Summay of Session 2

QCD spin structure of nucleons

Summary Session 2

Introduction

Helicity distributions

Gluon polarisation

transversity

Summary of Session 2

- six excellent plenary talks:
  Metz, Barone, Garçon, Hasch, Bressan, Saito

- 55 talks in parallel sessions, 16 h
  - half experiment / half theory
- exp. talks: about 2/3 ℓp, 1/3 pp
- theo. talks: about 1/3 on transversity and SSA

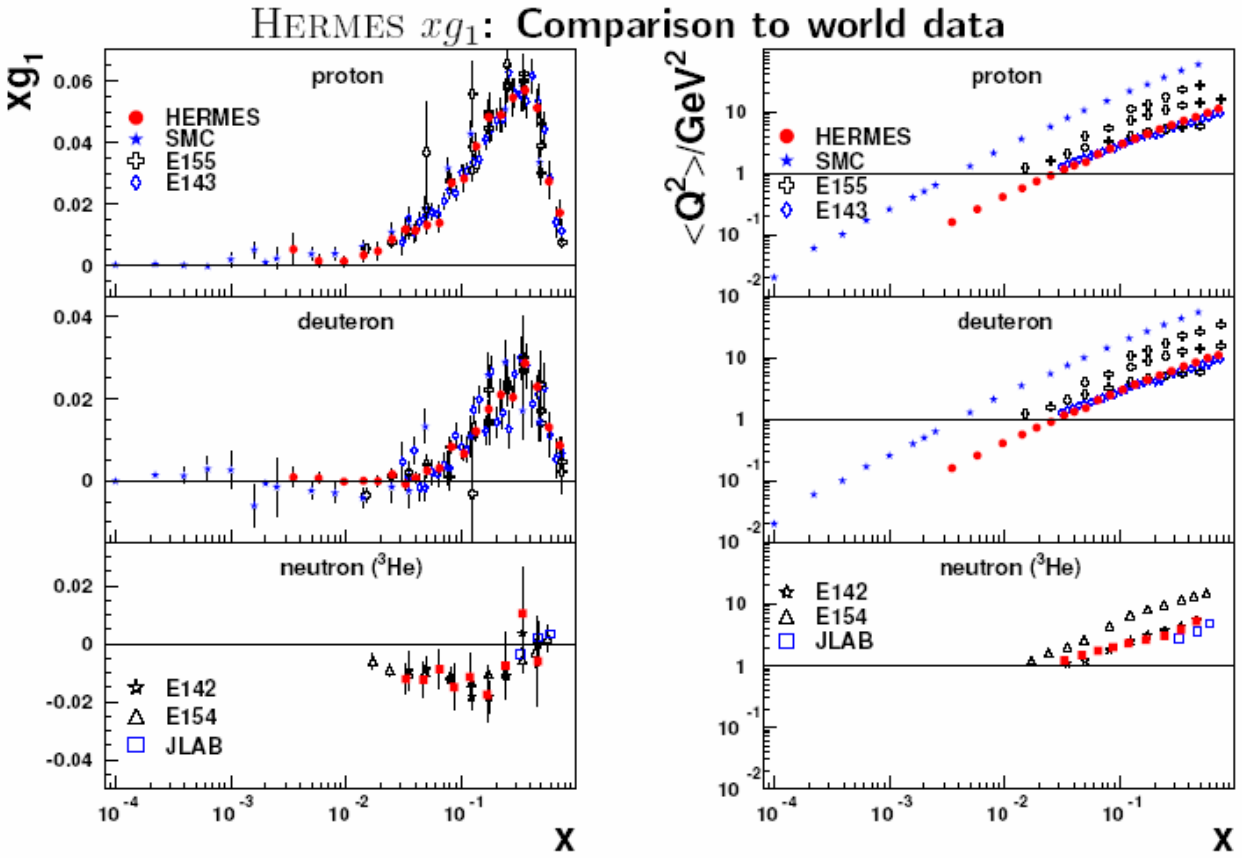
Apologies for not being able to cover everything appropriately

HELICITY DISTRIBUTIONS

Final g_1 for p, d, n

Riedl

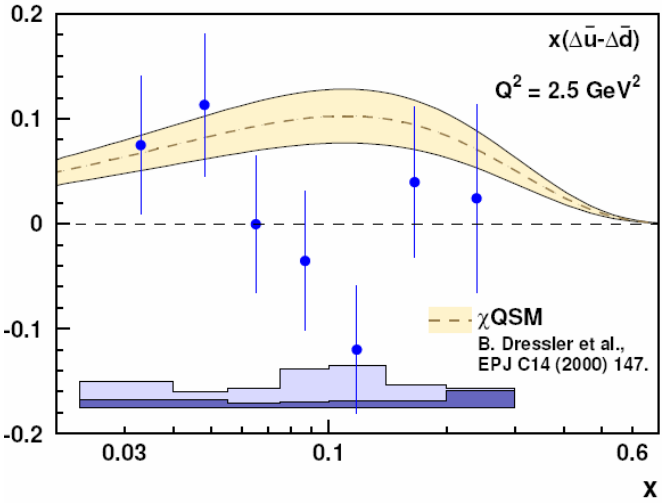
- quasi final data set for p and d
- corrected for smearing (radcor, detector)

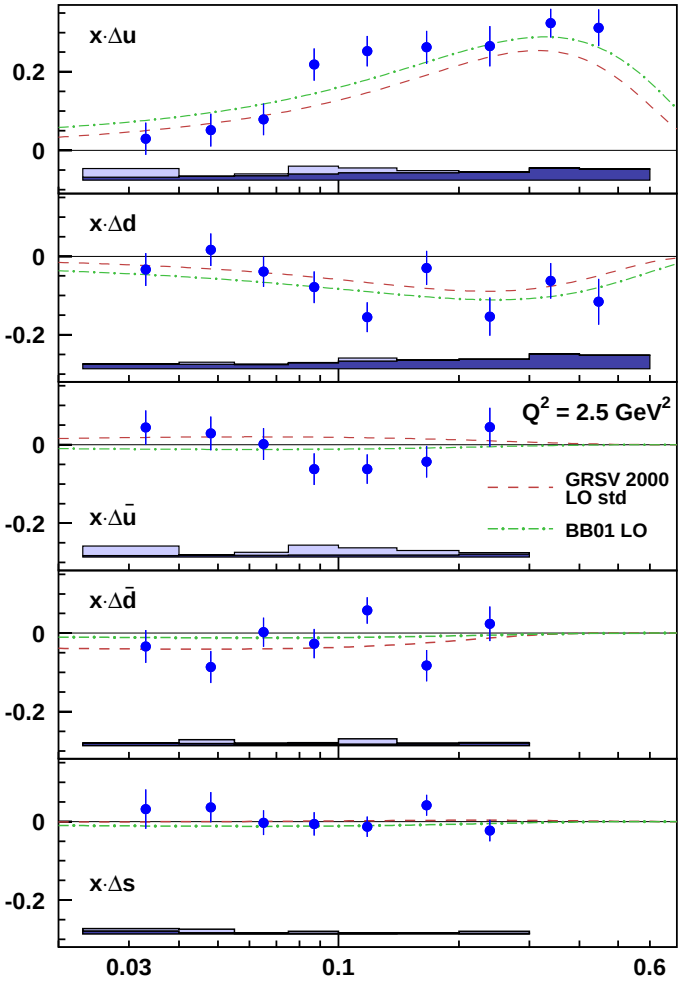


Quark helicity distributions

Rubin

$$x(\Delta\bar{u} - \Delta\bar{d})$$

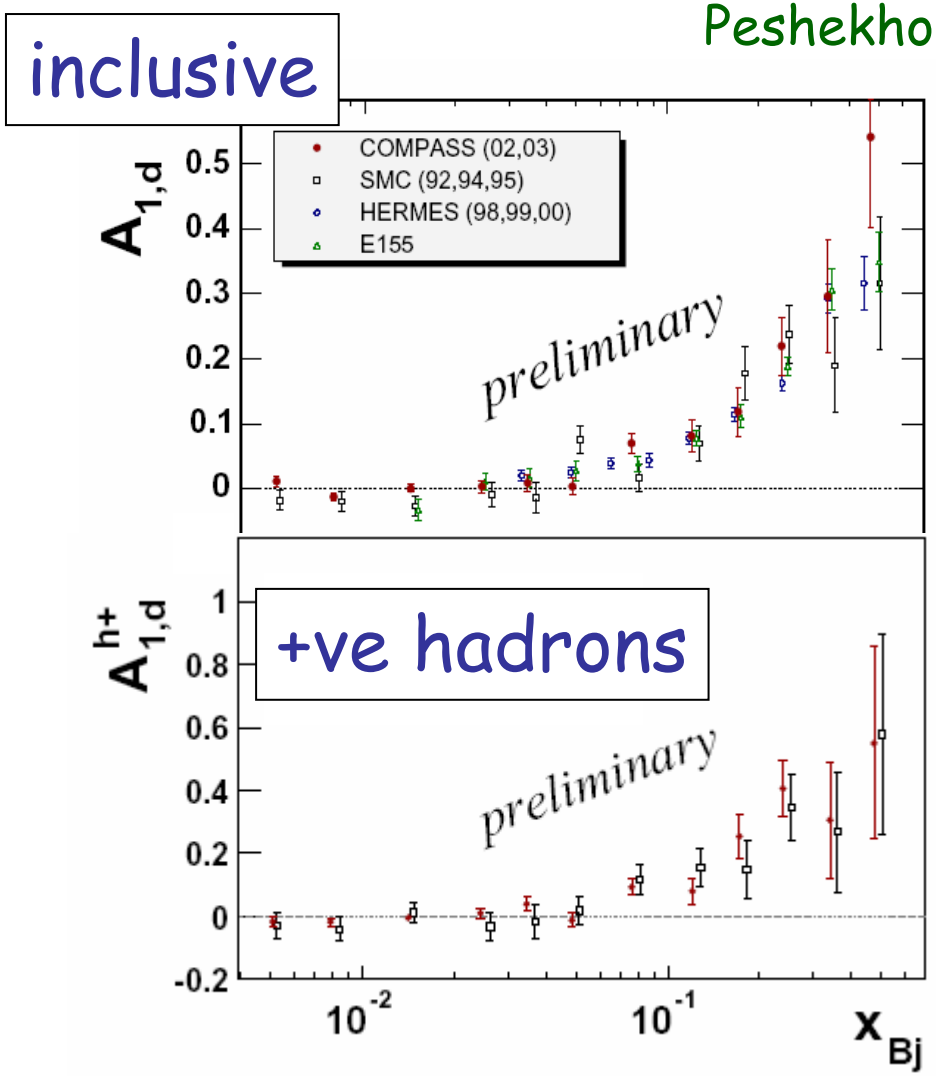




Inclusive asymmetries

Peshekhonov

- COMPASS deuteron data 2002 – 2003
- most precise data for $x<3\times10^{-2}$
- 2004 similar precision
- kaon/pion asymmetries to come



