FUTURE SPIN EXPERIMENTS

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A survey of presently planned spin experiments in the near future is given, and an outlook on prospects for spin physics is attempted, based on current trends in theories of polarization phenomena and experimental programs at future ultra-high energy facilities.

1 Introduction: Polarization Trends

A number of projects, approved or proposed, will usher high energy spin physics into the next century; their accomplishments may have far reaching consequences and set the stage for polarization studies at future colliders. These experiments can be classified according to the physics they address and the spin facilities they use; although polarization in the initial state is not indispensable for remarkable spin results (*eg* the well-known hyperon polarization), more detailed information is available with polarized beams and/or targets.

Spin dependence is unavoidable in the gauge theories that constitute the backbone of the Standard Model [1], giving distinct parity-violating (PV) asymmetries in weak processes and predicting substantial parity-conserving (PC) spin correlations in hadronic reactions [2]. These spin effects would be accessible in the short-distance regime of large $\sqrt{s}$ and momentum transfer $p_T\,(Q^2)$ at high energy colliders with polarized beams, provided the interacting elementary particles (leptons and partons) carry some of the initial beam polarization into the collision processes at constituents' level. Leptons (e,μ) can be directly polarized, but partons (quarks and gluons) need to inherit a share of their parent beam hadron (*eg* proton) polarization, much the same way as their energy fraction x. This may be plausible for leading (large-x) valence quarks, but not obvious for partons at small-x. The emerging [3] polarized nucleon structure, with the spin carried not only by valence quarks, but distributed among different internal degrees of freedom, including gluons and sea quarks [4], seems to confirm that an initial p-beam polarization will be effective, even at very high energies, where parton interactions at small-x become dominant.

Beyond the Standard Model, spin has been recognized as a sensitive probe for searches of new gauge bosons, supersymmetry and compositness [5]; for example to identify rare PV effects, that might pass unobserved in spin-averaged experiments, swamped with an overwhelming PC background from QCD.

2 Experimental Objectives

Spin measurements addressing some of the above topics can be divided in the following categories:

1. PV interactions and helicity asymmetries (A_L, A_{LL}) in:
   - production of W and Z bosons,
   - strong and electroweak interference effects [6],
   - contributions of higher mass bosons,
   - contact terms from quark compositeness;
2. PC interactions and
   (a) helicity correlations (A_{LL}, D_{LL},...) in:
      - jet, prompt photon or inclusive particle production at large p_T,
      - di-muon asymmetries at large effective mass and/or p_T,
      - heavy quark or supersymmetric particles' hadronic production;

   (b) single-spin (A_N) transverse polarization effects:
      - QCD predicts these effects to vanish in the perturbative regime,
      - existing results show unxpectedly large single-spin asymmetries.

3 Spin Facilities and Experiments

The status and perspectives of high energy spin experiments (Table 1) can be surveyed by addressing the following questions:

A) What's going on?

1 - Fixed-target experiments with polarized (extracted e, p or secondary μ, $p/\bar{p}$) beams and/or targets have produced the bulk of polarization data in the past decades:

- lepton-nucleon: a series of impressive results have been obtained on parity violating effects ($\gamma - Z^0$ interference) and on the spin composition of nucleons at SLAC, CERN and HERA; these will be followed-up by a next generation (COMPASS at CERN and E-158 at SLAC).
- hadron-nucleon: a large body of data has been collected in hadronic processes both in exclusive [7] and inclusive channels [8], rising questions on the role of spin in the strong interaction that are still waiting for fully convincing answers, despite considerable theoretical work [9].

Here the next generation of experiments would mainly rely on polarized beams in colliders (RHIC, HERA?). There are however plans for new fixed-target experiments [10], possibly using (polarized) gas targets [11].

2 - Collider experiments, principally on e^+e^- machines, have provided a welth of remarkable spin results:

- SLC with polarized beams, measured EW parameters at the Z^0 mass [12];
- LEP, where beam polarization was used for energy calibrations only, measured spin effects in the decays of final states [13];
- HERA has polarized e^+ (soon e^-) beams, that would allow detailed ep studies of charged currents and searches of new currents and particles.
- RHIC (starting in 1999) emerges [14] as leading facility for $p\,p$ spin physics, including studies of PC and PV processes up to $\sqrt{s} = 500$ GeV.

B) What's on next?

The present trend of spin physics towards colliders, might be rich in consequences; the accomplishments of SLC and HERA, and the expected performance of RHIC with polarized protons, could establish the best credentials for the feasibility of polarization experiments at future ultra-high energy colliders.

