# PRACTICAL SIMULATION OF EVENTS WITH A RELEVANT ROLE OF TRANSVERSE SPIN AND INTERFERENCE.

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1st question: what are my (generated) events needed for?

2nd question: what do I need in these events?

1A) Preliminary simulation for acceptance or feasibility study

1B) Data analysis (e.g. analysis of fake effects)

1C) Comparison model-experiment.

1D) The MC is a model itself.

2A) inclusive event in inclusive form: $A + B \rightarrow C + X$ and I don't care X

2B) inclusive event in exclusive form: $A + B \rightarrow C + X$ and I need X in detail

2C) I also need working on non-final steps of an event.

**Inclusive events in inclusive form,  intermediate-energy.**

AB's suggestion:   Do it yourself, sticking to phenomenology.

output: more realistic and more specific
code: much shorter
cpu: no match
error sources: less and easier to localize
frequent changes: easier to handle

Example applications:

Decide how many events are needed  to get  some asymmetry with 30 % relative error, on a molecular target where  50 % of the nucleons are polarized and Fermi motion has to be included.

Decide which kinematical region optimizes the tradeoff between the strength of an effect and the event number.

Repeat a large number of times an analysis that requires 1 Mevents (for tests, optimizations etc)

Mistake to be avoided:: poor care of the input section and of the instructions for users.

Mistake to be absolutely avoided: to exaggerate

Opposite case: In $A + B \rightarrow$ leptons + X **I need to know X in detail.**

example Drell-Yan: will the background pions hide the muon signal with a 2-meter Pb screen?

Example: fragmentation functions: to measure them, I need to know how many hadrons of a family are in a final state.

A model for EXCLUSIVE (or partially exclusive) multifragmentation is needed.

For implementing new theoretical ideas, you may even need to access to **unobservable variables** (e.g. quark momenta).

Acting on a pre-existing model and code (e.g. Pythia), the simplest strategy is **not to modify this code at all,** but:

1) taking a “bare” event (= as produced by pythia)
2) calculate the “reweight factor” sigma_new / sigma_old
3) using the reweight factor to accept/reject the event. If accepted, it is a “dressed” event

Alternative (not to waste bare events):
1a) random-modifying the bare event
1b) accept/reject the modified event only

Whichever strategy, some common theoretical problems:.

1) An **exclusive multiparticle event contains much more info than a DF*FF structure**

If I have e.g. 10 final $\pi^+$ in a jet, each with FF H(z,kT,S)

Obvious generalization: H(1,2,3,....,10) = H(1)*H(2)*H(3)......*H(10).

If S is a **common spin** (e.g. the spin of a special quark or hadron), this is **not correc**t:

Each H(i) is linear in S, but H(1,2,3,....10) must be linear in S as well.

↓ ↙

H(1) = A + BS, H(1,2,3....) = C(1,2,3,....) + D(1,2,3,.....) S.

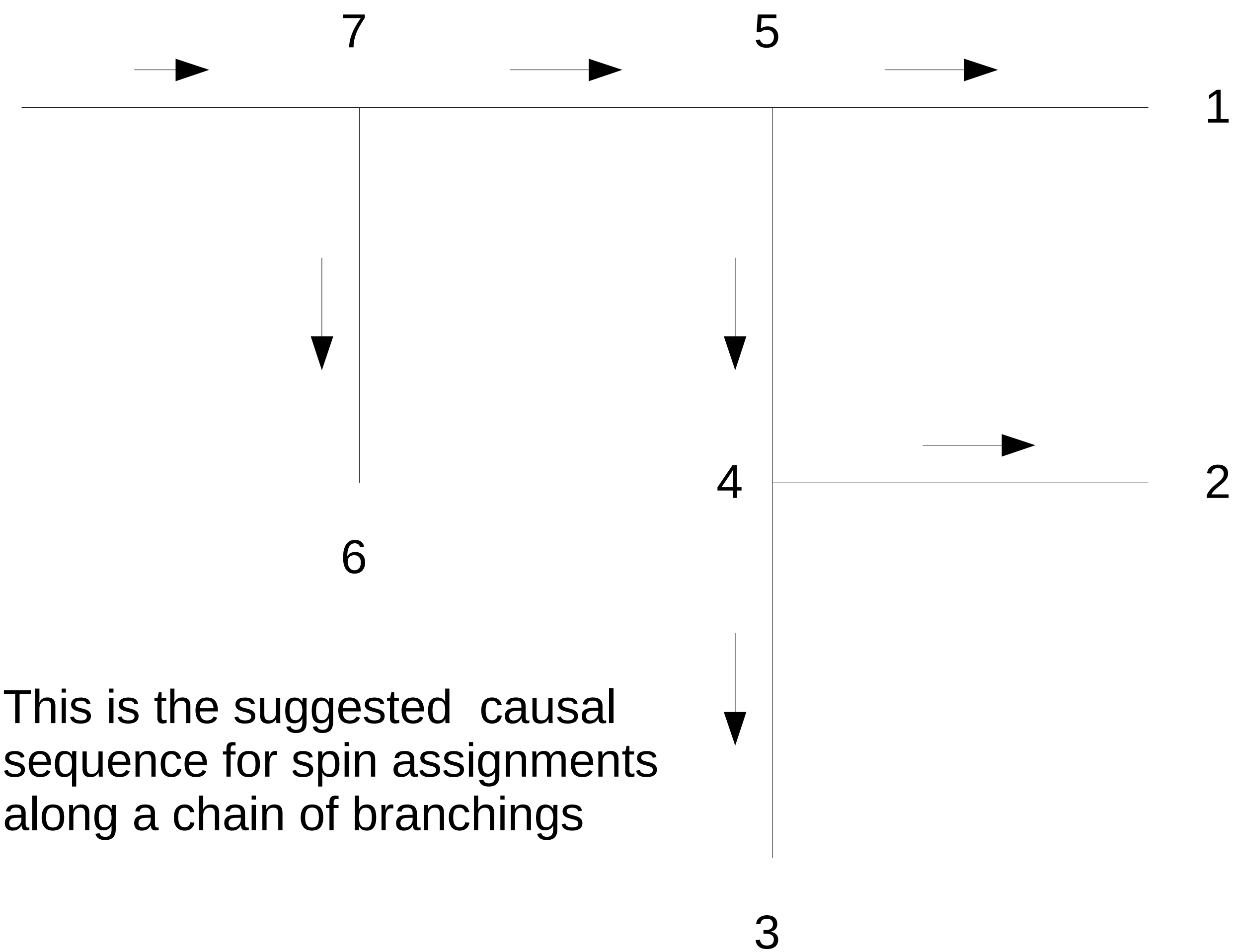
Possible exception: B/A << 1 → negligible nonlinear terms

