# Extraction of Quark Fragmentation Functions in Leading Order at COMPASS

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HK 47.1

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On behalf of the COMPASS collaboration

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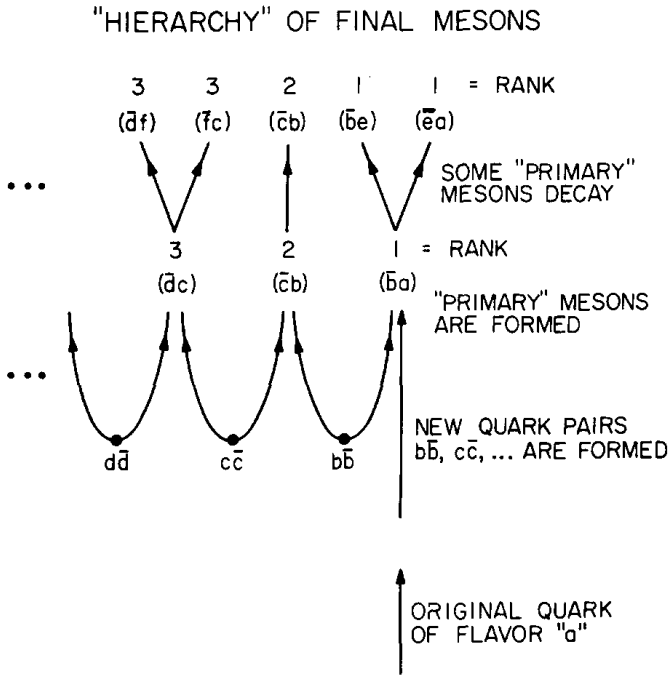
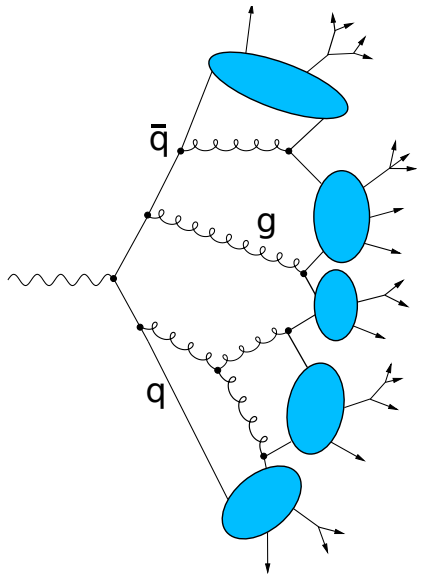
# Hadronisation Process

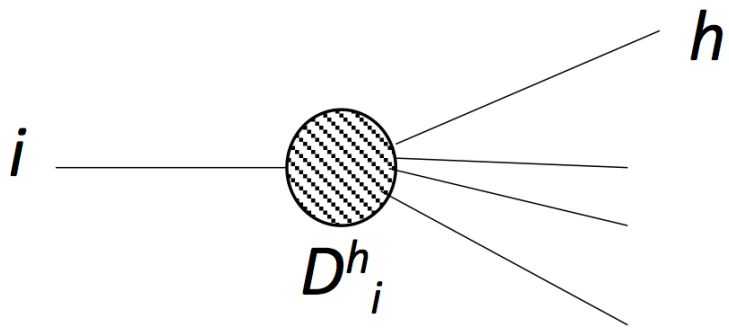
- Quark production, but no free quarks observed
- Hadronisation process
- Different hadronisation models: Field-Feyman-model, Lund-String model, Cluster model
- Input for Monte Carlo




**Described by *fragmentation functions*** $D_i^h$

# Properties of Fragmentation Functions




- Universal and process independent
- Charge and momentum conservation
- Favoured and unfavoured FFs
- *e.g.* $D_s^{K^-}$ is favoured FF
- Expectation: $D_{fav} > D_{unfav}$
- Fundamental properties
- Inverse of PDF $q(x)$

