Spin Physics Working Group: Theory Summary

Rodolfo Sassot
Universidad de Buenos Aires

DIS 2009, Madrid April 2009

Spin Physics Working Group:

Convenors: Carl Gagliardi, Rodolfo Sassot, Gunar Schnell

7 sessions + 2 joint sessions with Diffractive and Vector Mesons WG

45 talks (13 theory)

Topics/Theory Speakers:

Longitudinal Spin:	A. Kotzinian, M. Stratmann, F. Taghavi-Shahri
Transverse Spin:	F. Conti, U. D'Alesio, D. Boer, E. Boglione, K. Tanaka, B. Toedtli
GPDs, DVCS:	G. Goldstein, S. Liuti, A. Mukherjee.

Longitudinal Polarization

Marco Stratmann: improvements to the DSSV analysis

Marco Stratmann: improvements to the DSSV analysis

DSSV pPDFs presented at DIS 2008

first NLO global analysis DIS, SIDIS, RHIC

focused on Δg

uncertainties with Lagrange Multipliers

New: uncertainties with improved Hessian scheme

variations of the best fit available

detailed analysis of (anti)quark polarization

predictions for RHIC: A_{LL} for charged pions,

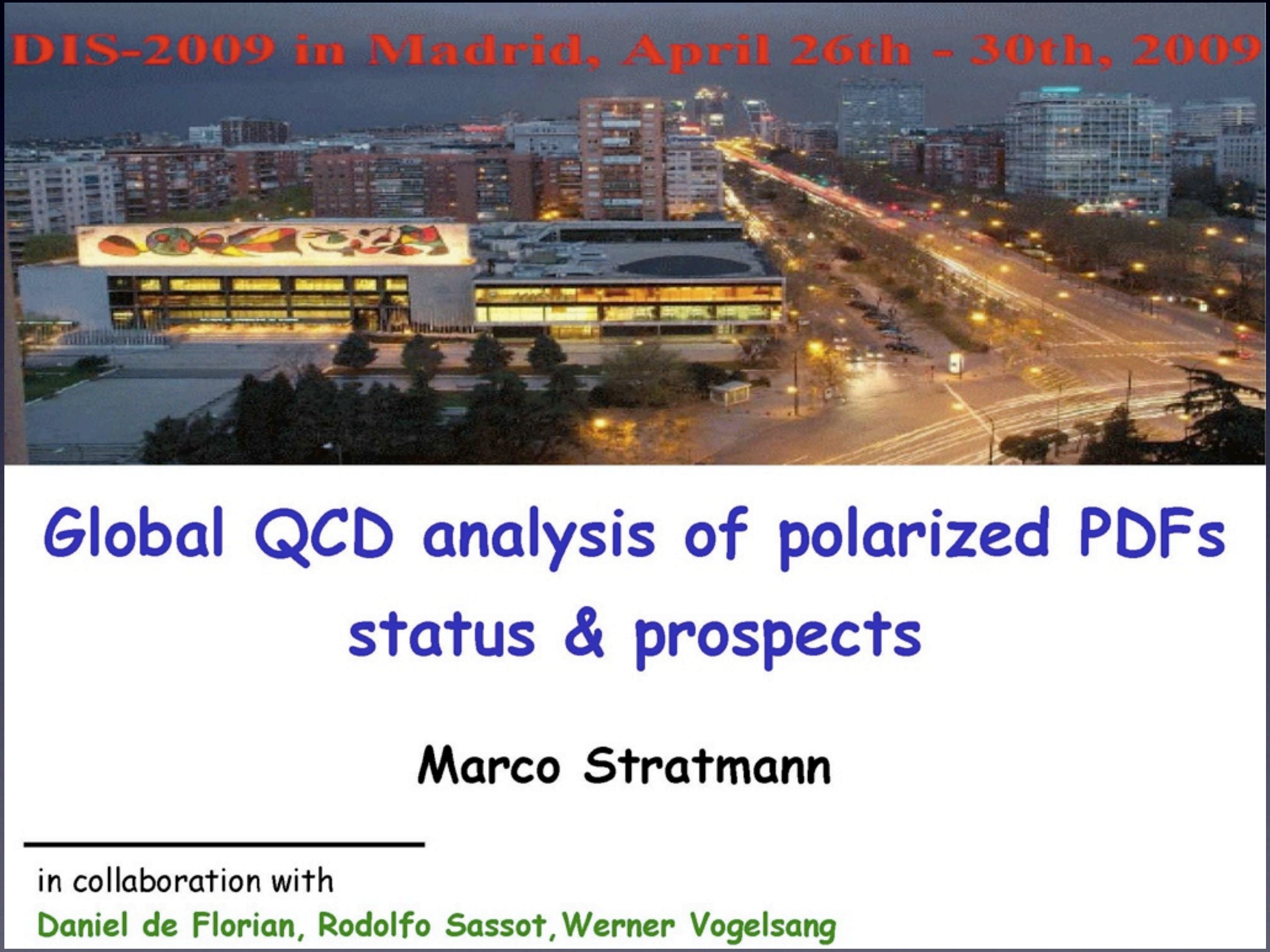
jet correlations,

A_L for W

arXiv:0904.3821

Marco Stratmann: improvements to the DSSV analysis

Questions raised:



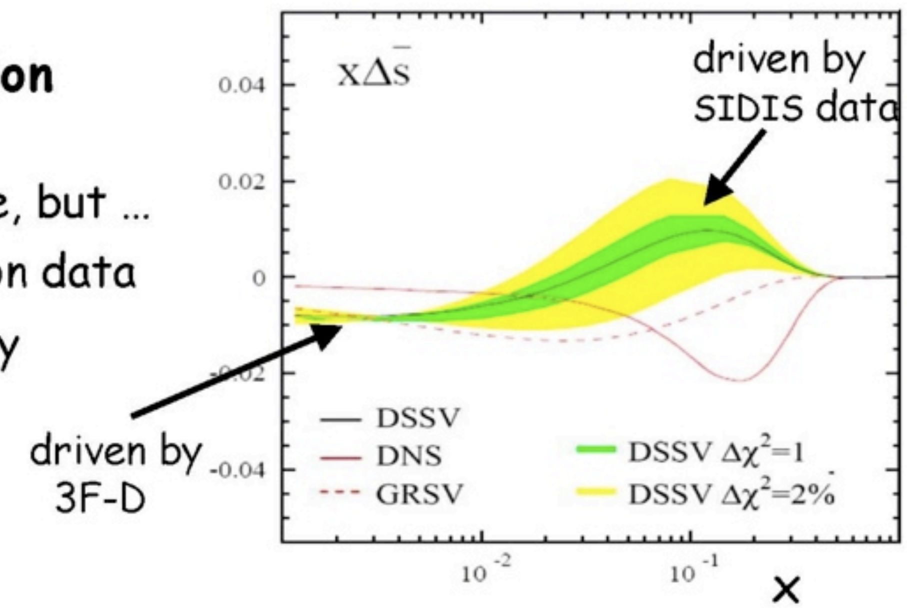
Marco Stratmann: improvements to the DSSV analysis

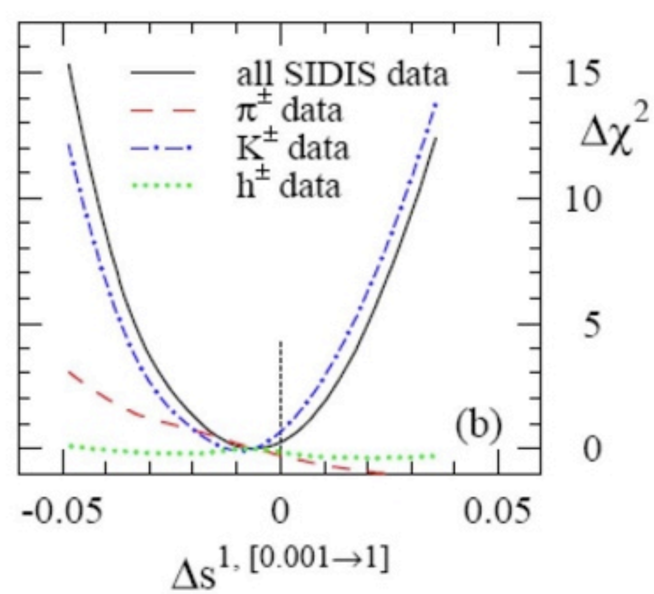
Questions raised:

“strange” issues

DSSV sea polarizations – cont’d

- **a strange strangeness polarization**
  - $\Delta s(x)$ always thought to be negative, but ...
  - mainly determined from SIDIS kaon data
  - consistent with LO-type analyses by HERMES and COMPASS





striking result, but relies on

- kaon fragmentation
  more data available soon (BELLE, ...)
- unpolarized PDFs
  unpol. strangeness not well determined

needs further studies – exp. & theory !