Δq - Theory

- method using $A^{\pm}$ and moments to determine Δq — Shevchenko
- model-independent determination of Δq from incl. and semi-incl. asym. in LO and NLO. Fragmentations functions cancel in — Christova

$$A_N^{h^+-h^-} = \frac{\Delta\sigma_N^{h+} - \Delta\sigma_N^{h-}}{\sigma_N^{h+} - \sigma_N^{h-}}$$

needs very precise data (➔Jlab)

remark: $A^{\pm}$ exp. diffcult with magnetic spectrometers

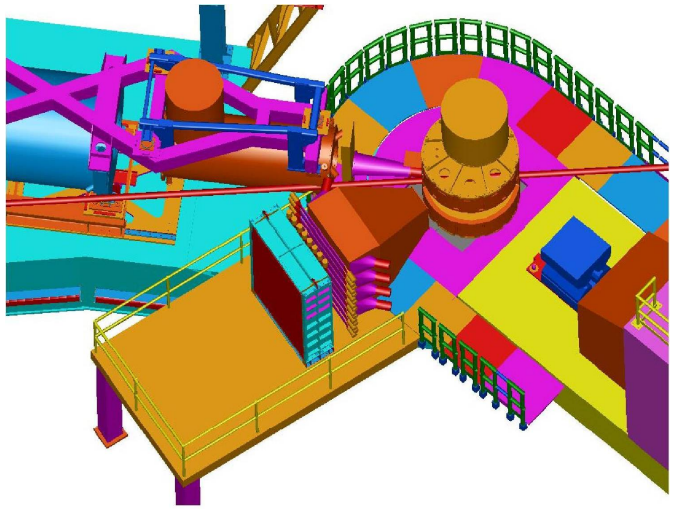
Δq - JLAB

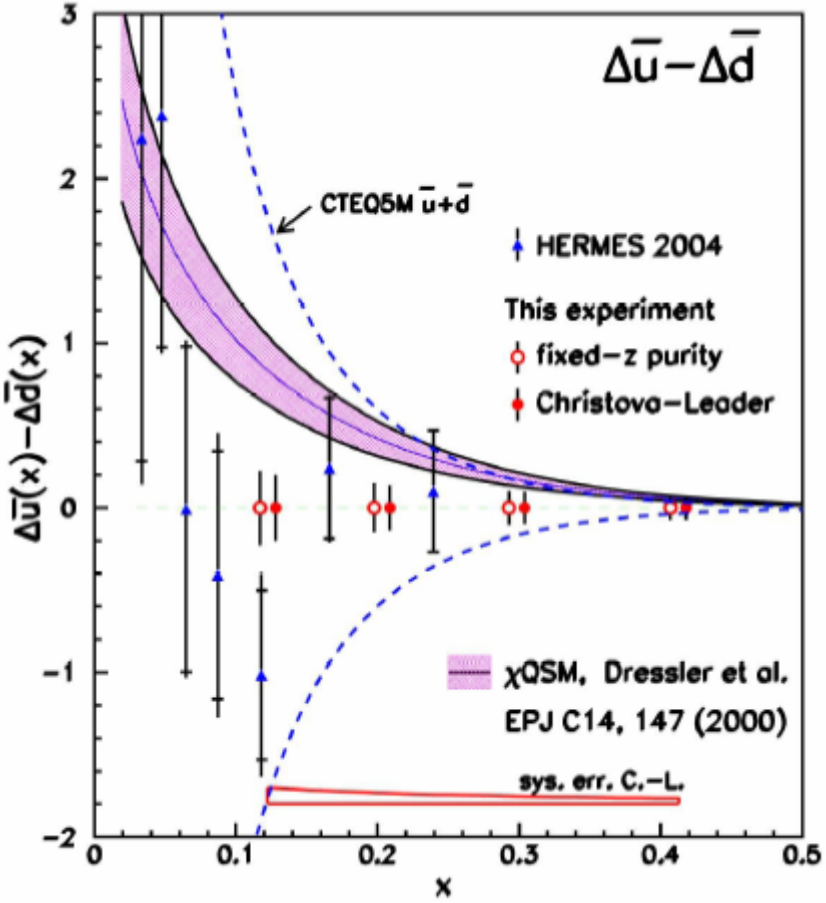
Jiang

Semi-SANE E04-113

$\Delta\bar{u} - \Delta\bar{d}$

- under construction (2006-2007)
- expect very precise data for $x > 0.1$
- apply $A_N^{h^+ - h^-}$ method



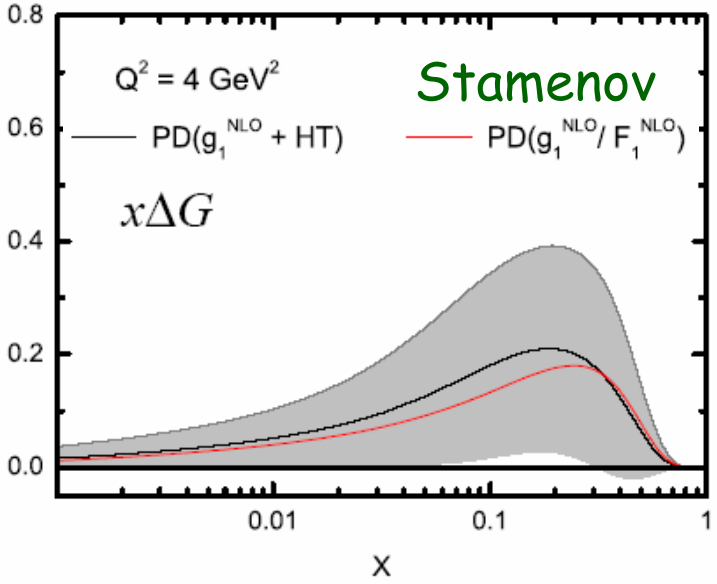


Evolution

- role of higher twist in the determination of PDF. HT cancels largely in A_1

.

- small-x evolution: double logarithm resummation important for g_1 for $x \leq 10^{-3}$ -10^{-4}



Ermolaev

•parametrisation-independent matrix solution of DGLAP

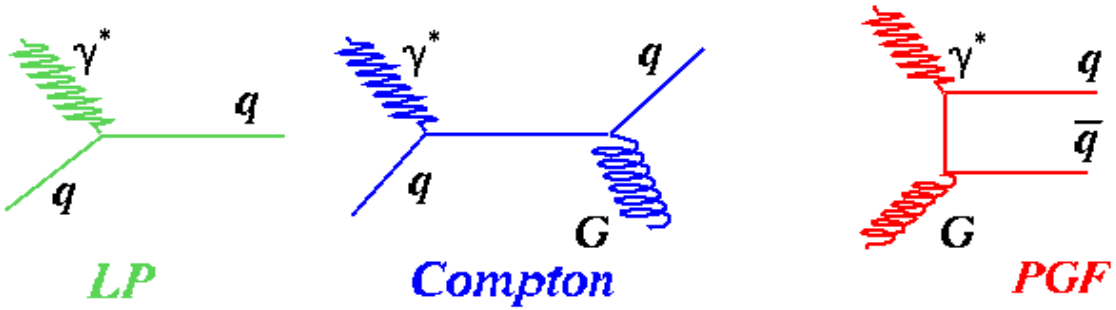
Goshtasbpour

•estimates of $\Delta G/G$ and L_q ranges

Ramsey

GLUON POLARISATION

ΔG/G - Photon-Gluon Fusion



$$A^{\ell h \to \ell h h X} = \frac{\Delta G}{G}\langle \hat{a}_{LL}\rangle^{PGF} R_{PGF} + \frac{\Delta q}{q}\left\{\langle \hat{a}_{LL}\rangle^{LP} R^{LP} + \langle \hat{a}_{LL}\rangle^{QCDC} R^{QCDC}\right\}$$