- Studies for the next e^+e^- linear collider rely on polarization [15], as well as the $\mu^+\mu^-$ option more recently considered [16]. In both projects, polarized beams are foreseen in the baseline design, either following the track of SLC, or as a natural byproduct of the muons' production process.
- The case for polarized protons in LHC is not established at the same level of consensus (despite serious theoretical work surveying the potential of spin physics at multi-TeV energies [17]), probably due to LHC emphasis on luminosity: even high-flux polarized proton sources could be viewed as a limitation to the extreme intensities required for LHC. Polarized beams, involving siberian snakes systems and fine tuning of the machine, might also appear as capital- and labour-intensive. Hands-on experience of such systems at RHIC, and sharper physics focus, might reverse this tendency and enhance the interest for polarized beams in LHC.

Table 1: A Flow-Chart of H. E. Spin Physics: Spin Facilities and Experiments

Physics	(SM and beyond)	QCD (Spin Structure)	QCD (Spin Dynamics)
Spin Facilities	Lepton-Lepton	Lepton-Hadron	Hadron-Hadron
Fixed-Target		3rd generation (compl./advanced) Pol. Beam/target E 80/ 130 (SLAC) EMC (CERN) SMC, E 143-155, HERMES	2nd generation (completed) Pol.Target: Exclusive ANL, BNL, CERN, FNAL, KEK, ... Pol. Beam: Inclusive ANL, BNL, FNAL, IHEP
	E-158 (SLAC) (approved)	4th generation (in preparation) COMPASS ($\geq$ 2000) Apollon (discussed)	3rd generation (discussed) RAMPEX HERA-N (pol.) jet target
Colliders	e^+e^- ($\mu^+\mu^-$?)	$e\,p$	$p\,p$ ($\bar{p}\,p$)
	SLC (completed?)	HERA (in operation)	FNAL (pol. p dismissed ?)
	(X)LC ($\geq$ 20??) $\mu^+\mu^-$ ($\geq$ 20??)	(polarized p ?) ($\geq$ 200?)	RHIC ($\geq$ 1999) LHC ($\geq$ 2005) (polarized ?) ($\geq$ 20??)

4 Future Experiments: Fixed Target

The clock is ticking already for the next generation of fixed-target experiments to study the gluon polarization $\Delta G/G$ in lepton-nucleon scattering:

(a) HERMES: This experiment at HERA has been running since 1995, taking data on inclusive and semi-inclusive polarized deep inelastic scattering [18]. It used the 27.6 GeV longitudinally polarized e^+ beam ($P_B \approx 60\%$), stored in the HERA collider and a polarized gas storage cell containing H (D) and ^3He with areal densities of $7. \times 10^{13}$ (H) and 10^{15} nucleons/cm^2 (^3He). The target polarization P_T was typically 92% and 47% respectively. Events were detected in a spectrometer with a 1.3 Tm dipole magnet and microstrip gas and drift chambers for track and momentum reconstruction. Positron-hadron separation was provided by a lead-glass calorimeter with preshower and TRD.

Recently an important upgrade program has been undertaken with the purpose of extending the sensitivity of the experiment to charm channels and having access to the gluon share ΔG of the nucleon spin, through the process $\gamma^* g \to c\,\bar{c}$, with production of $D\,(\bar{D})$ mesons (open charm) or of J/ψ. The upgrade includes a new RICH counter, a muon system, a large angle calorimeter and a forward quadrupole spectrometer; the experiment is presently running (fall '98) with a good deal of new equipment in operation and aims at determining ΔG around $x_g \approx 0.3$ with a preliminary error $\delta[\Delta G/G] \approx 0.4$ after the first two years of running and ≈ 0.25 with two more years; improvements of luminosity and beam polarization might lead to an additional reduction of 2. If these expectations materialize, HERMES will be able to provide a significant measurement of ΔG for the first time since the so-called "spin crisis" has attracted attention in 1988 to the gluon for explaining the nucleon spin [19].

(b) COMPASS: This recently approved CERN experiment [20], expected to start data taking in year 2000, will be installed on the muon beam previously used for EMC/SMC and will extend their experimental program to a direct measurement of the gluon polarization through the same charm process considered by HERMES. The experiment will also provide high statistics data on g_1, semi-inclusive muon scattering and the transversity polarized structure function h_1.