Marco Stratmann: improvements to the DSSV analysis

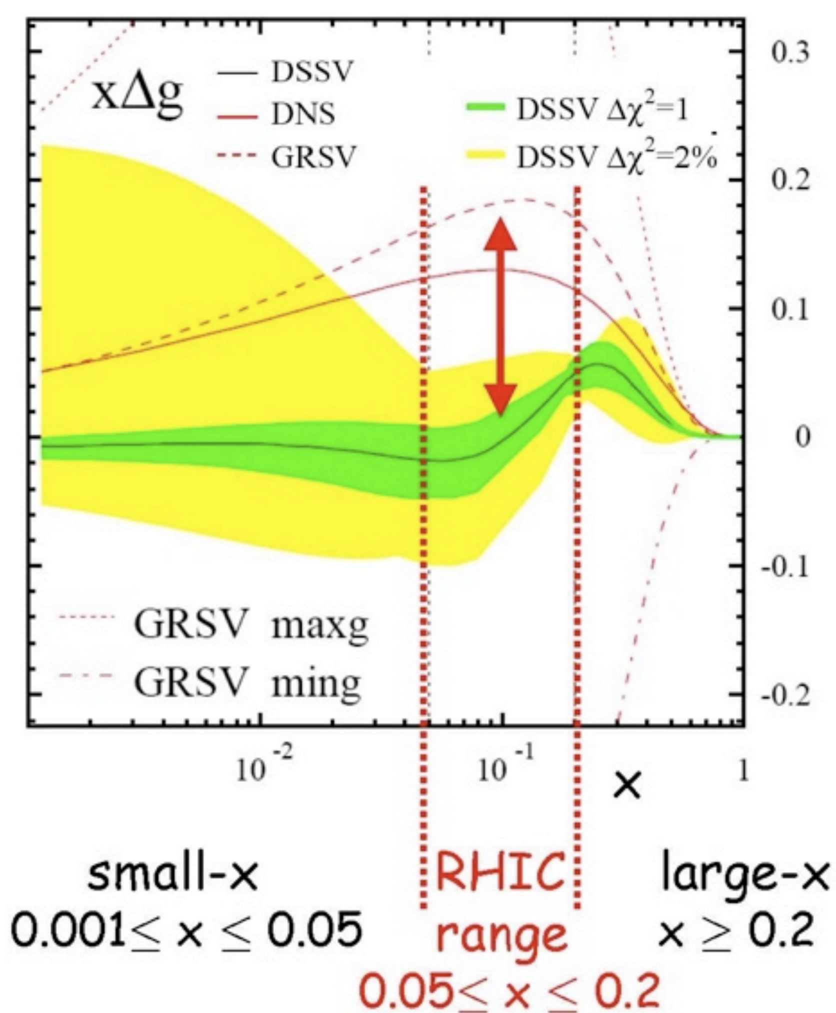
Questions raised:

“strange” issues

$$\Delta\chi^2 = ?$$

DSSV gluon polarization

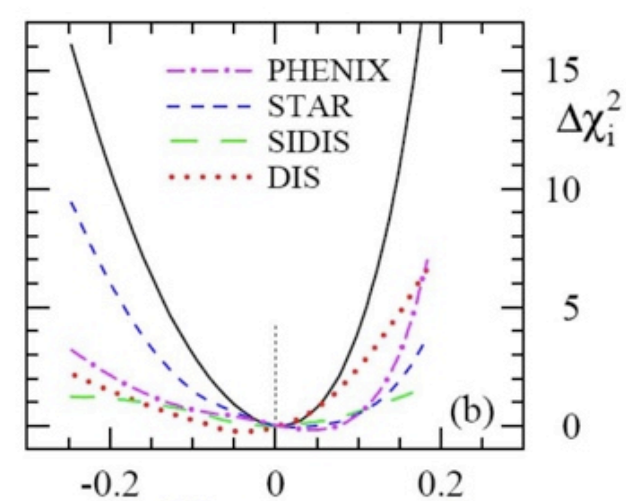
error estimates more delicate: small-x behavior completely unconstrained



study uncertainties in 3 x-regions

find

- $\Delta g(x)$ very small at medium x (even compared to GRSV or DNS)
- best fit has a node at $x \simeq 0.1$
- huge uncertainties at small x



$$\delta g \equiv \int_{0.05}^{0.2} \Delta g(x, 10\,\mathrm{GeV}^2)\,dx$$

Marco Stratmann: improvements to the DSSV analysis

Questions raised:

"strange" issues

$\Delta\chi^2 = ?$

extrapolations

numerical results

$Q^2 = 10\ GeV^2$

$$\Delta f^{1,[x_{\min},1]} \equiv \int_{x_{\min}}^{1} \Delta f(x)dx$$

	$x_{\min}=0$	$x_{\min}=0.001$	
	best fit	$\Delta\chi^2=1$	$\Delta\chi^2/\chi^2=2\%$
$\Delta u+\Delta\bar{u}$	0.813	$0.793\ ^{+0.011}_{-0.012}$	$0.793\ ^{-0.028}_{-0.034}$
$\Delta d+\Delta\bar{d}$	-0.458	$-0.416\ ^{+0.011}_{-0.009}$	$-0.416\ ^{+0.035}_{-0.025}$
$\Delta\bar{u}$	0.036	$0.028\ ^{+0.021}_{-0.020}$	$0.028\ ^{-0.059}_{-0.059}$
$\Delta\bar{d}$	-0.115	$-0.089\ ^{+0.029}_{-0.029}$	$-0.089\ ^{+0.090}_{-0.080}$
$\Delta\bar{s}$	-0.057	$-0.006\ ^{+0.010}_{-0.012}$	$-0.006\ ^{+0.028}_{-0.031}$
Δg	-0.084	$0.013\ ^{+0.106}_{-0.120}$	$0.013\ ^{-0.702}_{-0.314}$
$\Delta\Sigma$	0.242	$0.366\ ^{+0.015}_{-0.018}$	$0.366\ ^{-0.042}_{-0.062}$

- Δs receives a large negative contribution at small x
- Δg: huge uncertainties below $x \simeq 0.01$ → **1st moment still undetermined**

very difficult to give reliable estimates for full moments

both quark and gluons may not contribute much to proton spin
but we need to go to smaller x to settle this issue
→ case for a high-energy polarized ep-collider

Is the present pPDF picture satisfactory?

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NO!

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fundamental questions
unanswered

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Δg ?

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12 observables

fundamental questions
unanswered

Δg ?

Δs ?

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surprisingly small in the measured region

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Remarkable!

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we have learned how to do it

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pEIC

Aram Kotzinian: $\overline{\Lambda}$ SIDIS as a probe for Δs

sensitivity to strangeness

Longitudinal target polarization dependence of $\bar{\Lambda}$ polarization and polarized strangeness PDF

Aram Kotzinian

CEA-Saclay, IRFU/Service de Physique Nucléaire, 91191 Gif-sur-Yvette, France

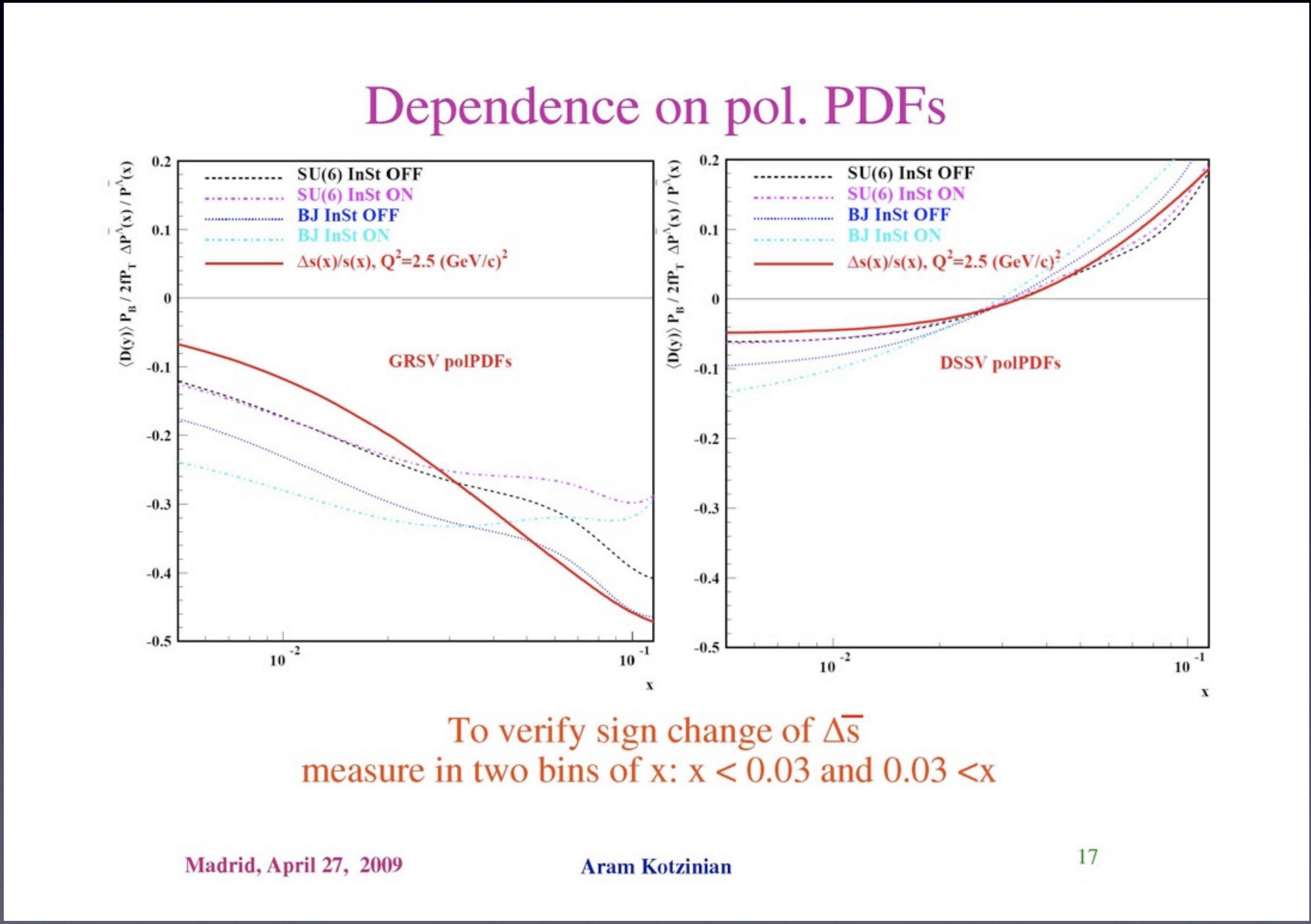
On leave in absence from YerPhI, Armenia and JINR, Russia

