Workshop at ETC*, Trento, July 3-7, 2006
„Observables in p̄p-interactions and their relevance to QCD"
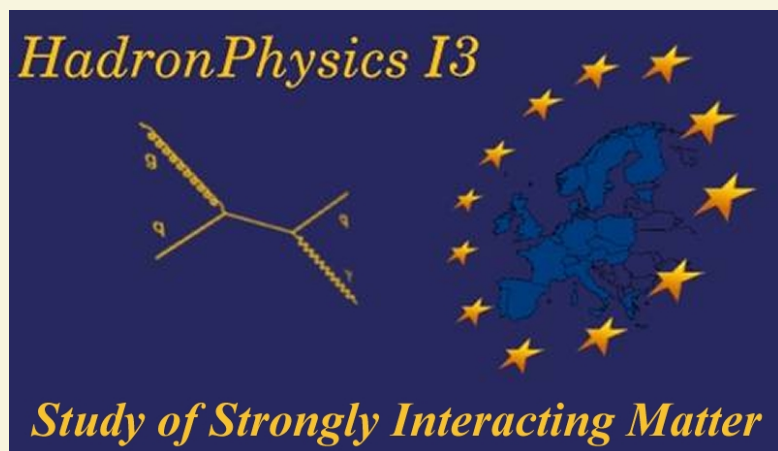
Organizers: Mauro Anselmino, Helmut Koch (Coordinator), Ulrich Mosel, Dan-Olof Riska

All talks available: http://www.ep1.ruhr-uni-bochum.de/~dagmar/Trento.htm

Program of the Workshop

Sunday Evening: Welcome Pizza

Time	Monday	Tuesday	Wednesday	Thursday	Friday
9.00 – 9.45					Weise (pdf 4.6MB) Notes on Spectroscopy and String Breaking
9.45 – 10.30		Mosel (pdf 1.3MB) Hadrons in Matter: Theory and Observables	Brodsky (pdf 25.1MB) Testing Novel Phenomena in QCD and AdS/CFT using Antiprotons	Mulders (ppt 520KB) Single spin asymmetries in $\bar{p}p$ scattering	Vairo (pdf 548KB) Use of EFT's in the Charmonium system
Coffee Break					
11.00 – 11.45	Ritman (ppt 12.1MB) Precision spectroscopy in the charmonium mass region using antiproton annihilation	Kroll (pdf 452KB) Quarks and Gluons in $\bar{p}p$ Annihilations	Brodsky continuation	Oelert (ppt 35.1MB) Physics with low Energy Antiprotons	Timmermans (pdf 5.6MB) Partial-wave analysis of $\bar{p}p$ reactions: (LEAR) and future (FAIR)
11.45 – 12.30	Anselmino (ppt 2.1MB) Spin and $k_\perp$ dependent parton distributions (pdf 1.3MB)	Barnes (ppt 10.6MB) Meson and exotics decays in QCD inspired models	Leupold (pdf 1.3MB) Drell-Yan process in a parton model with offshellness	Pire/Szymanowski (pdf 1.3MB) Hard exclusive reactions in ppbar interactions	Pochodzalla (ppt 24.7MB) Hypernuclear experiments at PANDA
Lunch					
14.00 – 14.45	Kienle (ppt 7.1MB) Some Perspectives of Antiproton and Antikaon Physics	Metag (ppt 8MB) Hadron modifications seen with electromagnetic probes	14:00 Excursion to Bolzano Visit of "Oetzi" in Museum of Archeology	Bettoni (pdf 1.6MB) Charmonium Spectroscopy	
14.45 – 15.30	Morningstar (pdf 668KB) Towards the spectrum of Hadrons using LatticeQCD	Gillitzer (ppt 4MB) Study of hadron in-medium properties in antiproton-nucleus collisions		Lenisa (ppt 2MB) The PAX Project	
Coffee Break				Coffee Break	
16.00 – 16.45	Düren (ppt 10.1MB) Results from Hermes in view of future $\bar{p}p$ Experiments	Bali (pdf 444KB) Quarkonium on the lattice		Rathmann (ppt 2.6MB) Polarization of Antiprotons Nikolaev (pdf 304KB) Understanding the Filtex Results	
16.45 – 17.30	Lutz (ppt 2.5MB) Hadrogenesis and spectroscopy with PANDA	Oset (pdf 2.2MB) In medium properties of strange hadrons		Walcher (pdf 232KB) An alternative method for Polarizing Antiprotons	
17.30 – 18.15	Johansson (pdf 4.6MB) Polarization effects in $\bar{p}p$ interactions with final state hyperons	Metz (pdf 184KB) The Sivers effect and $\bar{p}p$-interactions	19:00 Conference Dinner	Große-Perdekamp (ppt 4.9MB) Hadron Physics at RHIC	