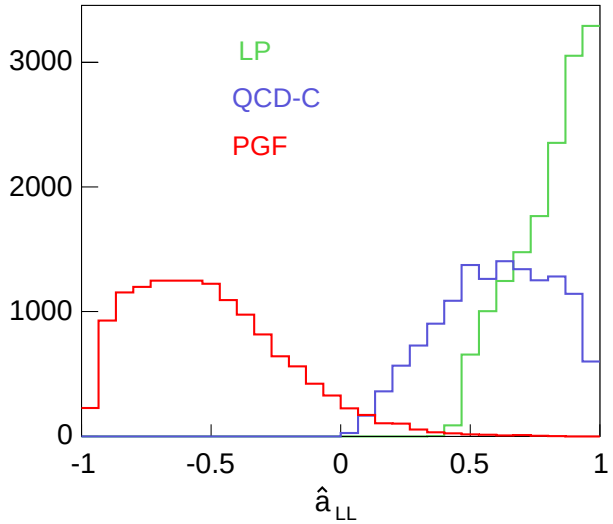
measured

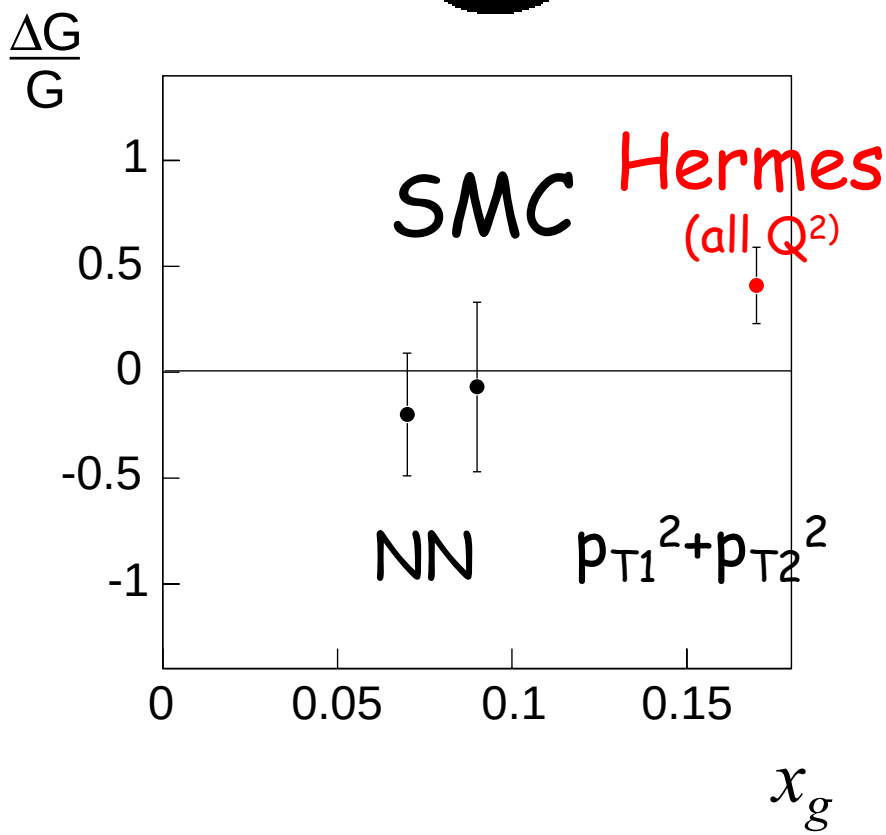
a_{LL}: calculable partonic asymmetries

R: Monte-Carlo (Lepto for $Q^2 > 1$ GeV^2)

$\Delta G/G$ - SMC

- event selection high-p_T pairs
  - $Q^2 > 1$ GeV^2
  - neural network
  - $\Sigma p_T^2 > 2.5$ GeV^2
- $R^{PGF} = 0.32$

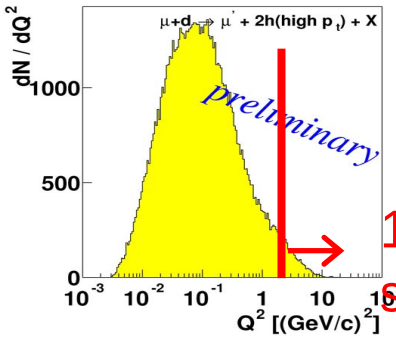




ΔG/G - COMPASS

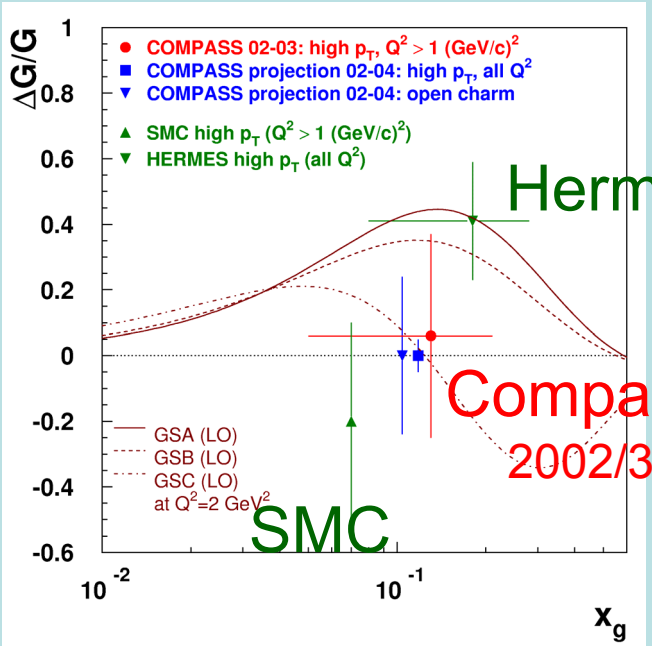
Schill

- Analysis a la SMC
  - $\Sigma p_T^2 > 2.5$ GeV², $Q^2 > 1$ GeV²
- open charm signal



10% of statistics

2002/3

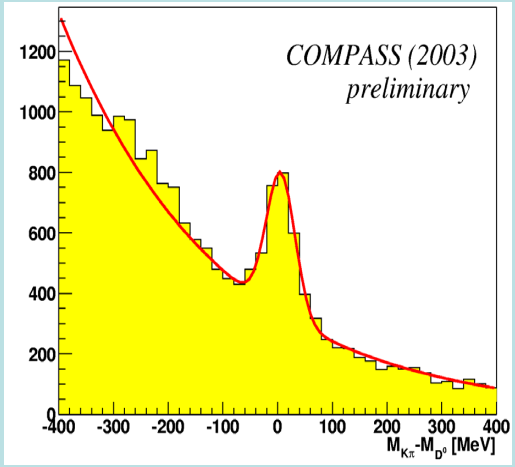


Hermes

Compass 2002/3

SMC

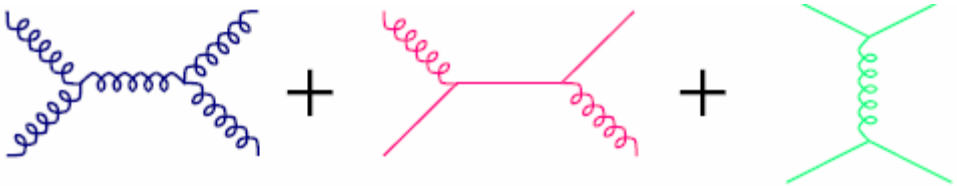
PGF: cc →open charm



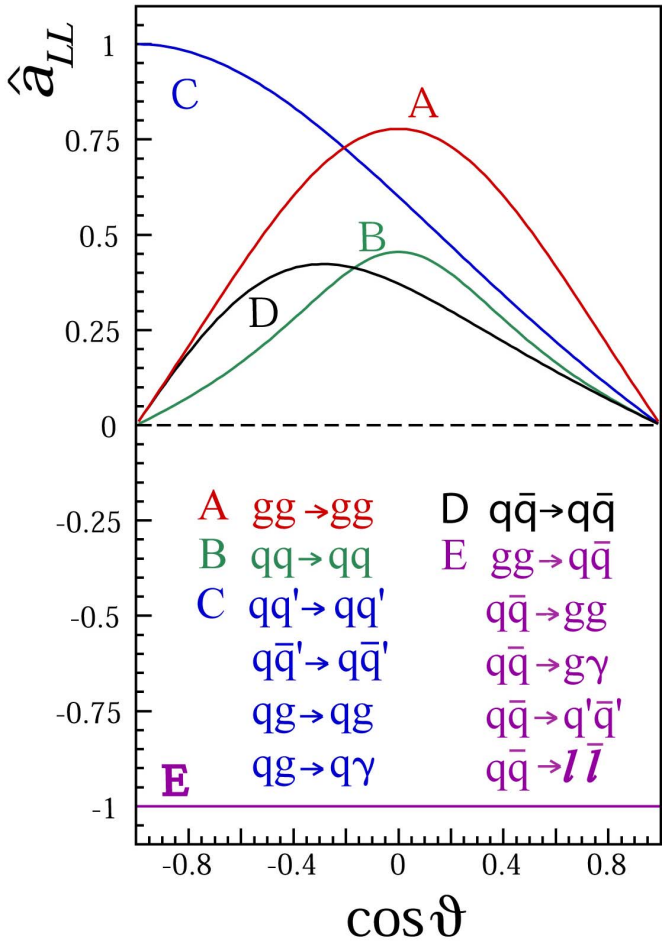
RN

ΔG/G - RHIC pp

$$A_{LL} \simeq \frac{\Delta p_1}{p_1} \times \frac{\Delta p_2}{p_2} \times \hat{a}_{LL}$$



$$\left(\frac{\Delta G}{G}\right)^2 \quad \frac{\Delta G}{G}\frac{\Delta q}{q} \quad \left(\frac{\Delta q}{q}\right)^2$$

