First results on the longitudinal double spin asymmetry for identified hadrons from the 2011 COMPASS data

HK 9.4

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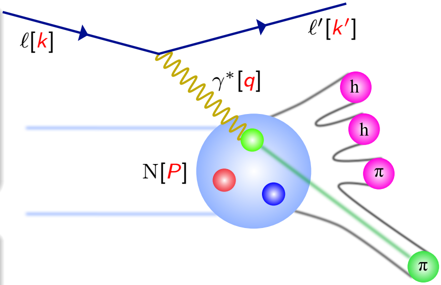
bmb+f - Förderschwerpunkt COMPASS Großgeräte der physikalischen Grundlagenforschung

Deep Inelastic lepton nucleon Scattering

- DIS: $\ell + N \longrightarrow \ell' + X$
- SIDIS: $\ell + N \longrightarrow \ell' + h + X$

DIS variables

- Photon virtuality: $\mathbf{Q^2 = -q^2}$
- Bjorken scaling variable: $\mathbf{x = \frac{Q^2}{2 \cdot P \cdot q}}$
- Relative photon energy: $\mathbf{y = \frac{E - E'}{E}}$



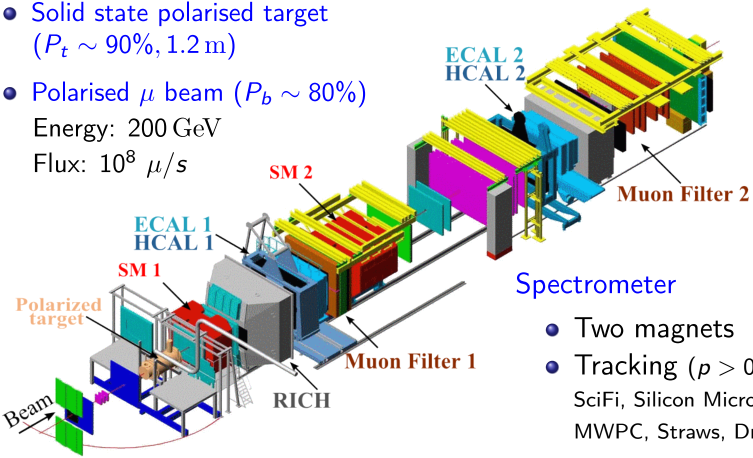
Hadron variables

- Hadron energy fraction: $\mathbf{z = \frac{E_h}{E - E'}}$
- Transverse momentum: $\mathbf{p_T}$
- Longitudinal momentum: $\mathbf{p_L}$

The COMPASS experiment

COmmon **M**uon and **P**roton **A**pparatus for **S**tructure and **S**pectroscopy

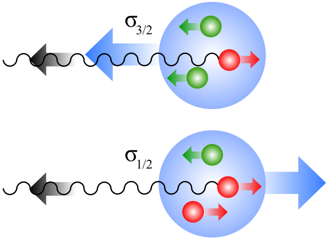
- M2 beamline
- Solid state polarised target
  ($P_t \sim 90\%, 1.2\,\mathrm{m}$)
- Polarised μ beam ($P_b \sim 80\%$)
  Energy: $200\,\mathrm{GeV}$
  Flux: $10^8\ \mu/s$



Spectrometer

- Two magnets
- Tracking ($p > 0.5\,\mathrm{GeV}/c$)
  SciFi, Silicon MicroMega, Gem, MWPC, Straws, Drift tubes
- PID: RICH(π, K, p)
  ECAL, HCAL, muon filters

Polarised Deep Inelastic Scattering



- Absorption of polarised photons
  $\sigma_{1/2} \sim q^+$
  $\sigma_{3/2} \sim q^-$
- Parton distributions:
  $q(x) = q(x)^+ + q(x)^-$
  $\Delta q(x) = q(x)^+ - q(x)^-$

- Photon nucleon asymmetry

$$A_1(x, Q^2) = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \overset{\text{LO}}{\approx} \frac{\sum_q e_q^2 (q(x)^+ - q(x)^-)}{\sum_q e_q^2 (q(x)^+ + q(x)^-)}$$

- Spin structure function

$$g_1(x, Q^2) = A_1(x, Q^2) \cdot F_1(x, Q^2) \overset{\text{LO}}{=} \frac{1}{2} \sum_q e_q^2 \Delta q(x)$$