The generalization H(1) → H(1,2,3,4,.....) requires a MODEL:
How information on a single spin drifts through the full cascade?

Implementation will use Bayes' theorem

H(1,2) = H(1)*G(2|1) ← first generate 1, and next 2 using 1. And so on for 3, ...

In the most general form this procedure is applied to ALL the partons and hadrons of the event, in the form suggested by J.Collins, NPB B304 (1988) 794




This is the suggested causal sequence for spin assignments along a chain of branchings

Problem 2. **Spin assignments in the same or different points of the events must be reciprocally compatible.**

In quantum mechanics I cannot assign both the z and the x components of a spin.

Case A) The montecarlo I want to modify already uses the helicity of a quark for deciding the later evolution of a jet. This makes this helicity partially observable. Accessing the transverse spin of this quark may create conflict.

Case B) 1 and 2 are two different partons. A conservation law relates S1x and S2x.
Let me suppose that I first assign S1x.
Then an assignment of S2y in the same event is potentially conflicting with S1x.

Problem 3) **interference and loops**

Many observables of interest derive from interference functions and/or loops (e.g. Sivers function)

A MC-code may handle SOME interference processes, but not in general.
E.g. “destructive interference” may become “probability of cancellation”.

When you have a loop what matters is not the single event, but the cumulative effect of many events

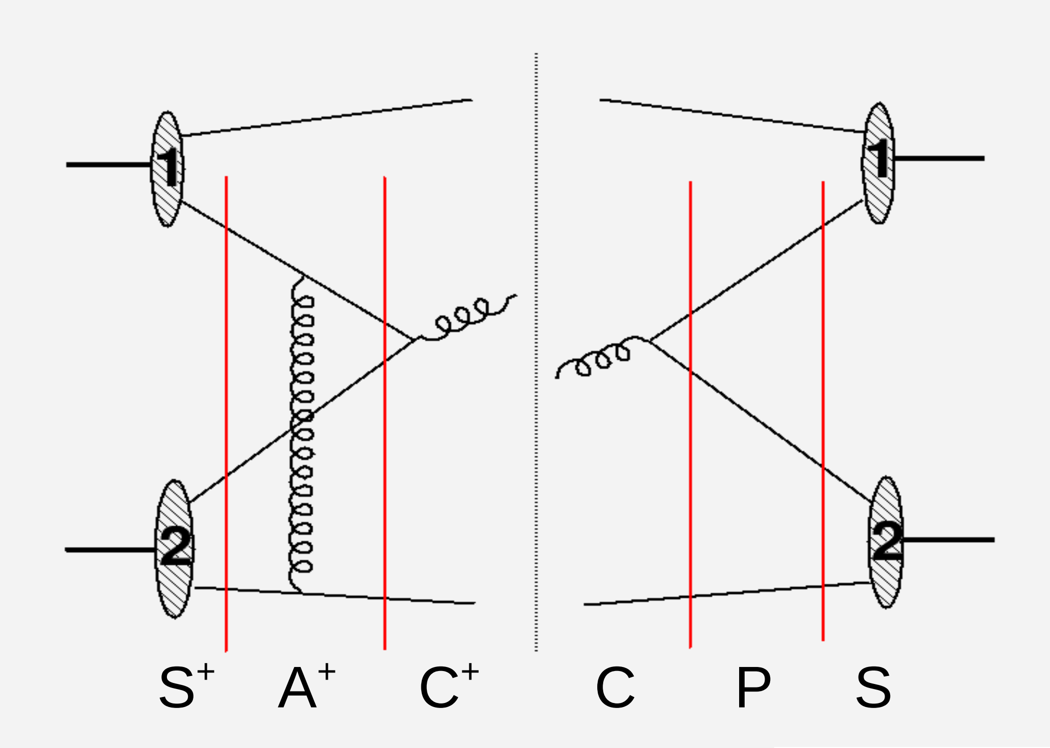
Loop = sum at amplitude level over events differing by the value of in internal variable.
MC loop = probabilistic sum over a set of many events, each associatged with a given value of the internal variable.