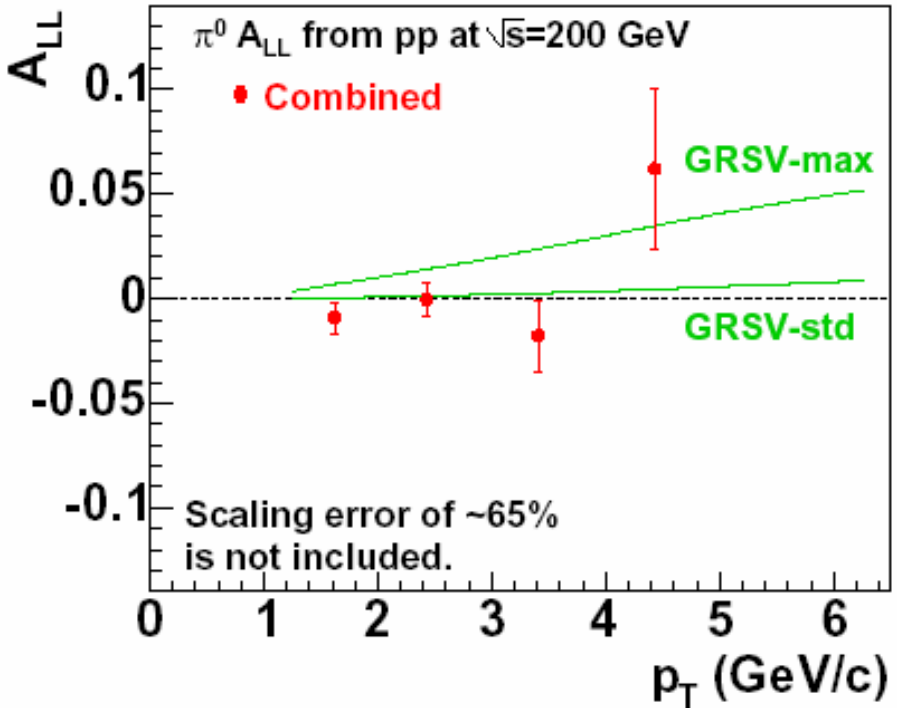


$\Delta G/G$ - Phenix: A_{LL} for π^0

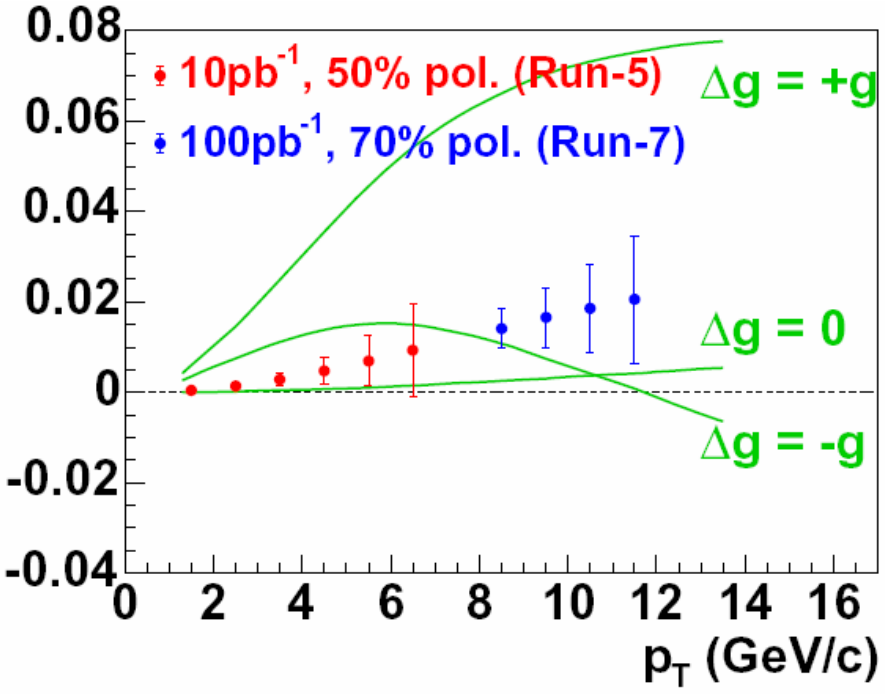
Fukao

PHENIX

2003/4



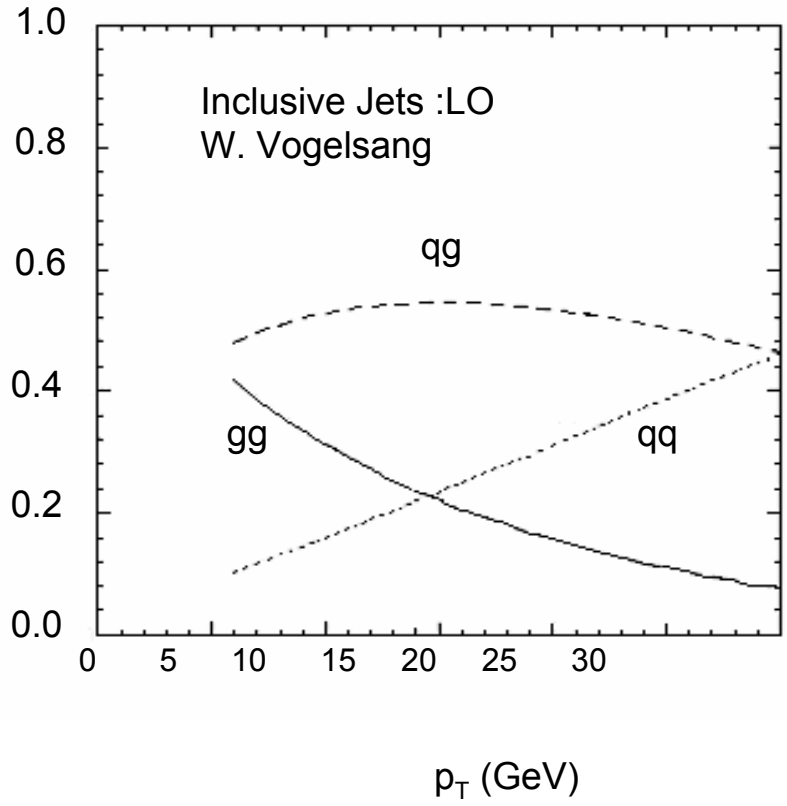
Outlook 2005/7

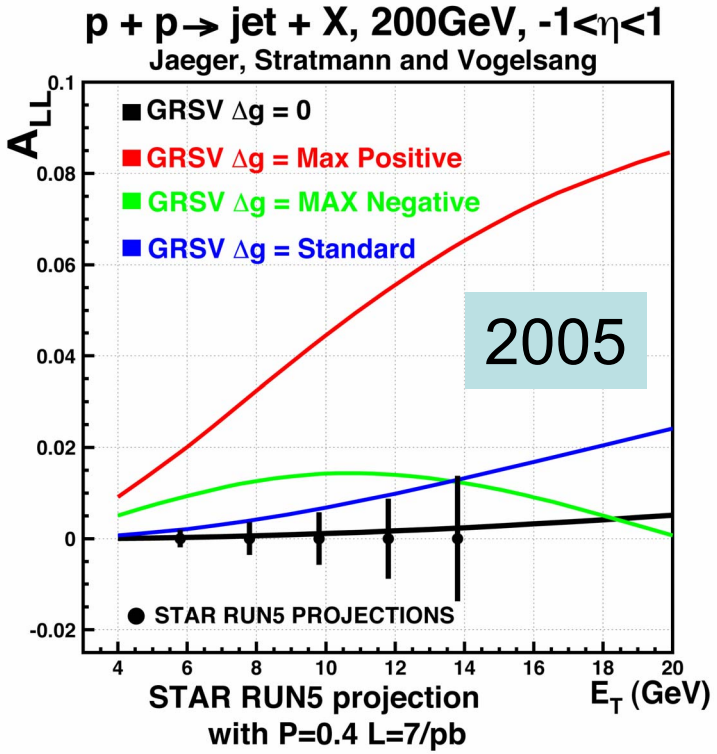


ΔG/G – Star: A_{LL} jets (2005)

