Instanton-Hunting Strategies at HERA

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in collaboration with

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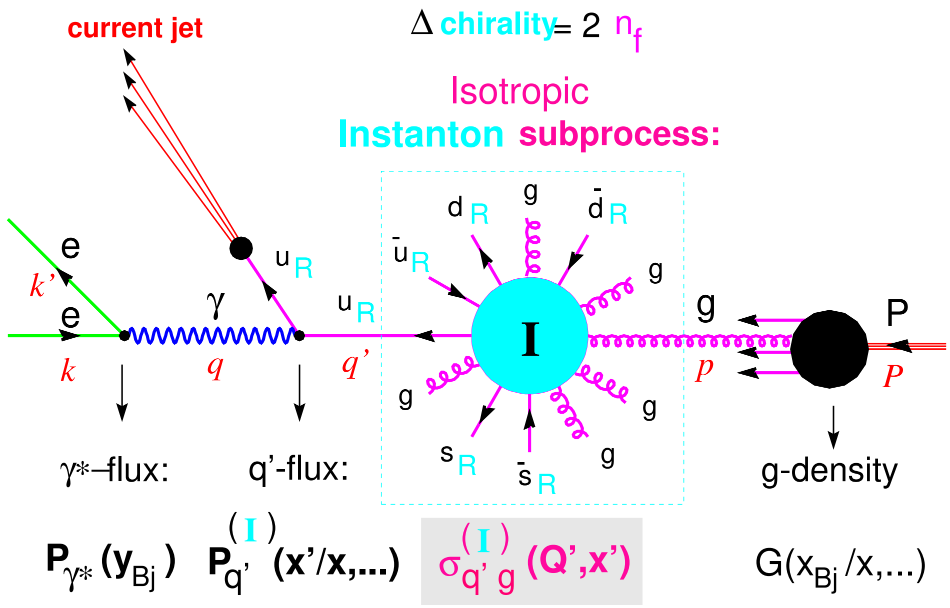
http://www.desy.de/~t00fri/talks.html

– Low x Physics at HERA, Zeuthen, June 1998 –

1. Brief Reminder

- Leading instanton-induced, chirality violating process in DIS regime of $e^{\pm}P$ scattering:



- Instanton-subprocess with own **Bjorken**-variables:

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

- show within $\boldsymbol{I}$-perturbation theory:

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

- calculable differential $q'g$ luminosity $d\mathcal{L}^{(I)}_{q'g}$ in $\boldsymbol{I}$-background:
  $\Leftrightarrow$ number of $q'g$ collisions per eP collision in intervals $(x', x' + dx')$, $(Q'^2, Q'^2 + dQ'^2)$,

- crucial instanton-dynamics in $\boldsymbol{I}$-subprocess cross-section $\boxed{\sigma^{(I)}_{q'g}(Q', x')}$!

- For minimal cuts, as extracted from UKQCD-lattice simulation,

$$\sigma^{(I)}_{\rm HERA}(x' \geq 0.35, Q' \geq 8~{\rm GeV}) \simeq 126~{\rm pb}$$

for $x_{\rm Bj} \geq 10^{-3}, 0.1 \leq y_{\rm Bj} \leq 0.9$.

- Hence, with total integrated luminosity accumulated by experiments at HERA, $\mathcal{L} = \mathcal{O}(100)~{\rm pb}^{-1} \;\Rightarrow$

$\mathcal{O}(10000)$ I-induced events on tape!

- Important tool: [Gibbs, Ringwald & F. Sch. '95; anonymous ftp: theopc3.desy.de]
"QCDINS 1.6.0" : MC-generator for I-induced DIS-events
  - Instanton-induced hard subprocess
  - Leading-log parton shower and hadronization (HERWIG 5.9)
  - "HZTOOLS" package fully integrated$\Rightarrow$ all published HERA data, jet analysis . . .