$$\sum_h \int_0^1 z D_i^h(z)\, dz = 1$$

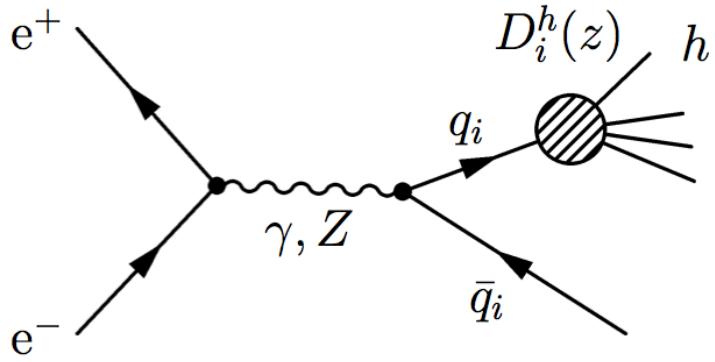
$$\sum_h \int_0^1 e_h D_i^h(z)\, dz = e_q$$

$$s \to \begin{pmatrix} s \\ \bar{u} \end{pmatrix} = \text{favoured}$$

# How to Access Fragmentation Functions

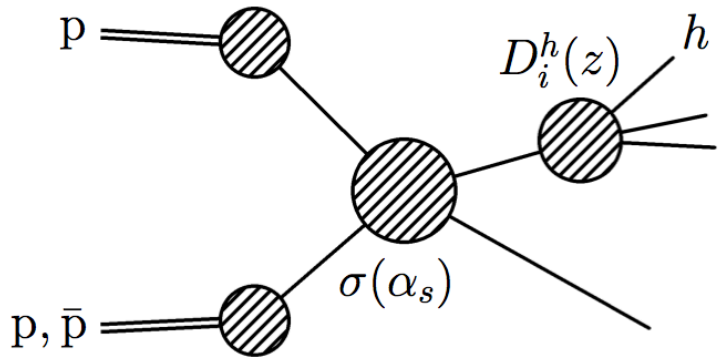
## $e^+e^-$ annihilation

Precise and clean data
Only depends on FF
$q\bar{q}$ fragmentation not distinguishable
Charge sum
(LEP, BELLE,...)



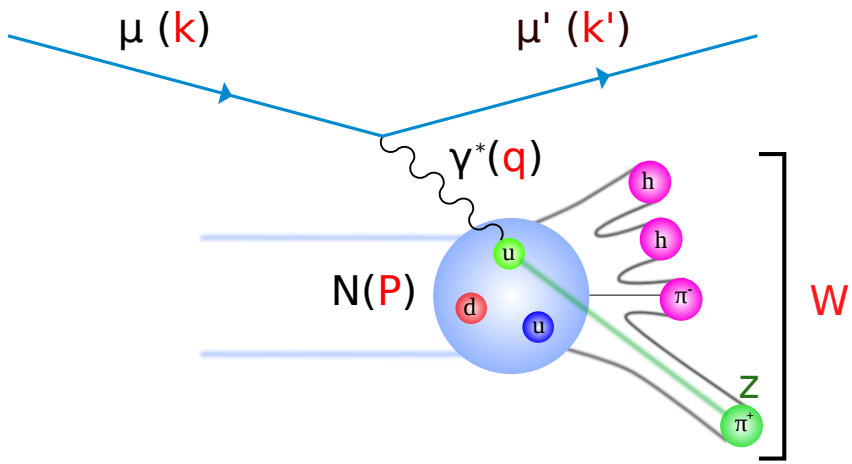

## pp collision

Gluon FF
Strongly dependant on PDFs
Difficult theoretical description
(RHIC, Fermi Lab., ...)



$$\text{SIDIS:} \Rightarrow \ell + N \xrightarrow{\gamma^*} \ell' + h + X$$

- High energy lepton on nucleon
- QPM: lepton scatters off one quark
- Quark fragmentation
- Allows flavour separation




## Kinematic

| | | | |
|---|---|---|---|
| $x$ | = | $\frac{Q^2}{2P\cdot q}$ | Bjorken scaling variable |
| $y$ | = | $\frac{E-E'}{E}$ | relative photon energy |
| $Q^2$ | = | $-q^2$ | four-momentum transfer |
| $z$ | = | $\frac{E_h}{E-E'}$ | hadron energy fraction |

