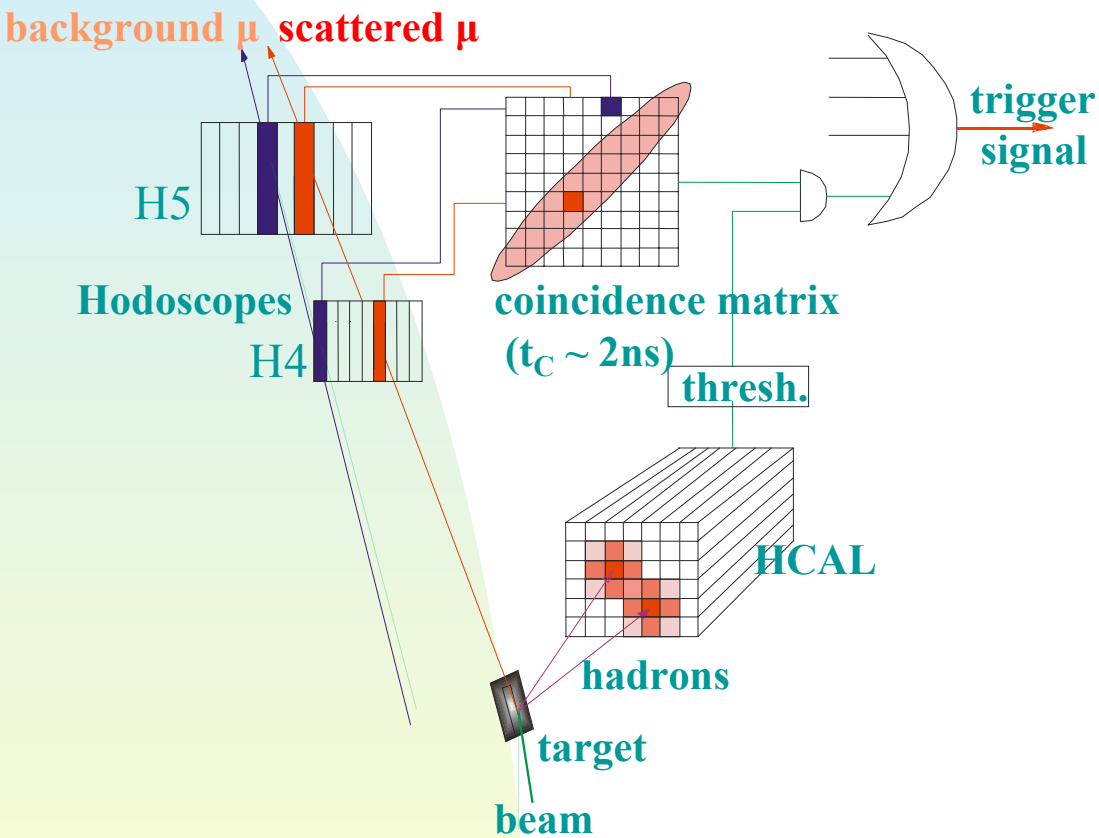


- 80 m^3 C_4F_{10} radiator
- 116 mirrors
- 5.3 m^2 of Cherenkov photon detectors
  - MWPC CsI photo-sensitive cathodes
  - 8x8 mm^2 pads
- 84000 readout channels (10-bit ADCs)



