Zooming-in on Instantons at HERA

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in collaboration with

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Plan

1. **Instantons**
2. **Deep-Inelastic $e^{\pm}\mathrm{P}$ Scattering**
3. **First Dedicated-Search Results (H1)**
4. **Conclusions**

Copy available via WWW:

http://www.desy.de/~t00fri/talks/talks.html

– Warsaw, Nov 2000 –

1. Instantons

1.1 Topological Objects in Field Theory

- Quantum-field theory in perturbative approximation: enormously successful.
  - For weak coupling $g \ll 1$: (power) expansion about trivial field configurations $\Phi_i(x) = 0$.
  - Matter fields $\Leftrightarrow$ point-like, elementary objects (particles).

♣ **However. . .** classical field equations in

Non-linear field theories | Non-abelian gauge theories

also have stable, localized solutions with
non-vanishing space (-time) extension:

solitons | vortices, magn. monopoles & **instantons**.

♣ **Common** reason for existence and stability $\Leftrightarrow$

Non-trivial **topology** of boundary conditions!

♣ New perturbation theory about such solutions $\Rightarrow$ information on important quantum effects outside of usual perturbation theory about $\Phi_i(x) = 0$!

1.2 Instantons in Quantum Chromo Dynamics

- **Ground State in QCD ("Vacuum"):** "Soup" of gluons and quarks with complicated, non-perturbative interaction.

- **Consider first:** "Pure" $SU(3)_{\text{color}}$ gauge theory (only gluon fields $A_\mu(x)$ without quarks) $\Leftarrow$ **Topology?**

- **Local gauge symmetry**: For all $U(x) \subset SU(3)_{\text{color}}$, QCD Lagrange-density $\mathcal{L}[A_\mu(x)]$ is invariant under

$$A_\mu(x) \Rightarrow A'_\mu(x) = U^{-1}(x)(A_\mu(x) + \tfrac{i}{g}\partial_\mu)U(x)$$

- **Ask for:** possible ground states, characterized by

finite Action $S = \int d^4x\, \mathcal{L}$, i.e. $\mathcal{L}[A_\mu(x)] \overset{|x|\to\infty}{\Rightarrow} 0$

◇ Satisfied by trivial field configuration $A_\mu(x) \equiv 0$, $S = 0$ ($\Leftarrow$ usual perturbation theory).

◇ Much too restrictive due to local gauge invariance $\Rightarrow$

boundary conditions for ground state

$$\vec{A}(x) \overset{|x|\to\infty}{\Rightarrow} -\tfrac{i}{g}\underbrace{U^{-1}(\vec{x})\nabla U(\vec{x})}_{\text{"pure gauge"}};$$

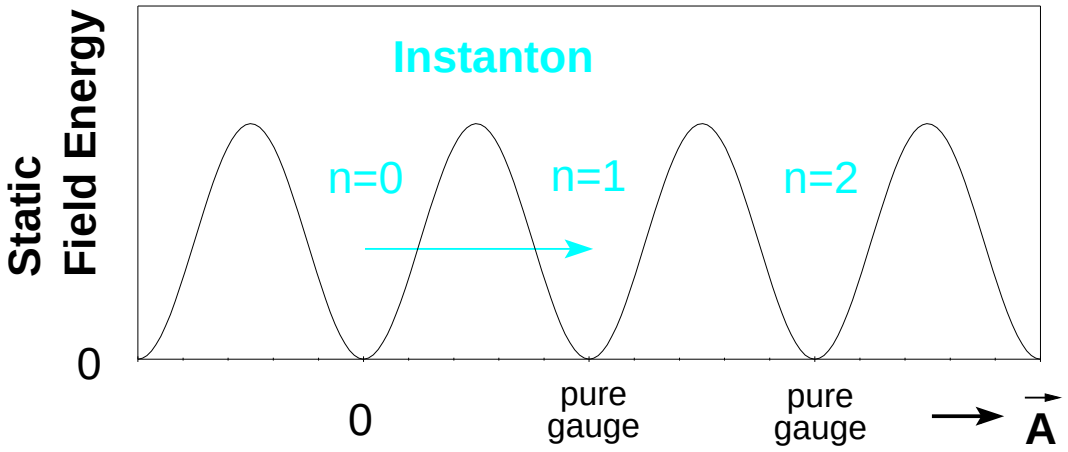
$$A_0(x) = 0, \text{ without restriction}$$

- Possible ground state gauge fields $\vec{A}_\infty[U(\vec{x})]$
  $\Leftrightarrow$ (homotopy-) classes of maps $\{\vec{x}\} \Rightarrow \{U_n\}$, characterized by topol. winding number $\boldsymbol{n} = 0, \pm 1, \pm 2, \ldots$

  $\Leftrightarrow$ gluon fields $A_\mu(x)$ carry an integer, conserved

  topological charge $\boldsymbol{Q}$ ($= n - n_0$)

♣ $\Rightarrow$ ∞ many, energetically degenerate but topologically inequivalent classical ground states (Fig)!



Instantons (I), Anti-Instantons ($\overline{I}$):

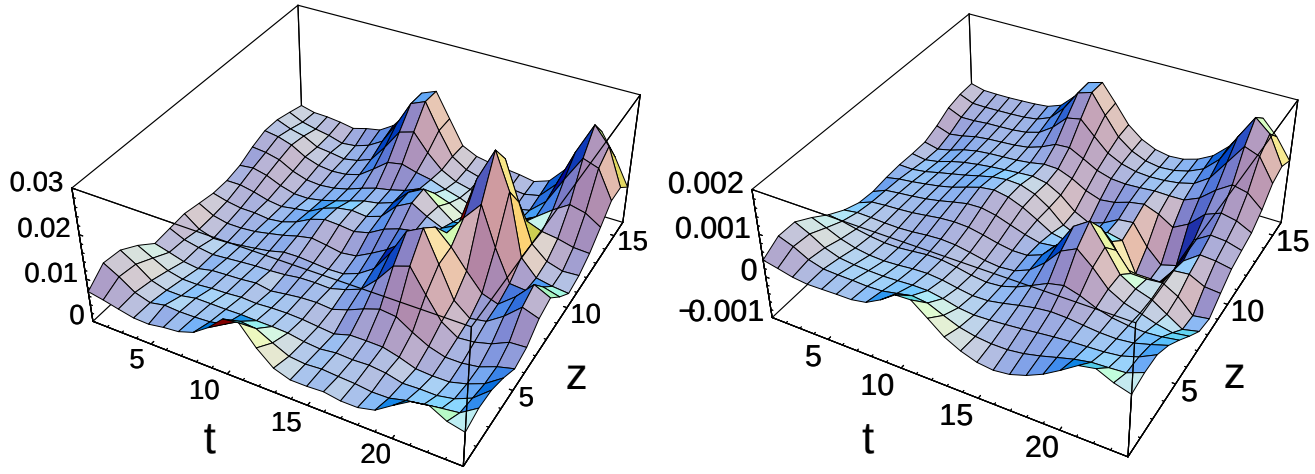
[Belavin *et al.* '75, 't Hooft '76]

◇ Tunnelling transitions between neighbouring vacua $n \rightleftharpoons n+1, \boldsymbol{Q} = \Delta n = \pm 1$ (Fig.)

