AT THE BORDERLINE BETWEEN INCLUSIVE AND EXCLUSIVE PHYSICS.
FRAGMENTS IN THE DRELL-YAN PROCESS: AZIMUTHAL ASYMMETRIES

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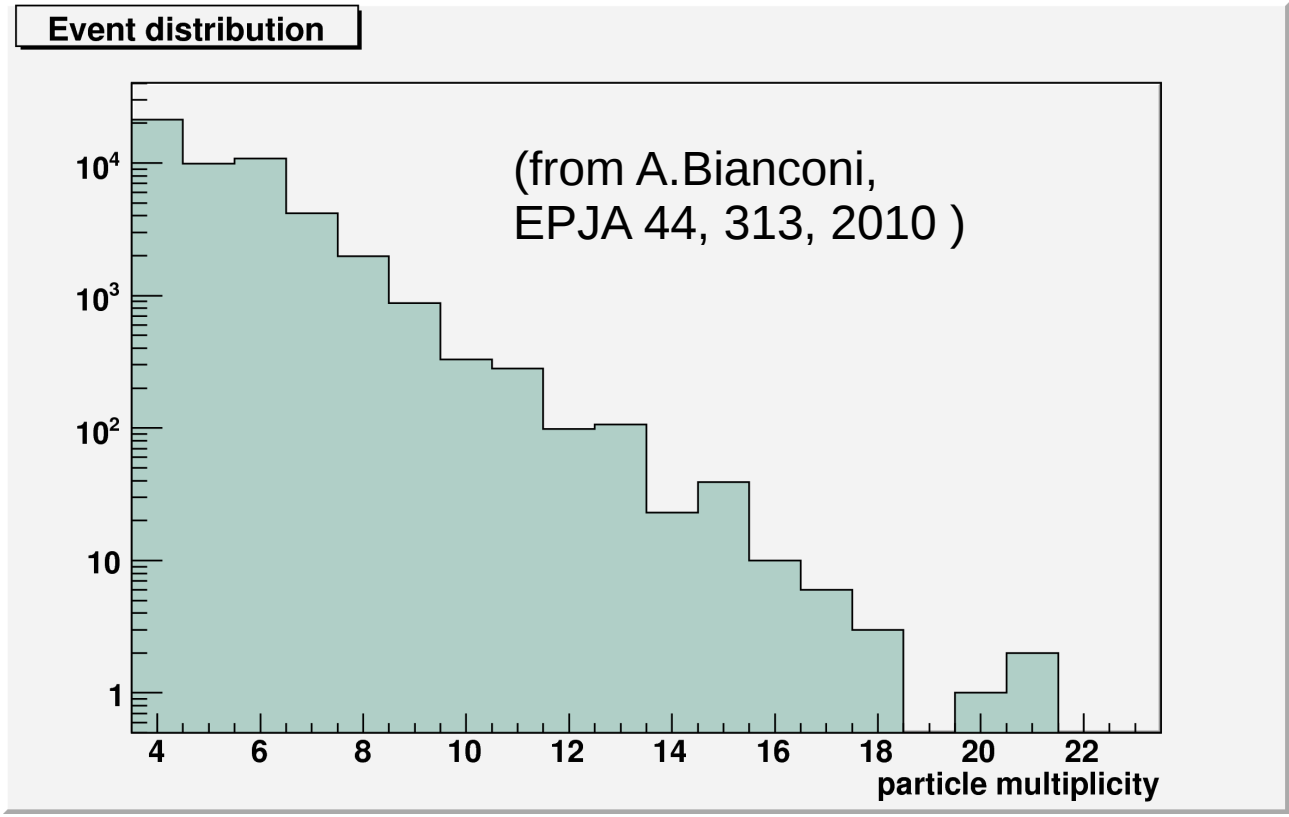
PANDA (s = 30 GeV^2)

Pythia simulation

The number of the fragments
Is very small

An N-Nbar pair is
always present

Almost half of the events are
Dilepton plus N-Nbar only



total number	50000
no (anti)baryons	179
1 N-Nbar pair	49805
2 N-Nbar pairs	16
1 p-pbar	21765
1 n-nbar	20078
mixed pair	7993

4 / 1000 of the total

half with no more hadrons
or hard photons

Ratio p-pbar : n-nbar : mixed = 11 : 10 : 4

Means: u-ubar annihilation
+ random creation of u-ubar and d-dbar pairs.