Trigger system

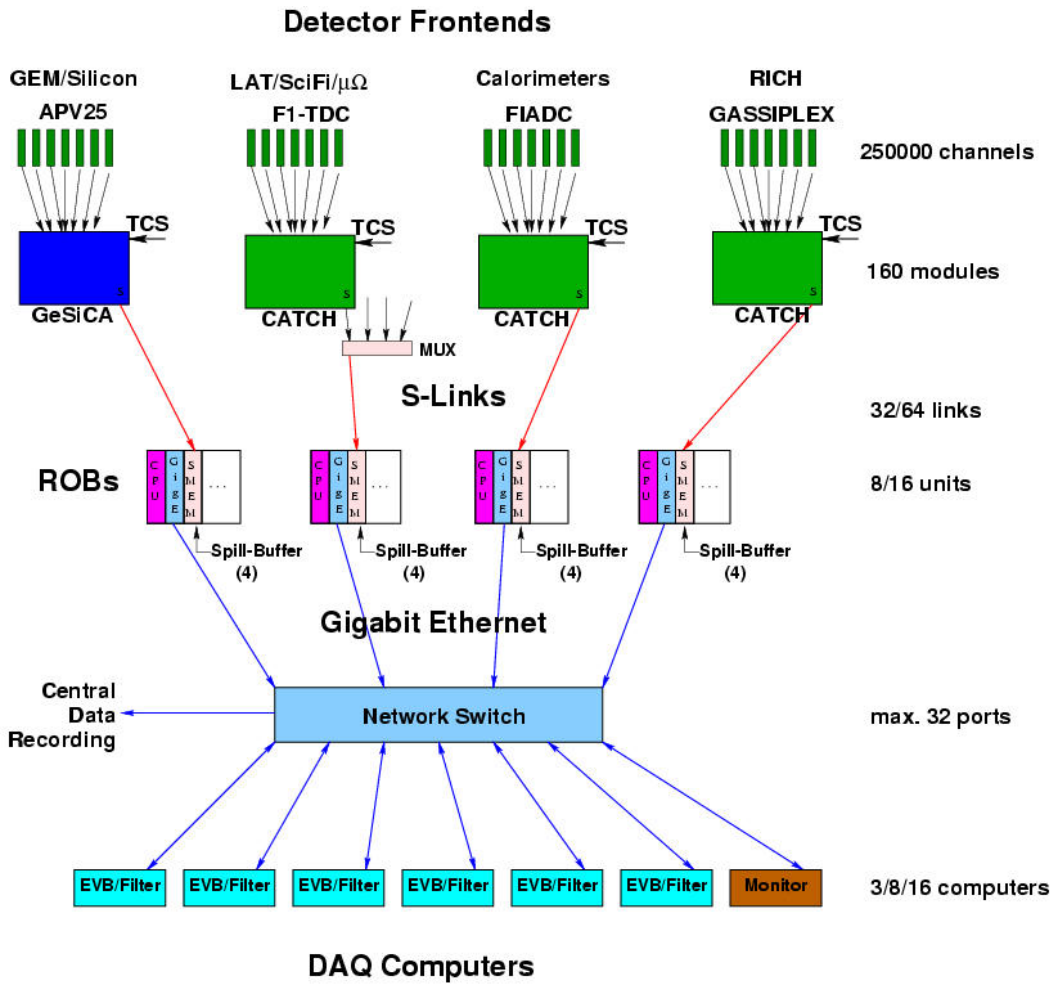
Trigger : (H4 * H5) * (Hcal1 U Hcal2)



Kinematics ranges of triggers

Frontends and Data Acquisition System

- **only 4 types** of front-end chips (COMPASS development) for readout of all detectors.
- **only 2 types** of front-end interface modules (with identical output protocol)
- "pipeline" readout architecture
- ~ 250,000 channels
- event size ~ 50 kB
- trigger rate: up to 5 kHz
- data rates 220 MB/s in spill (60 MB/s average)



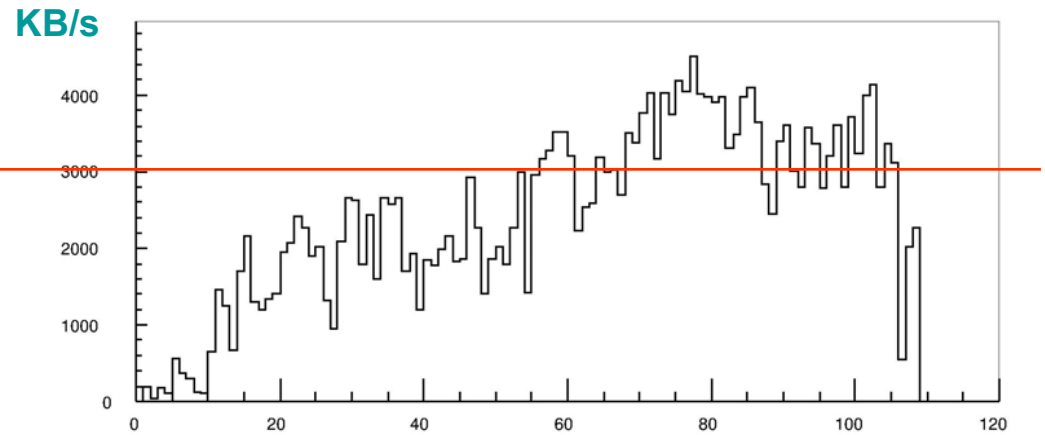
Central Data Recording

It is “experimental hall” ⇒ “CERN mass storage” data transfer hardware + software.