Three main topics:

Spectroscopy
(Ritman, Kienle, Morningstar, Lutz, Kroll, Barnes, Bali, Brodsky, Bettoni, Weise, Vairo)

Hadrons in matter
(Kienle, Lutz, Mosel, Metag, Gillitzer, Oset, Brodsky)

Nucleon Structure
(Anselmino, Brodsky, Düren, Kroll, Metz, Mulders, Pire, Szymanowski, Lenisa, Große-Perdekamp)

+ $\bar{p}p$-reactions in general
    (Brodsky, Johansson, Kienle, Timmermans)

+ Contributions to $\bar{p}$-polarization
     (Rathmann, Nikolaev, Walcher)

+ FLAIR
   (Oelert)

+ Hypernuclei
    (Pochodzalla)

Experiment (Ritman, Kienle, Bettoni)

Many new states (hidden and open charm) seen recently by B-Factories, Cleo-c and BES. Several of them very narrow.

Problems: Γ_{Total} often not measurable, only few decay modes accessible,
Low statistics

↳ Job for PANDA: Measure Γ_{Tot} and $\Gamma_{Part.}$ for as many decays as possible

↳ Nature of states, which are probably often mixtures of $Q\overline{Q}$, $Q\overline{Q}Q\overline{Q}$, and Hybrids
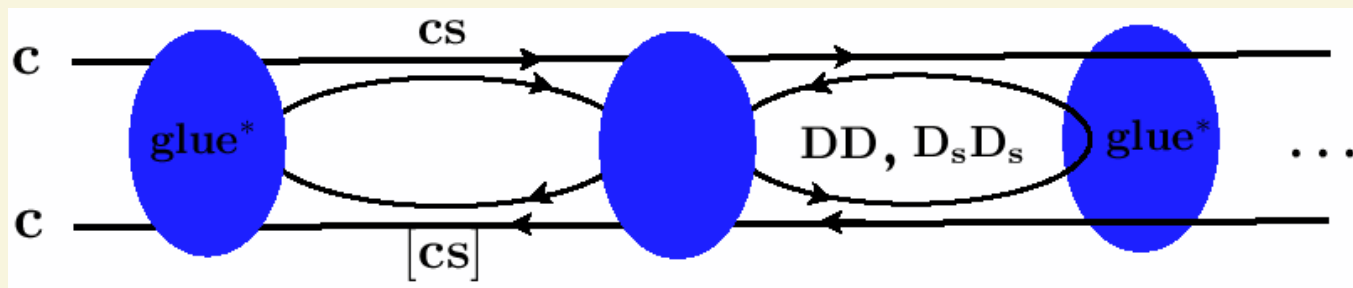
Theory

LQCD (Bali, Morningstar)