STAR

Sowinski

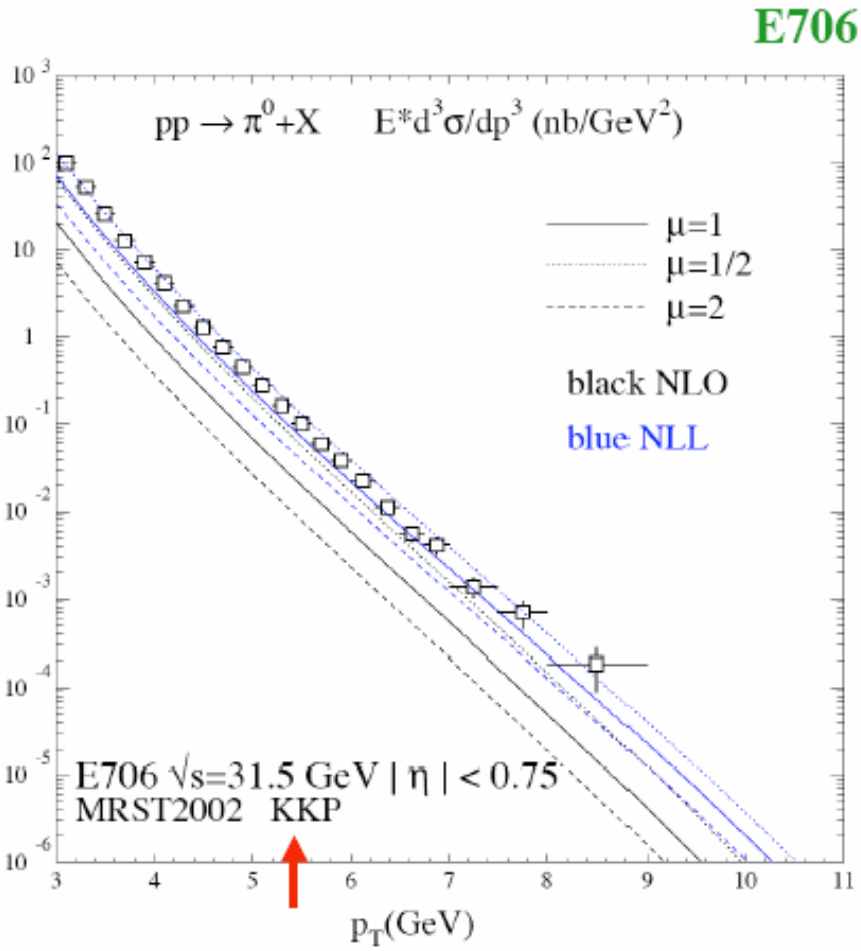




NLO and NLL

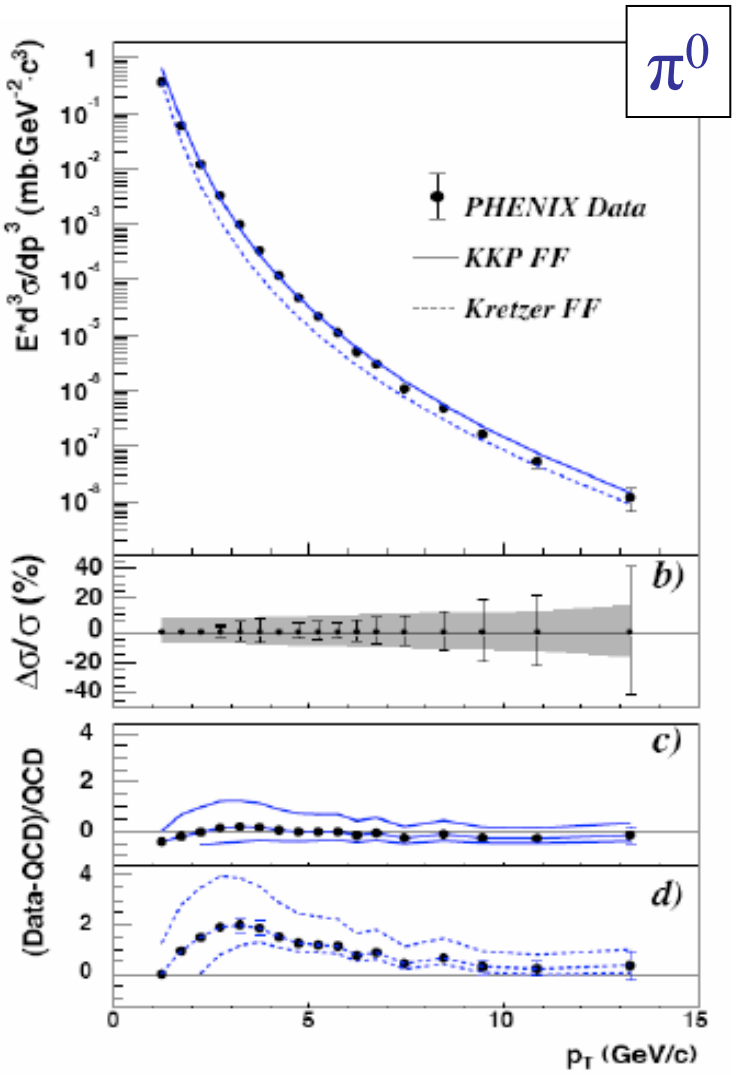
Vogelsang

- Resummation of NLL important for single-inclusive processes ($pp \to \pi^0 X$, $\to \gamma X$)
- Crucial for lower energy fixed target $pp \to \pi^0 X$
- Excellent agreement of NLO + NNL calculations with collider data!
- prompt photons good probe for $\Delta G/G$ at RHIC



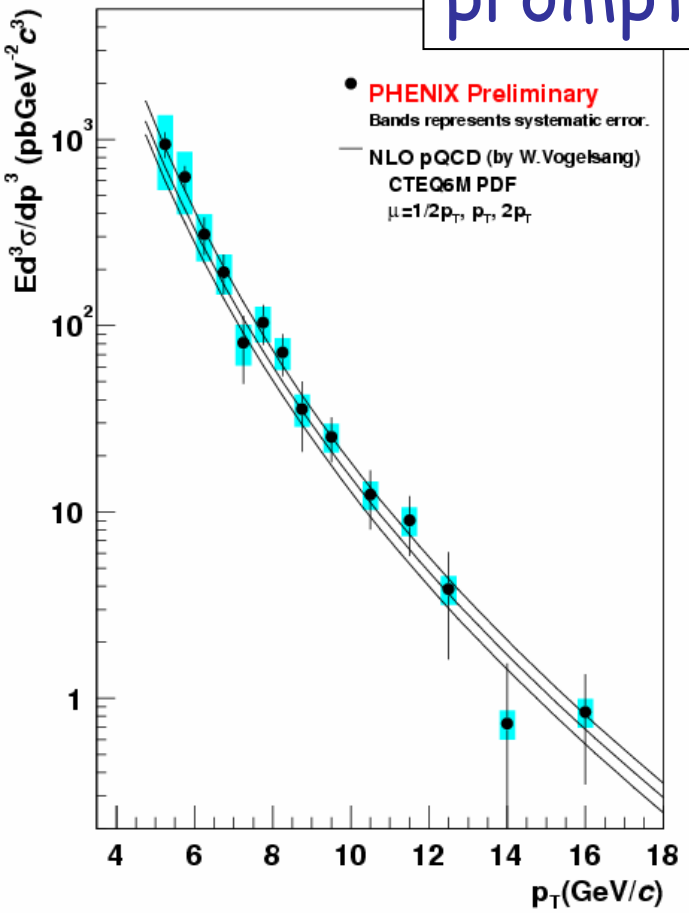
Prompt photons/π^0

Vogelsang, Okada



PHENIX

prompt γ

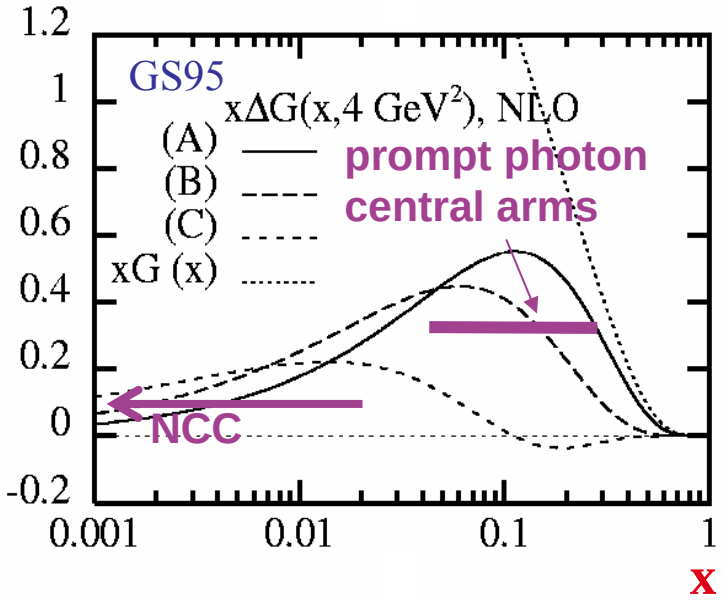


RHIC detector upgrades

- important enlargement of x_g coverage → first moment

Kinney

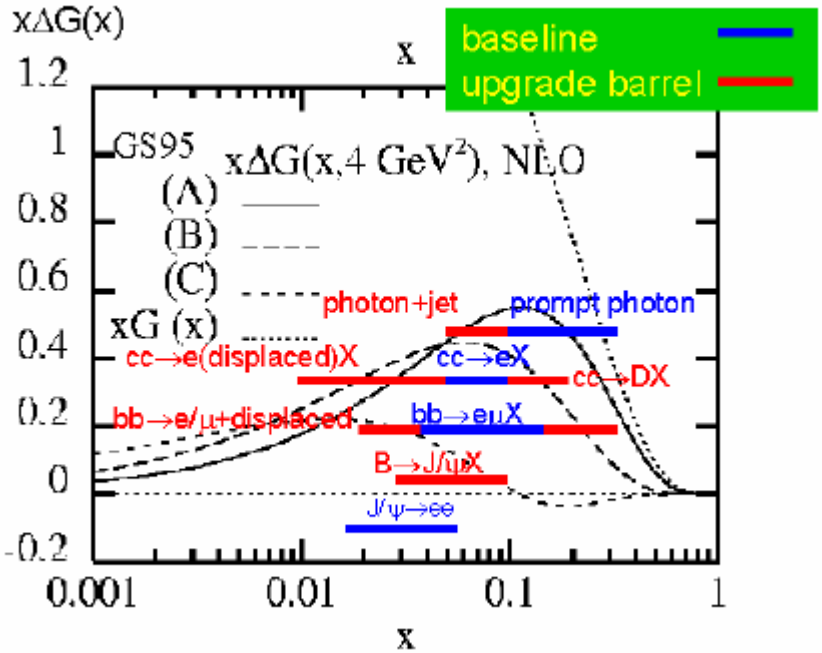
Tungsten-Silicon sampling calorimeter



2009

Togawa

Silicon vertex barrel detector



2007-2008

Proposals

- Spintransfer in Hyperon production in pp
  Xu, Rykov

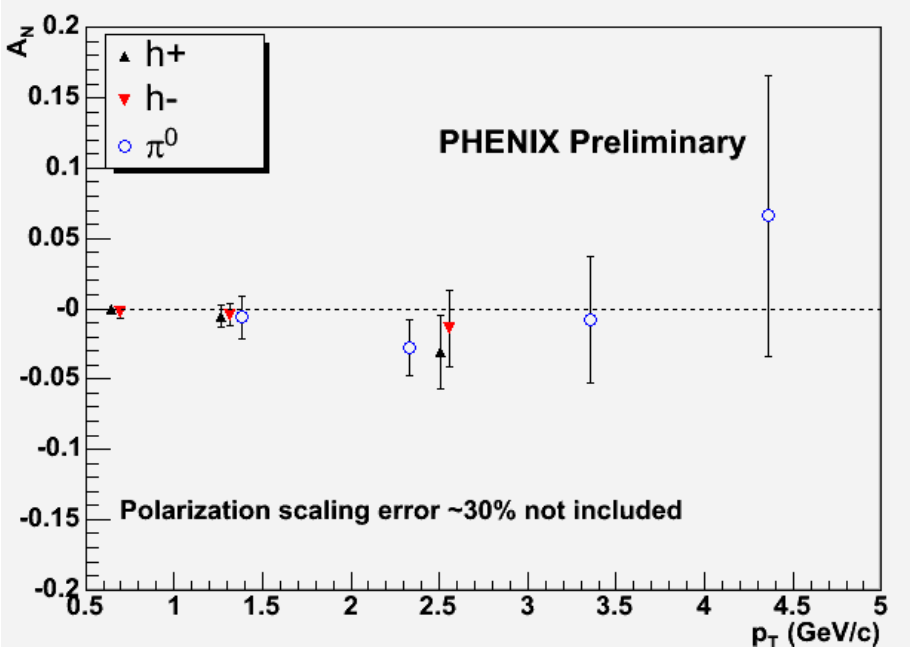
- Polarised DY $p\uparrow\ \bar{p}\uparrow$ at GSI (transversity)
  Efremov