◇ Explicit solutions $A_\mu^{(I)}(x)$ of classical field eqs. (in 4d Euclidean space-time, i.e. for imaginary time!);

◇ Non-perturbative, topologically non-trivial fluctuations of gluon fields, localized ("instantaneous") in time und space

Lagrange Density **Topological Charge Density**



(Realistic, non-perturbative lattice simulation, [Chu *et al.*'94], 3 I's und 2 $\overline{I}$'s visible!)

- Lattice simulations (c.f. below)⇒ Typical I-size $\rho \approx 0.5$ fm

  ⇔ Theory: I's, important in transition region between partonic and hadronic description of strong interactions:

  – "$U_A(1)$ problem" ($m_{\eta'} \gg m_\eta$) ; Veneziano-Witten relation; ['t Hooft '76, Veneziano '79, Witten '79, 't Hooft '00]
  – Breaking of chiral symmetry [Diakonov '96 (Review)]
  – Hadron and glueball spectrum [Schaefer, Shuryak '96 (review)]

- Instantons, a basic non-perturbative aspect of QCD !

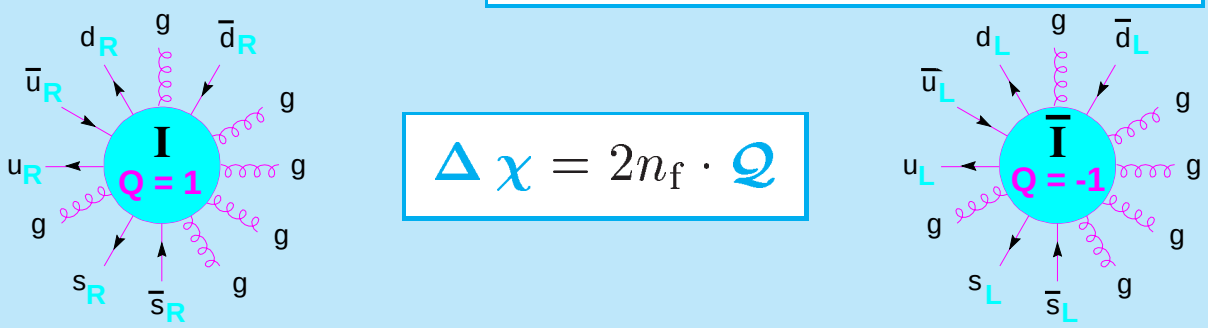
1.3 Hard, Instanton-Induced Processes

- But direct experimental verification of instantons **lacking** up to now!

- **However. . .** [Ringwald & F. Sch. '94 - '00]

  Exploit characteristic manifestation of instantons at short distances for experimental search!

['t Hooft '76]: QCD -instantons induce hard processes with **violation of "chirality"** $\chi = \#(q+\bar{q})_{\rm R} - \#(q+\bar{q})_{\rm L}$



$$\Delta\chi = 2n_{\rm f}\cdot\mathcal{Q}$$

- ♢ forbidden in usual perturbation theory ($\mathcal{Q}=0$!)
- ♢ Selection rule in agreement with the general Adler-Bell-Jackiw chiral ANOMALY relation for full QCD

♣ **Deep-inelastic $e^{\pm}$P scattering at HERA**, a unique opportunity for discovery of these hard instanton-induced processes, due to

♢ their predicted, characteristic final-state signature
[Ringwald & F. Sch. '94 - '99,
Carli, Gerigk, Ringwald & F. Sch. hep-ph/9906441]

♢ a measurable rate,
calculable in framework of "instanton-perturbation theory"
[Ringwald & F. Sch., Phys. Lett **B459** (1999) 249; **B438** (1998) 217;
Moch, Ringwald & F. Sch., Nucl. Phys. **B507** (1997) 134]

♣ Key-property: hard deep-inelastic scale $\mathcal{Q}$ suppresses instantons of large size, $\rho \gtrsim \mathcal{Q}^{-1}$, for which theoretical control is lacking!

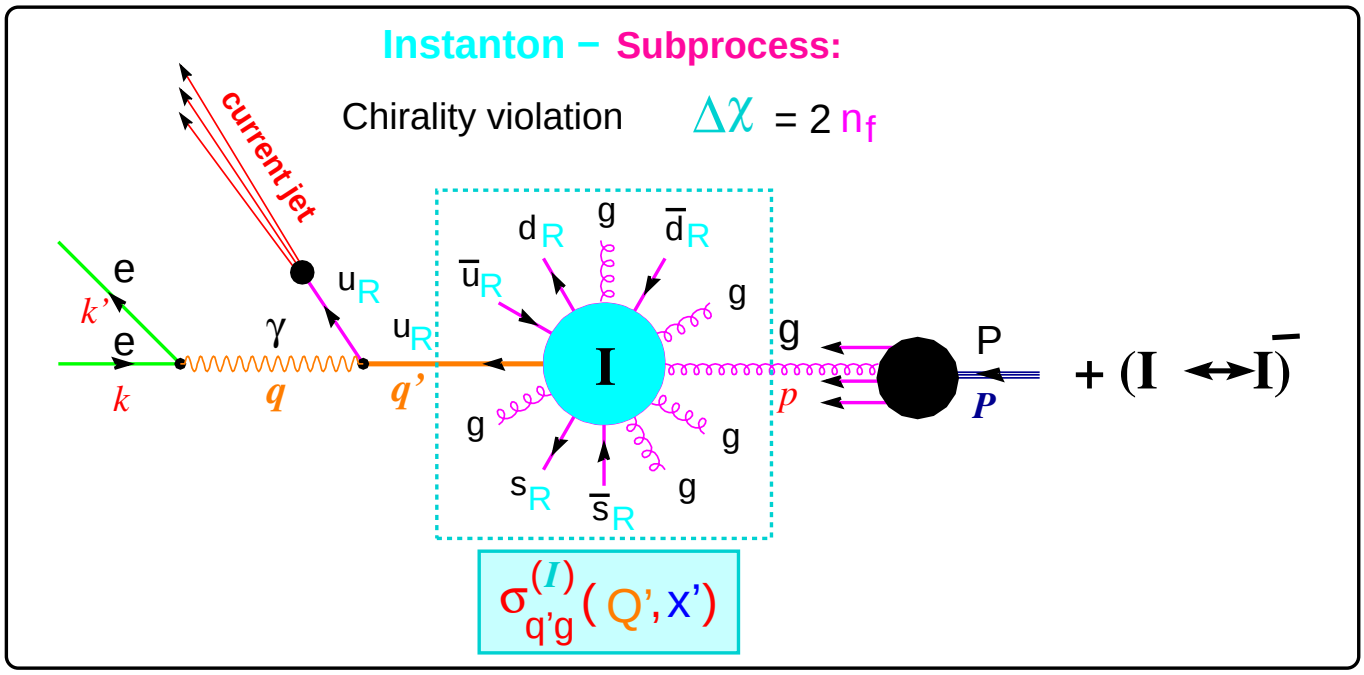
2. Deep-Inelastic $e^{\pm}\mathrm{P}$ Scattering

2.1 Instanton-Perturbation Theory

[Ringwald & F. Sch., Phys. Lett **B438** (1998) 217,
Moch, Ringwald & F. Sch., Nucl. Phys. **B507** (1997)]

- **Theoretical framework**: "I-perturbation theory"
for a dilute "gas" of I's, $\overline{I}$'s and small α_s, i.e. expansion about known, classical I-solution $A_\mu^{(I)}(x)$ (instead of $A_\mu(x) = 0$).