Systematic approach to ground state- and excited hadrons: Lattice Hadron Physics Collaboration (LHPC).
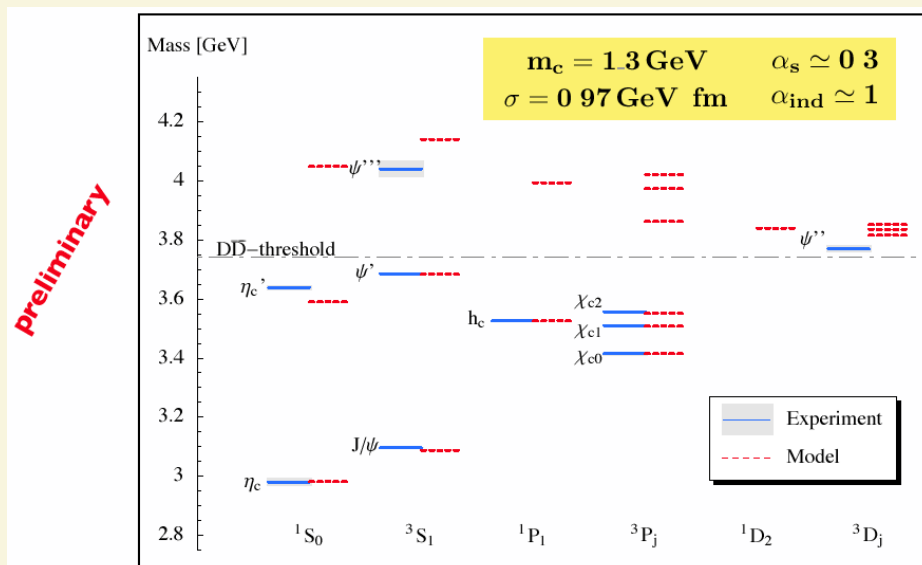
Goal: Spectra of Hadrons (first: Baryons)

Hadron Structure (Form Factors, Structure Functions)

Hadron-Hadron Interaction

Slow progress: Extension of the basis, Many (multi-hadron) operators,

First Results in one year

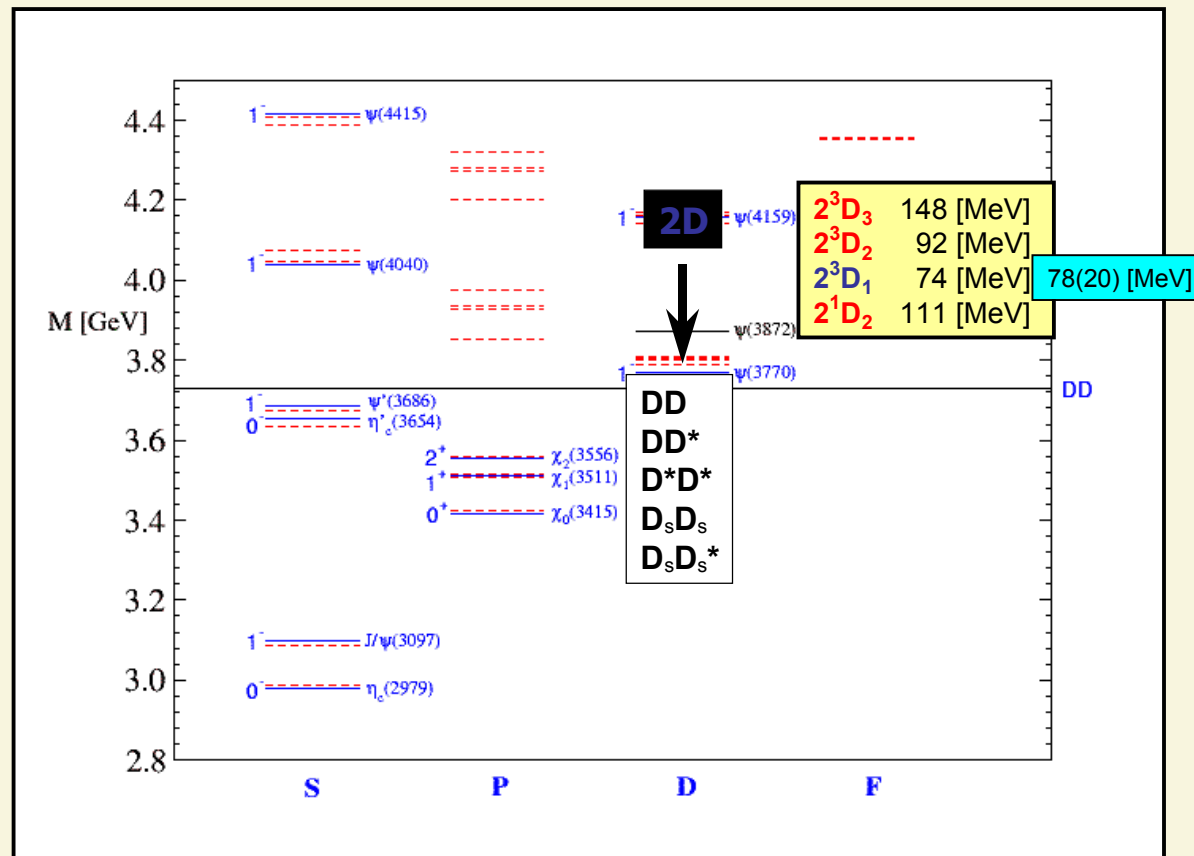Effective Field Theories (Vairo, Weise, Kroll, Lutz)