- Instanton-hunting strategies:

Experimentalist's view:

  - top priority: Discovery of $\boldsymbol{I}$-induced events,
  - try to produce an $\boldsymbol{I}$-enriched data sample by means of a set of cuts.
  - Predicted rate of secondary importance; event topology crucial.
  - Try to look also somewhat beyond the "fiducial" (Q', x') region, assuming that topolgy remains similar. . .
  - Need to understand pQCD background in tails of distributions!

Theorist's view:

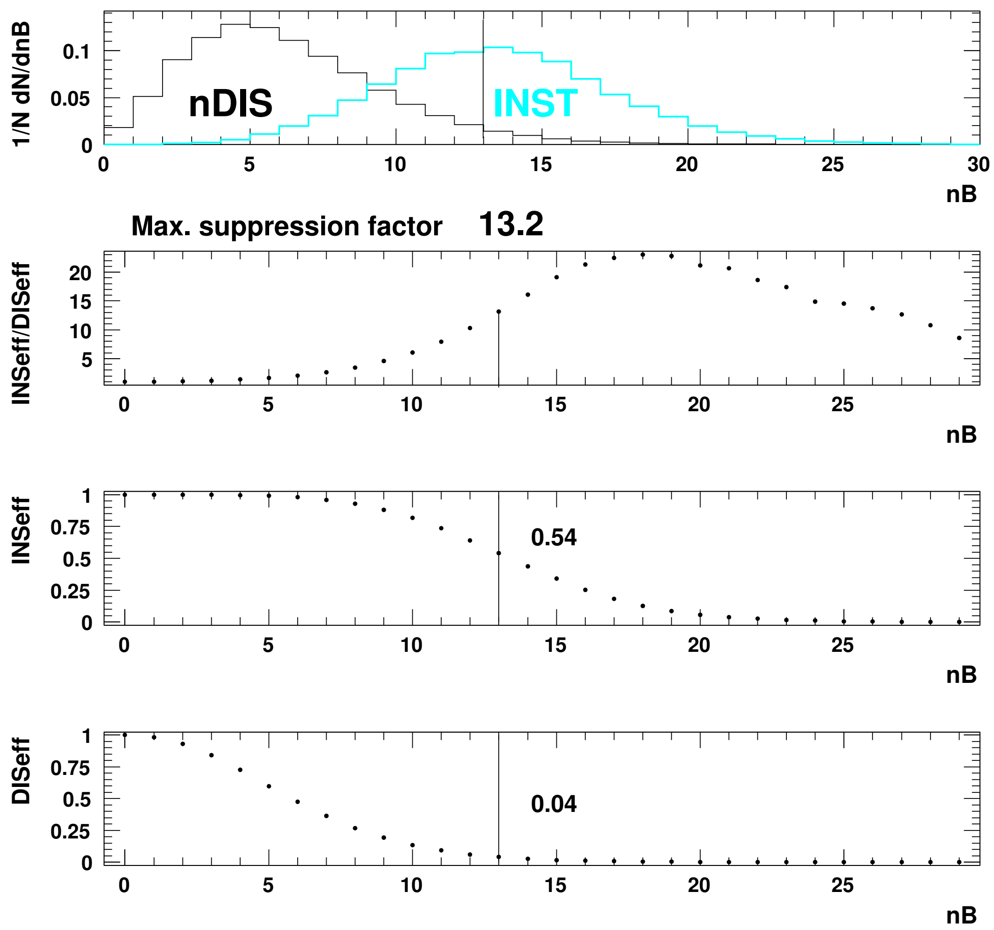
– More emphasis on confirmation of predicted rate$\Rightarrow$