- Leading, I-induced, chirality-violating process in **deep-inelastic** regime of $e^{\pm}\mathrm{P}$ scattering:



- I-subprocess with own **Bjorken**-variables, (Q'^2, x'):

$$\text{large}\quad Q'^2 = -q'^2 > 0; \quad x' = \frac{Q'^2}{2p\cdot q'} \leq 1 \quad \text{fixed}$$

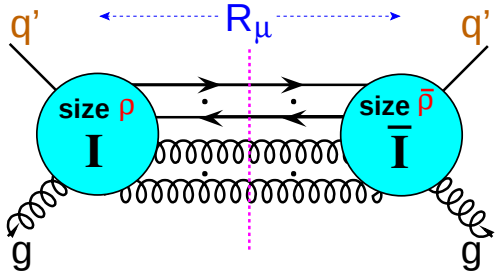
- Factorization in I-perturbation theory (Bjorken limit):

$$\frac{\mathrm{d}\sigma_{\mathrm{HERA}}{}^{(I)}}{\mathrm{d}x'\mathrm{d}Q'^2} \simeq \frac{\mathrm{d}\mathcal{L}^{(I)}_{q'g}}{\mathrm{d}x'\mathrm{d}Q'^2} \cdot \sigma^{(I)}_{q'g}(Q', x')$$

- Differential luminosity, $\mathrm{d}\mathcal{L}^{(I)}_{q'g}$: number of $q'g$ collisions per $e\mathrm{P}$ collision $\Leftrightarrow$ integrals over known flux-factors.

- Essential instanton-dynamics in total cross-section of I-subprocess $q'g \overset{I}{\Rightarrow} X$!

$\sigma^{(I)}_{q'g}$ ~



$$\sigma^{(I)}_{q'\,g} = \int d^4R\; e^{i\,(p+q')\cdot R} \int_0^\infty d\rho \int_0^\infty d\overline{\rho}\; e^{-(\rho+\overline{\rho})Q'}$$

$$\times\; D(\rho)\,D(\overline{\rho}) \int dU\; e^{-\frac{4\pi}{\alpha_s}\,\Omega\left(U,\frac{R^2}{\rho\overline{\rho}},\frac{\overline{\rho}}{\rho}\right)} \{\ldots\}$$

Integration over all **"collective $(I,\overline{I})$-coordinates"**: $(\rho,\overline{\rho})$ = $(I,\overline{I})$-size, R_μ=$I\overline{I}$-distance, U= relative $I\overline{I}$ color-orientation.

$\sigma^{(I)}_{q'g}(Q',x')$ depends on 2 crucial objects of I-calculus:

$D(\rho)$ = I-size distribution ; $\Omega\left(U,\frac{R^2}{\rho\overline{\rho}},\frac{\overline{\rho}}{\rho}\right)$ = $I\overline{I}$-interaction

♢ Both are **known** in I-perturbation theory, formally for

$\alpha_s(\mu_r)\ln(\mu_r\rho) \ll 1$ and $\frac{R^2}{\rho\overline{\rho}} \gg 1$

(μ_r = renormalization scale).

♢ $D(\rho) \propto \rho^{6-2/3n_f+\mathcal{O}(\alpha)}$ usually destroys calculability of I-observables, since $(\rho, \overline{\rho})$-integrals diverge for large ρ (**IR**)!

♣ **Exception** in **deep-inelastic scattering:** q'-form factor $\exp(-Q'(\rho+\overline{\rho}))$ ⇒ **small** $(I, \overline{I})$ with $(\rho, \overline{\rho}) \lesssim 1/Q'$

♣ For (large) $Q' \neq 0$, all collective-coordinate integrations in $\sigma^{(I)}_{q'g}$ via unique saddle point

$U^* \Leftrightarrow$ most attractive color-orientation

$$\rho^* = \overline{\rho}^* \sim \frac{4\pi}{\alpha_s(\frac{1}{\rho^*})}\frac{1}{Q'}; \qquad \frac{R^{*\,2}}{\rho^{*\,2}} \overset{Q' \text{ large}}{\sim} 4\frac{x'}{1-x'}$$

♢ Saddle point⇒ indeed, for large Q' and small $(1-x')$: dilute "gas" of small $(I, \overline{I})$, since $\frac{R}{\rho} \gg 1$ and $\rho \sim \frac{1}{Q'}$!

$D(\rho)$ and $\Omega\left(U, \frac{R^2}{\rho\overline{\rho}}, \frac{\overline{\rho}}{\rho}\right)$: Link between **DIS** and **lattice**-observables!

♢ **Lattice 'data'** ⇒ non-perturbative information on region of validity of I-perturbative form in (ρ, R)

♢ **Saddle-point** relation: $(\rho^*, R^*) \Leftrightarrow (Q', x')$ ⇒

Region of validity in (Q', x') for **DIS**!

2.2 Region of Validity of the Predictions

[Ringwald & F. Sch., Phys. Lett. **B 459** (1999) 249; **B 438** (1998) 217,]

- **QCD lattice simulations:** "Snapshots" of QCD - vacuum in (Euclidean) space-time, including all non-perturbative, topological effects like Instantons!

- Reanalyze recent lattice 'data' for $\mathrm{QCD}_{\mathrm{n_f=0}}$ of high quality [UKQCD, Smith & Teper, '98]

♢ Region of validity of I-perturbation theory in (Q', x')?

♣ ≈ **parameter-free** comparison of I-size and $I\bar{I}$-distance distributions with I-perturbation theory versus (ρ, R):

♣ QCD -scale for $n_f = 0$ with small error also from lattice:

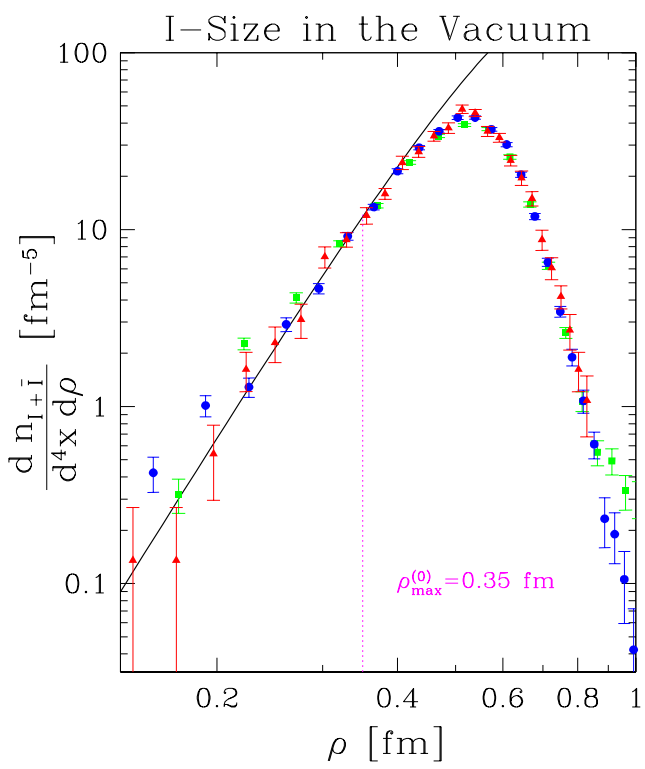
$$\Lambda_{\overline{\mathrm{MS}}}^{(n_f=0)} = (238 \pm 19)\ \mathrm{MeV}$$