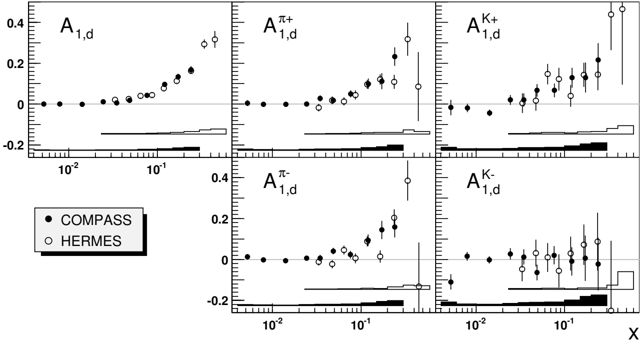
Hadron Asymmetries

$$A_1(x) = \frac{\sum_q e_q^2(\Delta q(x)+\Delta\overline{q}(x))}{\sum_q e_q^2(q(x)+\overline{q}(x))}$$

$$A_1^h(x,z) = \frac{\sum_q e_q^2\left(\Delta q(x)D_q^h(z)+\Delta\overline{q}(x)D_{\overline{q}}^h(z)\right)}{\sum_q e_q^2\left(q(x)D_q^h(z)+\overline{q}(x)D_{\overline{q}}^h(z)\right)}$$

- Calculate asymmetry for hadrons ($\pi^\pm, K^\pm$)
- Particle identification needed
- Use the RICH detector
- Determine identification efficiencies
- Access to all helicity distributions $\Delta q(x), \Delta\overline{q}(x)$
  $q = u, d, s$
- Dependence on fragmentation functions $D_q^h(z)$

Measured asymmetries



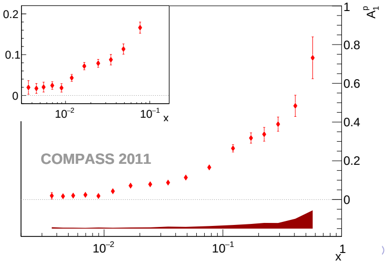
- $A^{\mathrm{h}}_{1,\mathrm{d}}$, $A_{1,\mathrm{d}}$ already measured

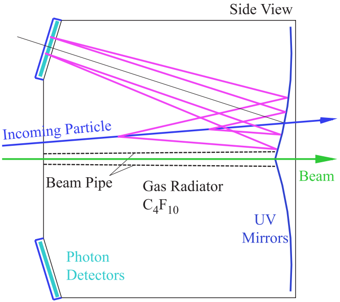
  PLB 680 (2009) 217

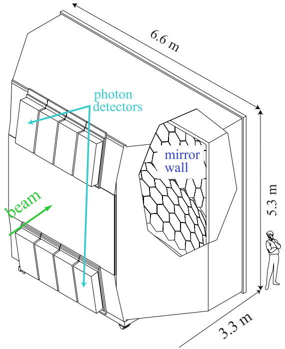
- $A^{\mathrm{h}}_{1,\mathrm{p}}$ needed to disentangle pol. PDFs

- $A_{1,\mathrm{p}}$ already published

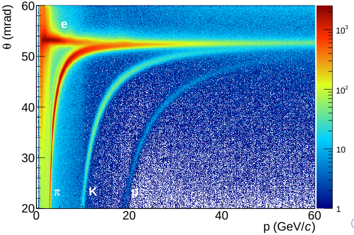
  PLB 753 (2016) 18







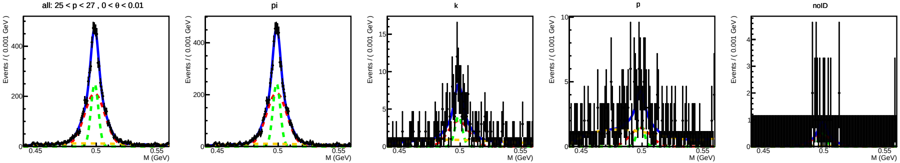
- Using the Cherenkov effect
- Ring projected on photo detectors
- Likelihood method for identification