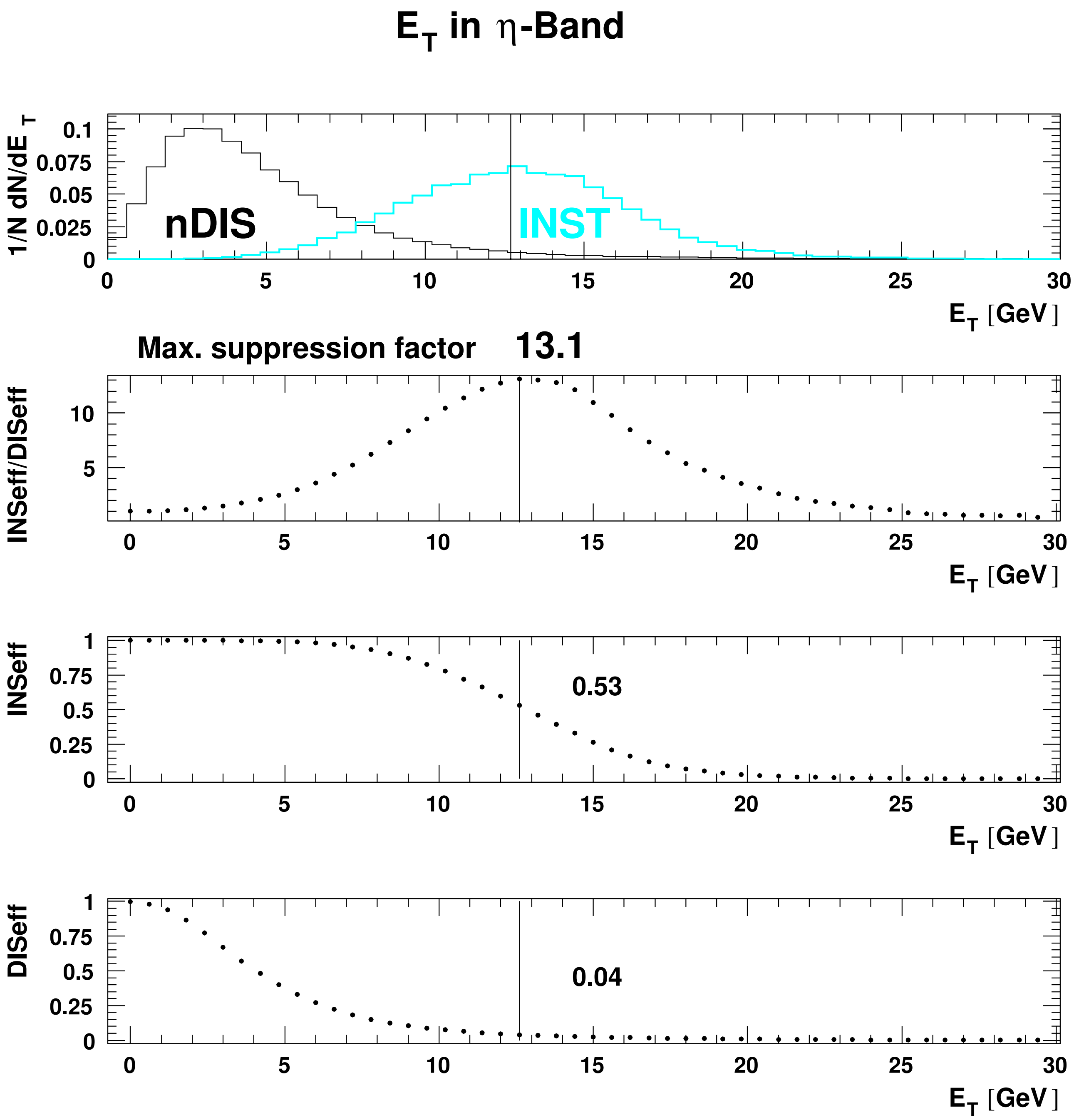
– (Q', x')-reconstruction most important.

2. Instanton-Enriched DIS Data

- Instanton-induced events are expected to yield high multiplicity and high E_T, notably in the "band" of width $\Delta\eta = \pm\mathcal{O}(1)$.
- Place optimal single-variable cuts to produce I-enriched data samples, assuming INSefficiency> 0.5. All plots im $\gamma^* P$ c.m.s;
- $Q^2 > 5$ GeV^2, $0.1 < y_{\rm Bj} < 0.6$, i.e. $x_{\rm Bj} \gtrsim 10^{-4}$; no detector-sim.