DIS 2009, 26-30 April 2009, Madrid

- $\bar{\Lambda}$ polarization
  - Unpolarized target
    - Strangeness distribution in nucleon
  - Polarized target
    - Polarized strangeness in polarized nucleon
- Conclusions

Aram Kotzinian: $\overline{\Lambda}$ SIDIS as a probe for Δs

sensitivity to pPDFs
(model dependent)



F. Taghavi Shahri: from pPDFs to valence quark model

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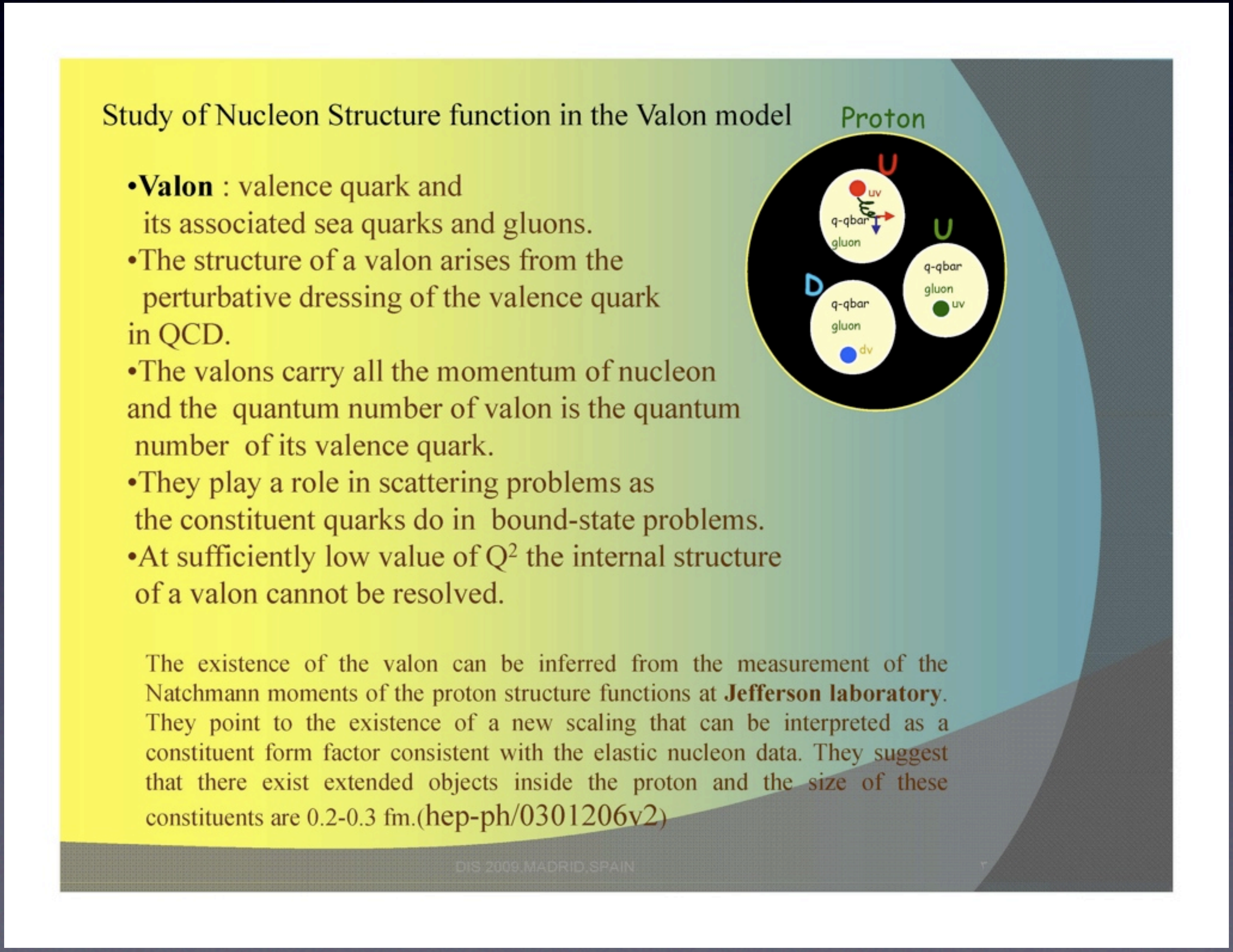
extending unpolarized results

good agreement with data



Transverse Polarization

DIS 2008: precise extraction of transversity, Sivers and Collins functions from SIDIS and e+e- data.

(Anselmino et al. 2008)

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systematic phenomenology

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path of PDFs, pPDFs and FFs, but for distributions relevant for transversely polarized nucleons

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towards global fits

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towards global fits
check and exploit factorization and universality

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systematic phenomenology
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towards global fits
check and exploit factorization and universality
higher order QCD on the way

Umberto d'Alesio: phenomenological study SSA $lp \rightarrow \pi + X$

as intermdiate step between SIDIS $pp \rightarrow \pi + X$

using Anselmino's group parameterization.