Efficiency determination - method I

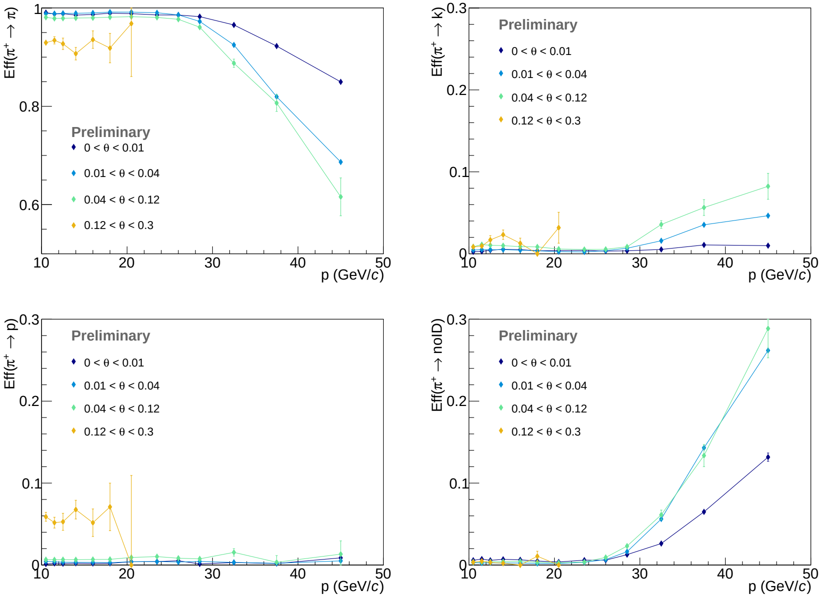
- Needed: Known particle ID without RICH information
- Use:
  - $K^0 \longrightarrow \pi^+\pi^-$
  - $\phi \longrightarrow K^+K^-$
  - $\Lambda \longrightarrow \pi^- p$
- Tag one of the decay particles using the RICH (e.g. π^- from K^0 decay)
- ID of the second particle known (must be π^+)
- Check the answer from the RICH (Identified as $\pi/K/p/\mathrm{noID}$)
- Assumption Efficiency depends mainly on particle momentum and entry angle
  - Strong momentum dependence: 13 bins ($10 - 50\,\mathrm{GeV}/c$)
  - Weak angular dependence: 4 bins ($0 - 0.3\,\mathrm{rad}$)

Efficiency determination - method II



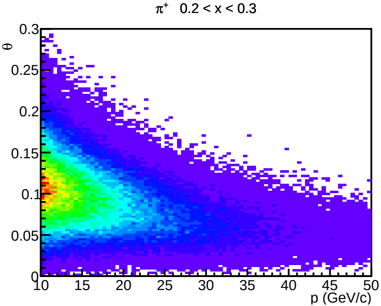
- Fit of the invariant mass spectra
- Fit simultaneously all five histograms
- Constrain on $N(all) = N(\pi) + N(K) + N(p) + N(\mathrm{noID})$
  $\rightarrow$ Efficiency between 0% and 100%
- Efficiency $\epsilon(\pi^+ \rightarrow K^+) = N(\pi \rightarrow K)/N(all)$
  - $N(all)$ constrained by first histogram (all particles)
  - $N(\pi \rightarrow K)$ from third histogram (π identified as K)

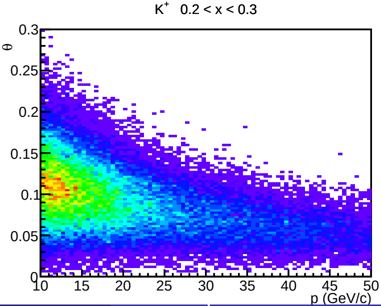
RICH efficiency



Purity determination

- Coverage in the angle θ and momentum p
- Only one x-bin shown
- So far: RICH efficiency
  $\rightarrow$ detector property
- Needed: Purity/Contaminations
  $\rightarrow$ physics quantity
- Determined by:
  - Number of true hadrons
  - Number of Identified hadrons
  - RICH efficiency





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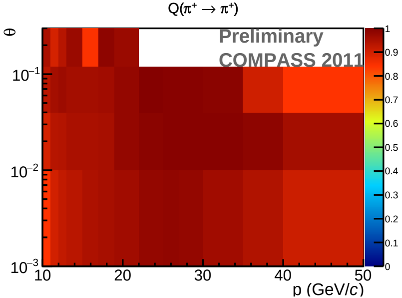

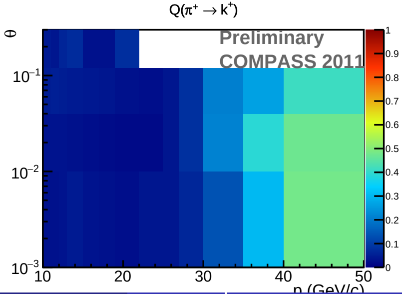

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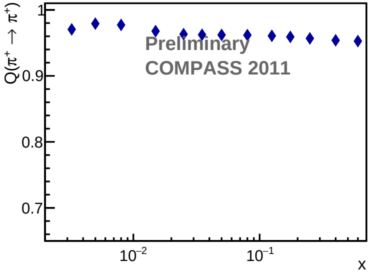

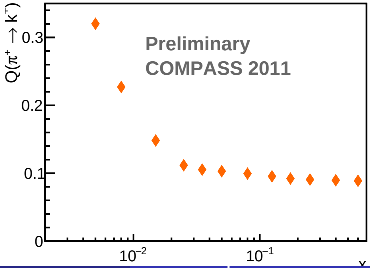

Summary and Outlook

- Identified hadron asymmetries
  - Method for extracting RICH efficiencies
  - Determination of the hadron purities
- Outlook
  - Final results for the identified hadron asymmetries
  - Extraction of polarised PDFs for each flavour