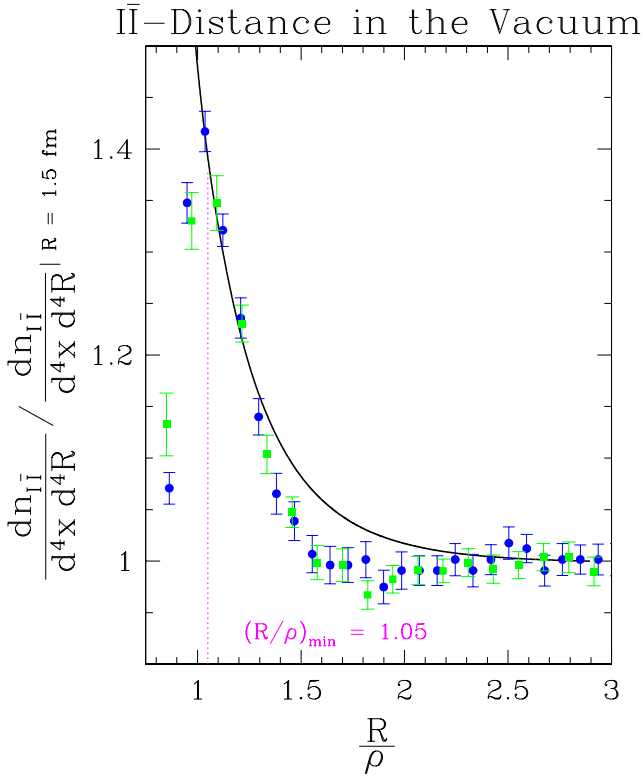
[ALPHA-Collaboration, Nucl. Phys **B 544** (1999) 669]

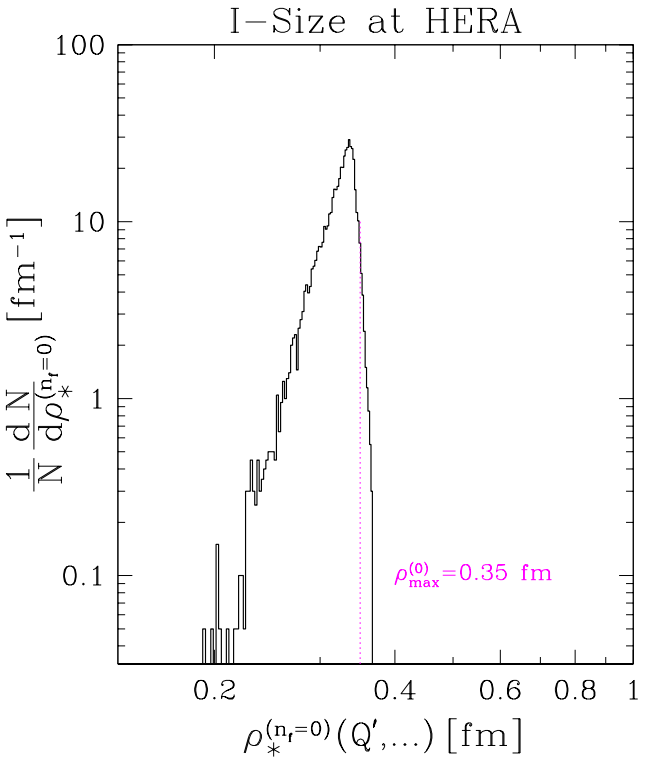
♣ **Find:** I-perturbation theory quantitatively valid for

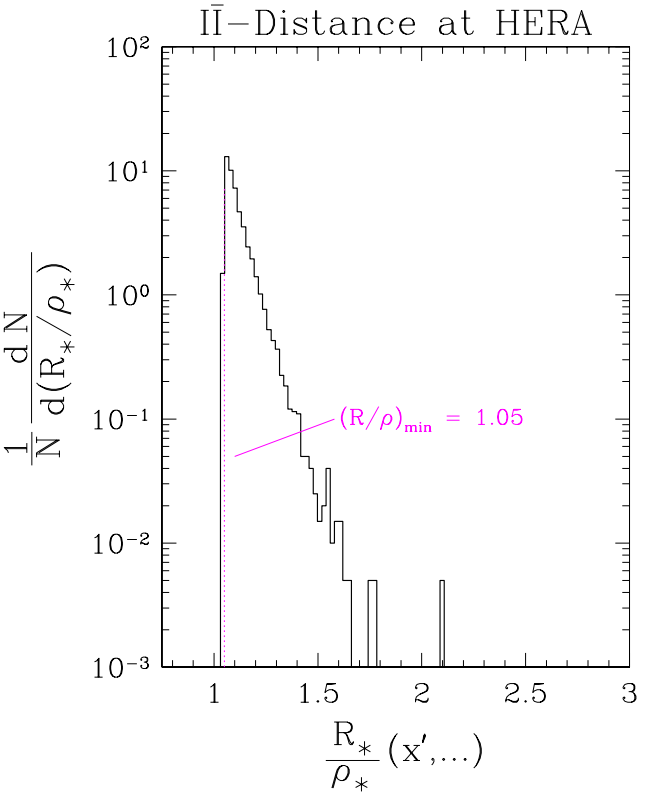
$$\left.\begin{array}{lll} \rho \cdot \Lambda_{\overline{\mathrm{MS}}}^{(n_f=0)} & \lesssim & 0.42 \\ R/\rho & \gtrsim & 1.05 \end{array}\right\} \overset{\text{saddle pt}}{\Rightarrow} \left\{\begin{array}{lll} Q'/\Lambda_{\overline{\mathrm{MS}}}^{(n_f)} & \gtrsim & 30.8, \\ x' & \gtrsim & 0.35, \end{array}\right.$$

Illustration: [UKQCD] Lattice data $\overset{?}{\Leftrightarrow}$ I-perturbation theory (—, Figs. top) and distributions at **HERA** (Figs. botttom)!









Exploitation of **lattice results** increases the reliability of our theoretical predictions for **HERA** dramatically!

Promising: Try replacing $D(\rho)$ and $I\overline{I}$-interaction Ω by the actual form measured on the lattice! $\Rightarrow$ **DIS**-cuts may be much relaxed,. . . [F. Sch & A. Utermann, in progress]

Must require:

additional "technical" cut in Q^2: $Q^2_{\rm min} \approx Q'^2_{\rm min}$

Assures dominance of "planar" graphs in $\sigma^{(I)}{}_{\rm HERA}$ and final-state observables;

"Non-planar" contributions very hard/slow to calculate, but known to be $\mathcal{O}\left(\left[\frac{\mu_{ren.}}{Q}\right]^n\right)$, $\mathrm{n} > 2 \Rightarrow$ ignored!