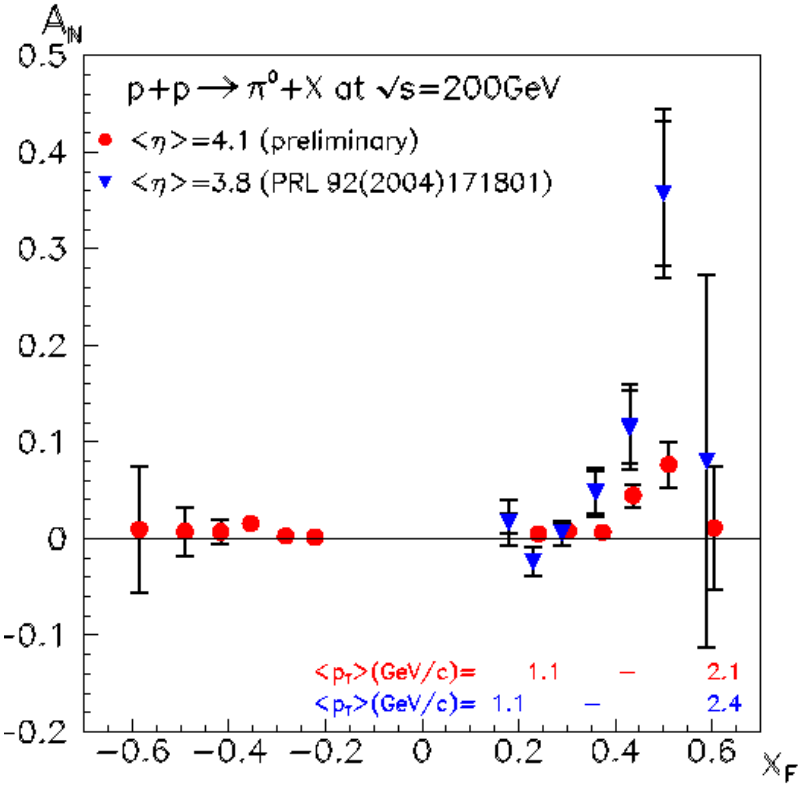
TRANSVERSE SPIN

A_N for pp -> π^0X

PHENIX Makdisi STAR Ogawa

$$x_F = 0$$

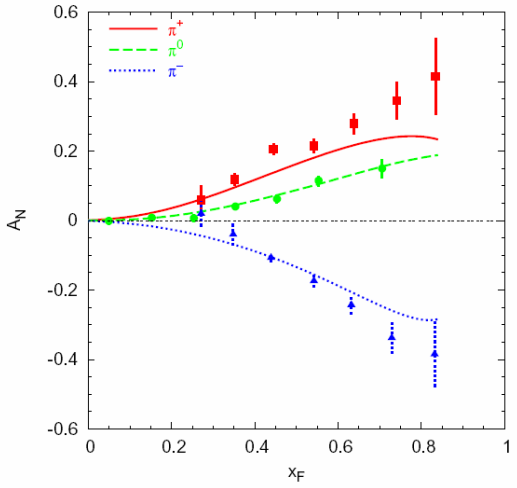


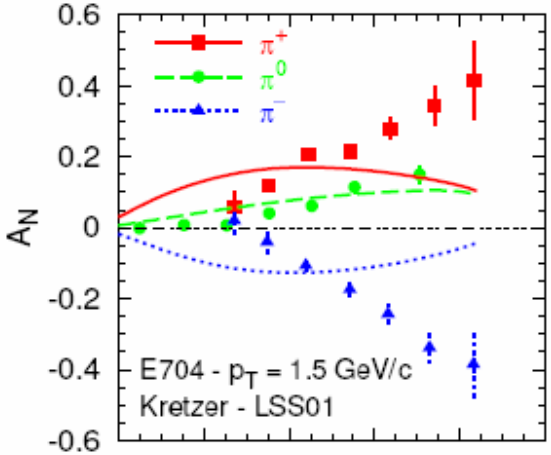


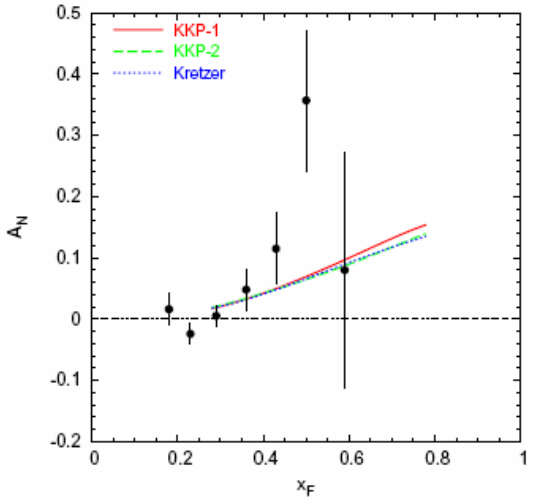
SSA and intrinsic k_T

Murgia, D'Alesio

- A generalized pQCD approach to SSA and unpol. cross sections: LO.pQCD + spin and new k_T-dependent PDF and FF
- $A_N(p\uparrow p \rightarrow \pi X)$:
  - Sivers effect contributes, Collins effect suppressed
  - suppressed for $x_F<0$ for all mechanisms
  - good agreement with STAR data $A_N(p\uparrow p \rightarrow \pi^0 X)$







ERN

Intrinsic k_T (continued)

Boglione

In the same model it was shown that

- A_N(p↑p→DX) is an ideal process to study the Sivers distribution functions of quarks and gluons

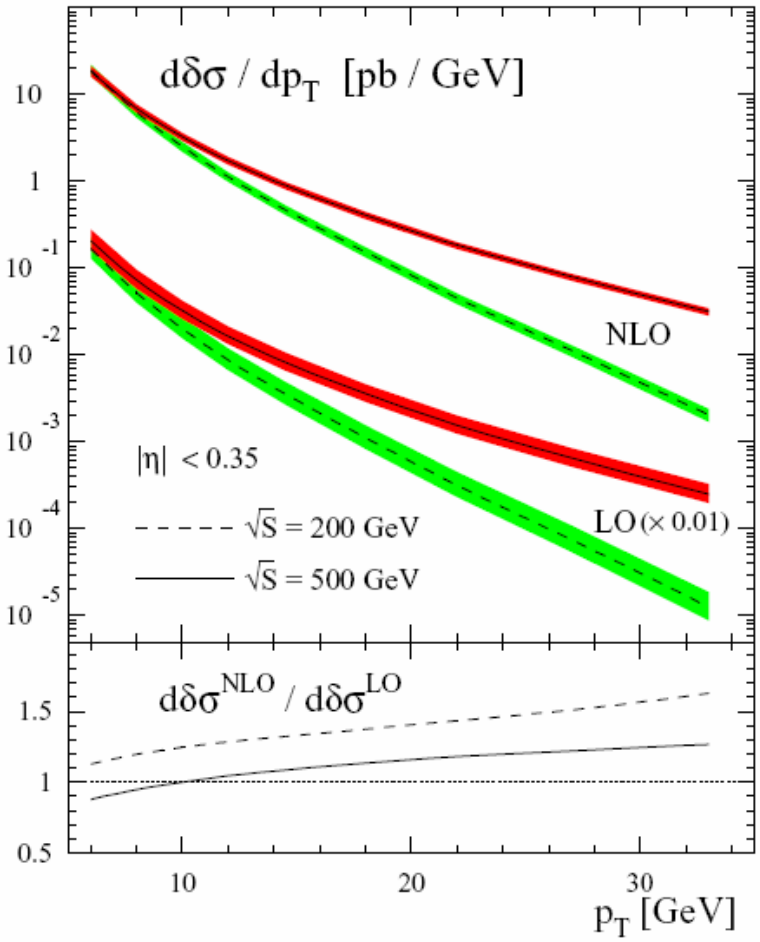
Prokudin

- The $A_{UT}^{sin(\phi_h - \phi_S)}$ Hermes data can be described as well as the unpolarised Cahn asymmetries from EMC using $\langle k_\perp^2 \rangle = 0.25\ \mathrm{GeV}^2$

p↑ p↑ cross section in NLO

Mukherjee

- first NLO calculation
- example: prompt photon at Phenix
- scale dependence significantly reduced