We exploit that the internal variable itself is not observable, to modify the loop structure.

Strategy A) Effectively modify the probability structure, so to put the interference effects in a “localized” probabilistic step
Strategy B) Save some of the possible averages, and give up with the other ones.

## Reorganization of interference, Example Drell-Yan (low energy)

AB, Eur. Phys. J. A 45, 301-310 (2010)




For each set of (anti)quark spins

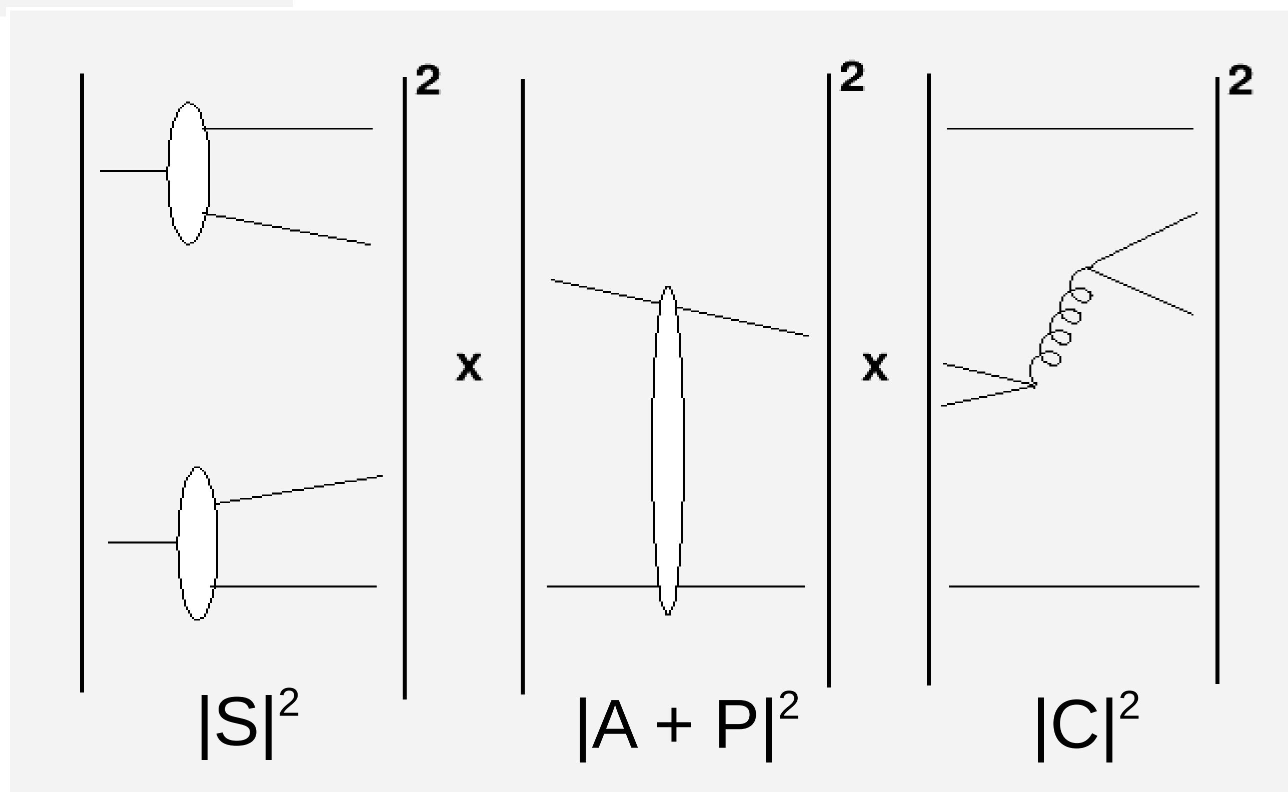
$$|S\,P\,C + S\,A\,C|^2$$

$$\Rightarrow \quad |S|^2 \; |P+A|^2 \; |C|^2$$