2.3 Rate and Final-State Signatures at HERA

Cross-section $\sigma^{(I)}_{\text{HERA}}$

'Upgrade' of
[Ringwald & F. Sch.,
Phys. Lett **B438** (1998) 217]

♢ $\Lambda^{(n_f=3)}_{\overline{\text{MS}}}$**-dependence?**

$\Leftarrow$ PDG'98 $\Leftarrow$ PDG '96
$\Leftarrow$ $Q'_{\min} \propto \Lambda^{(n_f)}_{\overline{\text{MS}}} \Leftarrow$ lattice

- Throughout, 3-loop relations $\alpha_s \Leftrightarrow \Lambda^{(n_f)}_{\overline{\text{MS}}}$
- Strongly reduced uncertainty due to $\delta\Lambda_{\overline{\text{MS}}}$

	PDG '96 $\Rightarrow$	PDG '98	PDG '98
$\alpha_s(M_Z)$	0.113 (DIS!)	0.119 ± 0.002	0.119 ± 0.002
$\Lambda^{(3)}_{\overline{\text{MS}}}$ [MeV]	260^{+66}_{-64}	346^{+31}_{-29}	346^{+31}_{-29}
Cuts	$Q' \geq 8$ GeV	$\frac{Q'}{\Lambda^{(n_f)}_{\overline{\text{MS}}}} \geq 30.8$	$\frac{(Q,Q')}{\Lambda^{(n_f)}_{\overline{\text{MS}}}} \geq 30.8$
	$x' \gtrsim 0.35,\ x_{\text{Bj}} \geq 10^{-3},\ 0.1 \leq y_{\text{Bj}} \leq 0.9$		
$\sigma^{(I)}_{\text{HERA}}$ [pb]	126^{+300}_{-100}	89^{-15}_{+18}	$29^{-7.5}_{+10}$

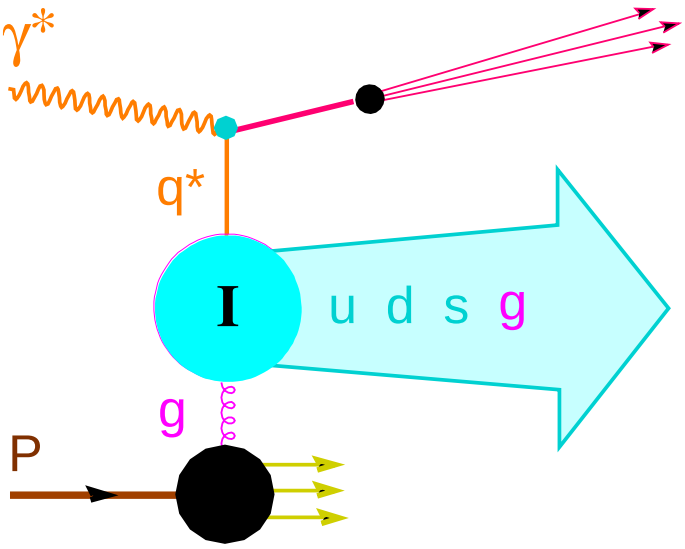
♣ **H1 $\oplus$ ZEUS**: $\int_{1996}^{2000} \mathcal{L}dt = 2\,\mathcal{O}(75)\ \text{pb}^{-1}$,
with $\sigma^{(I)}_{\text{HERA}} = 29$ pb $\Rightarrow$

$\mathcal{O}(4350)$ I-induced events within region of validity of I-perturbation theory on tape !?

♢ Characteristic Final-State Signature

- **Indispensable Tool:** Monte-Carlo generator package for simulation of instanton events at **HERA**:

  "QCDINS 2.0" [Gibbs, Ringwald & F. Sch. '95, Ringwald & F. Sch, Comp. Phys. Com. **132** (2000) 267 (**long-wite-up**); **WEB**: http://www.desy.de/~t00fri/qcdins/qcdins.html]

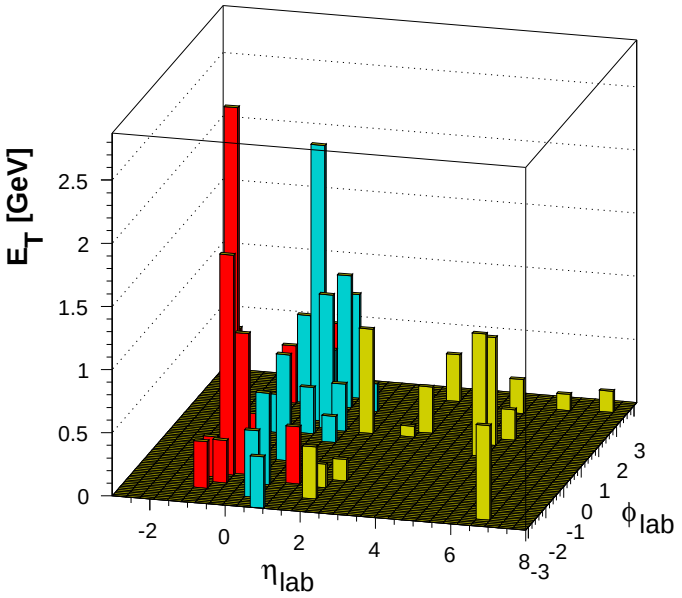


- current jet
- "band"-region: ⇔

  In I-rest system: "Fireball" decaying **isotropically** into

  $n_f \cdot q + n_f \cdot \overline{q} + \mathcal{O}(\frac{1}{\alpha}) \cdot g =$

  $\mathcal{O}(10)$ partons



- ♢ Large total E_t
- ♢ Large multiplicity
- ♢ "u, d, s flavour democracy": **Strangeness** ⇒ $K's, \Lambda's$
- ♢ No further jets

3. First Dedicated Search Results (H1)

[S. Mikocki for H1-Collaboration, *DIS2000*, Liverpool 25.-30. April 2000; H1-Collaboration, *ICHEP2000*, Osaka, July 2000, www-h1.desy.de/psfiles/confpap/ICHEP2000/H1prelim-00-025.ps]

3.1 Search Strategy and Observables

[T. Carli, J. Gerigk, A. Ringwald & F. Sch., hep-ph/9906441]

- Isolation of "I-enriched data" by means of cuts to a set of most I-sensitive observables. Place cuts such as to maximize

$$I\text{-separation power} = \frac{\epsilon_I}{\epsilon_{\mathrm{nDIS}}}$$

  in terms of efficiencies $\epsilon_I > 10\%$ and ϵ_{nDIS} for instanton and normal DIS events, respectively ($\Leftarrow$ **MC**-generators).

- For individual observables, I-separation power $\lesssim \mathcal{O}(20)$!

- $\Rightarrow$ **Analysis with several cut observables required**. E.g. set of " 3 best" (among ~ 30) increase I-separation power to $\mathcal{O}(90)$!

- Work mostly in "hadronic CMS" $(\vec{\gamma}^* + \vec{P} = 0)$.

- **"Current jet":** $\Leftrightarrow$ Jet with largest Et, via 'cone'-algorithm.