Madrid, April 26-30, 2009

Single Spin Asymmetries in $\ell p \longrightarrow h + X$ processes

Umberto D'Alesio
Physics Department and INFN
University of Cagliari, Italy

DIS 2009

XVII International Workshop on Deep-Inelastic Scattering and Related Subjects

April 26-30, 2009 Madrid

M. Anselmino, M. Boglione, UD, S. Melis, F. Murgia, A. Prokudin

Umberto d'Alesio: phenomenological study SSA $lp \to \pi + X$

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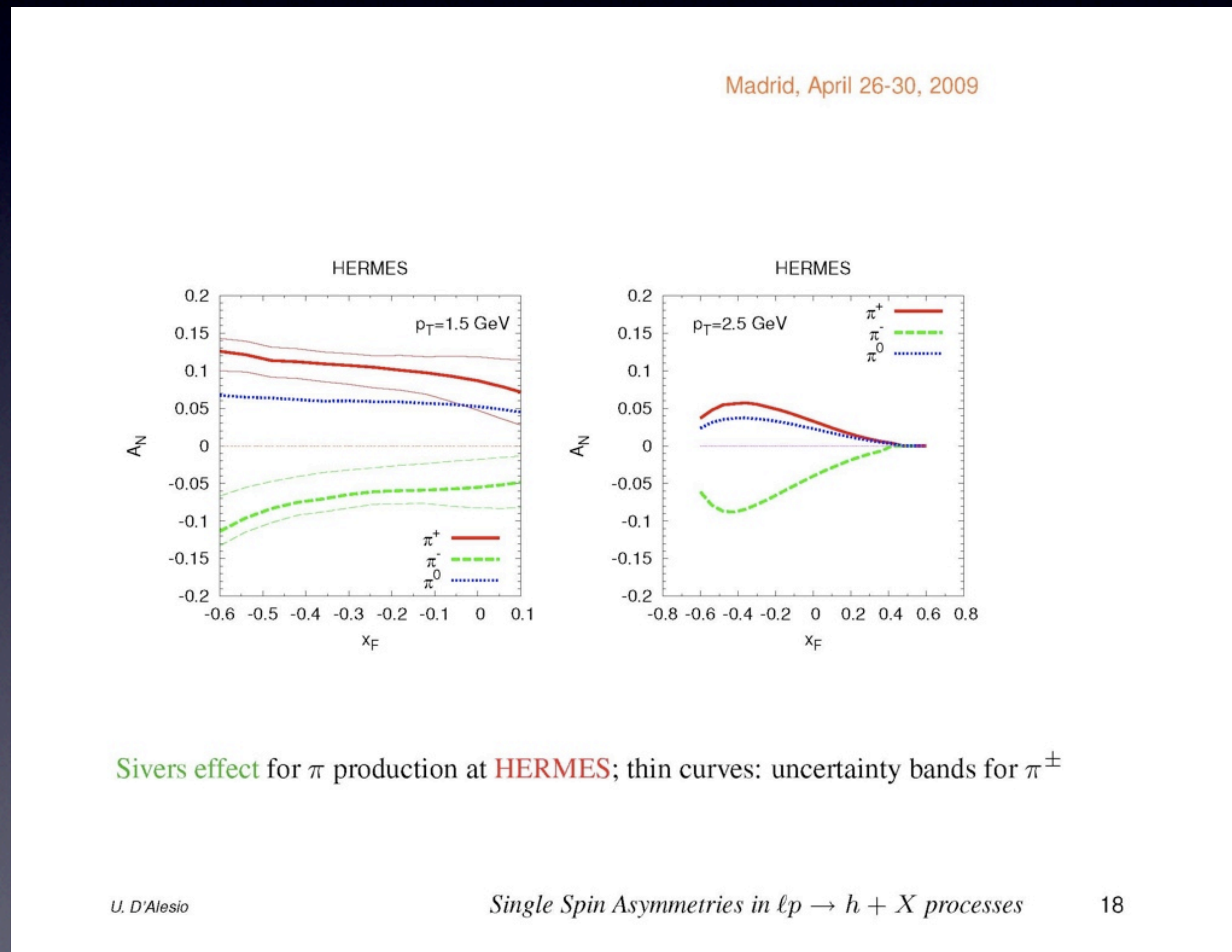
significant Sivers effect



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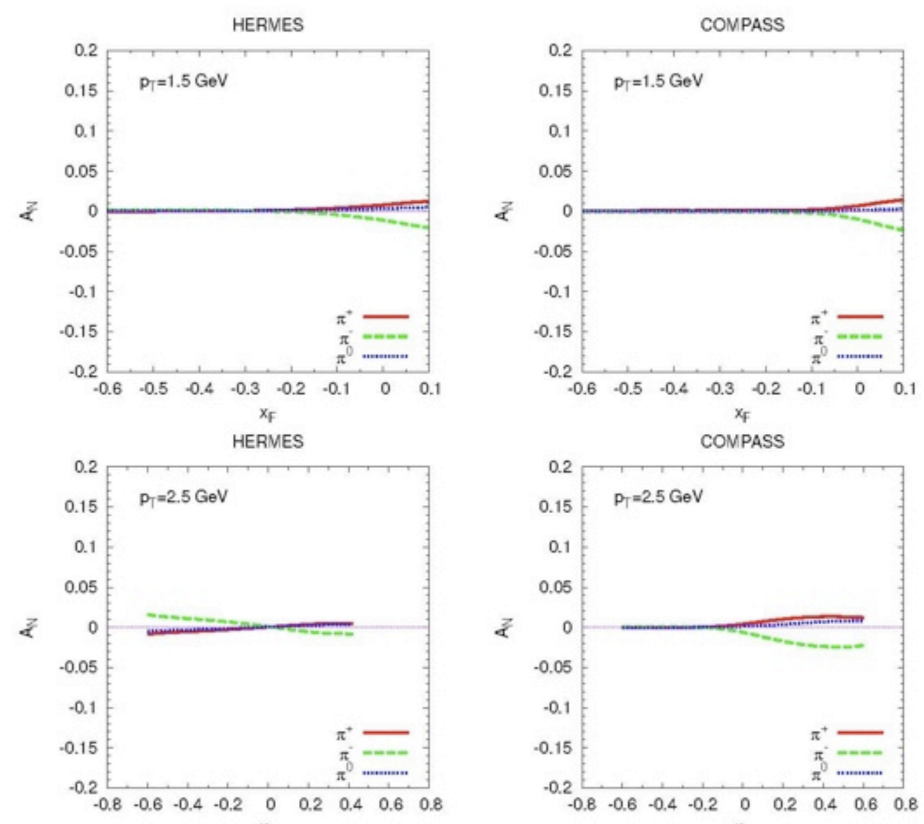
significant Sivers effect

negligible Collins effect

Madrid, April 26-30, 2009



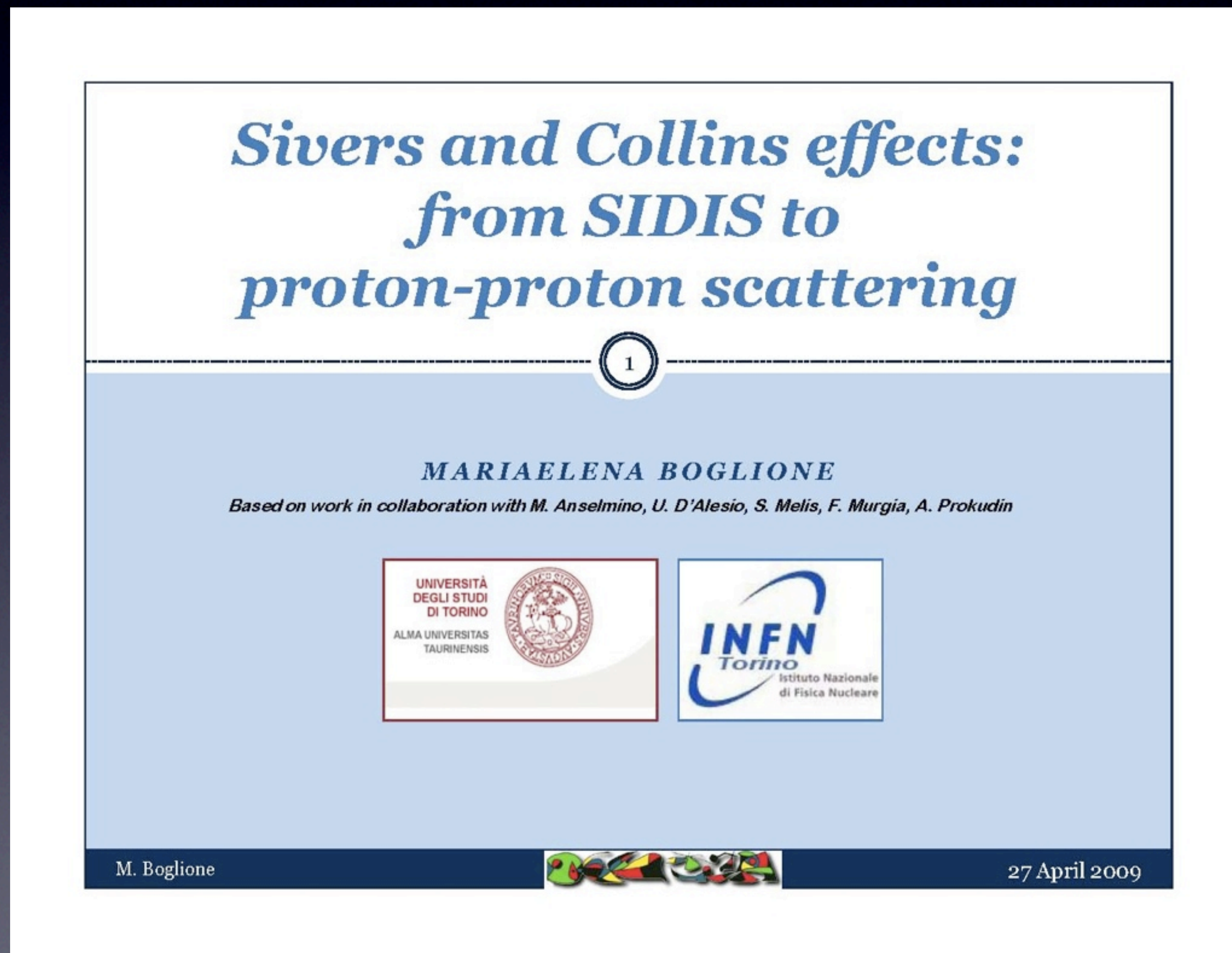
Collins effect for π production at HERMES and COMPASS

