Learning to See at the LHC

Chris Quigg

Fermilab

LHC Physics Center · 6 April 2010

arXiv:1001.2025

New Worlds Opened by the LHC

Do not know what the new wave of exploration will reveal

True for lightly triggered events
as well as high mass scales

Staged commissioning of LHC: opportunity to map gross features of particle production over a wide energy range

- Validate assumptions that underlie searches for new phenomena in hard-scattering events
- Develop intuition: LHC experimenters (+ theorists!)
- Opportunity for exploration and discovery

Ken Wilson's Ancient Program CLNS-131 (1970)

Some Experiments in Multiple Production

- Multiplicities: diffractive + multiperipheral?
- Feynman scaling: $\rho_1(x \equiv k_z/E, k_\perp, E)$ indep. of E?
- Factorization: πp, pp same in backward hemisphere?
- dx/x spectrum (flat rapidity plateau)?
- Double Pomeron exchange?
- Short-range order:
  $\rho_2(y_1, y_2) - \rho_1(y_1)\rho_1(y_2) \propto \exp(-|y_1 - y_2|/L)$?
- Factorization test with central trigger (no diffraction)

Isn't "Soft" Particle Production Settled Knowledge?

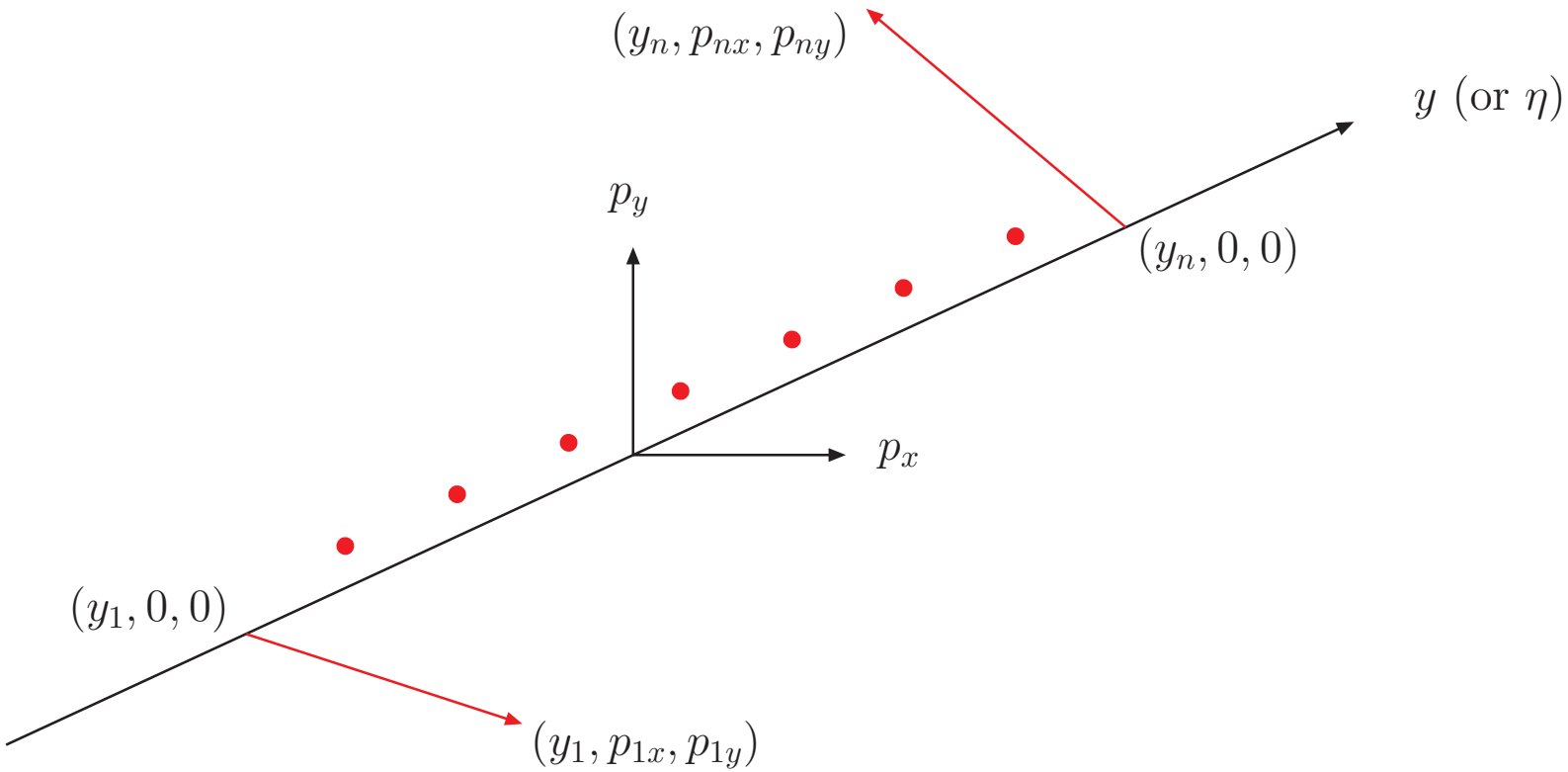
Diffractive scattering + short-range order