- ***I*-"band": $\eta \subset \bar{\eta} \pm 1.1$**, with $\bar{\eta} = \frac{\sum_{\mathrm{h} \not\subset \mathrm{jet}} \eta_h \cdot Et_h}{\sum_{\mathrm{h} \not\subset \mathrm{jet}} Et_h}$

- 3 ***I***-sensitive observables with ***I***-optimized cuts:

$n_{ch,\,b}$	number of charged hadrons in ***I***-"band" region
Sph	sphericity in rest system of "non-jet"-particles
$Q'^{\,2}_{\mathrm{rec}}$	reconstructed virtuality of ***I***-subprocess quark q'

- 3 further ***I***-sensitive observables without additional cuts:

Et_b	total transverse energy in ***I***-"band" region
Δ_b	Et-weighted azimuthal-isotropy
Et_{jet}	transverse energy of 'current-jet'

3.2 Data vs. Theory and Main Uncertainties

- 1997 data only: $\int \mathcal{L} dt = 15.78\,\mathrm{pb}^{-1}$; $2.8\,10^5$ used events.
- **nDIS**: Two different Monte-Carlo's (**uncertainties!**)

  { **CDM** = "Color Dipole Model" ($\Rightarrow$ ARIADNE) and
  MEPS ($\Rightarrow$ RAPGAP) }
- Altogether, good description (5 - 20 %) of data sample before cuts (c.f. $\Rightarrow$ talk by S. Mikocki).

- **3 cut scenarios: A), B), C)**:
  $\Leftrightarrow$ increasing $\boldsymbol{I}$-separation power ($\Leftarrow$ **MC** generators), focussing on basic characteristics of $\boldsymbol{I}$-induced events!

- **Caveat: H1** data sample has **no** x'-cut and **no** Q^2-cut.

- **H1** compared data to our predictions from **QCDINS MC with default** x'**-cut**, $x' \geq 0.35$, and **without** Q^2**-cut** $\Rightarrow$

- Implications:

  ▽ **Missing** x'**-cut in data:** Not too bad, since

  QCDINS($x' \geq 0.35$) $\Leftrightarrow$ model for sharp suppression of $\boldsymbol{I}$-effects, in lattice data of $\boldsymbol{I\overline{I}}$-distance distribution for $R/\rho \lesssim 1.0 - 1.05$, i.e. $x' \lesssim 0.3 - 0.35$ (Fig.)!

  - Remaining uncertainty $\delta x'_{\rm min} \approx -0.05$ on setting-in of this suppression $\Rightarrow$
  - $\approx$ factor 2 increase in size of $\boldsymbol{I}$-effects for each of 6 observables, relative to default cut $x' \geq 0.35$!

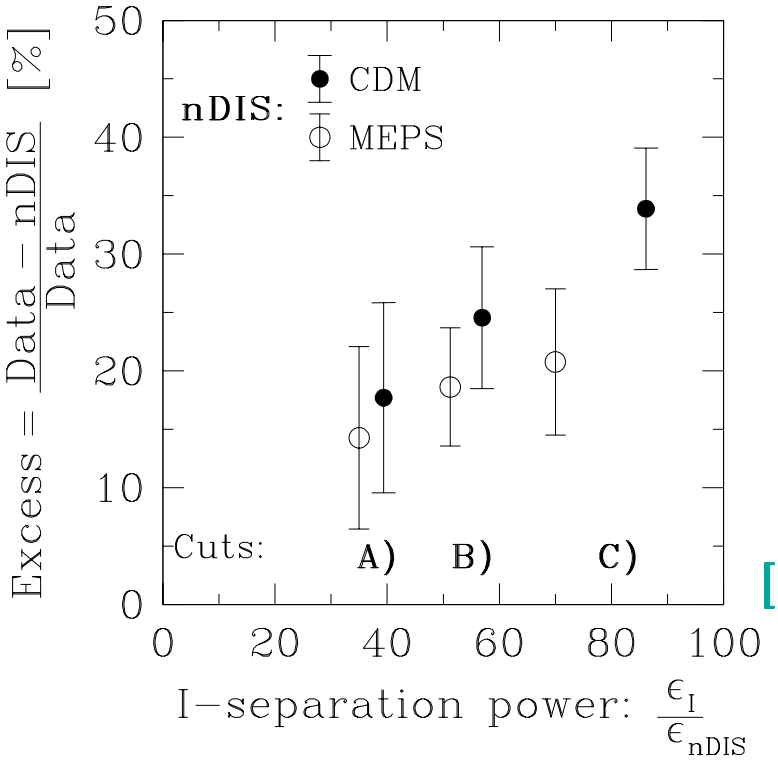
  ▽ **Missing** Q^2**-cut:** Among the 6 observables, **expect** incorrect **QCDINS** results for the 2 that depend strongly on Q^2 spectrum:

  $\langle \boldsymbol{Et}_{\rm jet} \rangle$ and $\langle \boldsymbol{Et}_{\boldsymbol{b}} \rangle$ **too large** (see later).

Despite these warnings . . .

♣ Intriguing and encouraging observations by **H1**:

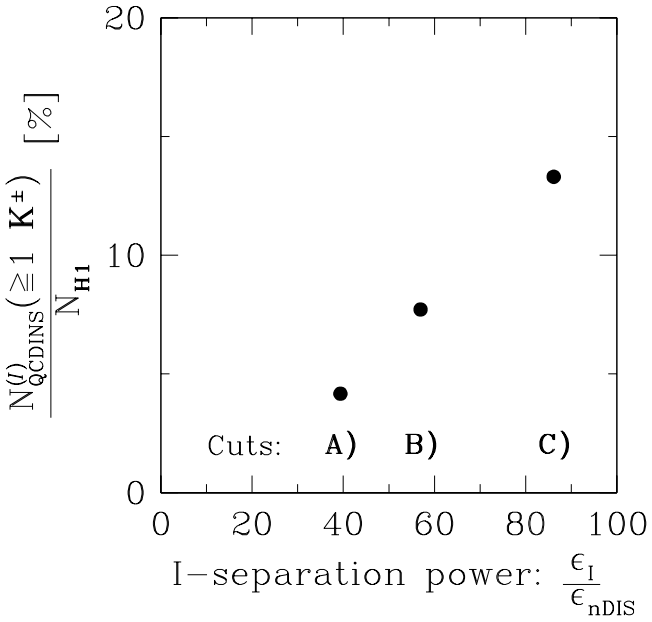
Significant excess, increasing with I-separation power!



[H1 preliminary]

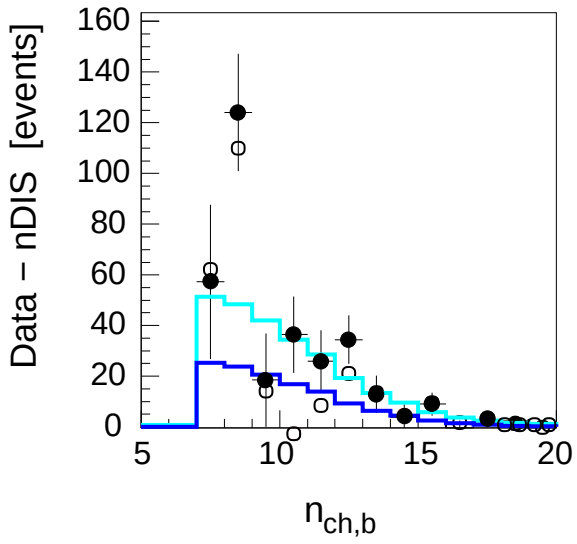
Still in progress: Search for $K^{\pm}$**-excess** (dE/dx) in the same I-enhanced **H1**-data sample.