Expansion in terms of (several) small parameters, Effective Interactions

Theory

Models (Barnes)

Very comprehensive overview on different models. Emphasis on the
$^3P_0$-model, which works well in many cases

Prediction: $\bar{p}p \rightarrow D^*_{s0}(2317) + D_s$ with high rate   **D^*_{s0}-Factory !**

Theory

New developments (Brodsky)

Duality between Conformal Field Theory and Anti-de Sitter Space (5 Dim.)
AdS/CFT
It is claimed that this model has impact on many observables

- Non-Perturbative Derivation of Dimensional
  Counting Rules (Strassler and Polchinski)

- Light-Front Wavefunctions: Confinement at Long
  Distances and Conformal Behavior at short
  distances (de Teramond and Sjb)

- Power-law fall-off at large transverse momentum, $x \rightarrow 1$
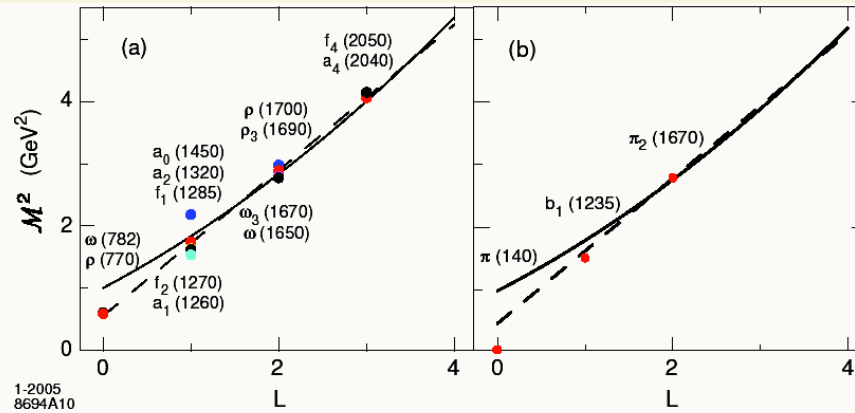
- Hadron Spectra, Regge Trajectories
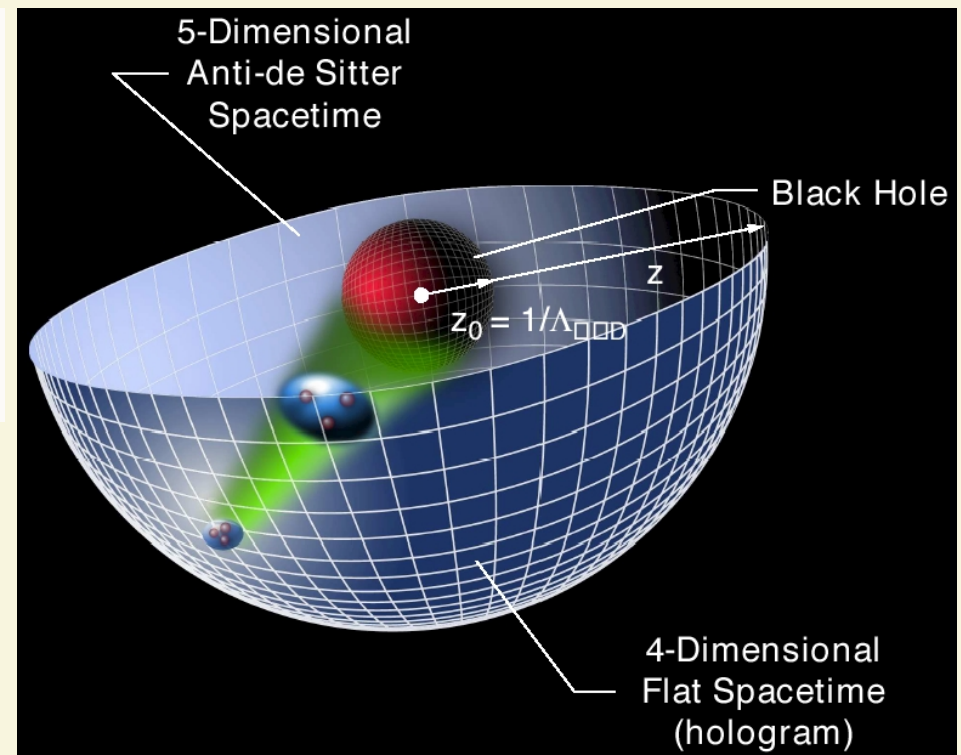
Fig: Light meson orbital spectrum: 4-dim states dual to vector fields in the bulk, $\Lambda_{QCD} = 0.26$ GeV