- (Not exhaustively studied at Tevatron)
- Long-range correlations?
- High density of $p_z = 5$ to 10 GeV partons
  $\rightsquigarrow$ hot spots, thermalization, . . . ?
- Multiple-parton interactions, perhaps correlated
  $q(qq)$ in impact-parameter space, . . .
- PYTHIA tunes miss 2.36-TeV data (ATLAS & CMS)

Few percent of minimum-bias events ($\sqrt{s} \gtrsim 1$ TeV)
might display an unusual event structure
We should look! How?

An Informative Event Display

(Avoid pathological attachment to blind analysis!)



(unwrapped LEGO plot for particles)

Bjorken, SLAC-PUB-0974 (1971)

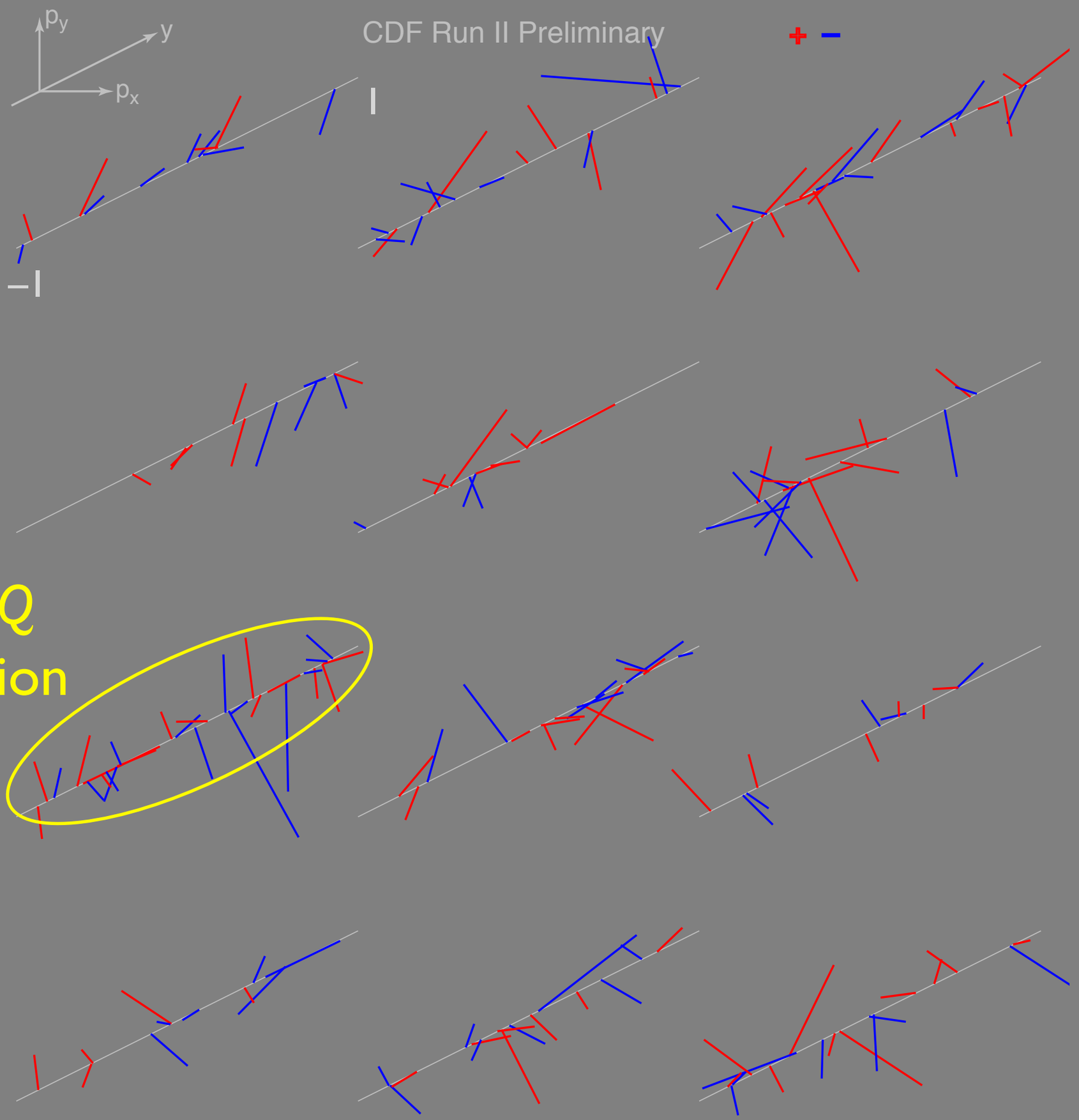