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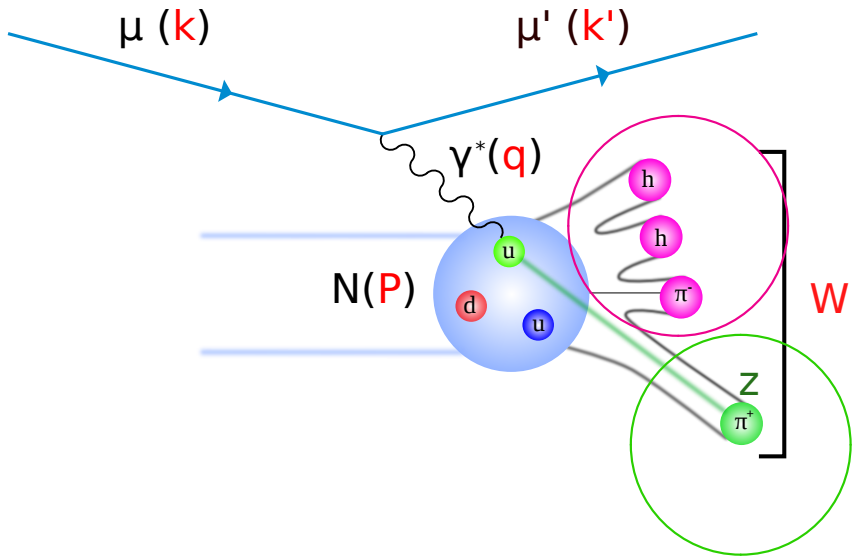


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Cut on z to separate quark fragmentation and target fragmentation

# Multiplicities as Observable

- Factorisation ansatz
- SIDIS cross section in leading-twist

Hard scattering cross section
Parton distribution function
Fragmentation functions

$$\sigma^{\mathrm{h}} = \sum_i e_i^2 \sigma^0 \cdot q_i(x) \cdot D_i^h(z)$$

Extraction of FF from hadron multiplicities

$$M^h(x,z) = \frac{1}{\sigma^{DIS}} \frac{d\sigma^h}{dx\,dz} = \frac{\sum_i e_i^2\, q_i(x)\, D_i^h(z)}{\sum_i e_i^2\, q_i(x)}$$