2002

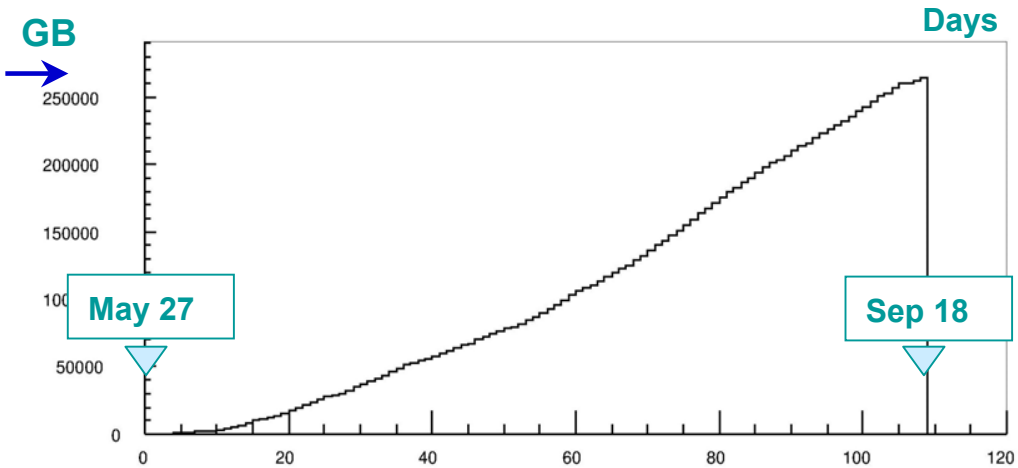
Design value: 35MB/s

3TB/day



260 TByte in ~100 days

5 billion events



2003: up to 6TB/day

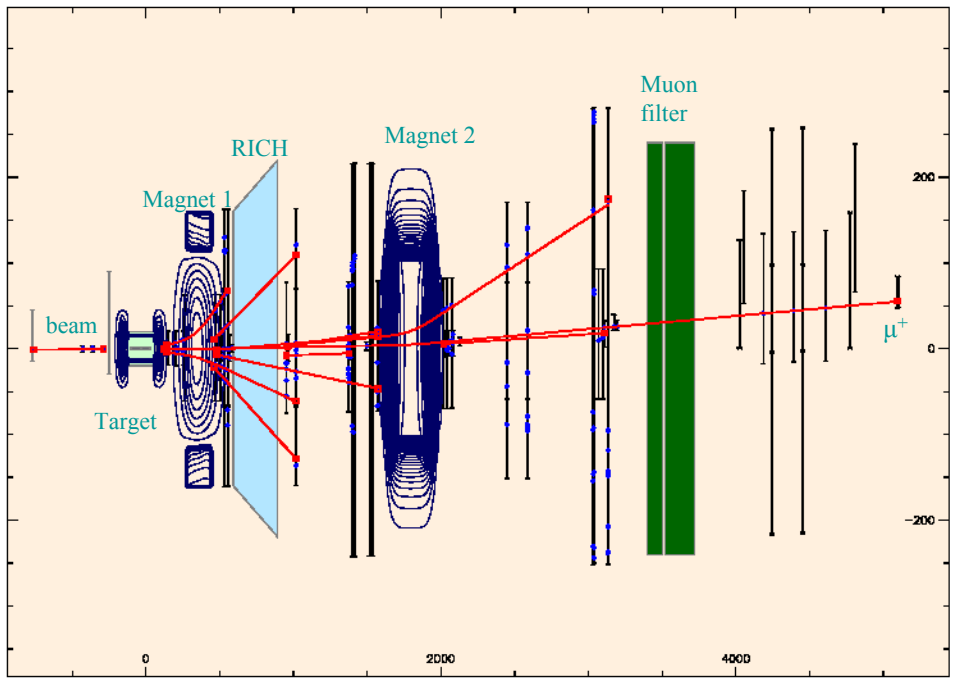
Event reconstruction

1) Track finding and fit. 2) RICH reconstruction. 3) Calorimeters reconstruction. 4) Beam momentum determination. 5) Vertex reconstruction.