Interference features of the loop are partly lost

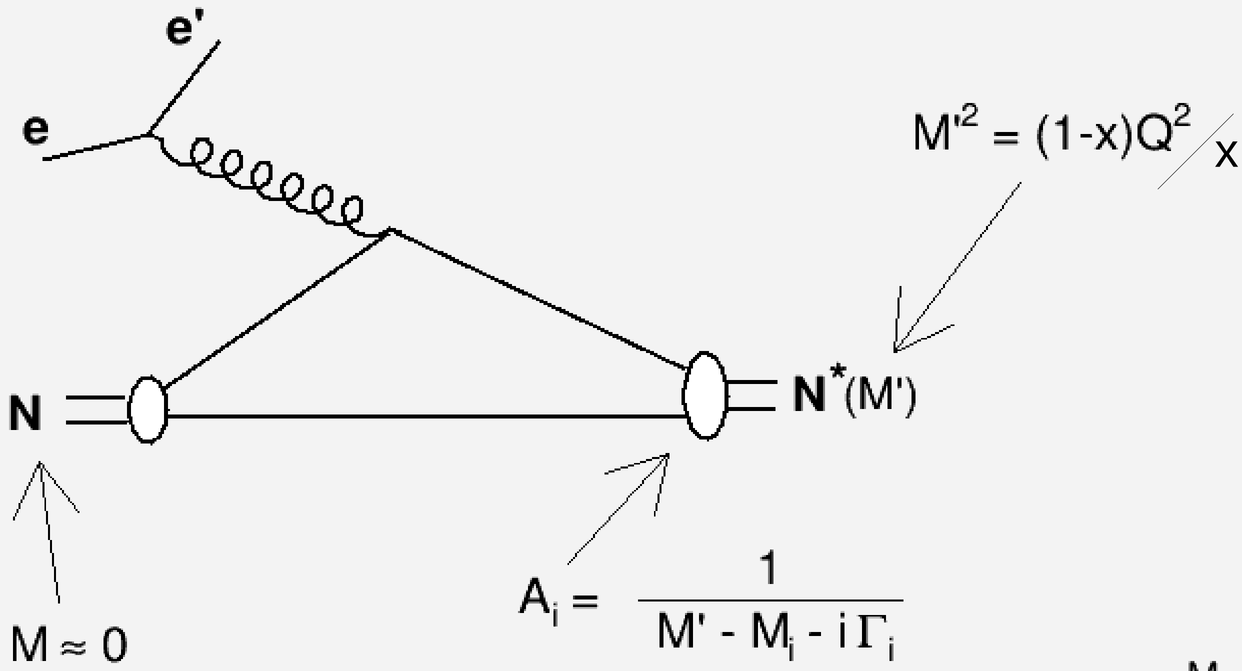
Theory or guess must tell me **what $|P+A|^2$ can be**

In this case a spin-orbit form reproduces the azimuthal lepton distribution (known), but also produces a final hadron nontrivial distribution. Will it be true?



## Example 2: duality and HT In SIDIS. A toy model

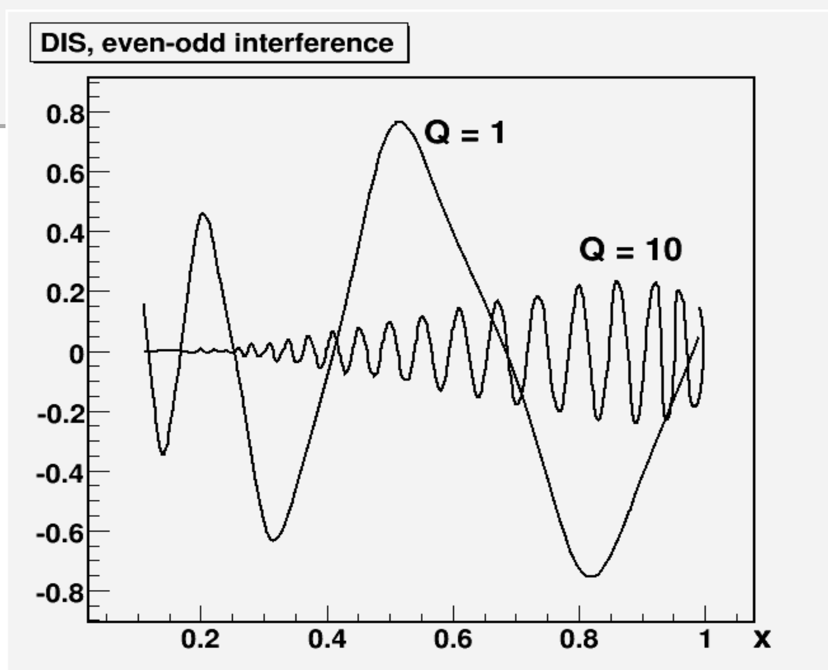
Basic DIS Duality Model (Inspired by works by Isgur, Close, Jeschonnek, Van Orden, Melnitchouk, years 2001-2007)
DIS = coherent sum over excitation of a set of final bound states