For this new experiment a major upgrade program to rejuvenate the whole EMC/SMC apparatus is under way, with important additions such as large RICH counters for particle identification, electromagnetic and hadronic calorimeters and tracking detectors adapted to the increased intensity. The 100 GeV/c beam should provide $2 \times 10^8\,\mu$/spill ($P_B \approx 80\%$), giving a nominal luminosity $L = 5 \times 10^{32}\,cm^{-2}\,s^{-1}$. The polarized target (2 cells 60 cm long, oppositely polarized) will contain either NH_3 or ^6LiD, for reactions on protons or deuterons, with polarizations of 85% and 50% respectively. At 100 GeV/c beam momentum the sensitivity to $\Delta G/G$ peaks at $x_g \approx 0.14$ and covers the range $0.07 \leq x_g \leq 0.4$; at 200 GeV/c, smaller values of x_g can be explored. The statistical precision on $\Delta G/G$ for 1.5 years of running (150 days/year and 0.25 combined efficiency of beam and apparatus) would be $\delta[\Delta G/G] \approx 0.1$ for charm production. Also production at 200 GeV/c of hadron pairs ($\pi^+\pi^-$, K^+K^-,...) at $p_T \geq 1.5$ GeV/c was considered [21]; in this case the photon-gluon process is accompanied by leading-order and Compton scattering contributions, which have to be properly accounted for; the statistical accuracy can be improved, giving in 1 year, $\delta[\Delta G/G] \approx 0.05$ (*eg* for K^+K^-).

COMPASS and HERMES may dominate the spin arena for years to come; a similar project (E156), proposed at SLAC, will instead give way to:

(c) E158, using the 48 GeV polarized electron beam at SLAC scattering off unpolarized electrons in a liquid hydrogen target, for a precision measurement of the purely leptonic weak neutral current coupling (now measured only at the Z^0 mass) at small $Q^2 \approx 0.03\,(GeV/c)^2$ in Moeller scattering, giving a precision of about 8×10^{-4} on the weak mixing angle[22]. This ambitious project completes the contingent of fixed-target experiments with lepton beams that will hopefully provide matter for excitement in the coming years.

5 Future Experiments: Colliders

Another momentous step forward will occur at BNL with the RHIC commissioning next year. With the acceleration, storage and interaction of the first polarized proton beam in a collider, hadron spin physics will enter a new domain, previously reserved to electron machines. Later on, HERA might take the lead by running polarized protons up to 800 GeV/c.

(a) The RHIC collider, filled with polarized protons ($P_B \approx 70\%$) and equipped with Siberian Snakes and Spin Rotators is expected[23] to provide collisions at top luminosity $L \approx 2 \times 10^{32}\, cm^{-2}\, s^{-1}$, in the range $(50 \leq \sqrt{s} \leq 500 GeV)$. RHIC construction should be completed in June '99 and commissioning with polarized protons of one ring equipped with snakes is planned in fall '99. By fall 2000 all snakes and rotators should be installed and the first spin physics run started soon after. This achievement will be made possible thanks to the AGS infrastructure and mastery of polarized proton beams and a substantial contribution from RIKEN (Japan). RHIC has an approved program of spin physics for the two major experiments (STAR and PHENIX) and one elastic scattering experiment (PP2PP)[24]. The specific features of each major detector, designed for heavy-ion physics, will be exploited/adapted for the spin program:

1 - PHENIX: With emphasis on high granularity lepton and photon detection, this apparatus[25] is instrumented with a central ($|\eta| \leq 0.35$) barrel spectrometer with axial magnetic field 1 Tm and an average azimuthal coverage of $\Delta\phi/\phi \approx 50\%$; the spectrometer consists of high resolution silicon microvertex, drift, pad and time expansion chambers, providing 1 % momentum resolution at 5 GeV/c, followed by electromagnetic calorimeters having 0.01 radian segmentation in azimuth and lateral directions and $\sigma_E/E \approx 7./\sqrt{E}$; particle identification and lepton/hadron separation are provided by RICH, TOF and TRD detectors. Two full-azimuth muon spectrometers are installed in the endcaps ($1.15 \leq |\eta| \leq 2.35$) with 3-10 % momentum resolution.

These features of the PHENIX detector are well suited for measurements of W and Z decays (despite the non-hermeticity of the central barrel), excellent for prompt photon reactions (thanks to the fine granularity) and for Drell-Yan and charmonium (J/ψ) di-muon decays. The sensitivity on $\Delta G/G$ from prompt photon production ranges in an interval ($0.045 \leq \delta[\Delta G/G] \leq 0.2$) at $\sqrt{s} = 500 GeV$ and for x_g between 0.05 and 0.1.