U. D'Alesio

Single Spin Asymmetries in $\ell p \to h + X$ processes 21

Mariaelena Boglione: Sivers and Collins effects in $pp \to \pi + X$

combined description of SSA in SIDIS and pp



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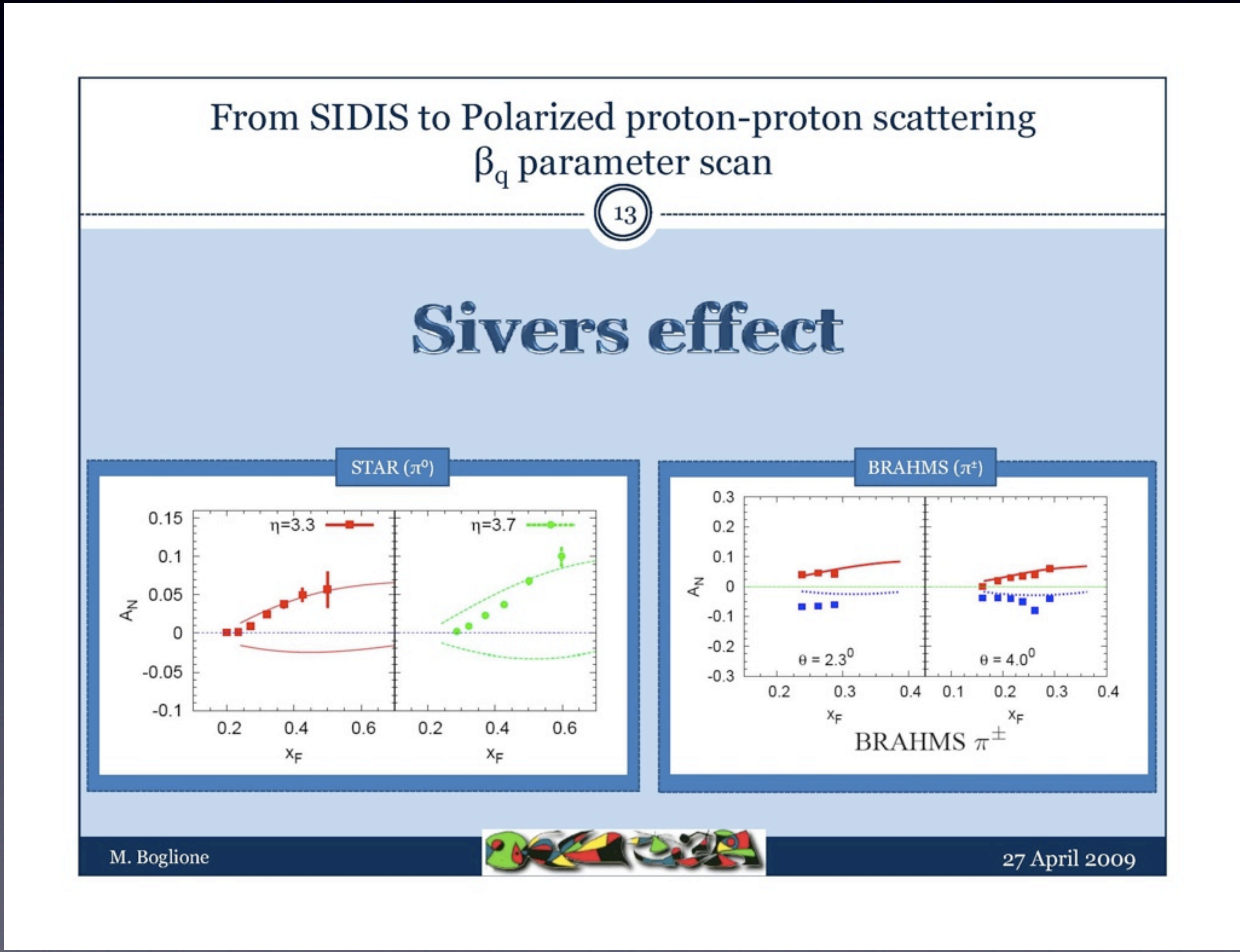
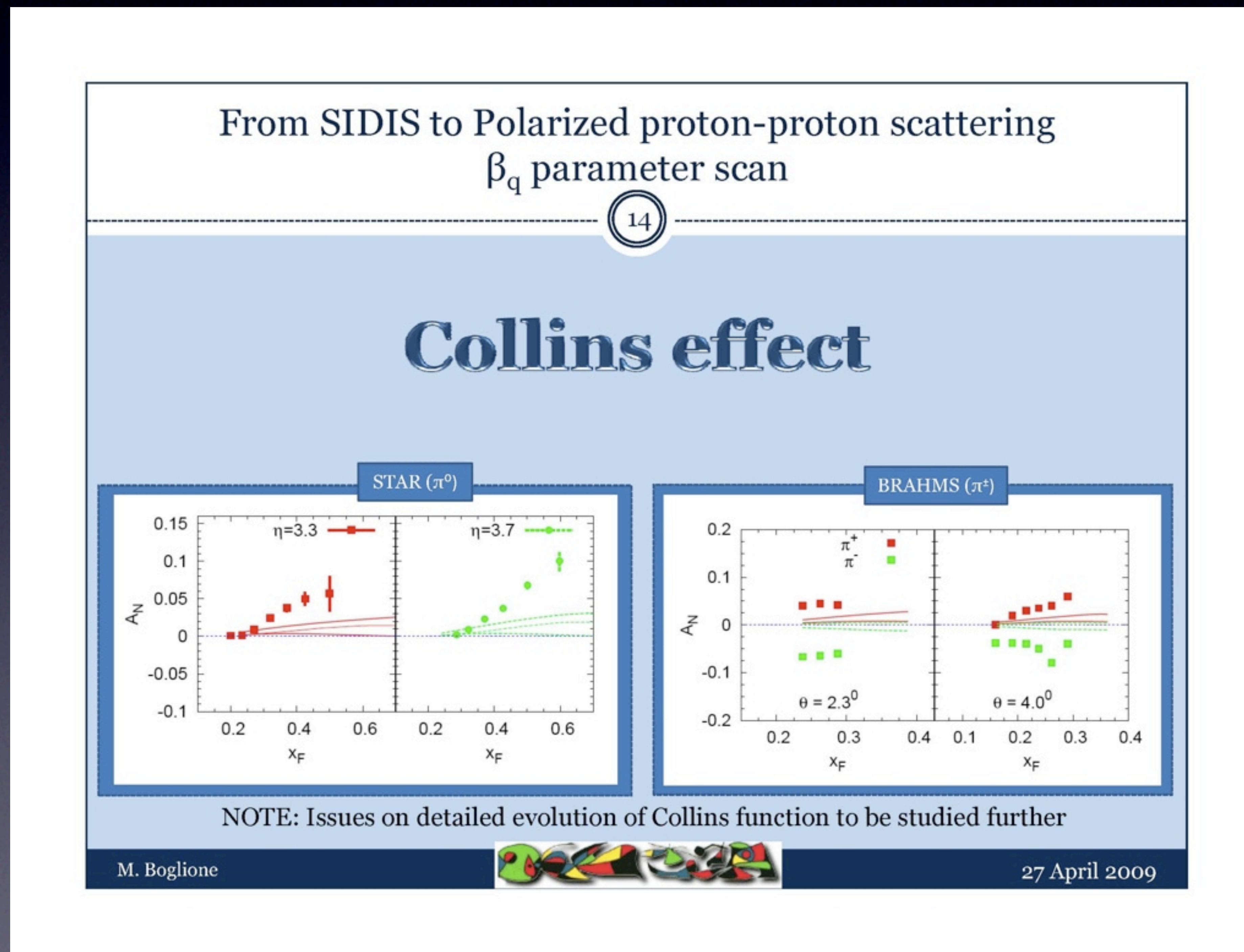


Mariaelena Boglione: Sivers and Collins effects in $pp \to \pi + X$

combined description of SSA in SIDIS and pp

towards a global analysis in transverse spin



Daniel Boer: Transverse Λ polarization at LHC in pp and pPb

test for polarization mechanisms/models

polarizing FF

saturation region

Transverse Λ polarization at the LHC

Daniël Boer
VU University Amsterdam

Outline

- Brief review of transverse Λ polarization in $p + p \to \Lambda + X$
- Possible underlying mechanism in the intermediate to high $\boldsymbol{p_T}$ region:
  transverse momentum and spin dependence in the fragmentation process
- Other consequences and suggestions for investigations at the LHC:
  - $p + p \to \Lambda^{\uparrow} + \text{jet} + X$ at midrapidity
  - $p + Pb \to \Lambda^{\uparrow} + X$ in the forward region

Kazuhiro Tanaka: update of SSA calculations

twist-3 quark-gluon correlations.