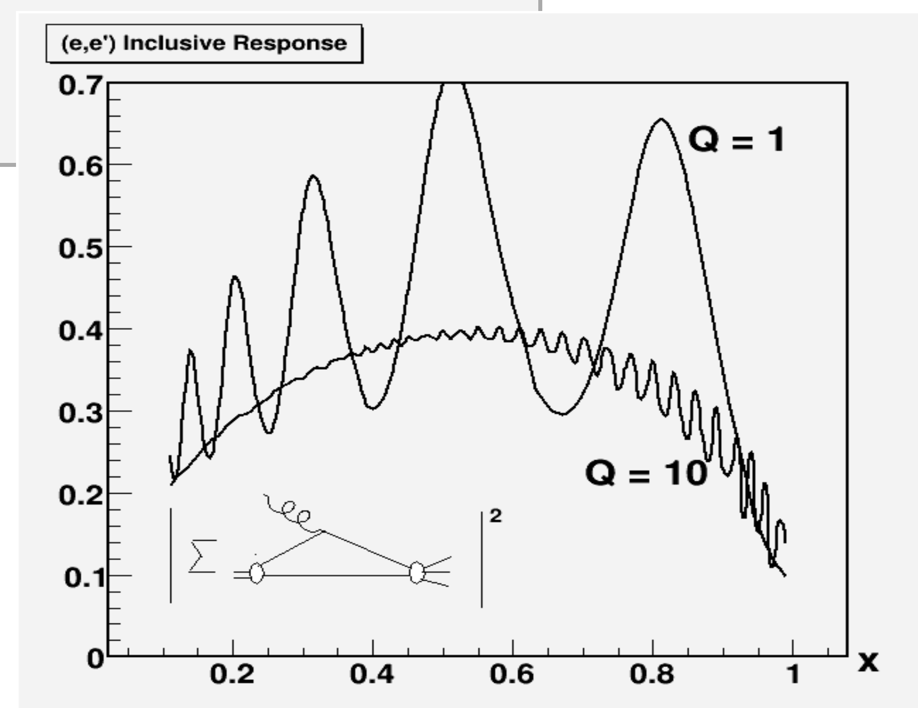


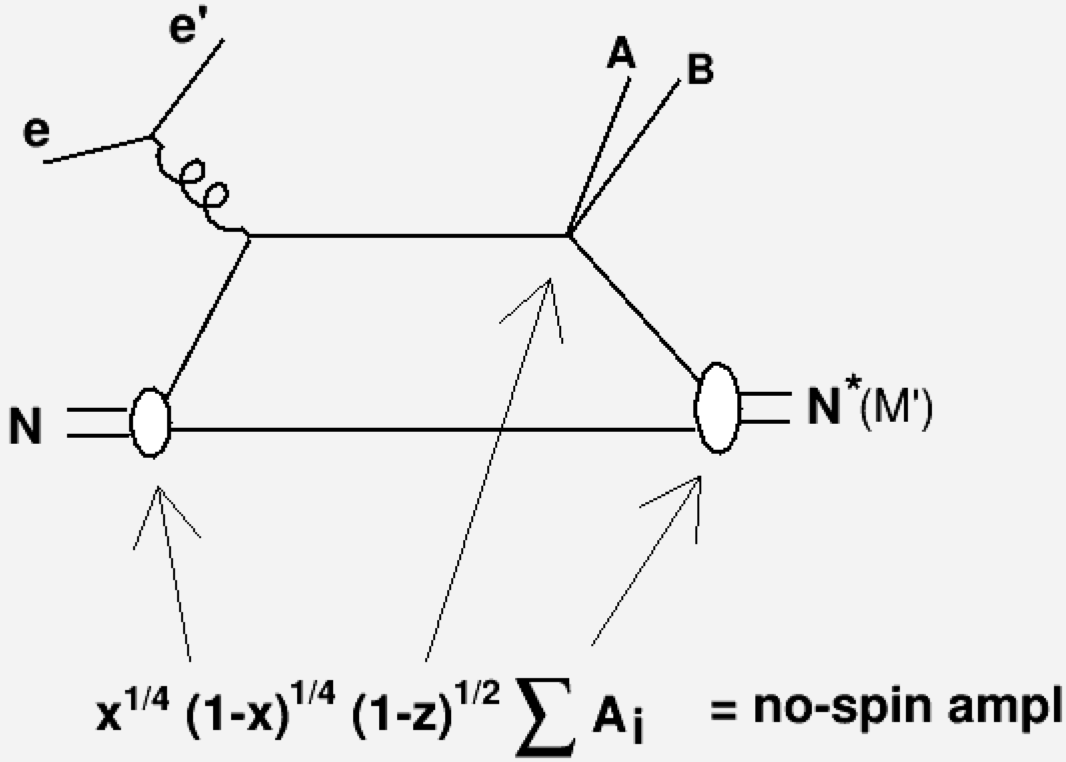

$M_i = 0.5$ GeV * i

$\Gamma_i = 0.15$ GeV * (1 + 0.1 i)