Guy de Teramond
SJB

Trento
~~July 5 2006~~   AdS/CFT, QCD, & GSI   Stan Brodsky, SLAC

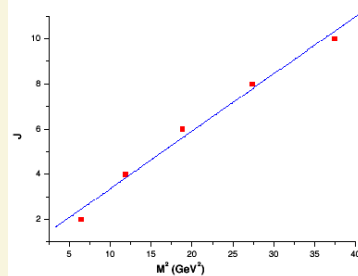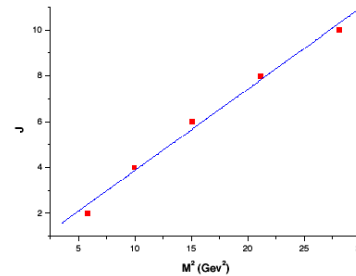Glueball Regge trajectories from gauge/string duality and the

Pomeron

Henrique Boschi-Filho,[*] Nelson R. F. Braga,[†] and Hector L. Carrion[‡]

Instituto de Física, Universidade Federal do Rio de Janeiro,

Neumann Boundary Conditions   Dirichlet Boundary Conditions

CAQCD   **LF Wavefunctions and QCD**   Stan Brodsky, SLAC
5-12-06   **Amplitudes from AdS/CFT**

Key experiments

Use the high statistics and precision of $\bar{p}p$-reactions

$\bar{p}$ (various fixed energies) p $\rightarrow$ many final states (π, K, D, Λ, ...)