Average time to process one event on CERN Linux farm: 600 ms. ⇒ Processing of year 2002 data took ~ 200 days on 200 CPUs (almost completed now)

Factors which make tracking one of the most CPU consuming parts of event reconstruction:

- 2-stage spectrometer with more than 200 detector planes of different type, different size and resolution.
- significant multiple scattering all over setup
- large beam pileup and halo ⇒ high detector occupancies
- 3 magnets. Complex superposition of target solenoid and magnet #1 fields



Analysis of 2002 data

Main directions:

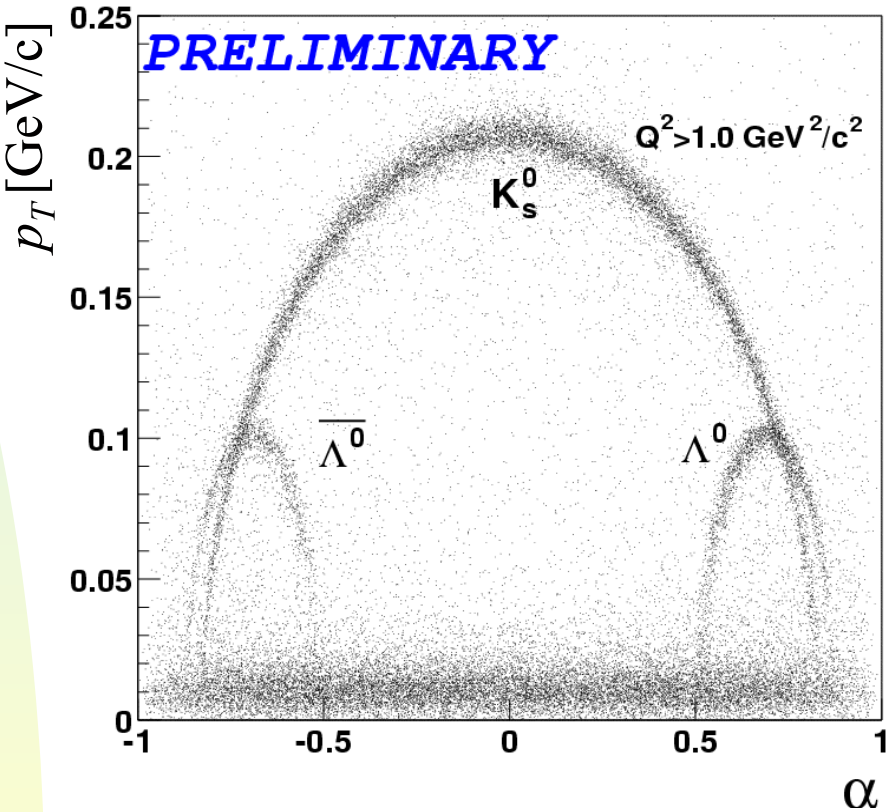
- Λ and $\bar{\Lambda}$ production and polarization
- Vector meson production: ρ, φ
- $\Delta G/G$ from open charm production
- $\Delta G/G$ from high-p_T hadron pairs
- Flavour decomposition of polarized parton distribution function
- Transversity and Collins asymmetry