Depends on the parton distribution functions $q_i(x)$

- Up/down PDFs well known
- Strange PDFs poorly known

# The COMPASS Experiment

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

Fixed target experiment (Forward spectrometer) @CERN

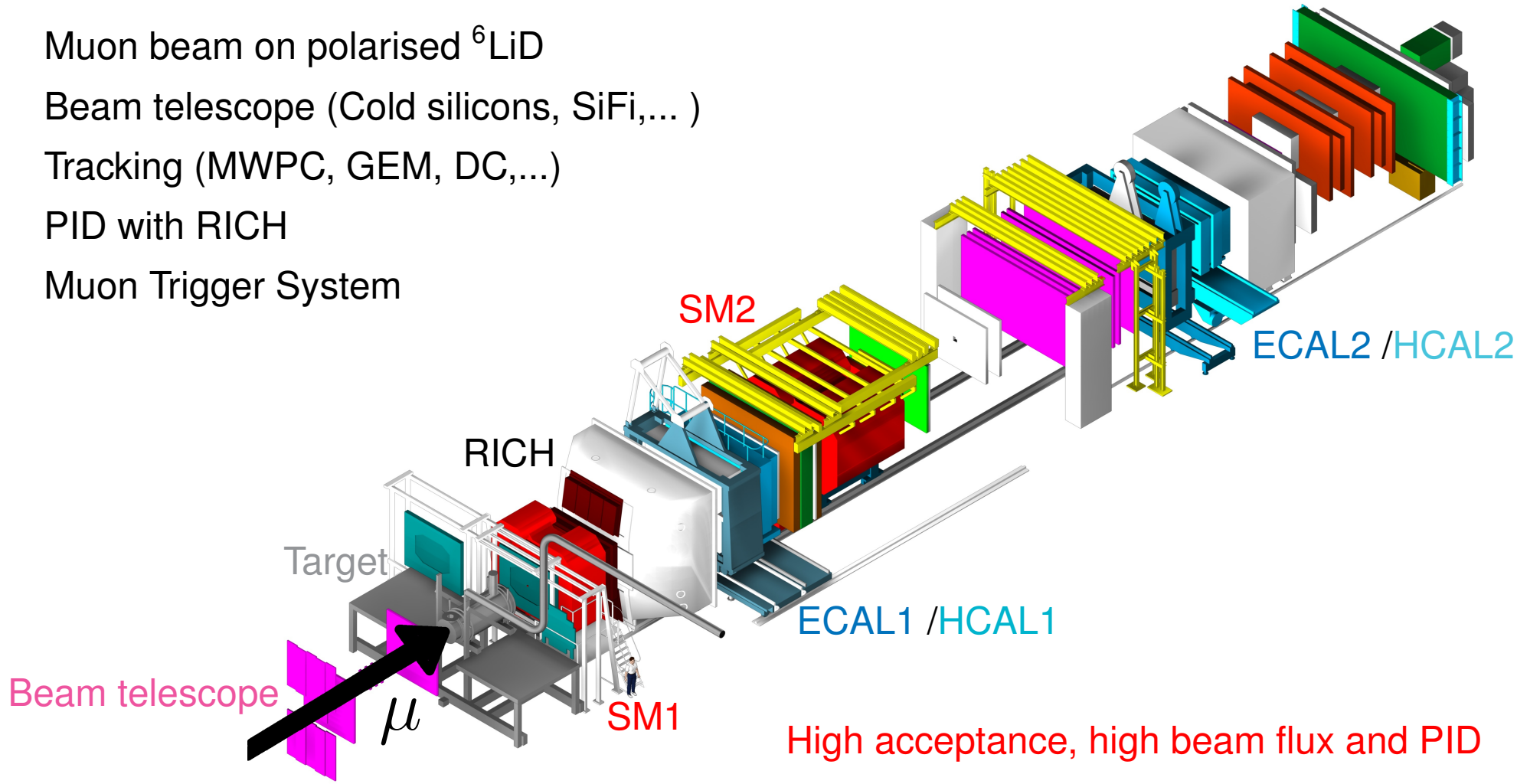
Muon beam on polarised $^{6}$LiD

Beam telescope (Cold silicons, SiFi,... )

Tracking (MWPC, GEM, DC,...)

PID with RICH

Muon Trigger System




High acceptance, high beam flux and PID

CERN-PH-EP/2007-001 hep-ex/0703049

# Data Selection

6 weeks of data taking 2006 on $^6\vec{\text{LiD}}$ target with 160 GeV muon beam
Average over target polarisation

- DIS cuts:

$Q^2 > 1$ GeV$^2$
$0.1 < y < 0.7$
$0.004 < x < 0.7$
$\Rightarrow W > 5$ GeV

- Semi-inclusive cuts:

$0.2 < z < 0.85$
$12 < P_h < 40$ GeV
(RICH)

- Analysis method

3-dimensional binning (x,y,z)
Get raw hadron multiplicities $M^h(x,y,z) = \frac{N^h(x,y,z)}{N_{DIS}(x,y)}$
(Un)identified hadrons