↳ Look for new states

Scan around the energy of these states and other already known states

↳ Γ_{Tot}

Look for as many decay channels as possible

↳ Nature of the states

Partial Wave Analysis

↳ J^{PC}
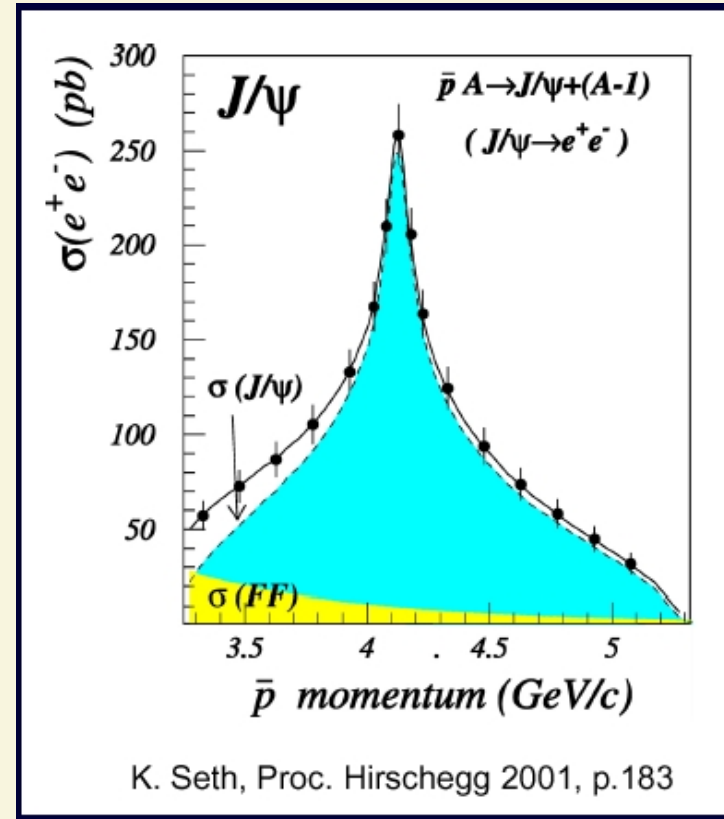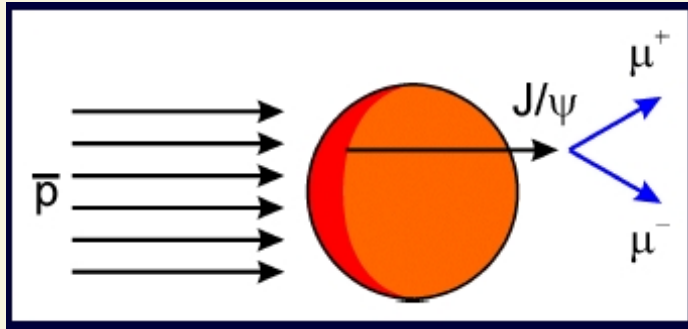
Experiment (Metag, Kienle, Gillitzer)

J/ψ nucleon interaction, important for QGP

PANDA: $\bar{p} + A \rightarrow J/\psi + X$

$$\Rrightarrow \ell^+ \ell^-$$

K. Seth, Proc. Hirschegg 2001, p.183

Recent Simulation: $\simeq$ 220 events/d   o.k. !

More problematic : $\bar{p} + A \rightarrow \psi' + X$: $\approx$ 8 events/d   difficult !

Mass shifts of PS mesons in matter

- Deeply bound pionic states
- K^+/K^- production in HI reactions
- High energy HI reactions (CERES, NA 60)
- Recent TAPS results: ω-mass shift in nuclei, $\Gamma(\omega)$ in nucleus, ω-nucleon bound state?

PANDA-Observables (Charmed Sector):

Subthreshold $\overline{D}\overline{D}$ production: Quantitative results under discussion (see theory)

D/$\overline{D}$-meson mass shift via widths of $c\overline{c}$-states: Assumes zero mass shift of $c\overline{c}$

Collisional width may dominate

D/$\overline{D}$ transverse momentum distribution: May work for some 10 MeV potentials

Problems: D's are fast

(Slow D's by 2-step process, e.g. D + d head-on collisions (Costs rate !))

Mass effects small

Mass shifts of $c\overline{c}$ in matter

Maybe small (see theory)

Hadrons in Matter (3)

Theory (Mosel, Oset, Brodsky))

    – QCD sum rules
    – Hadronic models
    – Connection with experiment through universal transport method for
       low and high energies

- In-medium changes seem to be established in light quark sector:

  CERES, NA60, TAPS/CB, Photoabs., hadronattenuation

- One common feature in all cases: influence of resonance-hole excitations, detailed spectral function not seen!