Lambda production

Armenteros-Podolanski plot:

for V^0 vertices

$$P_T \text{ vs. asymmetry } \alpha = \frac{P_L^+ - P_L^-}{P_L^+ + P_L^-}$$



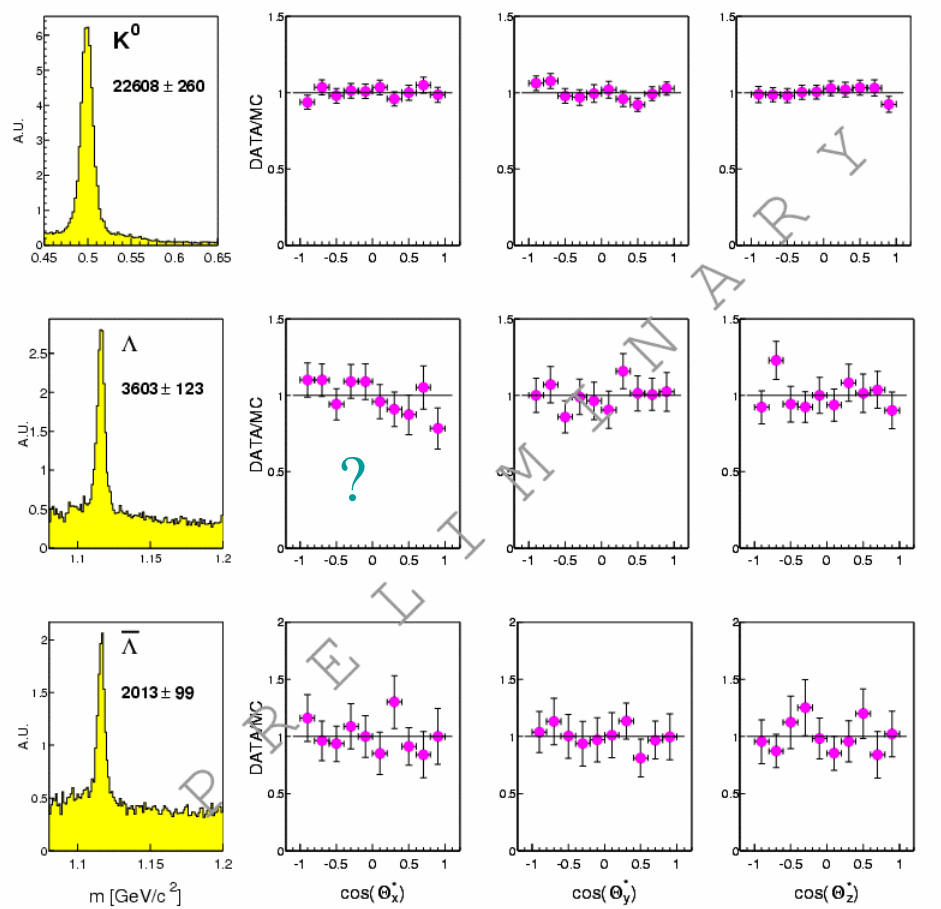
Lambda polarization (?)