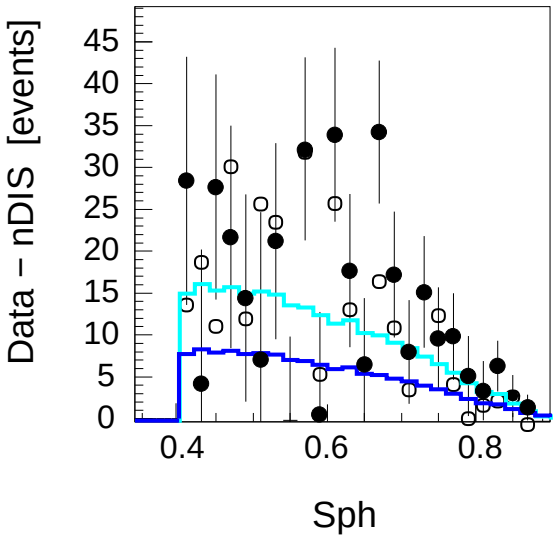
Crucial, independent signature, due to flavour democracy for I-events

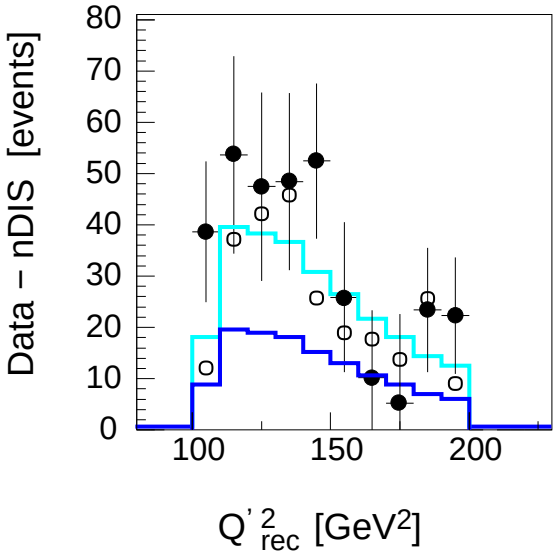


- **3** discriminating observables with optimized cuts:

Cuts B): 1332 events; excess: $\begin{cases} 327^{+82}_{-70} & \text{CDM} \\ 248^{+75}_{-46} & \text{MEPS} \end{cases}$







Data − CDM
Data − MEPS
} **no x' cut**

QCDINS 2.0 (default) x'>0.35
QCDINS 2.0 ; x'>0.325

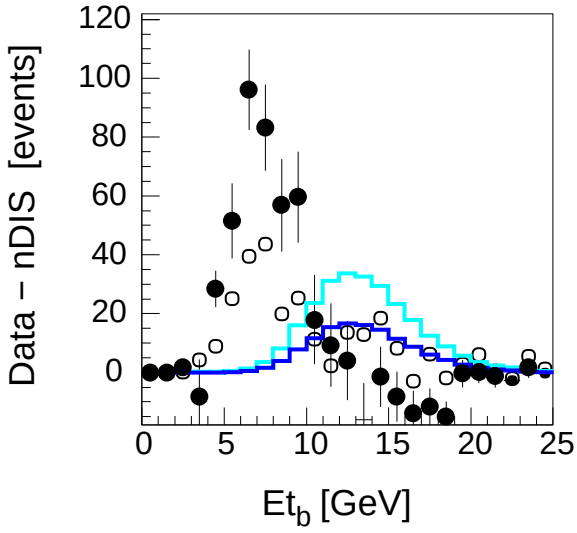
H1 preliminary

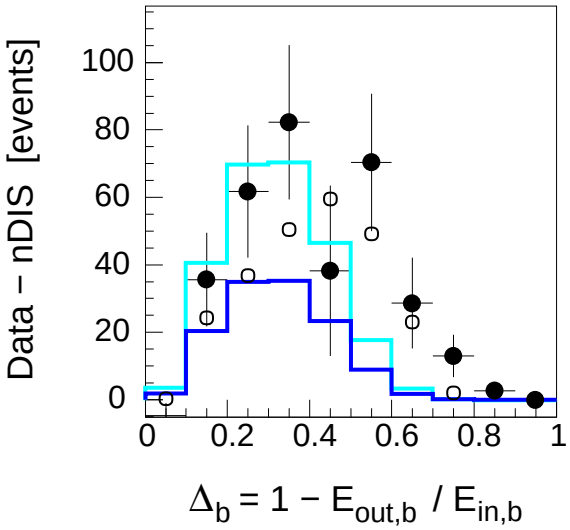
(DIS2000, ICHEP2000)

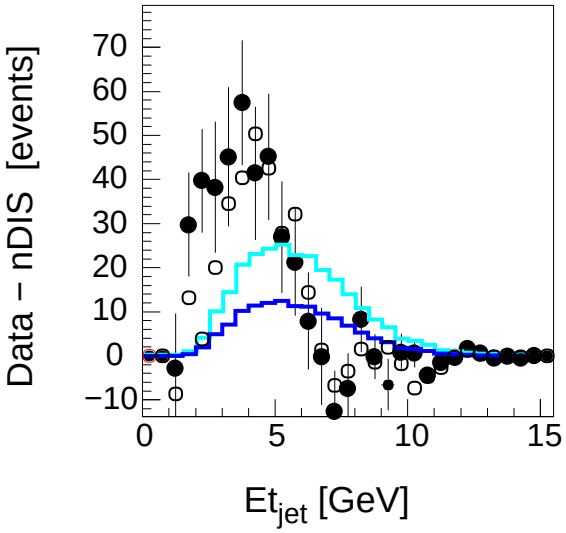
- Qualitatively similar excess for the 2 different **nDIS** Monte-Carlo's considered!
- Small decrease of fiducial x'-cut (well compatible with lattice data!) improves agreement considerably.

- **3** further observables without additional cuts:

Cuts B): 1332 events; excess: $\begin{cases} 327^{+82}_{-70} \text{ CDM} \\ 248^{+75}_{-46} \text{ MEPS} \end{cases}$







Data – CDM
Data – MEPS
} **no x' cut**

QCDINS 2.0 (default); x'>0.35
QCDINS 2.0 ; x'>0.325

H1 preliminary

(DIS2000, ICHEP2000)