- In heavy-quark sector main problems are:
  - Smallness of predicted effects,
  - Production mechanism that leads to large p
  - qualitative disagreement between theories

- Essential problem: link of in-medium props to observables → FSI must be part of theory

vacuum   nuclear medium

Pb

π⁻
25 MeV
π
π⁺

K⁺
K
100 MeV
K⁻

D
D⁻
50 MeV
D⁺

Hayashigaki, PLB 487 (2000) 96
Morath, Lee, Weise, priv. Comm.

nuclear matter

total energy at zero momentum (GeV)

D⁻

Δ = 164 MeV

D⁺

ρ$_B$/ρ$_0$

Key experiments (Kienle, Gillitzer)

See proposal, but critical view to the underlying theory. Are the observables firmly connected to QCD d.o.f.?

New ideas:

Produce $ppK^- -$, $pnnK^-K^- -$, $\bar{p} - {}^3He -$ and $\overline{\Lambda} -$ clusters in nuclei

(FINUDA, FOPI, KEK)

e.g.: $$\bar{p} + {}^3He \rightarrow \left[ppK^-\right] + K^0$$

$$\bar{p} + {}^4He \rightarrow K^+K^+ + \left[K^-K^-pnn\right]$$

$$\bar{p} + {}^4He \rightarrow n + \left[\bar{p}{}^3He\right]$$

Nucleon Structure (1)

Experiment (Düren, Lenisa, Große-Perdekamp)

Observables:

$k_\perp$ integrated parton distributions

$q(x, Q^2) = q_+ + q_-$ Quark distribution - well known

$\Delta q = q_+ - q_-$ Quark helicity distribution - well known (Chiral even)

$h_1 = \Delta_T q = q\uparrow - q\downarrow$ Transversity distribution - unknown (Related to Chiral odd)

$\Delta g = g_+ - g_-$ Gluon helicity distribution - pooly known

+   8 spin-$k_\perp$ dependent distribution functions: $q(x, \vec{k}_\perp)$

     $\rightarrow$ Sivers, Collins, Boer-Mulders-Asymmetries - first results

+   Space dependent distribution functions (GPD's; Handbag): $q(x, \vec{b})$

Processes:

DIS, SIDIS, Drell-Yan, DVCS, HEMP (HERMES, COMPASS, HERA, RHIC, JLAB)

Nucleon Structure (2)

Theory (Anselmino, Kroll, Metz, Brodsky, Leupold, Mulders, Pire, Szymanowski)

Two Approaches for hard, exclusive processes
- ERBL (Efremov, Radyushkin, Brodsky, Lepage)
  Describtion in terms of complete $(\vec{x}, \vec{p})$ dependent Wave Functions
  for valence quarks
- Handbag-Model (one active parton), Description of non-perturbative soft part: GPD's

Quantitive predictions for processes

Key experiments for FAIR (Lenisa, Düren)

Experiments with transverse polarized antiprotons and/or polarized target (PAX)

$\bar{p}\uparrow p\uparrow \rightarrow e^+e^-X$ (Drell-Yan): Observable: A_{TT}-Asymmetry $\rightarrow$ Transverse spin distribution of quarks (h_1)

Unique access: Direct measurement, No knowledge of polarized fragmentation functions needed

$\bar{p}\uparrow p \rightarrow e^+e^-X$, Single spin asymmetries (SSA) AN $\rightarrow$ Sivers-Function

$$\text{Sivers (DY)} \overset{?}{=} - \text{Sivers (DIS)}$$

$\overline{p}\uparrow p\uparrow \rightarrow \overline{p}\uparrow p\uparrow$ (elastic), Measure A_N, A_{NN}, A_{LL}, A_{SS}, A_{SL}

Spin mysteries like in pp?