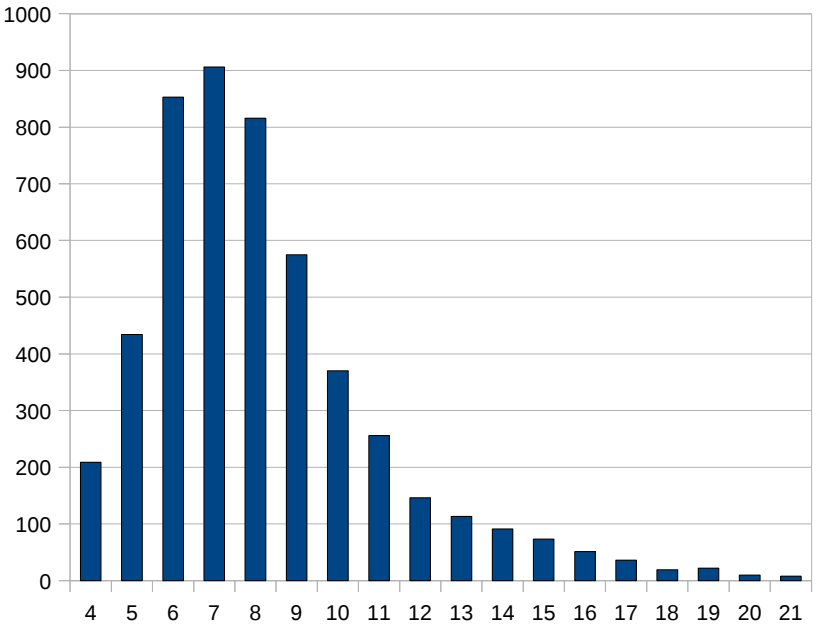
Remark: the rather complex Pythia machine in these events becomes very basic:
Quark-diquark splitting,
No gluons,
Final state pair creation with random relative (soft) p.

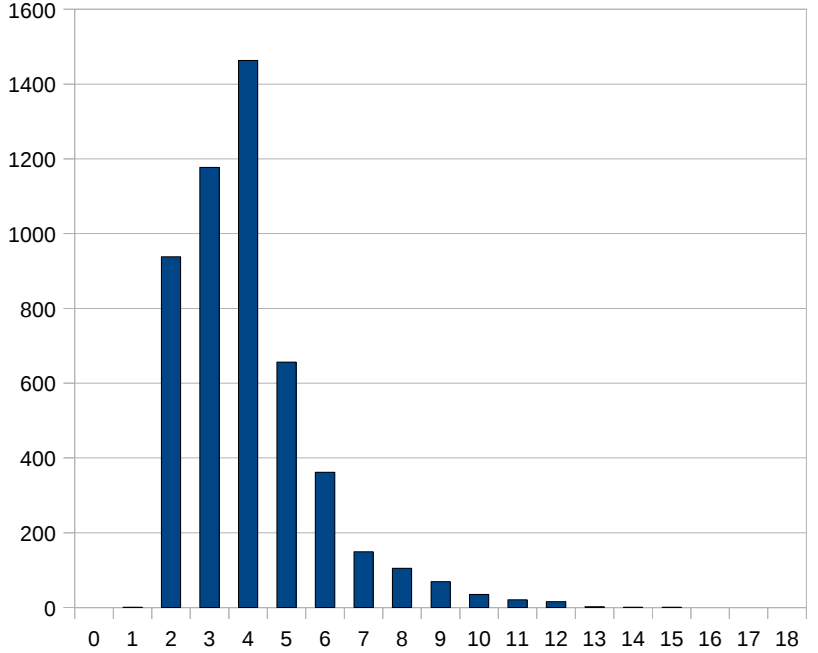
Antiproton-proton at s = 100 GeV^2

Final multiplicity distribution

Final hadron multiplicity distribution

4	209	0	0
5	434	1	1
6	853	2	938
7	906	3	1177
8	816	4	1463
9	575	5	656
10	370	6	362
11	256	7	149
12	146	8	105
13	113	9	69
14	91	10	35
15	73	11	21
16	51	12	16
17	36	13	2
18	19	14	1
19	22	15	1
20	10	16	0
21	8	17	0