mass $\cos\theta^*_x$ $\cos\theta^*_y$ $\cos\theta^*_z$

K^0

Λ

$\overline{\Lambda}$



Real data / Monte Carlo ratio

$Q^2 > 1\,\mathrm{GeV}^2$

$0.2 < y < 0.9$

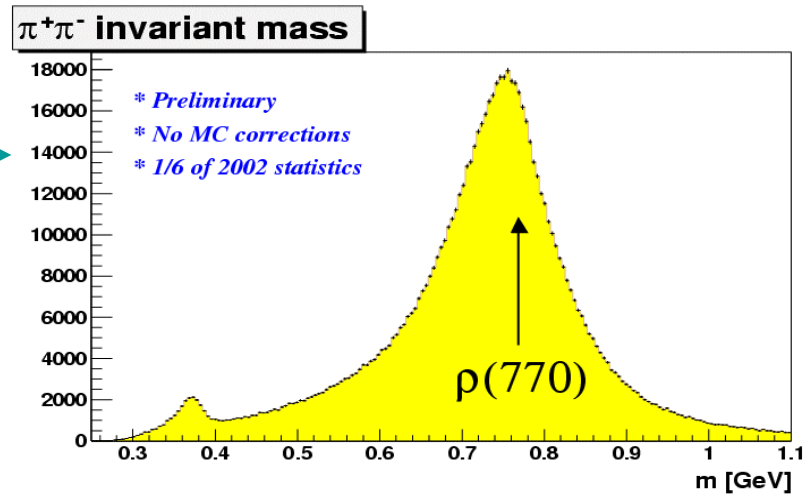
1/6 of 2002 data

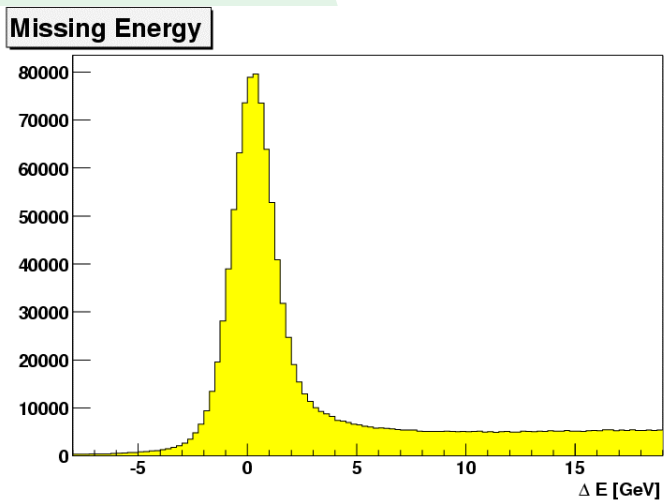
COMPASS 2002 data show good potential for Λ polarization measurements

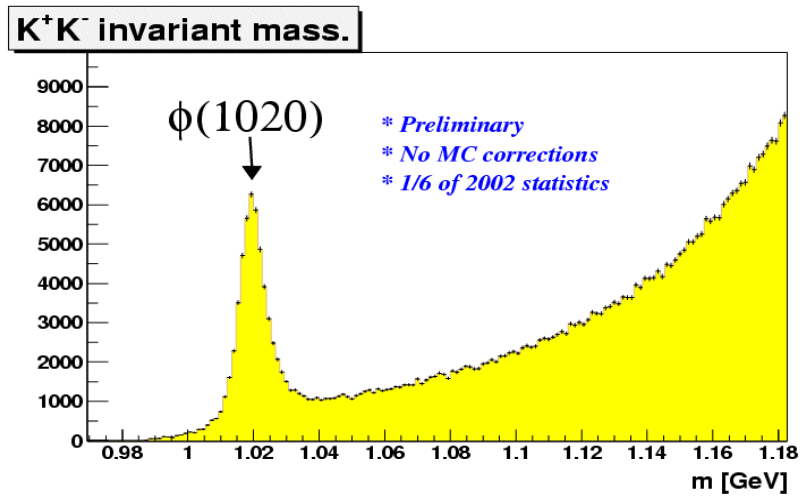
Exclusive ρ^0 and φ production

Skew shape of ρ^0 peak is due to interference between resonant ρ^0 production and "Drell type" background processes