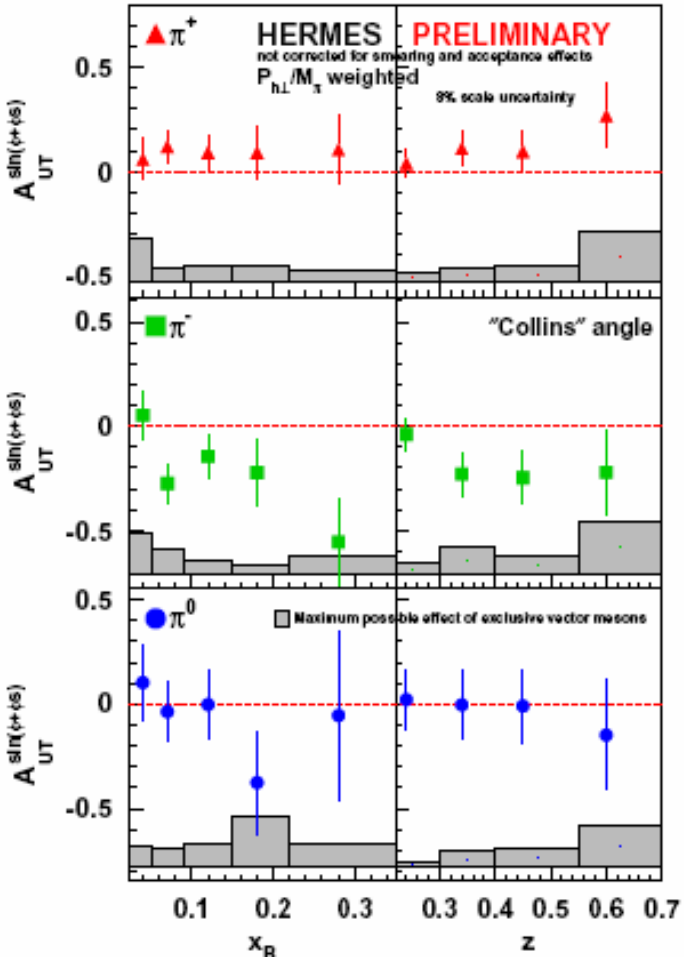
Ratcliffe

- study of K-factors for DY

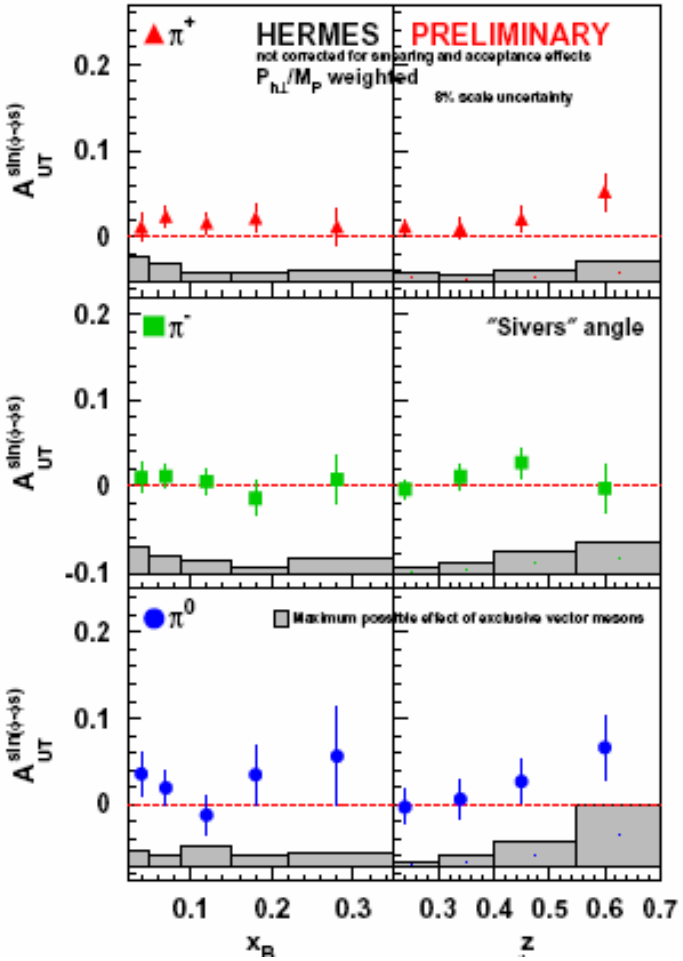
Hermes Collins & Sivers

Schnell

$$\tilde{A}_{UT}^{\sin\Phi} \propto \delta q(x) \cdot z\, H_1^{\perp(1)}(z)$$



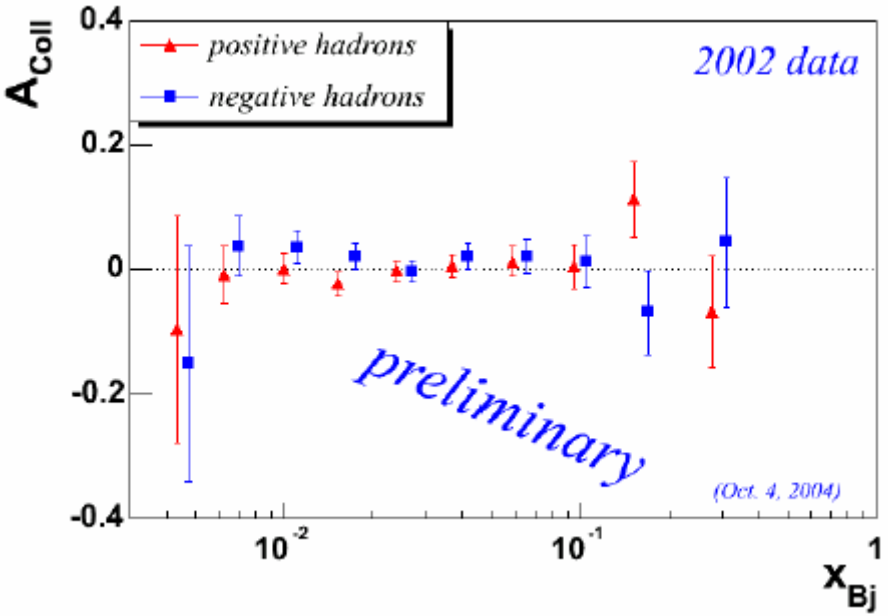
$$\tilde{A}_{UT}^{\sin\Phi} \propto -f_{1T}^{\perp(1)}(x) \cdot z\, D_1(z)$$