Table 2: Summary of $\Delta G/G$ Experiments

Experiment	HERMES	COMPASS	RHIC
Beam Momentum $< P_B >$	e^+ 27.6 GeV/c 60%	μ 100 (200) GeV/c 80%	pp 250+250 GeV/c 70%
Target $< P_T >$	H, D, ^3He 90% - 50%	NH_3, ^6LiD 85%, 50%	– – –
Luminosity $(cm^{-2}\, s^{-1})$	$4 - 30 \times 10^{31}$	5×10^{32}	2×10^{32}
Reaction (partonic process)	(a) $e^- N \to e^- DDX$ $(\gamma^* + g \to c + \bar{c})$ (b) $e^- N \to e^- J/\psi X$	(a) $\mu N \to \mu DDX$ $(\gamma^* + g \to c + \bar{c})$ (b) $\mu N \to \mu h^+ h^- X$	(a) $p\, p \to \gamma\, (jet)\, X$ $(g\, q \to \gamma\, q)$ (b) $p\, p \to 2\, jets\, X$
x_g-Range	0.2 - 0.4	(a) 0.07 - 0.4 (b) 0.04 - 0.15	(a) 0.02 - 0.25 (b) 0.01 - 0.2
$\delta[\Delta G/G]$	$\approx 0.4 \to \approx 0.25$ $(\to \approx 0.15$?)	(a) ≈ 0.1 (b) ≈ 0.05	(a) ≈ 0.03 (b) ≈ 0.02
Time scale	Running	Start 2000	Start 2000
Remarks	Low energy: $c\bar{c}$ cross-section 60 nb (threshold 7.2 GeV)	Limited charm vertex resolution; $c\bar{c}$ cross-section 1 μb	Run 2.5 months/year; 50% initial coverage; single photon detection

2 - STAR: With emphasis on charged particles' tracking and electromagnetic calorimetry, this detector [26] has a full azimuthal coverage in the pseudorapidity interval $|\eta| \leq 1.$, with a solenoid of 0.5 T, a silicon drift vertex tracker and a large TPC; TOF and electromagnetic calorimeter are used for charged particles' identification and photon/electron energy measurement $(\sigma_E/E \approx 15./\sqrt{E})$. The calorimeter is relatively coarse and implementation of a shower-max. plane was proposed to increase the spatial resolution for prompt photons; endcap calorimeters $(1. \leq |\eta| \leq 2.)$ will extend the coverage for jets, in order to tag the prompt photons. With these detectors STAR would be able to provide $\delta[\Delta G/G] \approx 0.03$ in a x_g range between 0.02 and 0.3. Distinctive merits of the STAR apparatus are large coverage and hermeticity, ideal for $W^\pm$, Z^0 and jet-photon or jet-jet reconstruction. Funding constraints, limiting full STAR instrumentation for the RHIC startup on spin physics, should be hopefully overcome in order not to impede the achievement of the most ambitious goals at least in the first stage.

3 - PP2PP: this experiment [24] aims at measurements of elastic scattering and total cross-sections, including their spin dependence, in order to explore the structure of the Pomeron, with its new "hard" features. The apparatus consists of precise silicon strip detectors, located in Roman Pots on the RHIC rings. Such detector is also suitable for providing beam polarization measurements, either in collider mode or by using a jet target with recoil detection [27].

Table 3: Summary of RHIC Experiments (800 pb^{-1})

Channel	Parton Process	Measurement	PHENIX	STAR
$pp \to W^+X$	$u\bar{d} \to W^+ \to e^+\nu$ / $\mu^+\nu$	V-A Tests – – – – – – $\Delta u/u; \Delta\bar{d}/\bar{d}$	15k (≈ 0.025) 6k	72k (≈ 0.015)
$pp \to W^-X$	$d\bar{u} \to W^- \to e^-\nu$ / $\mu^-\nu$	V-A Tests – – – – – – $\Delta d/d; \Delta\bar{u}/\bar{u}$	2.5k (≈ 0.05) 5k	21k (≈ 0.03)
$pp \to l^+l^-X$	$q\bar{q} \to \gamma^*, Z^0 \to e^+e^-$ / $\mu^+\mu^-$	$\Delta q/q \times \Delta\bar{q}/\bar{q}$ ($A_{NN} \to h_1$)	(120 Z^0) 30k (700 Z^0)	37k (4.2k Z^0) (≈ 0.2)
$pp \to j(j)X$	*New Currents; Contact Terms*	W', Z'; Λ_C	High p_T ($\geq$100 GeV/c) jets	
$pp \to \gamma(j)X$	$q\,g \to \gamma\,q$	$\Delta G/G$	120k (≈ 0.04) 18k (jet)	300k (≈ 0.025) 100k (jet)
$pp \to j(j)X$	*Many parton proc.:* $g\,g \to q\,\bar{q}$ *typical for gluons*	$\Delta G/G$	15k (≈ 0.04) 6k	72k (≈ 0.025)
$pp \to c\bar{c}\,X$ (also $b\bar{b}$)	$g\,g \to c\bar{c}\,(b\bar{b})$ $[\to \mu^+(\mu^-)]$	$\Delta G/G$ *Prod. Spin Dependence*	*High statistics* ($c\bar{c}$) *prod. and* ($\chi_2 \to$) $J/\psi \to e^+\,e^-$ / *or open* $c\bar{c}\,(b\bar{b})$ *prod.* $\to \mu^+/\mu^-$	