$$\Delta E=(M^2_X - M^2_P)/2M_P$$

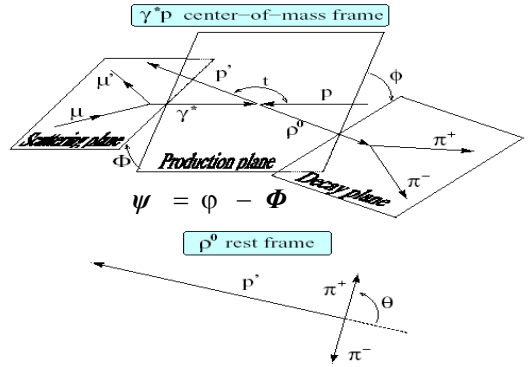






Angular distributions for $\rho^0 \to \pi\pi$

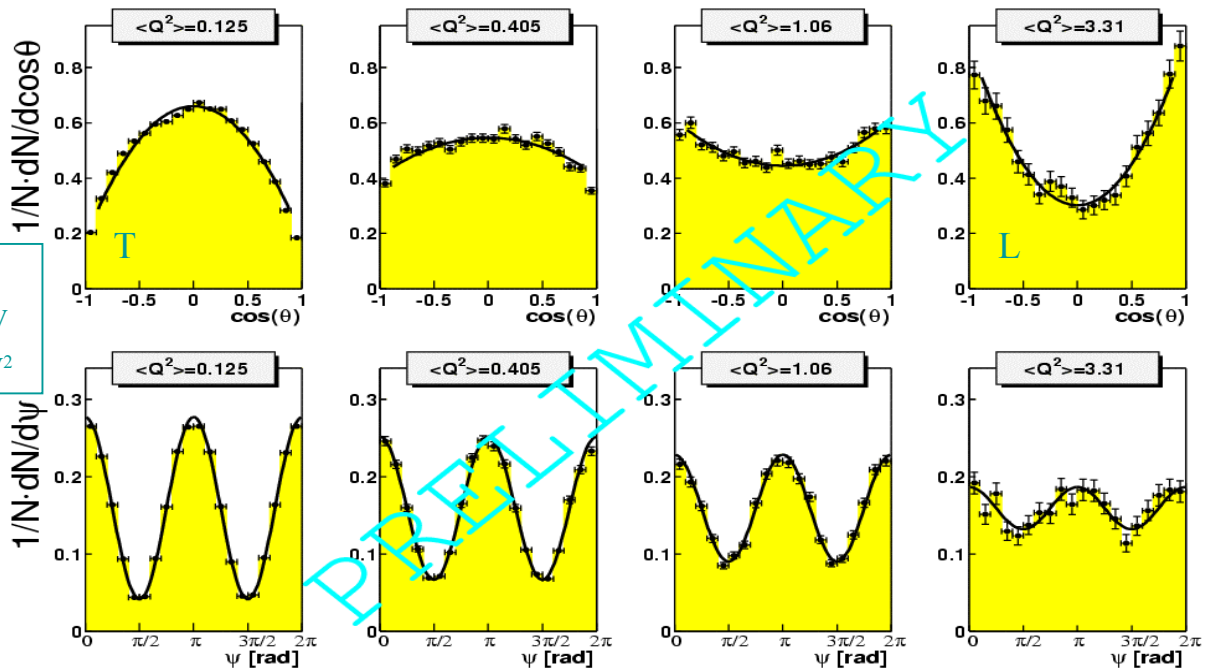
- Check polarization of vector meson:
  - small Q^2 – transversal polarization (as γ^*)
  - larger Q^2 – longitudinal polarization
- Confirm s-channel helicity conservation (all γ^* polarization goes to vector meson)
- First good data for small Q^2 (quasi real photon)



ρ^0 polarization

Cuts:
$P_T > 0.15$ GeV
$Q^2 > 0.05$ GeV^2

$\pi^+\pi^-$ emission in μ-scattering plane

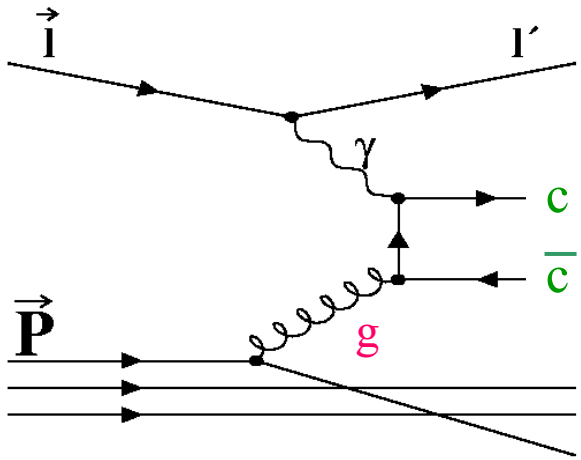


Open charm production

$D^{*\pm} \rightarrow D^0 + \pi^{\pm}_{slow}$ (Br = 67.7 %)

$\hookrightarrow K + \pi$ (Br = 3.8%)

Photon Gluon Fusion



Selection criteria:

- $Z_{D0} > 0.2$
- $|\cos(\Theta^*)| < 0.85$
- $10 < P_K < 35$ GeV
- K is identified by RICH