Theoretical update of twist-3 single-spin asymmetry in semi-inclusive DIS

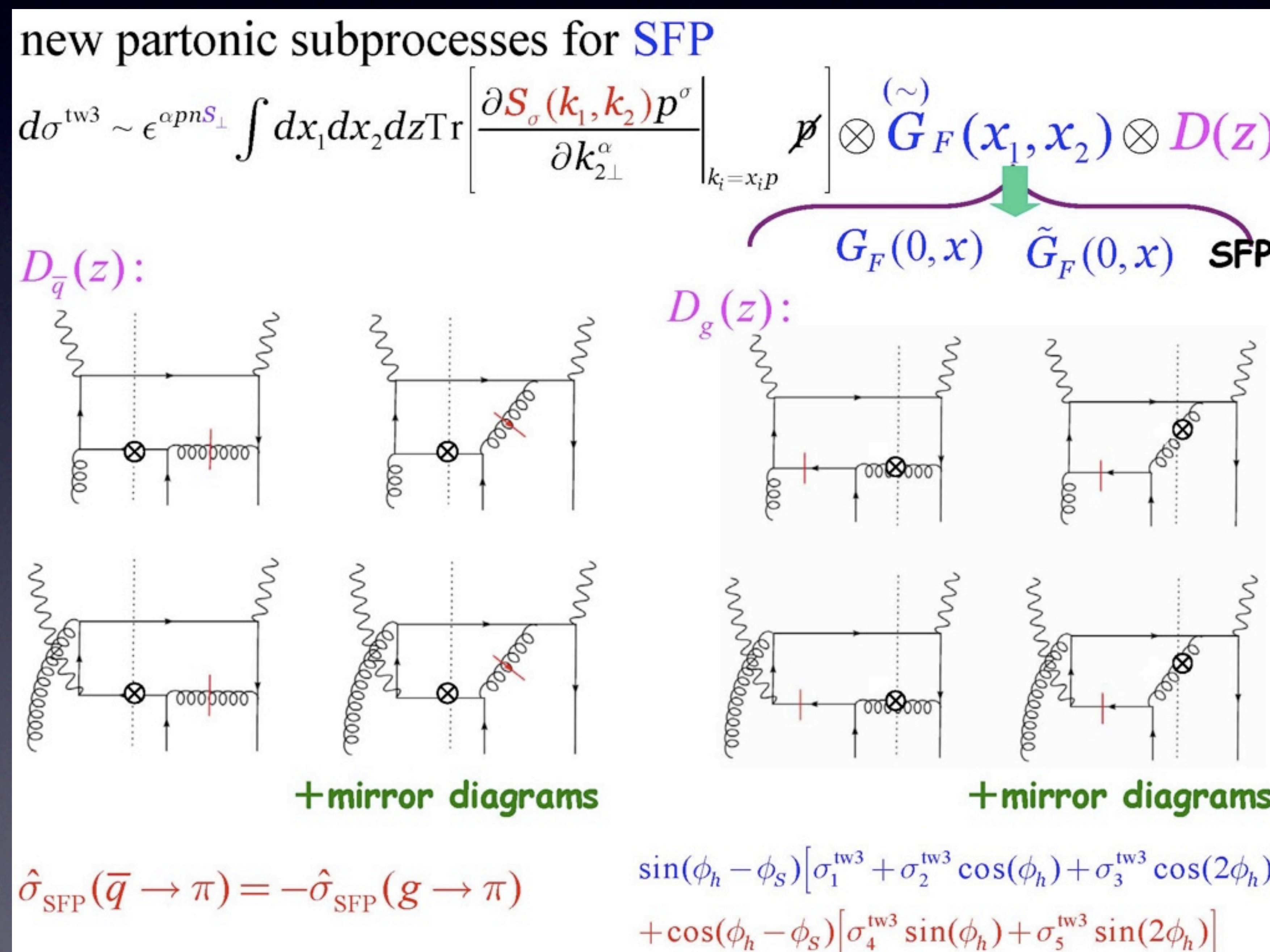
Kazuhiro Tanaka (Juntendo U)

with Y. Koike (Niigata U)

Kazuhiro Tanaka: update of SSA calculations

twist-3 quark-gluon correlations.

contributions without counterpart in TMD approach.



Beat Tödtli:

heavy flavor corrections to transversity

2- and 3-Loop Heavy Flavor Corrections to Transversity

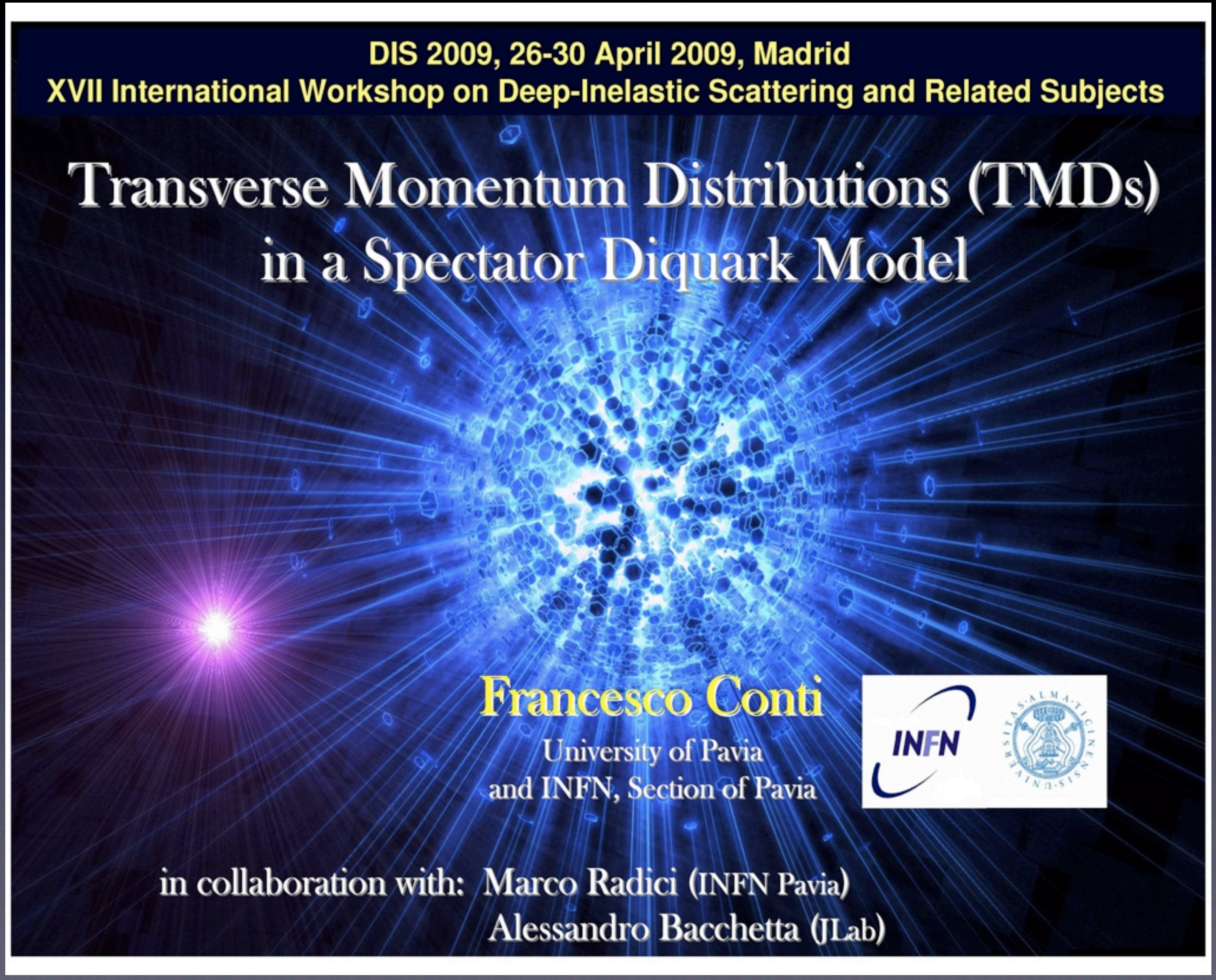
J. Blümlein, S.Klein, B. Tödtli

- Transversity also receives heavy flavor corrections. In high luminosity measurements of SIDIS one may even try to select just this sub-sample.
- These corrections are described by the Wilson Coefficients of the respective processes, which factorize at $Q^2 \gg m^2$ into heavy quark operator matrix elements (OMEs) and the light flavor Wilson coefficients.
- The OMEs, which are universal quantities, were calculated to $O(\alpha_s^2)$ completely, and to $O(\alpha_s^3)$ for the fixed Mellin moments $N = 1 ... 13$.
- $\Longrightarrow$ also obtain the $\propto T_f$ part of the 3-loop anomalous dimension confirming and extending earlier results in the literature.