Detailed Pythia event analysis: 3 ranges

PANDA: plain u-ubar + basic recombination: final N-Nbar pair

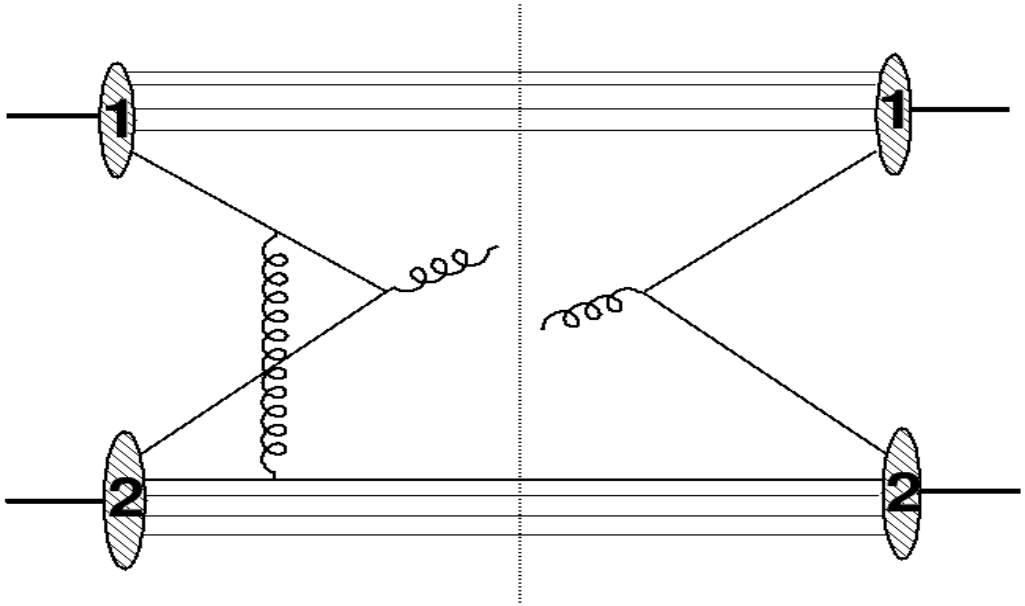
COMPASS: 2 / 3 primary final hadrons (Baryon and heavy meson) decaying into N + pions / photons

S > 400 GeV^2: high-order Fok states, 1st-order QCD, cascading

Larger Q → smaller multiplicity

(total fragment invariant mass $M^2 \approx (1- x_1)(1- x_2)\, s$)

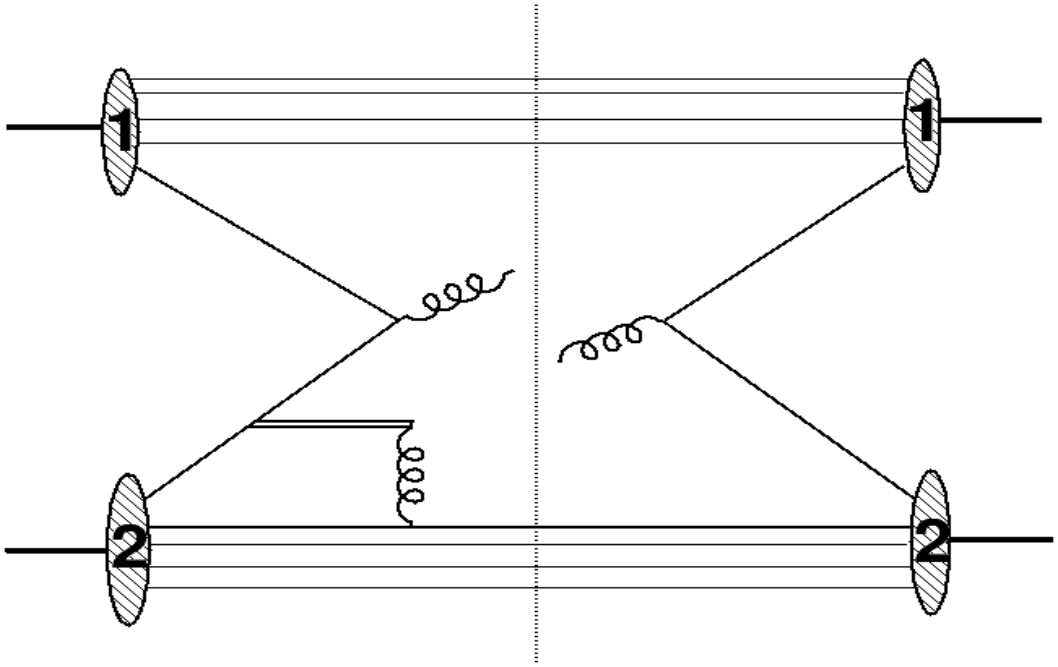
Attempt: build a parton-level MonteCarlo to produce lepton BM and other asymmetries, and fragments.
Initial goal: events with the dilepton, a final proton-antiproton pair, and nothing more.