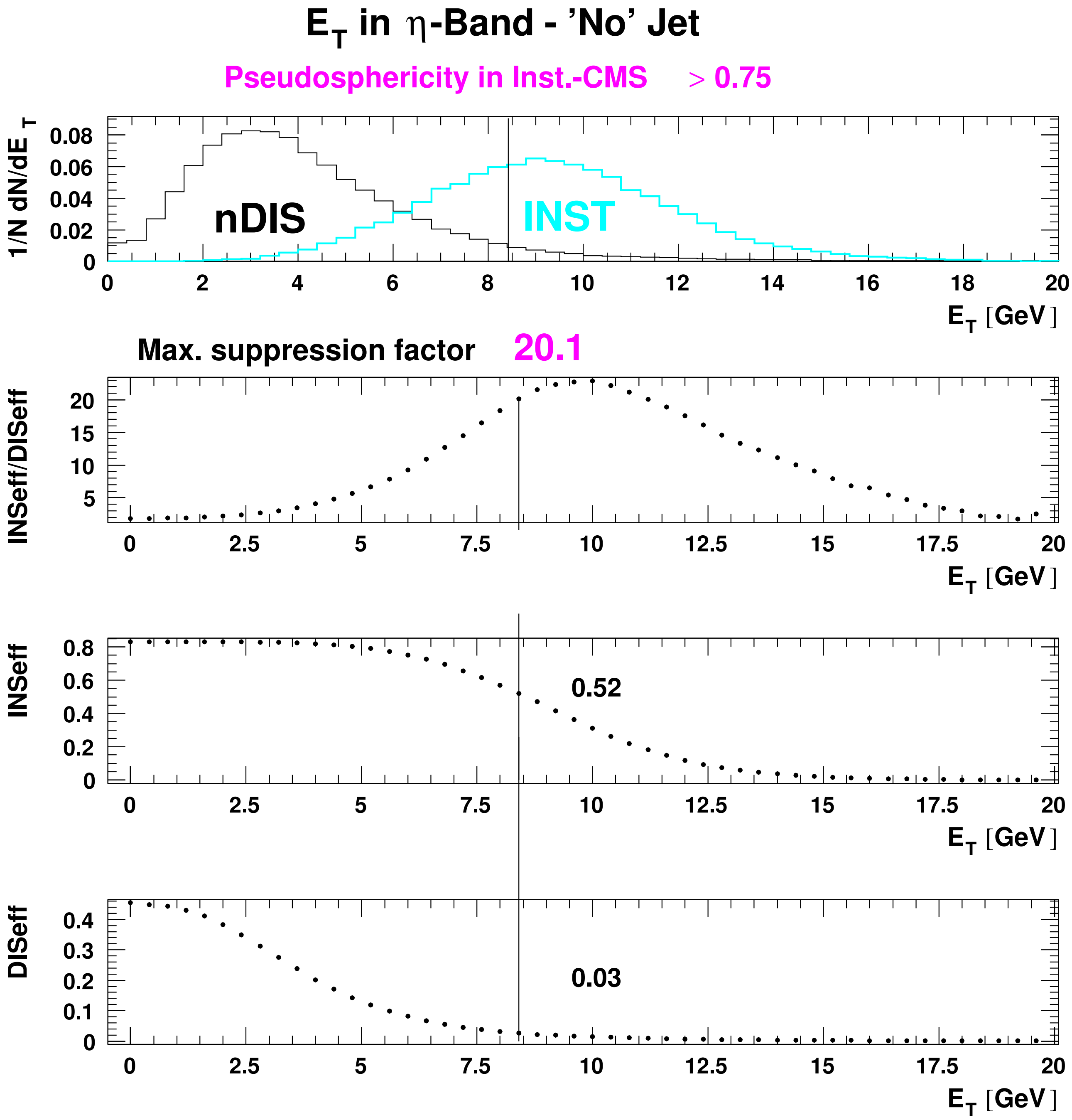
Charged Particles in η-Band (nB)





E_T in η-Band
1/N dN/dE T
nDIS
INST
E_T [GeV]
Max. suppression factor 13.1
INSeff/DISeff
E_T [GeV]
INSeff
0.53
E_T [GeV]
DISeff
0.04
E_T [GeV]