Francesco Conti: spectator diquark model for TMDs

comprehensive picture

potentialities



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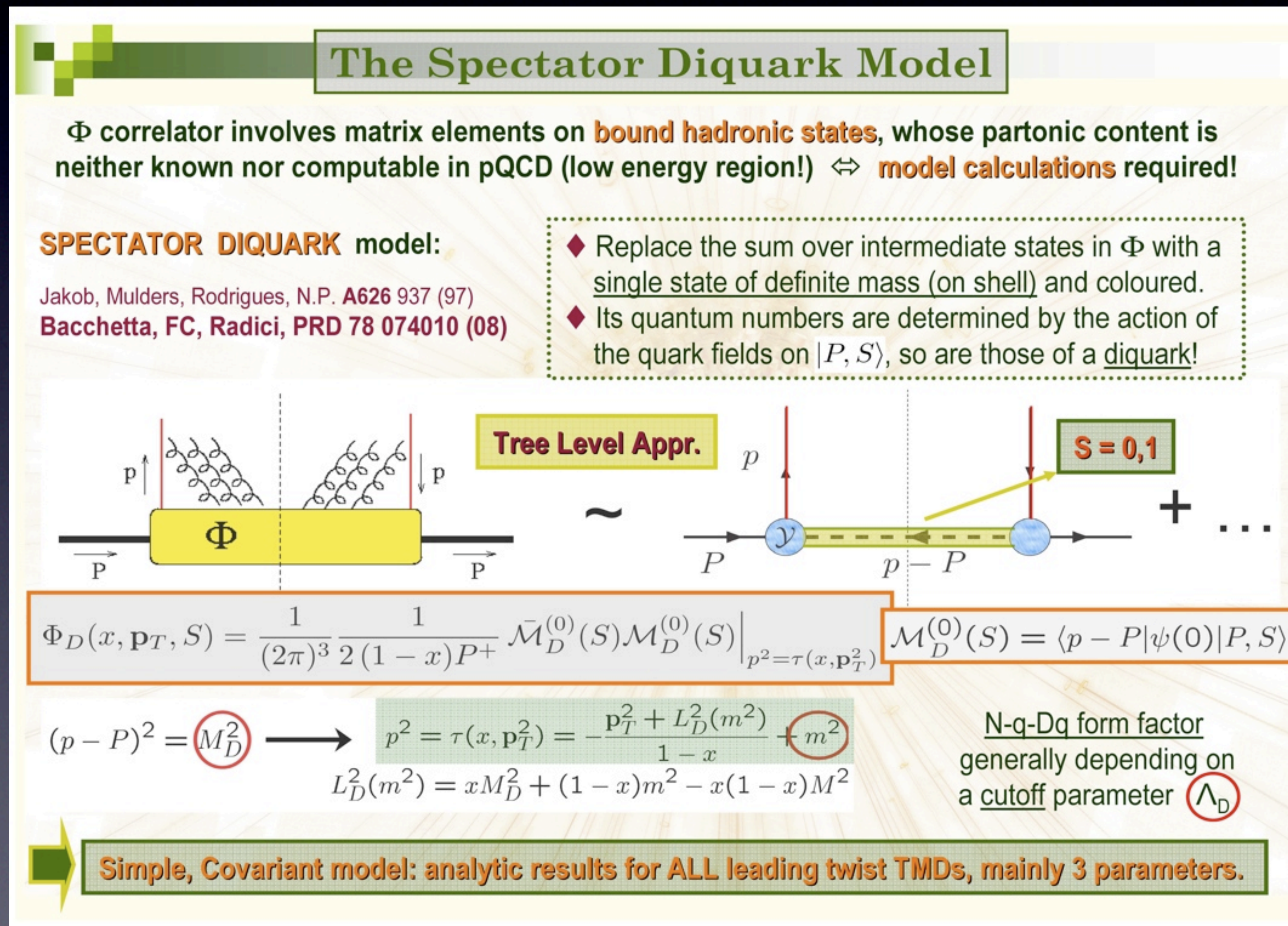

Generalized Parton Densities

Simonetta Liuti:

GPDs from data

how to combine data and theoretically motivated parameterizations

towards a global analysis

Strategies to extract GPDs from data

Simonetta Liuti
University of Virginia
DIS 2009, 26-30 April 2009
Madrid

Simonetta Liuti:

GPDs from data

how to combine data
and theoretically
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Summary of Constraints

Constraints from Form Factors

$$\int_0^1 dX\, H^q(X,t) = F_1^q(t) \qquad \text{Dirac}$$

$$\int_0^1 dX\, E^q(X,t) = F_2^q(t), \qquad \text{Pauli}$$

Constraints from Polynomiality

$$H_n^q(\xi,t) = \sum_{i=0}^{\frac{n-1}{2}} A_{n,2i}^q(t)\xi^{2i} + \mathrm{mod}(n,2)\xi^n C$$

$$E_n^q(\zeta,t) = \sum_{i=0}^{\frac{n-1}{2}} B_{n,2i}^q(t)\xi^{2i} - \mathrm{mod}(n,2)\xi^n C$$

Constraints from PDFs

$$q(x) = H_q(x,0,0)$$

Further Theoretical Constraints:

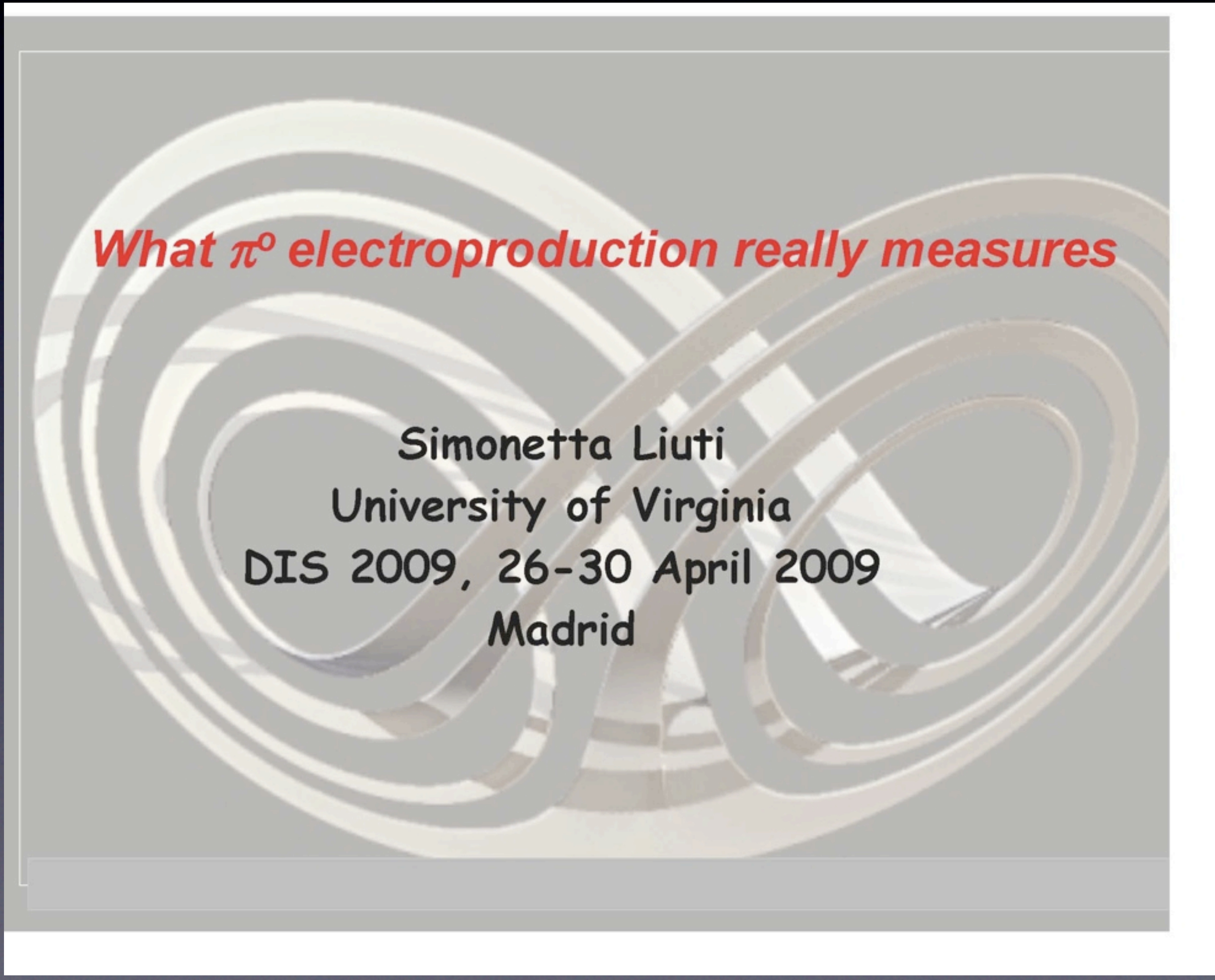
Sensible prediction for hadron shape at $x \to 1$

Sensible prediction for k_T dependence (connection with TMDs!