$D^{*\pm}$ and $D^0\bar{D}^0$ signals

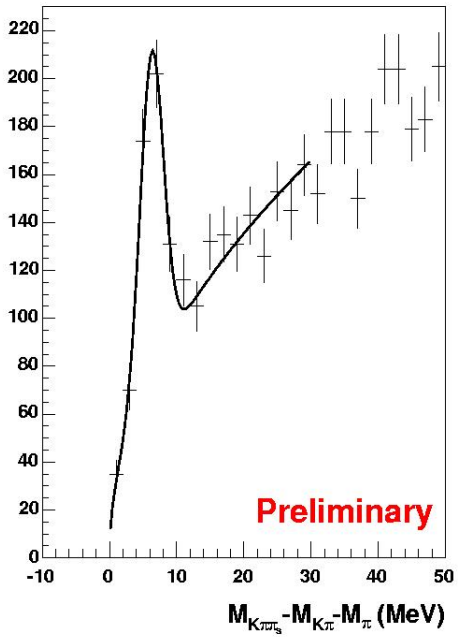
$$\Delta m = M(K\,\pi\,\pi_{slow}) - [M(K\,\pi\,) + M(\pi)] = M_{D^*} - M_{D0} - M_{\pi} = 5.85 \text{ MeV (PDG)}$$

$|\, M(K\pi) - M_{D0}\,| < 30$ MeV

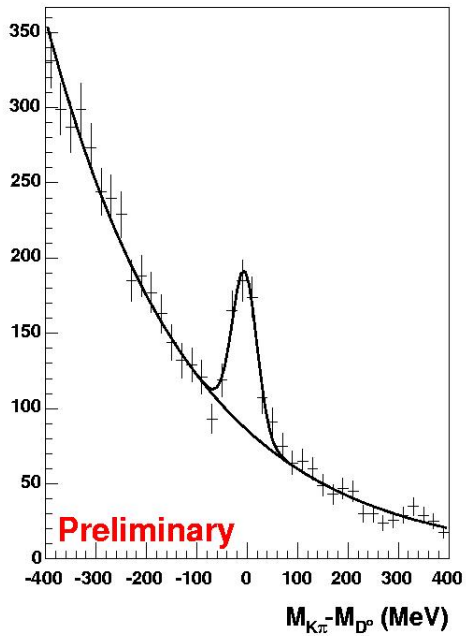
$3.1 < \Delta m < 9.1$ MeV

It is the first step towards extraction of gluon polarization in polarized nucleon ($\Delta G/G$)

$D^{*\pm}$



D^0



Future physics in COMPASS with hadron beams

Hadron beams 150-280 Gev/c

- Tests of χPT using Primakoff production (π scattering off virtual photons)

  π, K beams

- Light meson spectroscopy:
  - search for gluonic excitations ('glueballs')
  - search for exotics ('hybrids')

  π, K beams

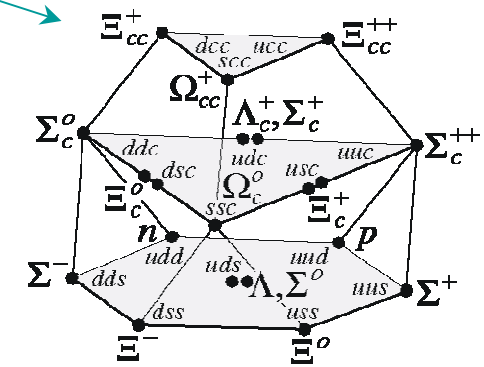
- Central Production of gluonic excitations of hadrons

  Proton beam

Future physics in COMPASS with hadron beams

- Double-charmed baryons
  - Spectroscopy
    - System in ground state is B-like
      (separate slow motion of heavy and fast motion of light quarks)
    - charmonium-like excitation via c-c excitation (tests dynamics of confinement)
    - Mass spectrum calculable rather reliably
  - Lifetimes
    - Prediction: $\tau(\Xi_{cc}^{+}) \leq \tau(\Omega_{cc}^{+}) \ll \tau(\Xi_{cc}^{++})$ where $\tau(\Xi_{cc}^{+}) \sim 400$ fs
    - First observation by SELEX experiment: $\tau(\Xi_{cc}^{+}) \sim 30$ fs

Proton beam



Summary

Status and perspectives

- COMPASS is up and running.
- Lots of high statistics data to come.
- First interesting results and good perspectives for physics with polarized target and polarized muon beam.
  - First glance at open charm production via photon-gluon fusion: key to measure $\Delta G/G$!
- Exciting program in hadron physics will follow.
- Physics program is broad and apparatus is flexible $\Rightarrow$ open to new ideas