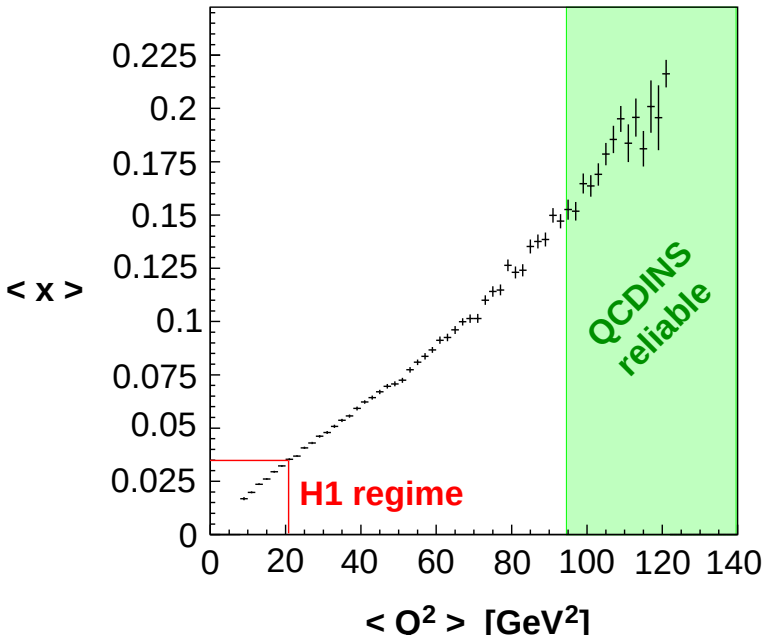
- Event-shape observable Δ_b agrees quite well, too.
- **Discussion of shift in $\langle Et_{\rm jet} \rangle$ and $\langle Et_b \rangle$:**

E.g. for $Et_{\rm jet}$, simple formula (parton level, hadr. CMS):

$$Et_{\rm jet} = Q' \sqrt{1 - \tfrac{x}{x'}} \sqrt{1 - \tfrac{x}{x'} \tfrac{Q'^2}{Q^2}}, \qquad (*)$$

with $x = Q^2/2p\,q =$ Bjorken-x of $\gamma^*(\,q\,) + g(\,p\,) \Rightarrow X$

Note: Strong correlation: $\langle Q^2 \rangle \Leftrightarrow \langle x \rangle$! (Fig.)

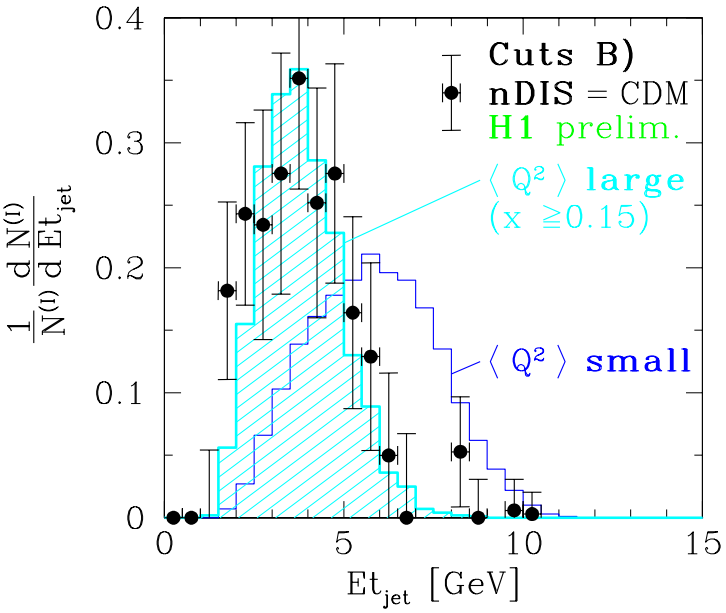


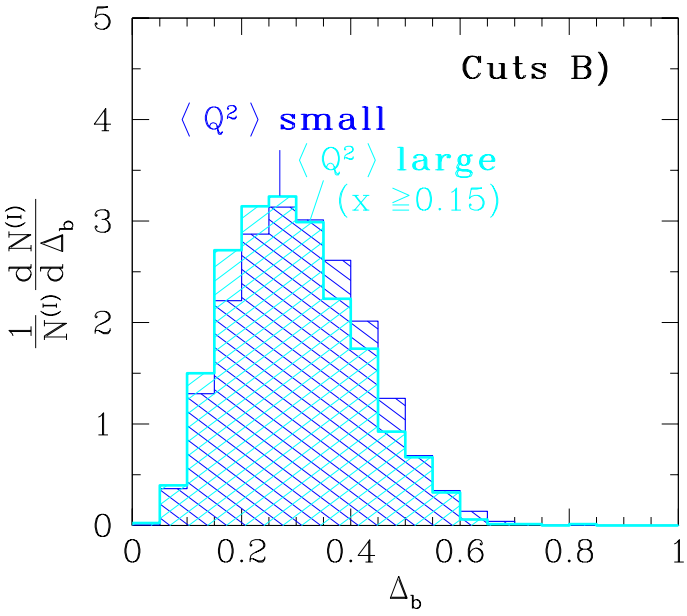
QCDINS $\oplus$ cuts A)..C) $\oplus$ no Q^2-cut: $\Rightarrow$
$\langle Q^2 \rangle$ **small**, ≈ 20 GeV^2, $\Rightarrow$ $\langle x \rangle \approx 0.035$ (Fig.)

$$\left\{ \begin{array}{lllll} \langle x' \rangle & \approx & x'_{\rm min} & = & 0.325 \\ \langle Q'^2 \rangle & \approx & Q'^2_{\rm min} & \approx & 113\ {\rm GeV}^2 \end{array} \right\} \overset{(*)}{\Rightarrow} \boxed{\langle Et_{\rm jet} \rangle \approx 6\ {\rm GeV}}$$

in good agreement with exact QCDINS results.

$\Rightarrow$ **Exercise:** Deplete low-Q^2 spectrum by means of (internal) x-cut: $x \geq 0.15$, $\Rightarrow$, **QCDINS** now reliable, since $\langle Q^2 \rangle \approx 95$ GeV^2 $\Rightarrow$





- $Et_{\rm jet}$-peak left-shifted to $\langle Et_{\rm jet}\rangle \approx 3.5$ GeV and narrower, in good agreement with shape-normalized **H1**-excess!
- Analogously for Et_b!
- Other **4** observables $\approx$ unaffected by $x > 0.15$ cut (Fig.), hence insensitive to Q^2-spectrum!. QCDINS $\approx$ reliable, here.

- ♣ Intriguing qualitative overall agreement and much improved understanding . . .
- ♣ Size of excess in correct ballpark.
- ♣ Both Q^2-cut and x'-cut **can** and **should** be implemented experimentally. $\Rightarrow$ Strong reduction of remaining (size-)ambiguities!
- Remaining problematics: Excess based on **MC** for **nDIS**. I-signal where **nDIS** not too well known . . .

4. Conclusions

- Instantons, as non-perturbative, topological fluctuations of the gluon fields, are an essential aspekt of QCD
- Tunnelling transitions, signalled by existence of characteristic, hard processes with chirality violation.
- Discovery of I-events would be of fundamental significance.
- **HERA** offere a unique opportunity in **DIS**
- Systematic theoretical and phenomenological investigation of the "discovery potential":

  calculable rate in measurable range; event signature!
- Results from first dedicated I-search [**H1**, preliminary]:
  - significant excess compared to **nDIS** Monte-Carlo's, increasing with I-separation power.
  - qualitative similarity with form of instanton-prediction for most of the 6 considered observables;
  - size in the required ballpark with default cuts and $\Lambda_{\overline{\rm MS}}$;
  - Improved understanding of agreement and apparent disagreement, while Q^2- and x'-cuts still lacking in data.
  - is there a marked excess of $K^{\pm}$ ($\Leftarrow \frac{dE}{dx}$) in the I-enhanced data sample??
- **Exciting times ahead . . .**