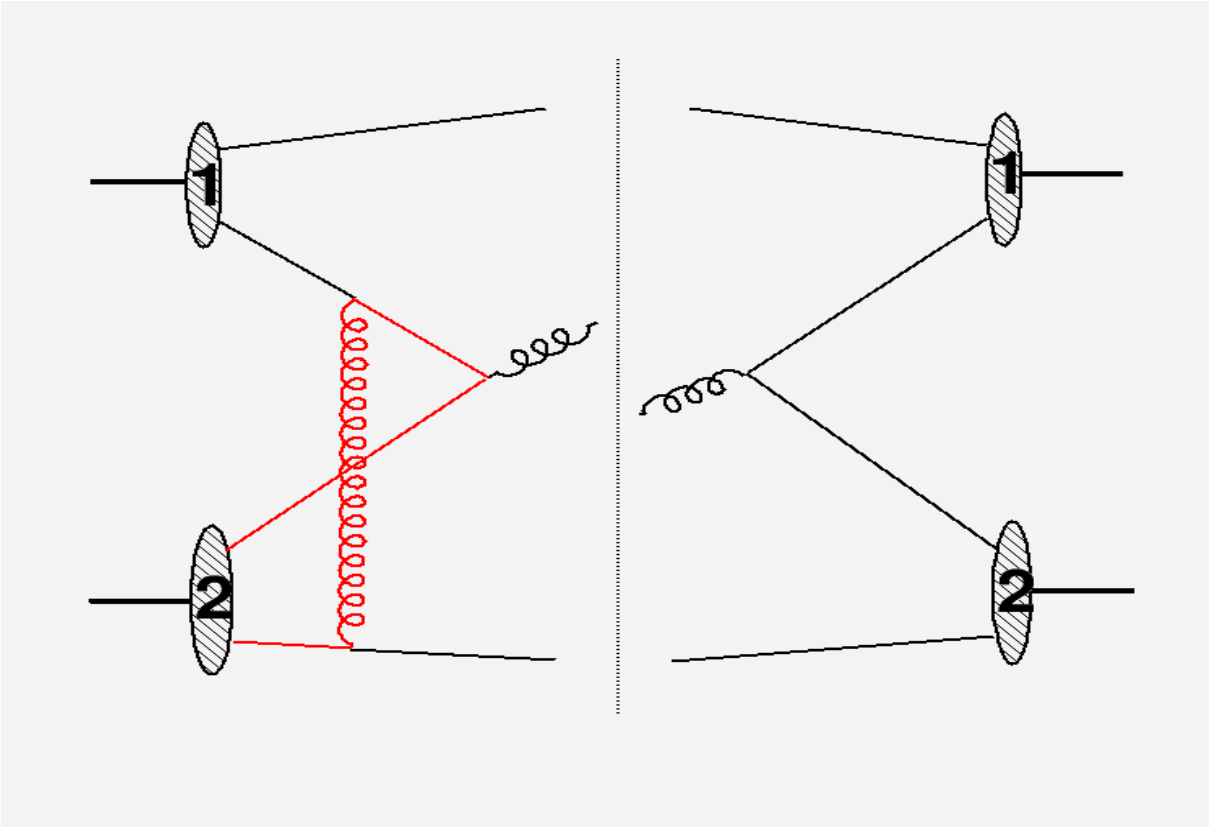


Theory

< 1988
Collins, Soper, Sterman,

2002
Brodsky, Hwang, Schmidt





How much of that knowledge may be transferred to this?