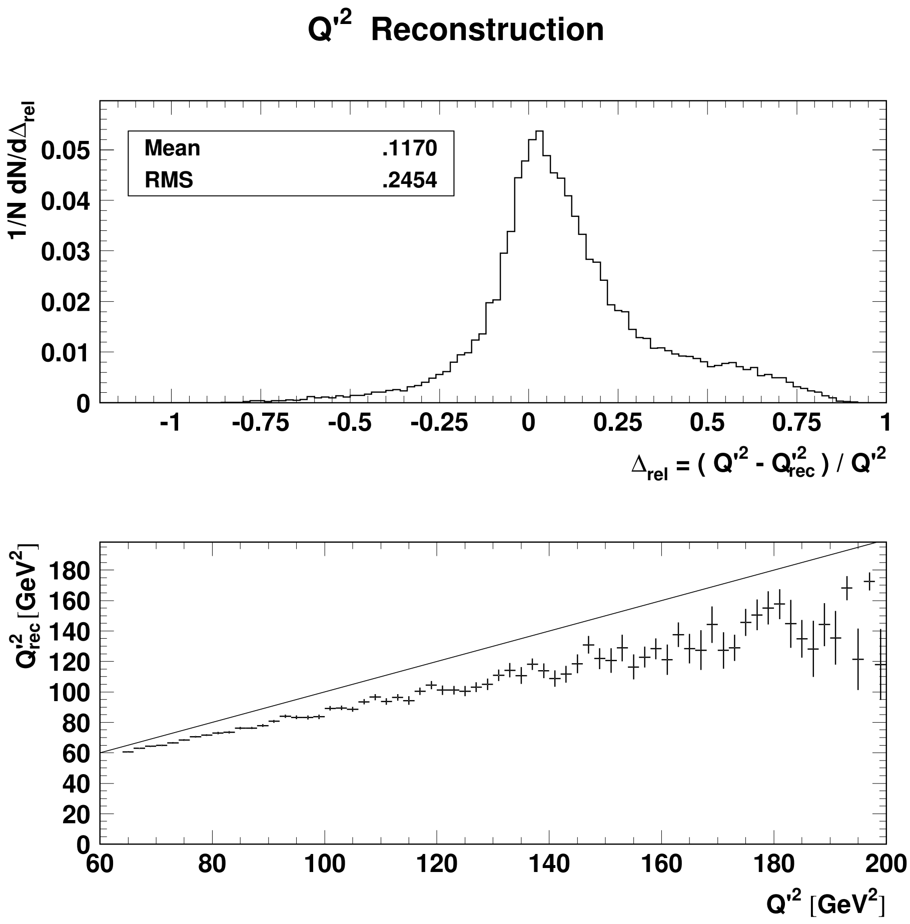
- much improvement in normal DIS suppression if
  - jet with highest P_T (jet1) from PXCONE jetfinder analysis is subtracted and
  - pseudo-sphericity > 0.75 is required in system close to INST-cms (ISOTROPY!): $(\vec{q}' + \vec{P} = 0;\ q' = q - p_{\mathrm{jet1}})$