The spin physics agenda of RHIC appears impressive: it includes $\Delta G/G$ measurements with precisions and x_g coverages estimated to be better than those of HERMES and COMPASS (Table 2), but also it spans a broad range of other fundamental measurements [28], listed in Table 3. These extend from basic studies of still undetected contributions to the nucleon spin, to searches for parity violating effects with exciting prospects of new physics [29]. The estimated statistical accuracies are in general adequate; however for certain types of measurements the control of systematic uncertainties might become crucial, as frequently occurring in polarization measurements. A source of certain concern here is partial coverage of PHENIX and maybe STAR in the initial stage.

(b) HERA is now running at design luminosity $L = 1.4 \times 10^{31} cm^{-2}s^{-1}$ ($\approx$ $36pb^{-1}$/year). Already with unpolarized protons and polarized e^+ (maybe soon also e^-), the two major experiments H1 and ZEUS, would have bright spin prospects; notably for the investigation of the EW structure of charged currents and possibly for searching right-handed currents and new particles, which are in the HERA sights since its conception [30]. These measurements would however demand integrated luminosities of 100 - 500 pb^{-1} and use of

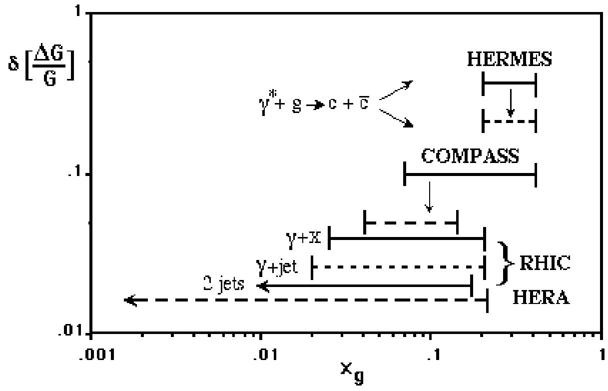

Figure 1: Typical error vs. x-range.

both e^+ and e^- beams (polarized). An upgrade to increase the luminosity to $L \approx 7. \times 10^{31} cm^{-2}s^{-1}$ is foreseen and should take place at the end '99.

The potential of polarized protons in HERA has been the subject of specialized workshops [31] and is presented in a talk at this Symposium [32], which I refer to, for a comprehensive discussion. Feasibility machine studies are in progress [33]: acceleration and storage at 820 GeV/c seem possible, at least with emittance and luminosity reduced (not drastically though) with respect to the design values for unpolarized protons. This option should be reviewed in spring '99; if positively evaluated, polarized *ep* collisions might occur in 2005 (or later), and provide the final keystone of the proton spin architecture, by mapping otherwise inaccessible regions of large-Q^2 and low-x. An accuracy of $\delta[\Delta G/G] \approx 0.02$ in a x_g range between 0.0015 and 0.3 should be obtained from 2-jet production with 500 pb^{-1} integrated luminosity [31]. From a combined QCD analysis of g_1 and 2-jet asymmetry [34], the first moment of the gluon spin distribution would be determined with an error $\delta(\int \Delta G(x)\, dx) \approx 0.1$, to be compared with a value of 0.3 from a similar analysis of the present g_1 data.

A study of charged current asymmetries at HERA would allow a flavor-spin decomposition for valence quarks [35], similar to the RHIC measurements of $W^\pm$ production [29], through their selective coupling to quarks (antiquarks) of definite flavor and helicity.

An internal polarized gas target for fixed-target *pp* measurements has been proposed (HERA-N) [11]: in the reaction $pN \to \gamma(J/\psi) + jet$, it could provide $0.03 \leq \delta[\Delta G/G] \leq 0.4$ in a x_g range 0.1-0.4 for 250 pb^{-1} integrated luminosity.

6 Prospecting Farther Afield

This survey of planned-out high energy spin experiments, reaches far into the next century, certainly farther then the first decade; one should be cautioned not to stretch it much further, considering the rapid evolution already experienced in particle physics. However all sorts of crystal-gazing become popular at the turn of a century, and it is tempting to hazard some guesses (to be proved wild or educated later on!).