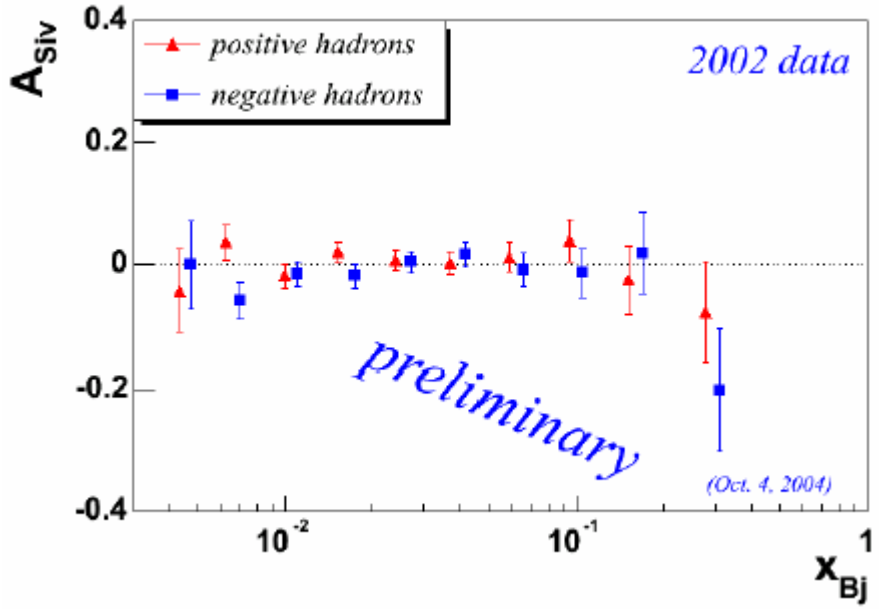
COMPASS Collins & Sivers

Pagano

Collins



Sivers

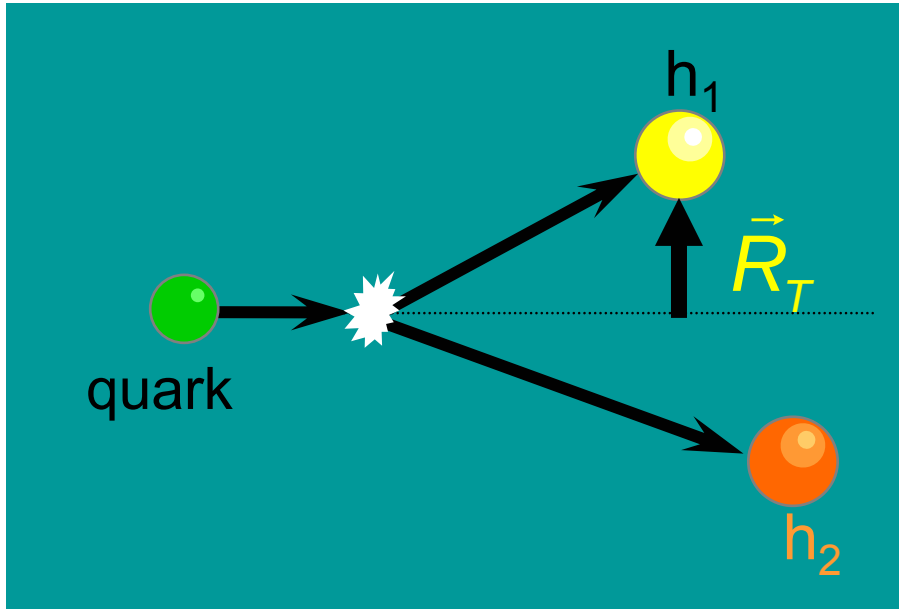


Dihadron fragmentation

Bacchetta

- New quark polarimeter

$$H_1^{\sphericalangle}(z, \cos\theta_R, M_{\pi\pi}^2)$$



- simpler, no k_T convolution, cf

$$H_1^{\perp}(z, k_T)$$

van der Nat

Joosten

More Asymmetries

Gamberg

- Boer-Mulders function $h_1^{\perp}(x)$

- 

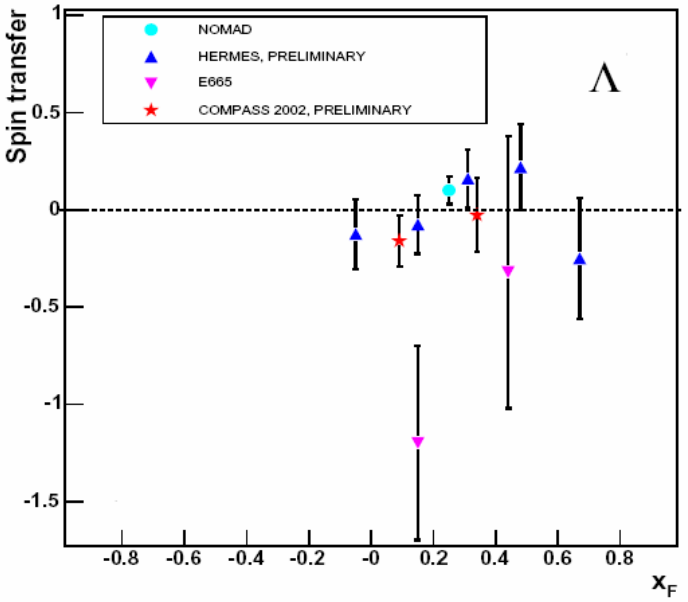
A_{UL} — Kinney

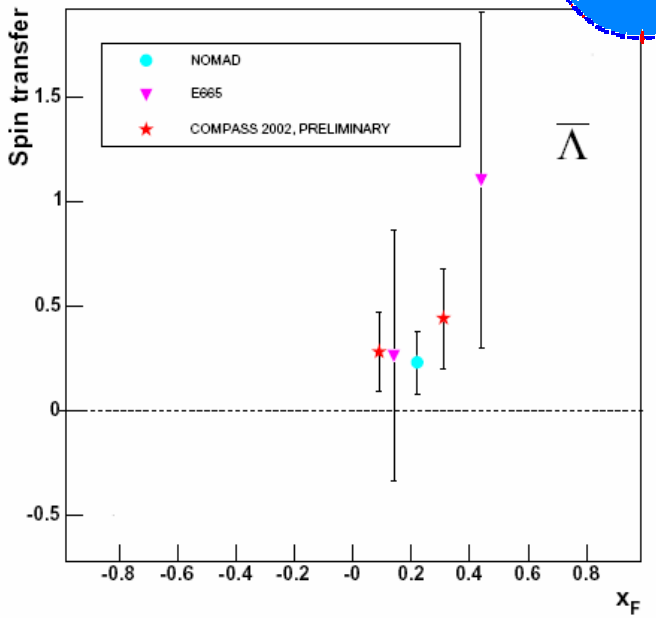
- Model for transversity and intrinsic motion of quarks — Zavada
- Chiral-odd twist-3 DF $e(x)$ — Wakamatsu
- New observables from color gauge invariance — Pijlman

Spin transfer to Λ

- Spin transfer to Λ

Alexakhin





$$S = \frac{P_\Lambda}{P_B D}$$

- transverse Λ polarisation

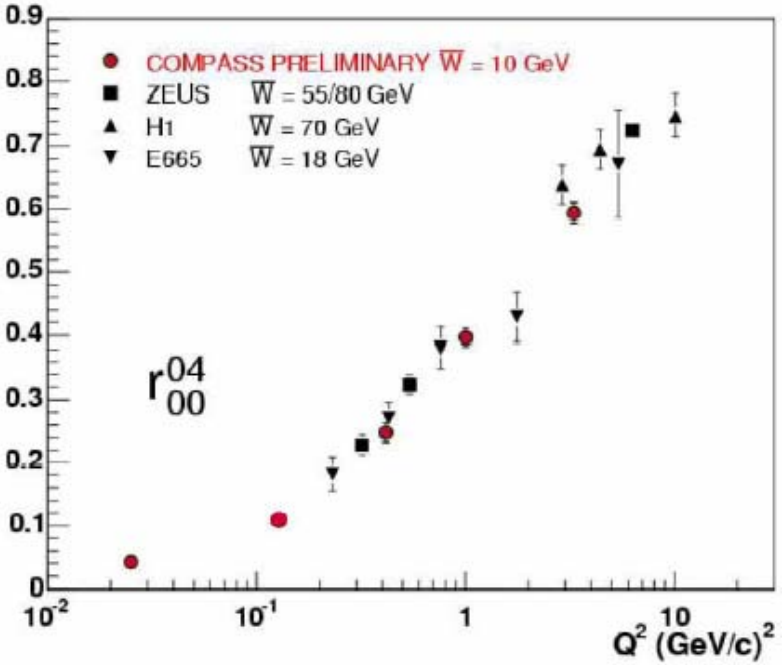
Friedrich

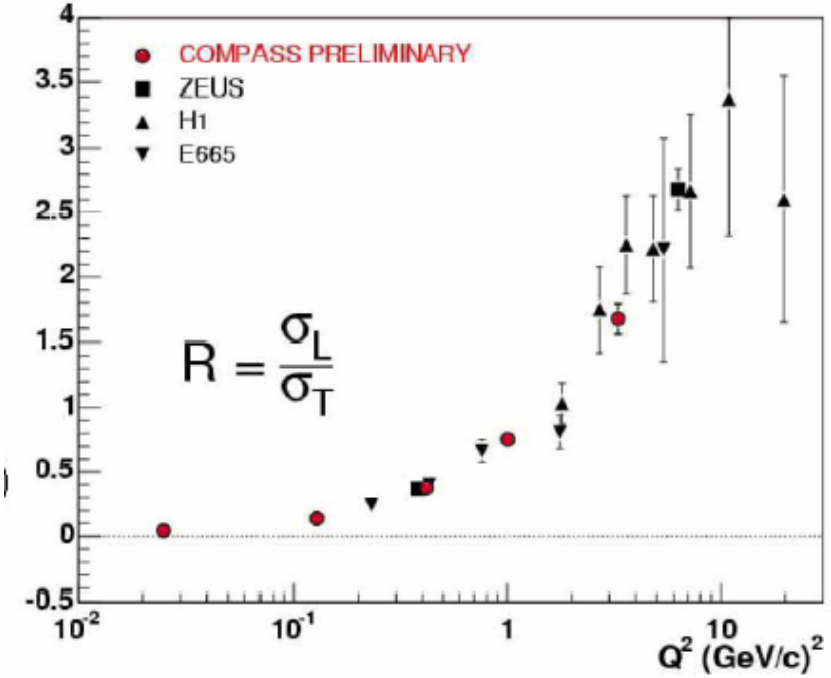
Belostotski

Exclusive ρ production

- SDME: r^{04}_{00} r^{1}_{1-1} r^{04}_{1-1} $\mathrm{Im}\, r^{3}_{1-1}$

Neyret





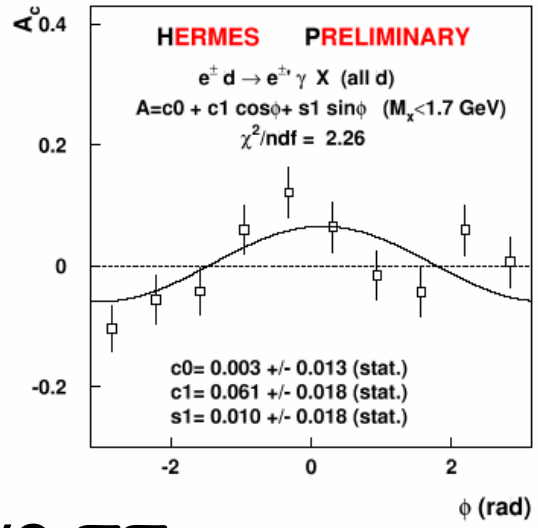
- Model

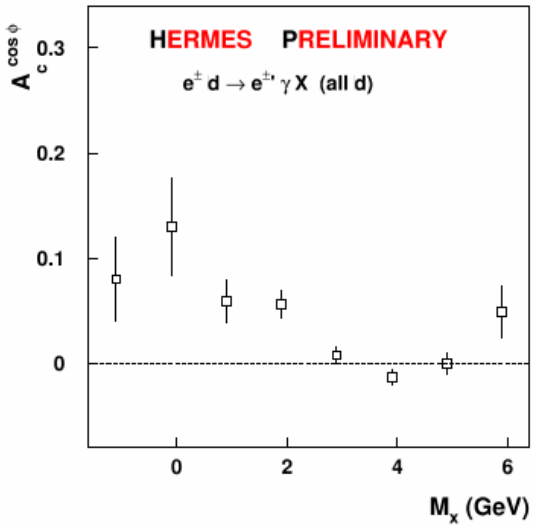
Goloskokov

GPDs

- DVCS Beam Charge Asymmetry — Marukyan
  new: deuteron

$$A_C(\phi) = \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$





- Hard exclusive $\pi\pi$ — Fabbri
- Exclusive π and vector mesons — Rostomyan
- Hermes recoil detector — Stewart

More from theory

Leader

- Spin sum rule revisited
  - problem in derivation of

$$\frac{1}{2} = \frac{1}{2}\sum \Delta q + \Delta G + \langle L_z \rangle$$

  - rigorous treatment yields miraculously same SR
  - new sum rule for transverse spin

Teryaev

- Higher twist resummation

Di Salvo

- Asymmetries in SIDIS

Fragmentation functions

- Determination of polarised fragmentation from Belle data in progress — Seidl
- Possible difficulties with LUND fragmentation at low energies — Kotzinian
- Q^2 dependence of GDH — Nagaitsev

Personal Impression

- Two new facilities are working perfectly:

RHIC and COMPASS

- Enormous progress on theory of transverse spin and SSA
- Is ΔG/G small?

Exciting times ahead