$\overline{p}\uparrow p \rightarrow e^+e^- \rightarrow$ Form Factors, also phase of G_E/G_M

Experiments without $\overline{p}$, p-polarization (PANDA) (Düren, Kroll, Brodsky)

Annihilation into two Photons $\quad : \quad \overline{p}p \rightarrow \gamma\gamma$
and related processes $\qquad\qquad\qquad \overline{p}p \rightarrow \gamma\pi, \rho, \phi$ $\Big\} \rightarrow$ Timelike GPD's

Annihilation into $\gamma^*\gamma \qquad\qquad : \quad \overline{p}p \rightarrow \gamma\gamma^*(\rightarrow \ell^+\ell^-)$ $\Big\}$ Check of Factorization

Drell$-$Yan Dilepton Production $: \quad \overline{p}p \rightarrow \ell^+\ell^- + X$ $\qquad \Big\}$ Boer$-$Mulders$-$Function

$\overline{p}p \rightarrow$ Dileptons $\qquad\qquad\qquad : \quad \overline{p}p \rightarrow \ell^+\ell^-$ $\qquad\qquad \Big\}$ Timelike Proton FF

Proposal (M. Düren): Transverse p-polarization not compatible with
PANDA,
but transverse polarization of ^{3}He possible

Test of reaction mechanisms (Brodsky)

Scaling predictions, dimensional counting: $(\overline{p}p)_{elastic}$, $\overline{p}p \rightarrow K^+K^-$, $\overline{p}d \rightarrow \pi^- p$, @ high $p_\perp$

Diffractive hidden charm production: $\overline{p}p \rightarrow \overline{p} + J/\psi + p$

Double diffractive DY: $\overline{p}p \rightarrow \overline{p} + \ell^+\ell^- + p$

Color Transparency: $d\sigma/dt(\overline{p}A \rightarrow \overline{p}p(A-1)) \rightarrow Z \times d\sigma/dt(\overline{p}p \rightarrow \overline{p}p)$

Non universal Anti-Shadowing in DY: $\overline{p}A \rightarrow \ell^+\ell^- X$

Final Analysis of $\overline{p}p(\uparrow) \rightarrow \Lambda\overline{\Lambda}$ @ LEAR (Johansson)

Diff. cross section, Asymmetries, Depolarization, Polarization Transfer,
Spin Correlations (24 Observables)

⇨ Complete determination of the scattering matrix (12 real numbers, overdetermined)

⇨ p($\overline{p}$)/$\Lambda(\overline{\Lambda}$)-structure + reaction mechanism

HESR: Study reactions in similar way in the 2, 3-strange sector (Ξ, Ω) and in the
        Charm-sector (up to Ω_c)
        Structure of $\Lambda(1405)$

Virtues of PWA-analyses (Timmermans, Walcher)

⤵   Very good initial interaction

       Resonance/background separation

       Search for exotics

       $Y\overline{Y}$ production

Should be extended to HESR energies

Antiproton Polarization

Spin Filtering method seems to work, but understanding still incomplete
(Rathmann, Nikolaev, Walcher)

- – Filtering by nuclear interactions (polarized fixed target)

- – Filtering via interaction with a high intensity polarized e^--beam

$\leadsto$ High $\bar{p}$-Polarization

Discussion going on (Time development of density matrix, ...)

Tests foreseen at COSY, TSR and AD

(Personal) Conclusions

Spectroscopy

Follow the proposed program with emphasis on the investigation of the nature of the recently discovered states
Look also for exotics in the Baryon sector (K⁻pp, ...)

Hadrons in Matter

Very good case : J/ψ-N absorption
Hadronic modifications in matter in the light quark sector seem to be established
No clear predictions in the Charm sector (More theory needed)

Nucleon Structure

Clear theoretical pictures and predictions
The aspects without polarized antiprotons should be investigated
at PANDA ($\bar{p}p \rightarrow \gamma\gamma$; $\gamma\gamma^*$, γM; Timelike FF)

General aspects

Scaling predictions, dimensional counting, production mechanisms should be an essential topic (Good for tests of the detector)