Much of the work on factorization is performed on the red loop, that is still there.

Pinch → gluon collinearity
No pinch → no glauber contribution
Ward on the upper quark line

No final state unitarity → surprises may come from here

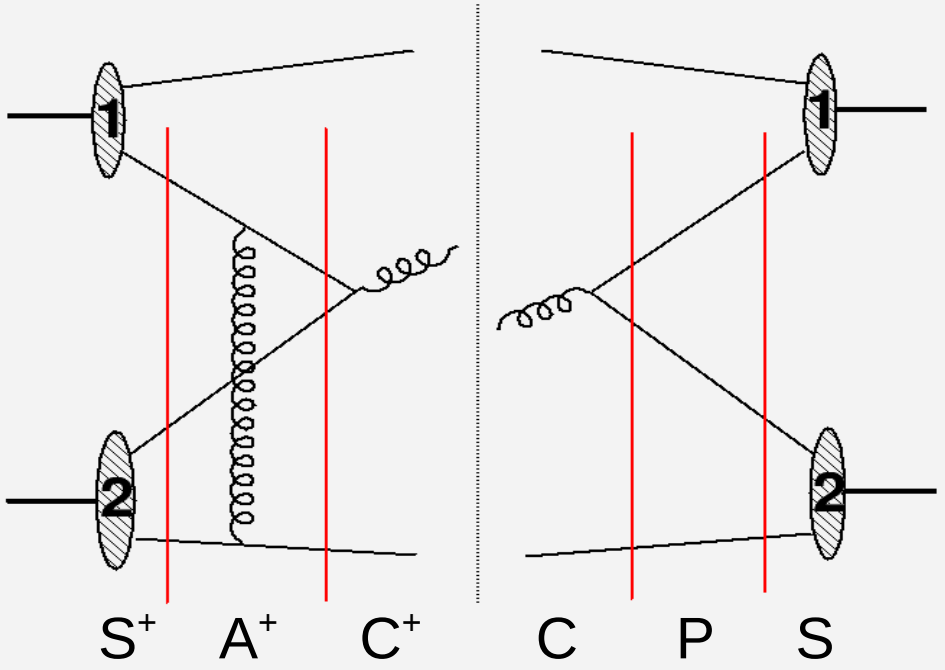
Two possible schemes

1) strict factorization scheme: -) no rescattering,
-) BM Sivers etc effects are “intrinsic” features of the nucleon-to-partons decay vertex

2) rescattering scheme: -) nucleon-to-partons = physically admitted isolated decay
-) BM Sivers etc from physically admitted rescattering
-) Rescattering restricted to exchange of transverse momentum with fixed-scale magnitude 0.1-1 GeV

By tuning parameters I may get the same results in both schemes.

I have worked in the rescattering scheme.



Reorganization of interference:

For each set of (anti)quark spins

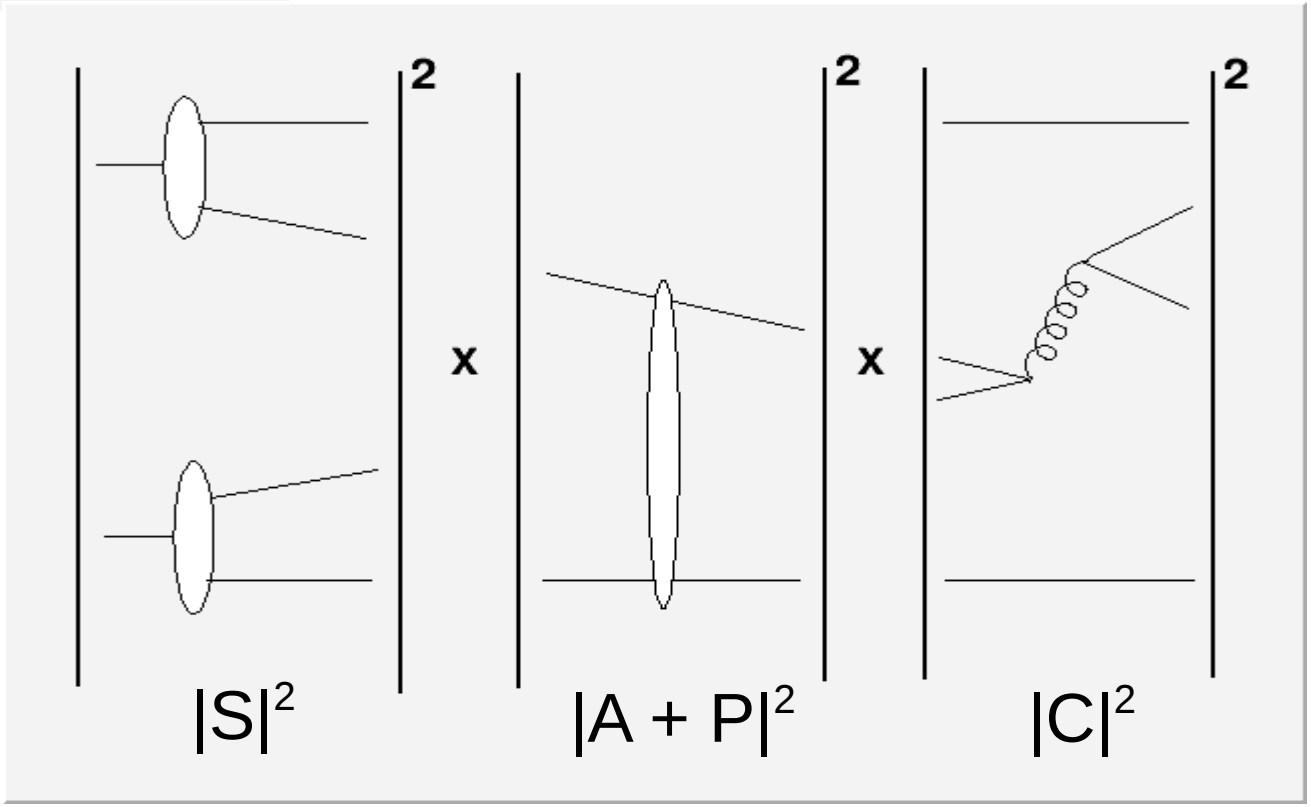
$$|S\,P\,C + S\,A\,C|^2$$

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

Interference features (for a given Initial state) are present in

$2\,\mathrm{Re}\,(AP^+)$,

Interference features of the loop are partly lost



Rescattering in spin-orbit form

interference between h-flip and h-no-flip channels (Goldstein-Moravscsik, 1982)

May change L by 1 unit

Does not touch J

Produces active parton asymmetries of the required tensor form

Implementation: y-spin up => random x-momentum shift, mainly positive
y-spin down => the opposite

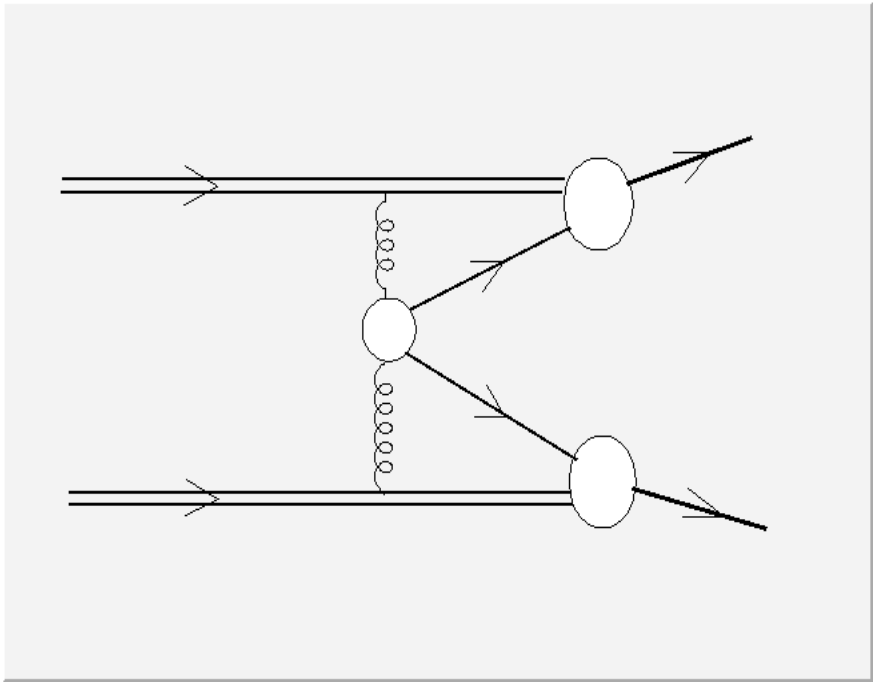
Gaussian shift,
average 0.5 GeV/c, fluctuation 0.27 GeV/c