(a) There are good reasons to expect a next e^+e^- linear collider, with $\sqrt{s} \sim 500 GeV$ or higher and luminosity $L \sim 5 - 10 \times 10^{33} cm^{-2} s^{-1}$, to be built somewhere in a timescale of a decade or so. Physics reviews [15] and design reports [36] emphasize polarization of the e^-beam ; unless unexpected effects occur during acceleration, $P_{e^-} \sim 70 - 80\%$ (as in SLC) can be expected. Interesting schemes for polarized positrons exist also [37], if deemed necessary. Although the physics scenario at the time such a machine will operate might be strongly influenced by earlier findings at LHC (or present colliders), the role of polarization asymmetry measurements would remain important either for more detailed investigations of newly discovered particles or interactions, or as a tool for furthering such searches.

(b) A similar case for polarization (of both beams) would be valid for the more recently proposed and more speculative, though fascinating, scheme of a $\mu^+\mu^-$ collider [16]. Muons are longitudinally polarized at production ($\pi \to \mu\nu$), but the elaborate steps for ionization cooling and acceleration in fast cicling rings make the final beam polarization less predictable than in the linear e^+e^- collider. After extensive R&D work, and successful demonstration of a (relatively) small-scale prototype (already rich in physics outcome), $\mu^+\mu^-$ collisions might be obtained at energies as high as $\sqrt{s} \sim 2\,TeV$ and luminosity $L \sim 10^{35} cm^{-2} s^{-1}$. This is quite a remote perspective, but certainly an exciting one.

(c) LHC is presently well on track and commissioning is planned for 2005. Even in absence of polarized beams, spin effects in the final states will be detectable in specific cases [38], as signature of relevant reaction/decay processes. These studies will represent a special chapter in the classification of heavy quark states, symmetry properties or new particles and interactions.

A prerequisite for considering the relevance of polarized p-beams for physics objectives at ultra-high energies is that the degree of partonic polarization in the polarized protons remains sufficiently large. This stresses the importance of knowing precisely the spin distribution in nucleons and in particular at small-x, that contribute predominantly at very high energies.

If HERMES, COMPASS and RHIC (possibly HERA) succeed in their task of mapping $\Delta G/G$ as shown in Fig. 1, and if the resulting gluon polarization is as sizable as expected by various models [4] ($|\Delta G/G| \approx 0.25$ around $x_g = 0.07$), not too different from estimates for quarks (in particular $\Delta u/u$) at the same x-values [29], it would become conceivable to use polarized proton beams at LHC energies ($\sqrt{s} = 14$ TeV) for measurements of asymmetries in interactions of polarized gluons and quarks, with effective parton polarizations of about 15-20% for proton beams 70% polarized. Benchmark processes to look for, in this regime, might be double spin asymmetries A_{LL} for $g + g \to \tilde{g} + \tilde{g}$, or A_L in jet production for contact-type interactions [5].

At a first glance, the overall conditions for acceleration and storage of polarized protons at LHC [39], seem manageable and encourage an *interim* feasibility study of a snake scheme conforming with the lattice design for LHC, presently being frozen and built soon, in order to ensure that such system meets all required constraints to be implemented, if deemed useful, at an appropriate later time.

7 Conclusions

Spin physics is stepping into the next century with a full gear of new tools and exciting projects. Their outcome, in the early 2000's, would hopefully demonstrate that the pieces of the intriguing nucleon spin puzzle may eventually all fit in place and form a clearer picture of the polarized nucleon. Maybe we'll realize then how the sparse fractions of $\hbar/2$, that nature judiciously distributes among various partons, could be of better use this way than if they were all concentrated in valence quarks only. For instance for pp asymmetry measurements at ultra-high energies, where collisions would occur mainly among all types of partons at small-x, and where new spin effects at new physics scales might appear. I wish we all witness this happen, soon or later; maybe at that time I will be asked to give a talk on "Experiments in the late 90's"...

Acknowledgements: This survey was made possible thanks to informations kindly provided by representatives of various projects and discussions with a number of colleagues; in particular I would like to gratefully acknowledge here N. Akchurin, D. Barber, F. Bradamante, A. Bravar, G. Bunce, W. Guryn, K. Imai, Y. Makdisi, W.D. Nowak, S. Nurushev, Y. Onel, N. Paver, T. Roser, N. Saito, J. Soffer, V. Solovianov, M. Tannenbaum, D. Underwood, A. Yokosawa. I thank also the Symposium organizers for invitation and hospitality.