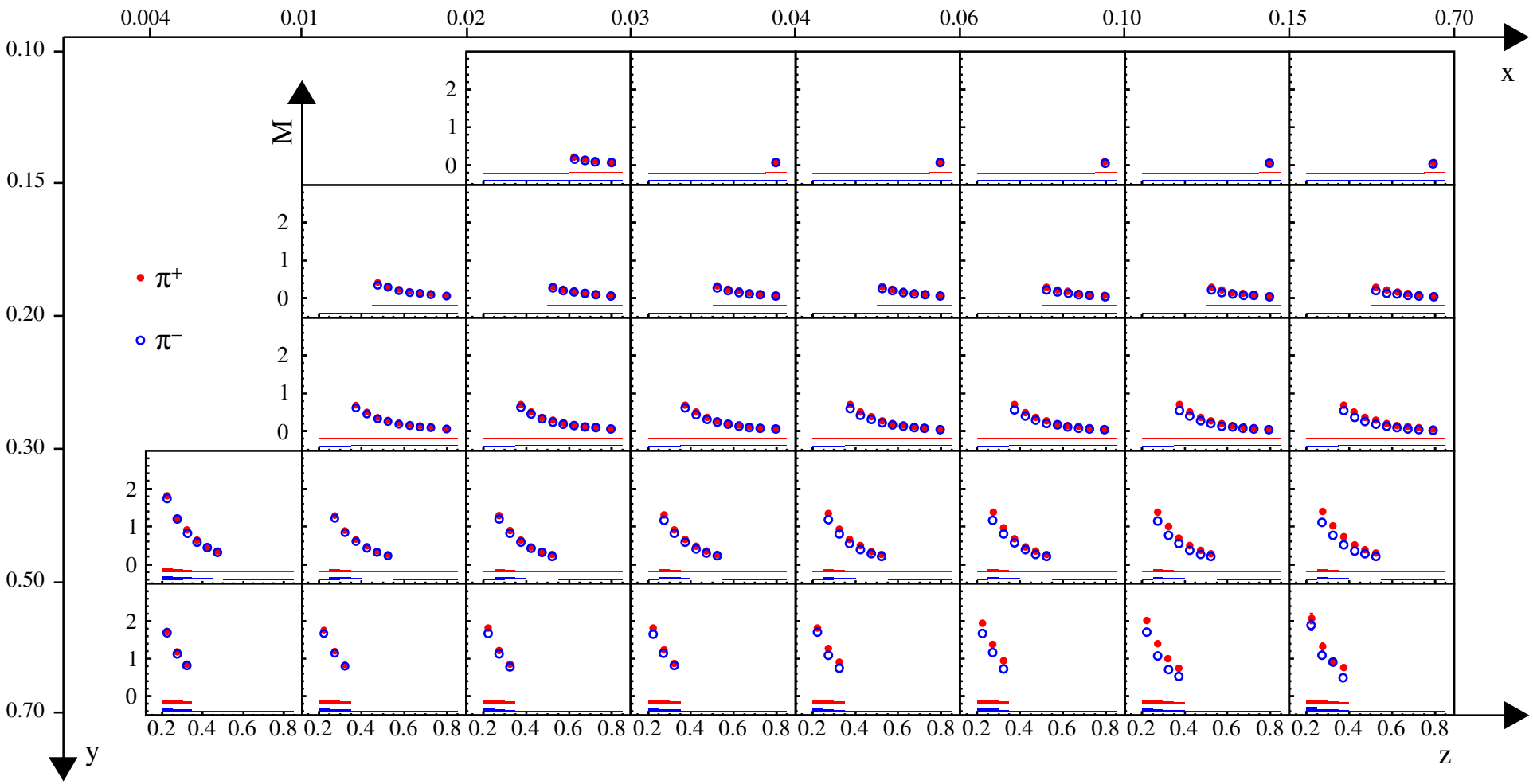
$\Rightarrow M^\pi(x,y,z)$ and $M^h(x,y,z)$

# Correction Factors and Systematic Uncertainties

- **Radiative corrections:** $1\gamma$ exchange approach
- **Acceptance correction:** From Monte Carlo simulation using LEPTO, JETSET and GEANT3
- **PID correction:** Momentum dependent RICH efficiencies from data
- **Particle contamination:** Correction for electrons ($e \rightarrow \pi$) and exclusive vector mesons ($\rho_0 \rightarrow \pi^{\pm}$). LEPTO and HEPGEN
- **Momentum extrapolation:** adding multiplicities of the non-measured range

Total systematic uncertainties reaches from 1-5 % for pions

# Results of Charged Pion Multiplicities PRELIMINARY!



# Extraction of Fragmentation Functions in Leading Order

## From charge and isospin symmetry of isoscalar target ($^6$LiD)

$$D_{\text{fav}} = D_u^{\pi^+} = D_{\bar{d}}^{\pi^+} = D_d^{\pi^-} = D_{\bar{u}}^{\pi^-}$$

$$D_{\text{unf}} = D_d^{\pi^+} = D_{\bar{u}}^{\pi^+} = D_u^{\pi^-} = D_{\bar{d}}^{\pi^-} = D_s^{\pi^\pm} = D_{\bar{s}}^{\pi^\pm}$$

## Multiplicities in LO

$$M(\pi^+) = \frac{(4(u+d)+\bar{u}+\bar{d})D_{\text{fav}} + (u+d+4(\bar{u}+\bar{d})+2(s+\bar{s}))D_{\text{unf}}}{5(u+d+\bar{u}+\bar{d})+2(s+\bar{s})}$$

$$M(\pi^-) = \frac{(u+d+4(\bar{u}+\bar{d}))D_{\text{fav}} + (4(u+d)+\bar{u}+\bar{d}+2(s+\bar{s}))D_{\text{unf}}}{5(u+d+\bar{u}+\bar{d})+2(s+\bar{s})}$$

## Fit on FF

$\chi^2$ Fit on experimental multiplicities
Fit at $Q_0^2$ and evolution to all $Q^2$ with DGLAP
$zD_{\text{fav}} = zD_{\text{unf}} = \mathcal{N} z^\alpha (1-z)^\beta [1+\gamma(1-z)^\delta]$