Spectators must recoil (opposite shift)

Hadronization:

Alternative 1: diquarks = final hadrons

Alternative 2: u-ubar or d-dbar pair created with random gaussian relative PT
(Andersson, Sjostrand etc, Lund model and Pythia)



Alternative 3: more complex spin-dependent schemes (e.g. Andersson et al 1979, Pomp et al 2002, Artru and Richard 2004, for Lambda and Lambda-Antilambda)

Full scheme for unpolarized scattering:

In a “collider” reference frame the xy plane is random-rotated about z

+/- transverse spins are sorted for quark and antiquark along y

x, Kx, Ky are sorted for quark and antiquark

Quark – antidiquark rescattering
Antiquark – diquark rescattering

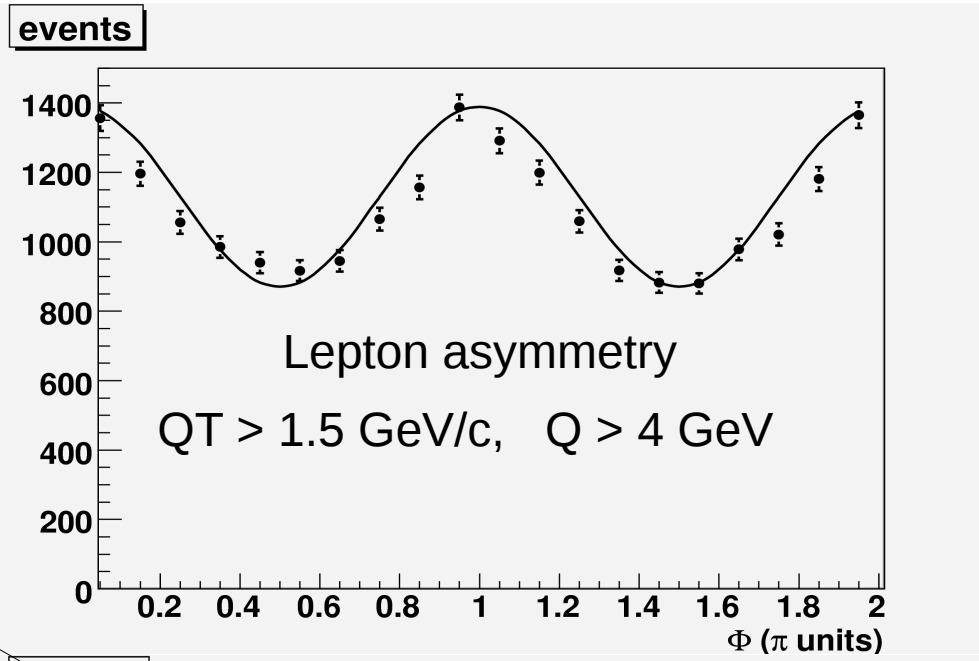
Sorted mu+/mu- momenta (for given virtual photon momentum)

Accept-reject procedure on the hard process quark-antiquark => lepton pair

Hadronization of the spectators.

Pair	Q	Kevents	Asymmetry
Leptons Hadrons	0-1.5 GeV/c	975	0.017 0.050
Leptons Hadrons	1.5-3 GeV/c	133	0.134 0.133

(AB, arXiv:0912.3872 & EPJA)



Alternative 1: spectators = final hadrons

Alternative 2: gaussian spread of the transverse relative momentum of the u-ubar pair created in the hadronization

Gaussian width (GeV/c)	Asymmetry
0	0.133
0.35	0.121
0.7	0.09