$$\mathbf{Amp = (x(1-x))^{1/4} \sum A_i}$$





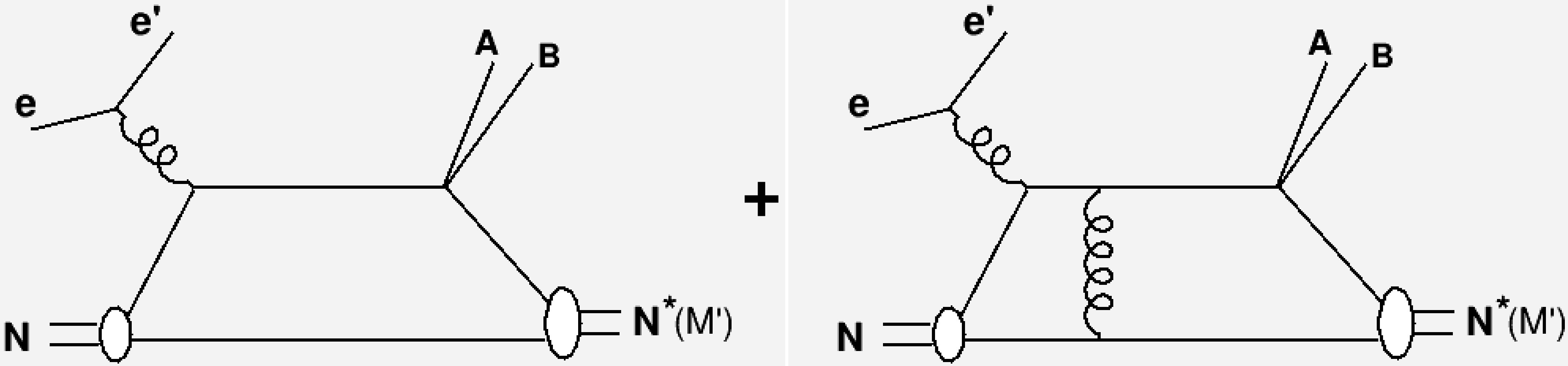

**Now I first generalize it to**
**2-pion SIDIS.**
**Next introduce azimuthal effects**

Fragmentation into a pair of opposite-charge pions.
Now M' is the **missing mass.**

Hypothesis: in the experiment, we may define a special **oriented plane** from momenta and spins of the leptons and of the target.

Events are binned w.r.t. the relative orientation of this plane and of the pion plane.

Leading twist diagram and amplitude.
Now we will add some more diagram for Higher Twist effects.



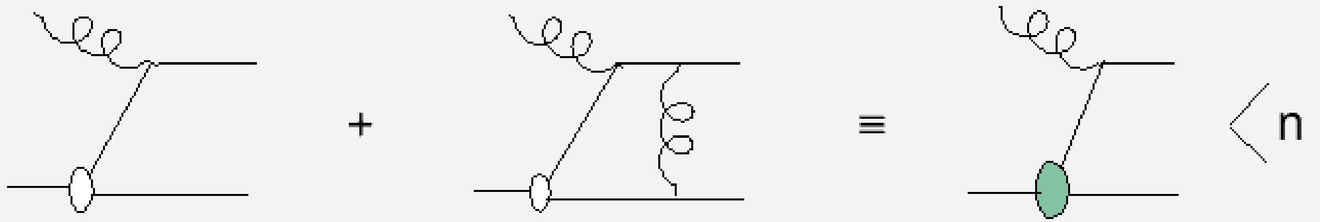

$$\sum \text{final states} \longrightarrow \sum (\text{even} + \text{odd}) \pm \sum (\text{even} - \text{odd})$$

## Fantasy toy model for duality spin and HT

This depends on the orientation of the AB-plane w.r.t. a plane defined by lepton and hadron momenta and spins

Normal “up” (def. “plus”) means even waves only
Normal “down” (def. “minus”) means odd waves only