(SL and Tane in 2004)

Simonetta Liuti:

neutral pion electroproduction



Simonetta Liuti:

neutral pion electroproduction

extraction of
- tensor charge
- Burkardt's moments

What goes into the quark-hadron amplitudes?

$$\boxed{\begin{aligned}\mathcal{F}(\zeta,t) &= -i\pi\sum_q e_q^2\left[F^q(\zeta,\zeta,t)-F^q(-\zeta,\zeta,t)\right]+\\ &\mathcal{P}\int_{1-\zeta}^{1} dX\left(\frac{1}{X-\zeta}+\frac{1}{X}\right)F^q(X,\zeta,t).\end{aligned}}$$

Generalized Form Factors

$$\mathcal{H}_T, \mathcal{E}_T, \widetilde{\mathcal{H}}_T, \widetilde{\mathcal{E}}_T$$

$H_T(X,0,0) = h_1(X)$ = transversity
$\int h_1(X,Q^2)dX = \delta q$ = tensor charge

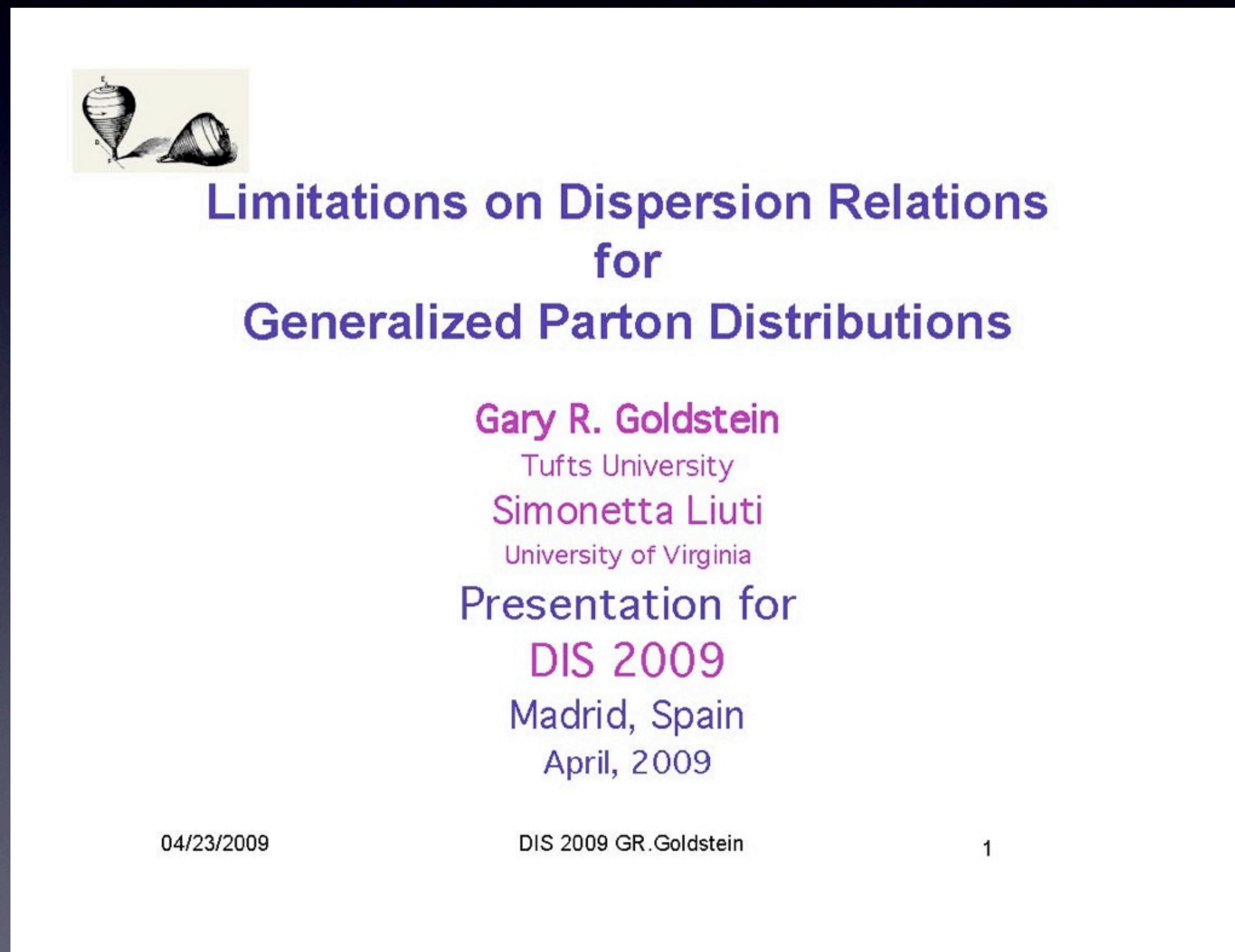
$$\widetilde{\mathcal{E}}_2 = 2\widetilde{\mathcal{H}}_T + \mathcal{E}_T$$

$\int E_2(X,0,0)\,dX = \kappa_T$ = Burkardt's mo

Boer-Mulders $\Rightarrow$ $\int h_1^{\perp}(X,k_T)\,dX \sim -\kappa_T$ (M. Burkardt, A.M

Gary Goldstein:

Dispersion relations for GPD



Gary Goldstein:

Dispersion relations for GPD

many interesting and subtle points

Lessons from examples

- Moderate reach of $E\gamma$ (Jlab<12 GeV) or $s<25$ $GeV^2=(5\ GeV)^2$ not far from t-dependent thresholds
- Non-forward dispersion relations require some model-dependent analytic continuation
- Difference between direct & dispersion Real $H(\zeta,t)$ depends on thresholds – is subtraction "constant" really constant?
- Antiquark distributions are critical for crossing symmetric amplitudes & GPDs
- DVCS & Bethe-Heitler interference measures complex $H(\zeta,t)$ directly – Direct Real from data complements DR constraints & necessitates determination of ERBL GPD region away from ridge $x=\xi$.

Asmita Mukherjee: chiral even & chiral odd GPDs

relativistic two body model inspired in field theory

Chiral-odd and Chiral-even Generalized Parton Distributions in Transverse and Longitudinal Position Space

Asmita Mukherjee
Indian Institute of Technology, Mumbai, India

- Chiral Odd GPDs : Why they are interesting
- Overlap representation of Chiral-odd GPDs
- Simple example : electron at one loop
- GPDs in position space
- Phenomenological study

DIS 09; Madrid, April 2009

In collaboration with D. Chakrabarti (IIT Kanpur), R. Manohar (IIT Bombay)

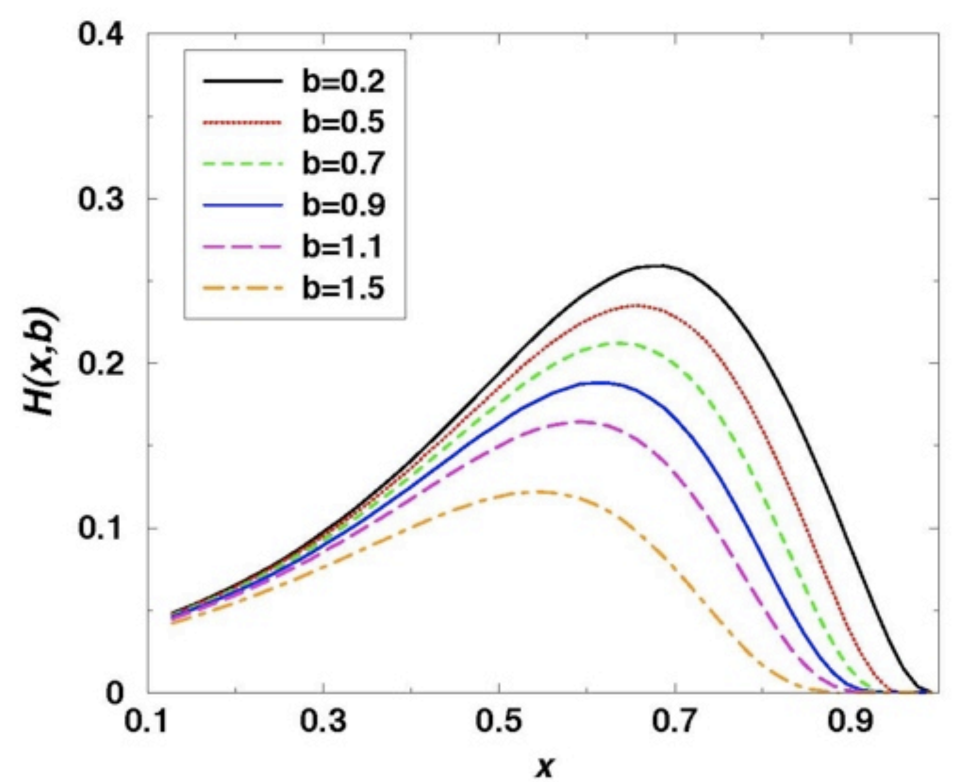
Asmita Mukherjee:

chiral even & chiral odd GPDs

relativistic two body model inspired in field theory

GPD parameterization in position space

GPD model in position space



- Used parametriztion of

Ahmad, Honkanen, Liuti, Taneja (2007)

- We have used parametrizations set I (u quark) at scale 0.09 GeV^2

Summary (Experimental Talks)

Outlook:

More than 20 years of sustained efforts to measure and extract pPDFs have matured significantly.

We have a clear and consistent picture of the quark/gluon helicity in the region covered by experiments.

Our knowledge on transverse polarization is evolving fast.