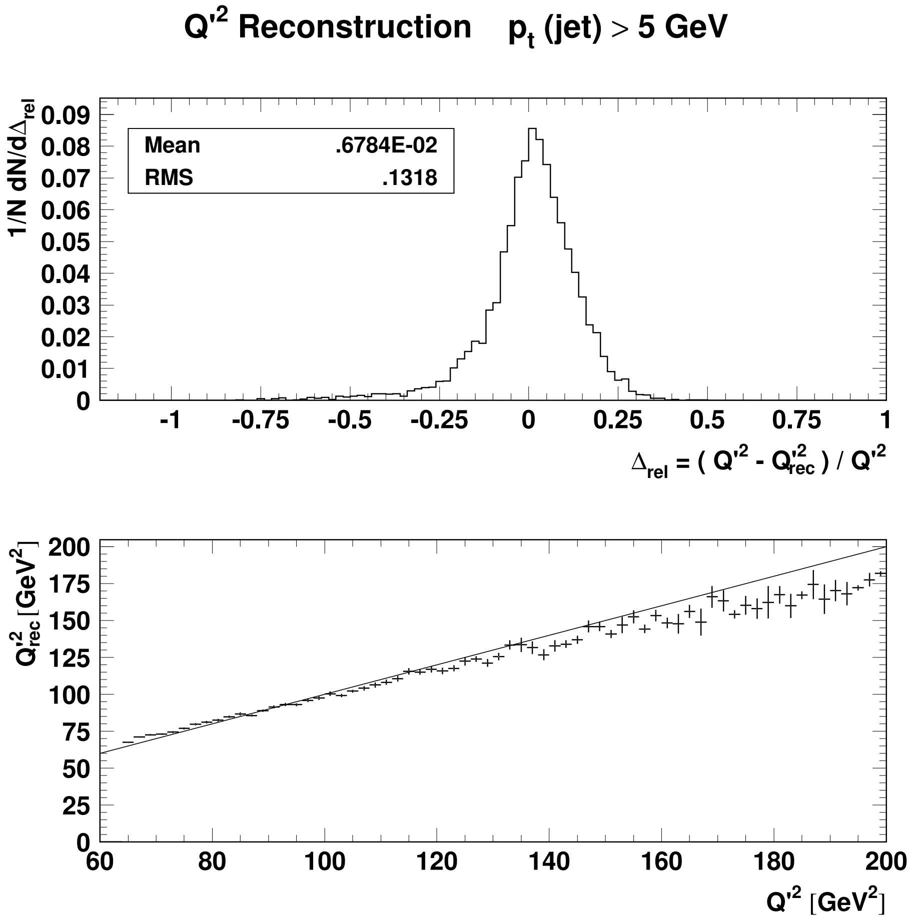
3. Reconstruction of Q'^2 and x'

Q'^2-Reconstruction:

- Find current jet (jet1, having highest P_T) via PXCONE jetfinder algorithm (Search radius R=1 $\rightarrow$ 0.5)
- Reconstruct $Q'^2 = -(q - p_{\mathrm{jet1}})^2$ (Fig.)



- Note the "shift", much improvement by requiring $p_{T\,\mathrm{jet1}} \gtrsim 5$ GeV:



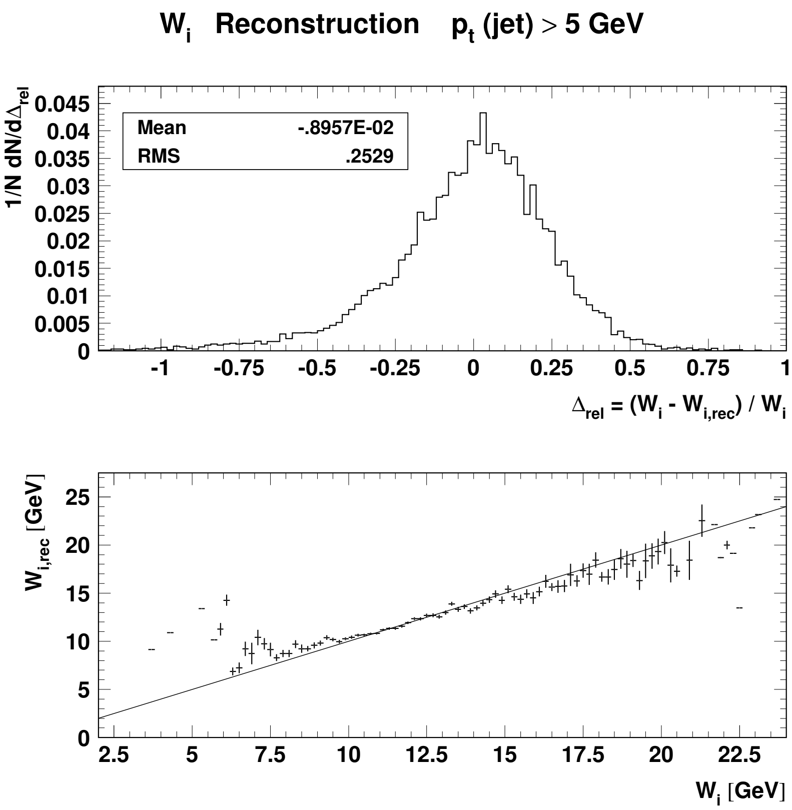
x'-Reconstruction:

1) Reconstruct first total energy in $\boldsymbol{I}$-rest system, $W_I = \sqrt{(q' + p)^2}$
   - Cut out hadrons belonging to current jet (jet1).
   - Form E_T-weighted $\langle\eta\rangle$ to find the center of the "band" (hadrons from instanton),

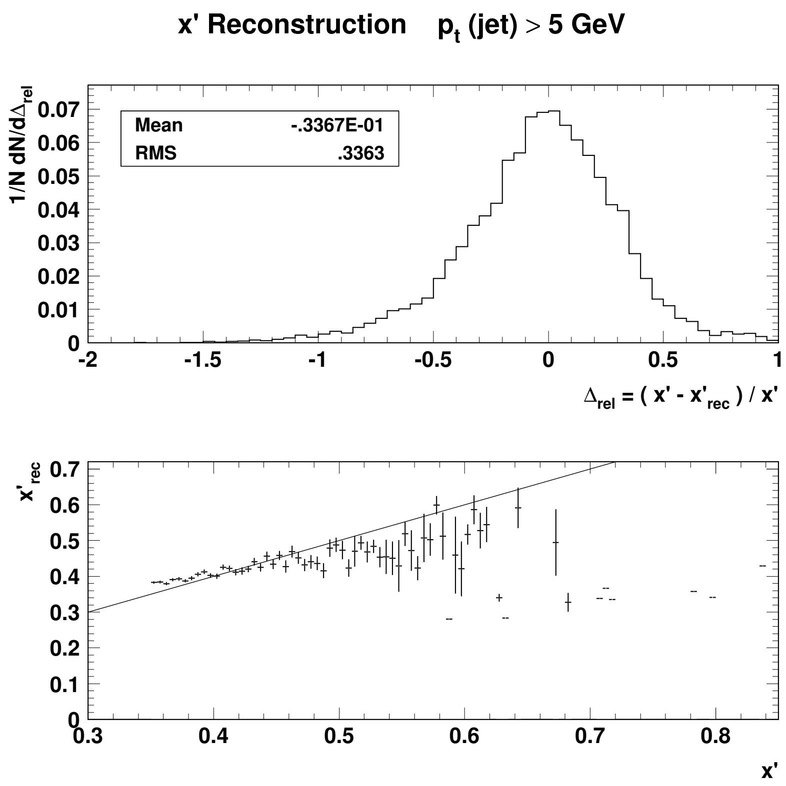
$$\langle\eta\rangle = \frac{\sum_{\text{hadrons h } \not\subset \text{ jet1}} E_{T\,h} \cdot \eta_h}{\sum_{\text{hadrons h } \not\subset \text{ jet1}} E_{T\,h}}$$

Define "band" by cutting $\langle\eta\rangle \pm 1.1$ and construct (Fig.)

$$W_{I,\mathrm{rec.}} \simeq \sqrt{\Big(\sum_{h \text{ in``band''}} p_h\Big)^2}$$



2) Now: $x' = Q'^2/(W_I{}^2 + Q'^2)$ (Fig.)



4. Conclusions

- Despite high rate of instanton-induced events at HERA, no single observable known (yet) with sufficient **nDIS** rejection.
- Hence, dedicated multi-observable analysis required.
- Neural network filters are being tried and have very good analysing power if applied to $\gtrsim \mathcal{O}(5)$ observables!
- The presented strategies to produce instanton-enriched data sample and to reconstruct (Q'^2, x') look quite promising!
- Instanton-hunting is great fun and well worth the effort!