References

1. C. Quigg, *Gauge Theories of the Strong, Weak, and Electromagnetic Interactions*, Addison-Wesley Publ. (1983); E. Eichten *et al.*, *Rev. Mod. Phys.* **56** (1984) 579; M. Peskin, *Helicity as a Skeleton Key to Particle Physics*, CERN Lecture Notes (1997).
2. J. Babcock *et al.*, *Phys. Rev.* **D19** (1979) 1483; N. Craigie *et al.*, *Phys. Rep.* **99** (1983).
3. J. Ashman *et al.*, *Nucl. Phys.* **B206** (1988) 364; *ibid.* B328 (1989) 1; K. Abe *et al.*, *Phys. Rev. Lett.* **74** (1995) 346; D. Adams *et al.*, *Phys. Rev.* **D56** (1997) 5330.
4. R. Ball *et al.*, *Phys. Lett.* **B378** (1996) 255; M. Gluck *et al.*, *Phys. Rev.* **D53** (1996) 4775; T. Gehrmannn and W. Stirling, *Phys. Rev.* **D53** (1996) 6100; G. Altarelli *et al.*, *Nucl. Phys.* **B496** (1997) 337; R. L. Jaffe and H. J. Lipkin, *Phys. Lett.* **B266** (1991) 458; R. L. Jaffe, *Phys. Lett.* **B365** (1996) 359; G. Ramsey *et al.*, *Phys. Rev.* **D55** (1997) 1244; M. Goshtasbpour, these proceedings.
5. C. Bourrely *et al.*, *Phys. Rep.* **177** (1989) 319; F.E. Paige, T.L. Trueman and T. N. Tudron, *Phys. Rev.* **D19** (1979) 935; P. Taxil, *Riv. N. Cim.* Vol. **16**, No. 11 (1993); P. Chiappetta, *Proc. Adriatico Conf. on Spin and Polarization Dynamics in Nucl. and Part, Physics*, Ed. A. Barut et al., World Scientific Publ. (1990) 29.
6. R. Casalbuoni *et al.*, *Phys. Rev.* **D56** (1997) 2812; R. Casalbuoni *et al.*, *Z. Phys.* **C60** (1993) 315.
7. D.G. Crabb *et al.*, *Phys. Rev. Lett.* **41** (1978) 1257; E.A. Crosbie *et al.*, *Phys. Rev.* **D23** (1981) 600.
8. L. G. Pondrom, *Phys. Rep.* **122** (1985) 57; K. Heller, *Proc. 1988 Adriatico Res. Conf. on Polarization Dynamics in Nucl. and Part. Physics*, Ed. A. Barut *et al.*, World Sci. Publ. (1990) 36.
9. J. Qiu and G. Sterman, *Phys. Rev. Lett.* **67** (1991) 2264; A. Contogouris *et al.*, *Phys. Rev.* **D48** (1993) 4902.
10. V. Solovianov, *RAMPEX Status Report*; these proceedings.
11. W.D. Nowak, *Proc. 1995 Adriatico Res. Conf. on Trends in Collider Physics*, Ed. Y. Onel *et al.*, World Sci. Publ. (1997) 169.
12. J. Johnson, *Proc. 1995 Adriatico Res. Conf. on Trends in Collider Physics*, Ed. Y. Onel *et al.*, World Sci. Publ. (1997) 83.
13. D. Buskulic *et al.*(ALEPH), *Phys. Lett.* **B374** (1996) 319; W. Bonivento (DELPHI), *Proc. 12th International Symposium on High-Energy Spin Physics* (Sept.1996) Amsterdam, Ed. C.W. de Jager *et al.*; World Scientific Publ. (1997) 229; P. Hansen, *ibid.* p. 343, and these proceedings;