# Steps to organize a MC



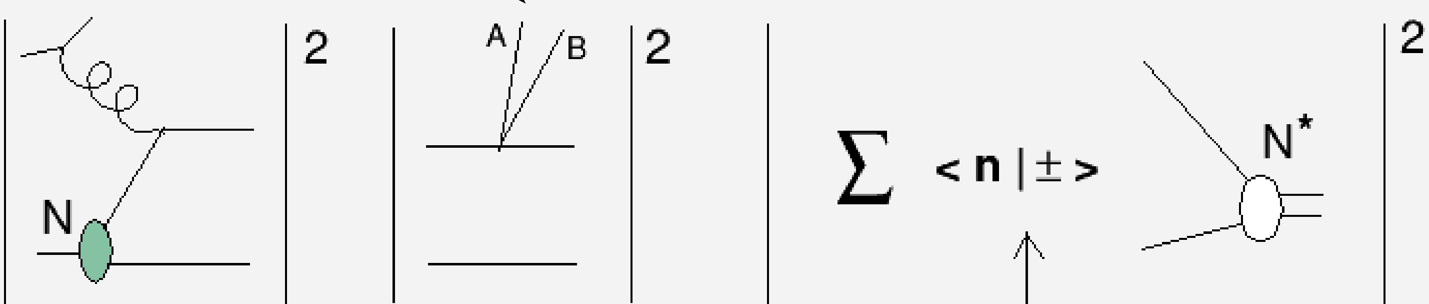

Needs some theory and a Factorization scheme

$< n^{+} \,|\, + > \;\rightarrow\; \sum \text{even}$

$< n^{+} \,|\, - > \;\rightarrow\; \sum \text{odd}$

Relative rientation of Pion plane and n

N-N* loop has lost coherence properties but for the phases in <n|+>.
Final state interference is OK




$x^{1/2}(1-x)^{1/2}$

(1-z)

only even or odd waves

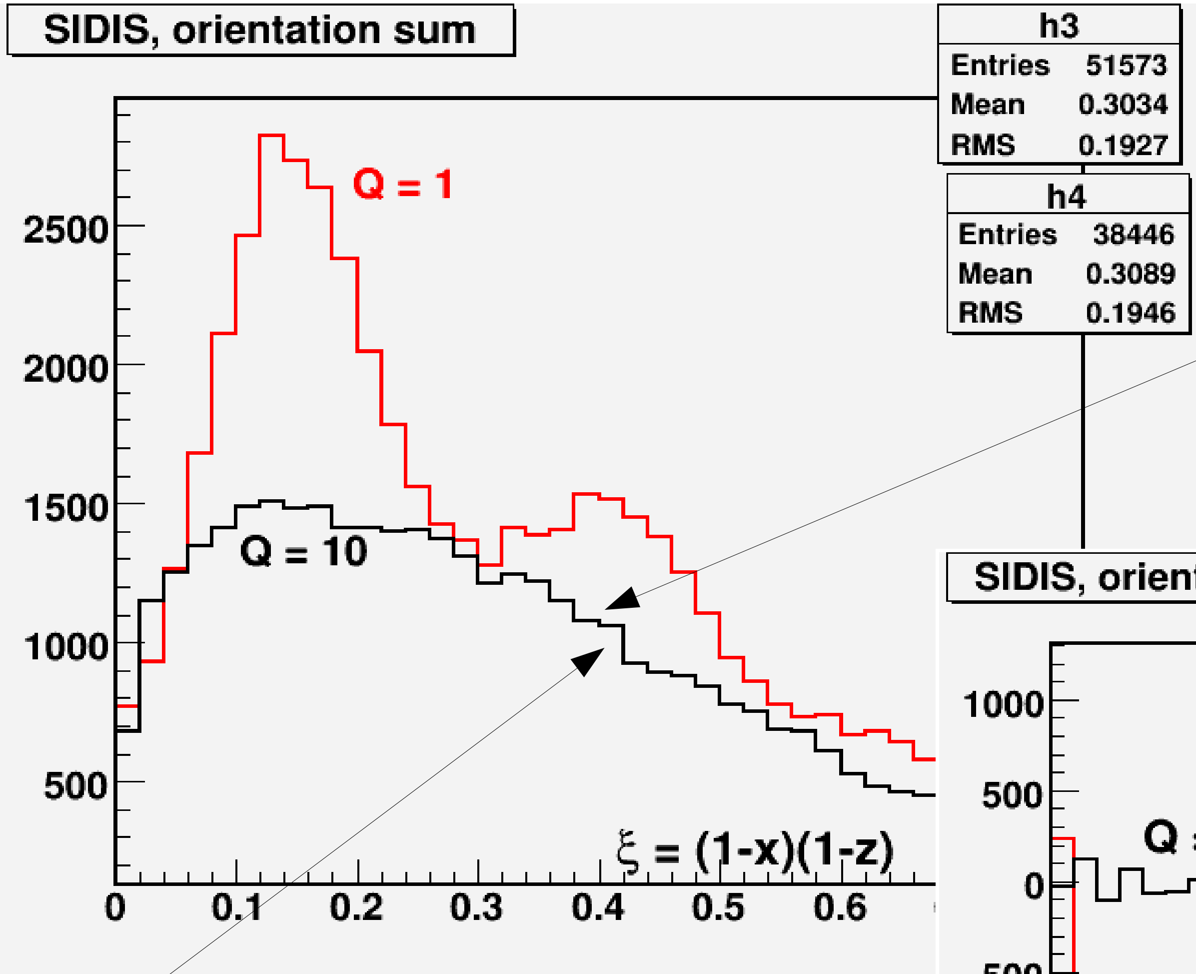
$L \equiv \sum$ (even + odd)