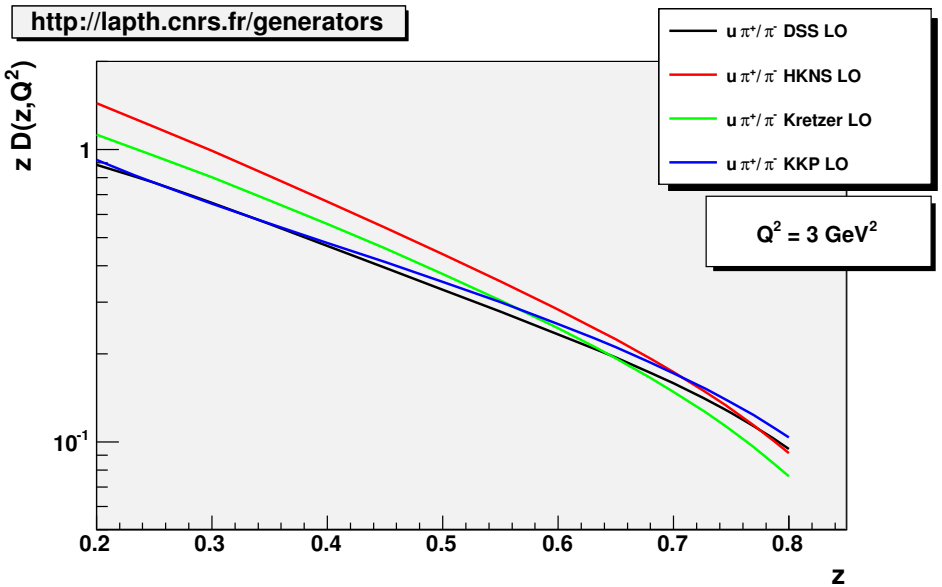
**DSS:**
( D. de Florian, R. Sassot and M. Stratmann)
$e^+e^-$, pp, SIDIS

**Kretzer:**
( S. Kretzer)
$e^+e^-$

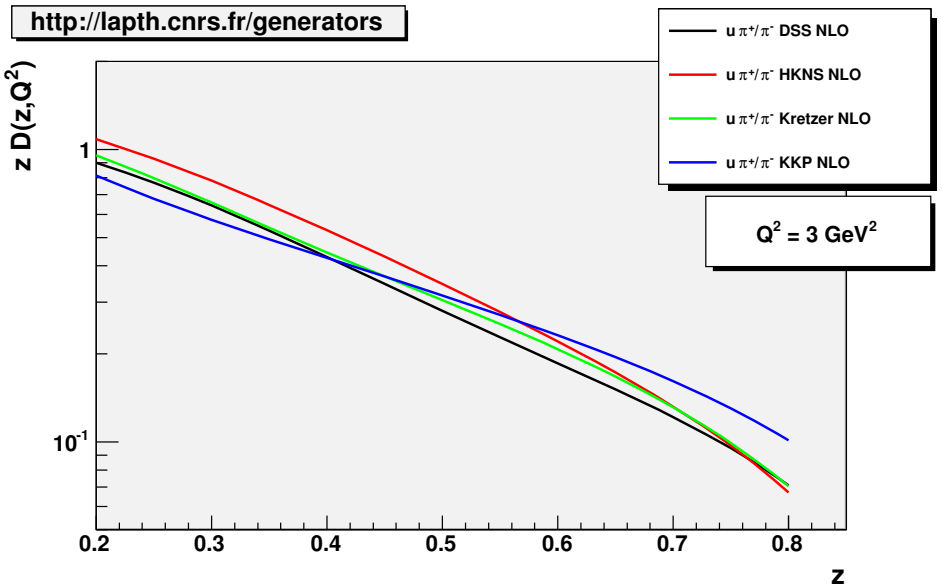
**HKNS:**
(M. Hirai, S. Kumano, T. H. Nagai and K. Sudoh)
$e^+e^-$