U. Stiegler (ALEPH), *Proc. 1995 Adriatico Res. Conf. on Trends in Collider Physics*, Ed. Y. Onel *et al.*, World Sci. Publ. (1997) 183;
14. G. Bunce *et al.*, *Part. World* **3** (1992) 1.
15. E. Accomando *et al.*, *Phys. Rep.* **299** (1998) 1; A. Babich *et al.*, *Polarized observables to probe Z' at the* e^+e^- *linear collider*, Report ICTP-Trieste, **IC-98-206** (1998)
16. R. Palmer *et al.*, *Muon Collider Overview: Progress and Future Plans*, Report **BNL-65627** (1998); V. Barger, *"Overview of Physics at a Muon Collider"*, *Proc. 4th Int. Conf. on Physics Potential and Development of* $\mu^+\mu^-$ *Colliders (MUMU97)*, Ed. D.B. Cline, AIP Conf. Proc. Vol. **441** (1998); S. Parke, *"Top Quark Physics at a Polarized Muon Collider"*, *ibid.*
17. J. Soffer and J.M. Virey, *Nucl. Phys.* **B509** (1998) 297; C. Bourrely and J. Soffer, *Phys. Rev.* **D53** (1996) 4067; C. Bourrely and J. Soffer, *Nucl. Phys.* **B423** (1994) 329; C. Bourrely, J.P. Guillet and J. Soffer, *Nucl. Phys.* **B361** (1991) 72;
18. P. Geiger *et al.* (HERMES), *Nucl. Phys.* **A629** (1998) 277; A. Bruell, these proceedings.
19. A. Efremov and O. Teryaev, Prepr. JINR, **E2-88-287** (1988); G. Altarelli and G. Ross, *Phys. Lett.* **B214** (1988) 381; R. Karlitz *et al.*, *Phys. Lett.* **B214** (1988) 229.
20. G. Baum *et al.*, *COMPASS: A proposal for a common muon and proton apparatus for structure and spectroscopy*, **CERN-SPSLC-96-14** (1996)
21. A. Bravar *et al.*, *Phys. Lett.* **B421** (1998) 349.
22. R. Carr *et al.*, **SLAC-PROPOSAL-E158** (1997)
23. T. Roser, *Proc. 1995 Adriatico Res. Conf. on Trends in Collider Physics*, Ed. Y. Onel *et al.*, World Sci. Publ. (1997) 139;
24. W. Guryn *et al.* (PP2PP Collaboration), *"Experiment to Measure Total Cross Sections, Differential Cross Sections and Polarization Effects in pp Elastic Scattering at RHIC"*, RHIC Proposal **PR7**, Jan. 1994; updated Sept. 1995.
25. D.P. Morrison *et al.*, *Nucl. Phys.* **A638** (1998) 565
26. M. Beddo *et al.*, *STAR: Coneptual design Report for the Solenoidal Tracker At RHIC*, **BNL-PUB-5347** (1992).
27. N. Akchurin *et al.*, *Proc. 12th International Symposium on High-Energy Spin Physics* (Sept.1996) Amsterdam; Ed. C.W. de Jager *et al.* World Scientific Publ. (1997) 810.
28. A recent review is given in *Proc. of Workshop on RHIC Spin Physics* (April 1998), RIKEN-BNL Research Center, Report **BNL-65615**; Org. G. Bunce *et al.* (1998).

29. C. Bourrely and J. Soffer, *Nucl. Phys.* **B445** (1995) 341; P. Taxil and J.M. Virey, *Phys. Lett.* **B364** (1995) 181.
30. R. Cashmore, *Proc. of Workshop on Prospects of Spin Physics at HERA*, Zeuthen, 1995; Ed. J. Blumlein and W.D. Nowak; Report **DESY 95-200** (1995) 233; F. Zetsche, *Proc. 12th International Symposium on High-Energy Spin Physics* (Sept.1996) Amsterdam; Ed. C.W. de Jager *et al.* World Scientific Publ. (1997) 637.
31. A. De Roeck *et al.*, *Eur. Phys. J.* **C6** (1999) 121; A. De Roeck, *Proc. of Workshop on Physics with Polarized Protons at HERA*, Zeuthen, 1997; Ed. J. Blumlein, A. De Roeck, T. Gehrmann and W.D. Nowak; Report **DESY 97-200** (1997) 523.
32. A. De Roeck, these proceedings.
33. D. Barber, *Proc. 1995 Adriatico Res. Conf. on Trends in Collider Physics*, Ed. Y. Onel *et al.*, World Sci. Publ. (1997) 116.
34. J. Lichtenstadt *et al.*, *Proc. 12th International Symposium on High-Energy Spin Physics* (Sept.1996) Amsterdam; Ed. C.W. de Jager *et al.* World Scientific Publ. (1997) 422; B. Adeva *et al.*, *Phys. Rev.* **D58** (1998) 2002.
35. J. Feltesse and A. Schafer, *Proc. 12th International Symposium on High-Energy Spin Physics* (Sept.1996) Amsterdam; Ed. C.W. de Jager *et al.* World Scientific Publ. (1997) 75.
36. N. Akasaka *et al.*, *JLC Design Study*, **KEK-REPORT-97-1** (1997); S. Kuhman *et al.*, *Physics and technology of the next linear collider*, Snowmass '96, Report **SLAC-R-0485** (1996).
37. T. Omori *et al.*, *A polarized positron source for linear colliders*, **KEK-PREPRINT-98-13** (1998); presented at 1st Asian Particle Accelerator Conference (APAC 98), Tsukuba, Japan (1998).
38. W. Bernreuther and A. Brandenburg, *Phys. Rev.* **D49** (1994) 4481; W. Dharmaratna and G. Goldstein, *Phys. Rev.* **D53** (1996) 1073; D. Chang *et al.*, *Phys. Rev. Lett.* **77** (1996) 1218.
39. N. Akchurin *et al.*, *Proc. of Workshop on Prospects of Spin Physics at HERA*, Zeuthen, 1995; Ed. J. Blumlein and W.D. Nowak; Report **DESY 95-200** (1995) 163.