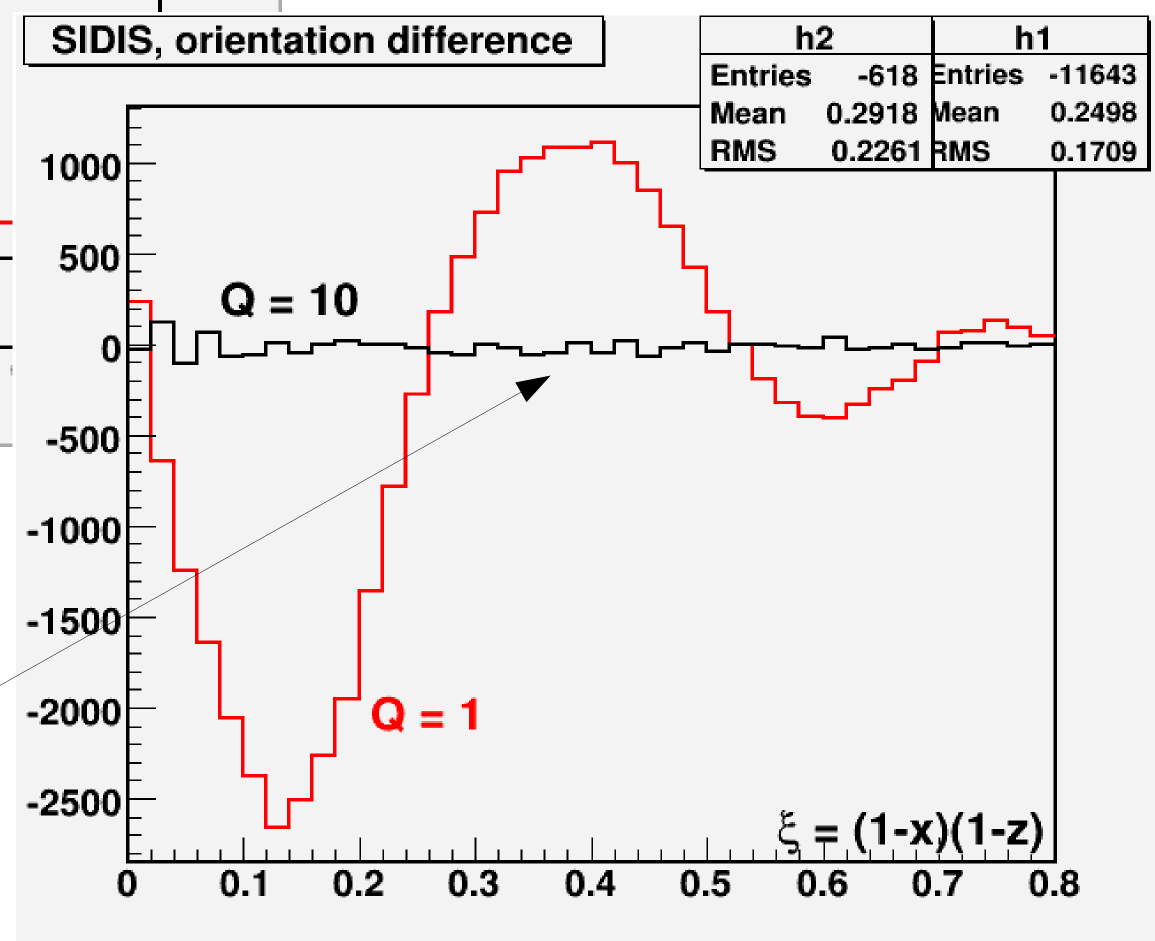
$H \equiv \sum$ (even - odd)

Inclusive(+) + Inclusive(-) = $|L|^2 + |H|^2$

Inclusive(+) - Inclusive(-) = $2\,\mathrm{Re}(L^{*}H)$

Remark: I take the square of the sum, not the sum of the squares.




**Leading Twist** (probably): Something has been lost for Q passing from 1 to 10 GeV, but not a factor 1/Q,

**This** curve could be approximated by the sum of the squares (inclusive calculation), but **only this one.**

**Higher twist**:the 10-GeV output is suppressed by some $1/Q^n$ factor

In the case of Leading Twist interference objects, Factorization gives us unambiguous indications about how to rewrite interference effects as probabilistic steps.

With Higher Twists there is no such general prescription. We have to risk, guess and wait for experimental confirmation. A MonteCarlo becomes a model itrself.

Conclusions: none (for the time being – work in progress)