**KKP:**
(B. Kniehl, G. Kramer and B. Potter)
$e^+e^-$

$u \to \pi^+ + \pi^-(LO)$




$u \to \pi^+ + \pi^-(NLO)$



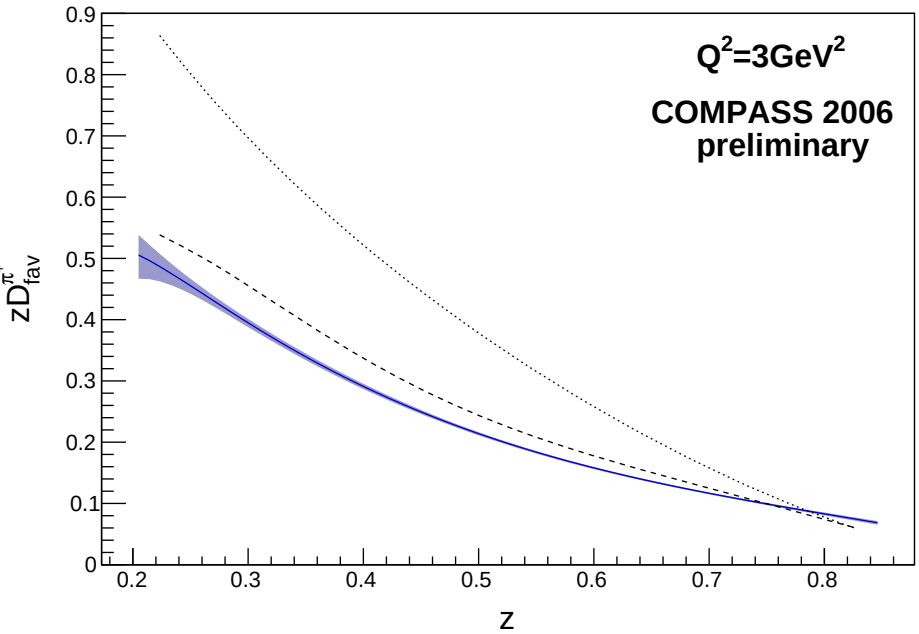
# Fit Result of FF in LO

COMPASS fit

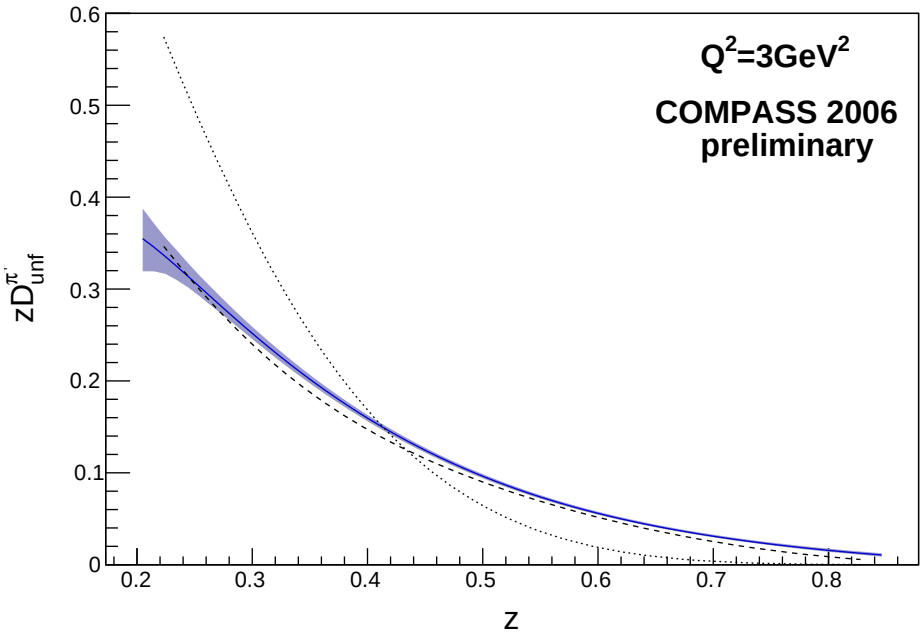
DSS D. de Florian, Phys. Rev. **D75** (2007)

HKNS Hirai et al. ,Phys. Rev. **D75** (2007)

favoured




unfavoured




- COMPASS data fit with statistical error only
- $D_{fav} > D_{unf}$
- Poor agreement with HKNS
- Good agreement with DSS

# Summary and Outlook

- Hadronisation process and fragmentation functions
- Introduction to semi-inclusive deep inelastic scattering (SIDIS)
- High statistic charged pion multiplicities at COMPASS
- Extraction of the LO FF

- Charged kaon multiplicities very soon
- $K^0$ multiplicities by D. Hahne (HK 40.3)
- More data of upcoming run with liquid hydrogen target 2016

**Thanks for your attention**

# Backup: Comparison $D_{unf}$ and $D_{fav}$