Example Event Displays from CDF Run II

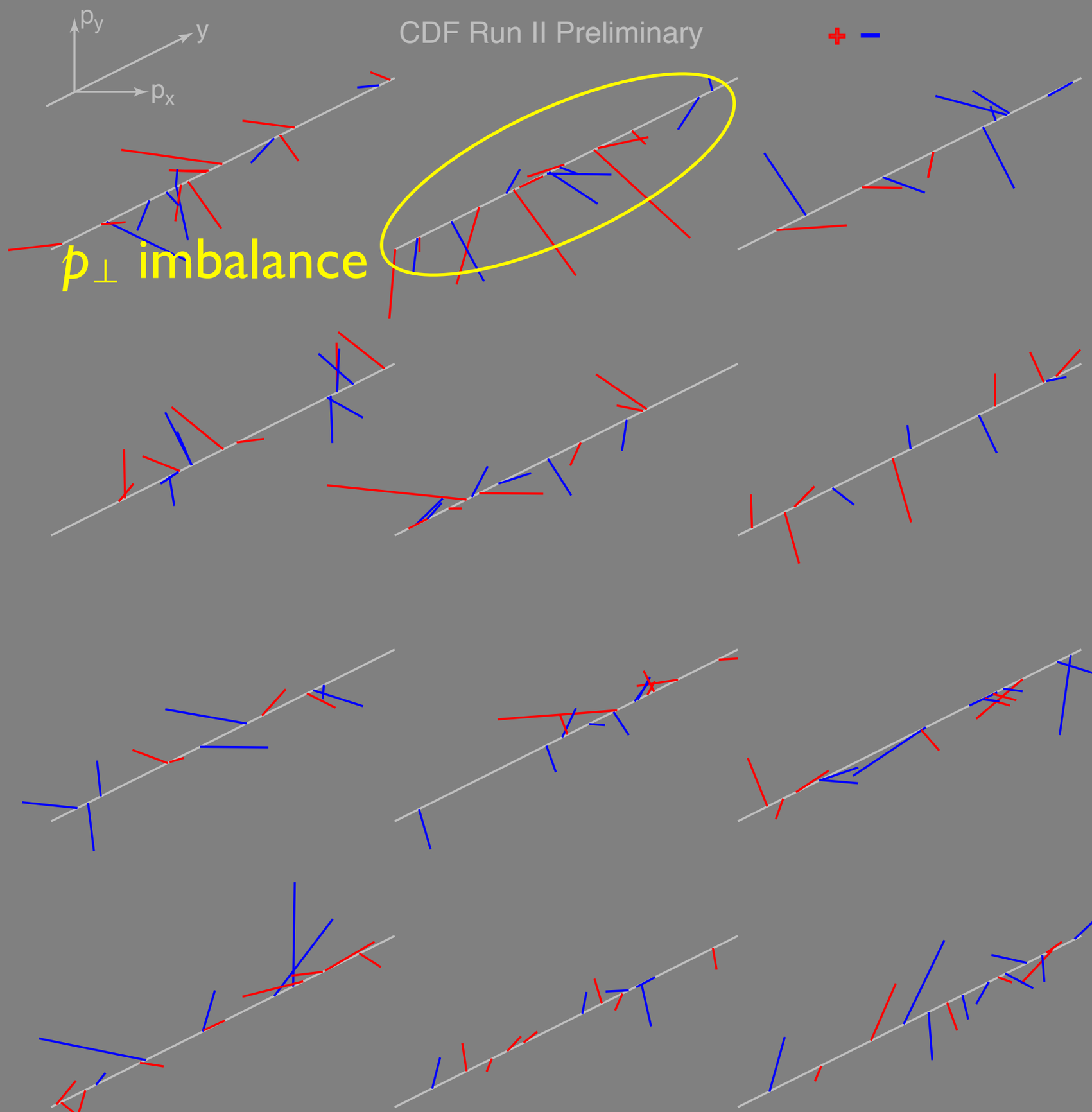
1.88 Million "zero-bias" events

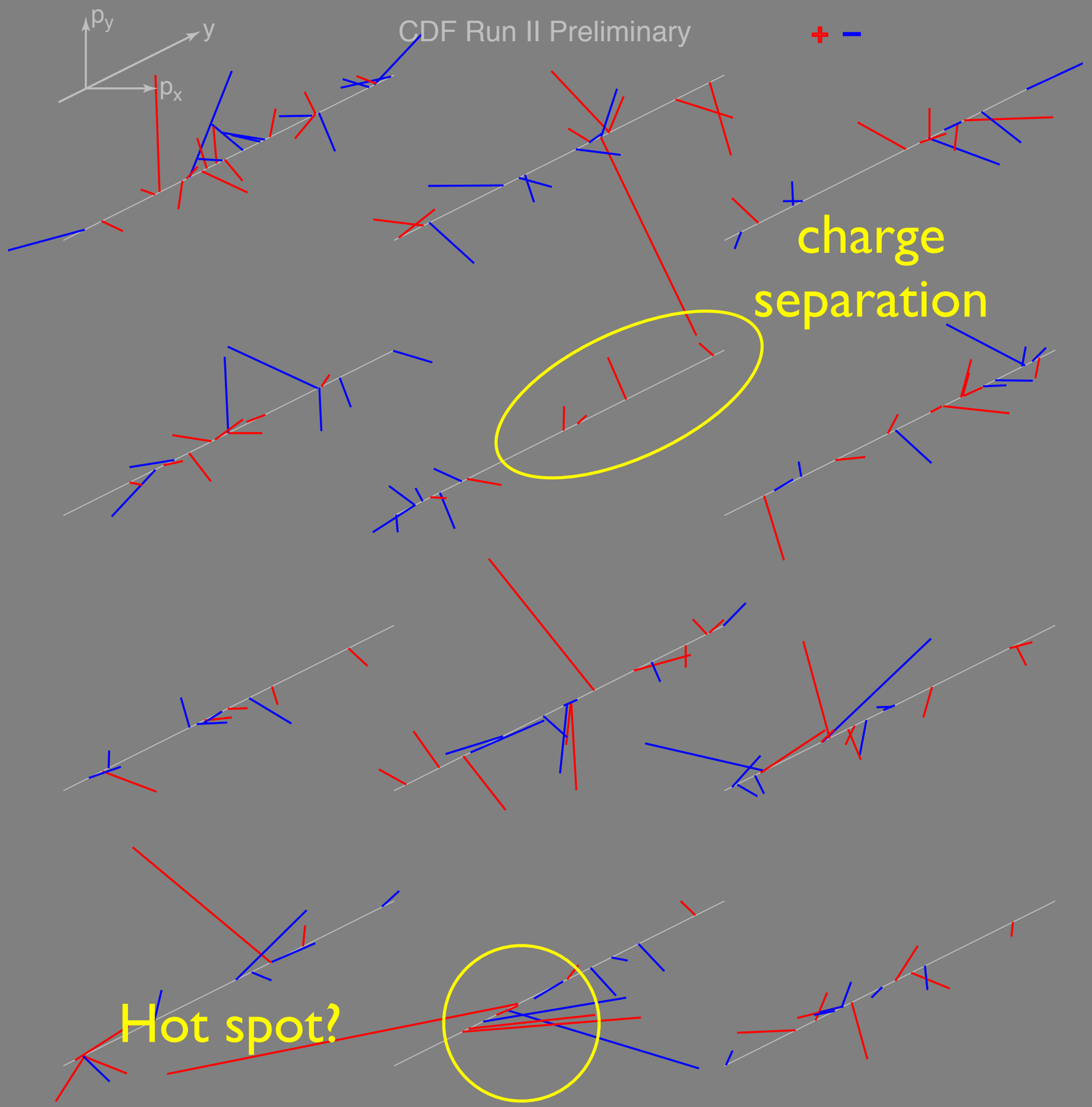
Selection for these examples:

- ≥ 10 tracks in $-1 \leq y \leq 1$
  (excludes $\gamma\gamma$, $\mathbb{PP}$ candidates)
- One primary vertex

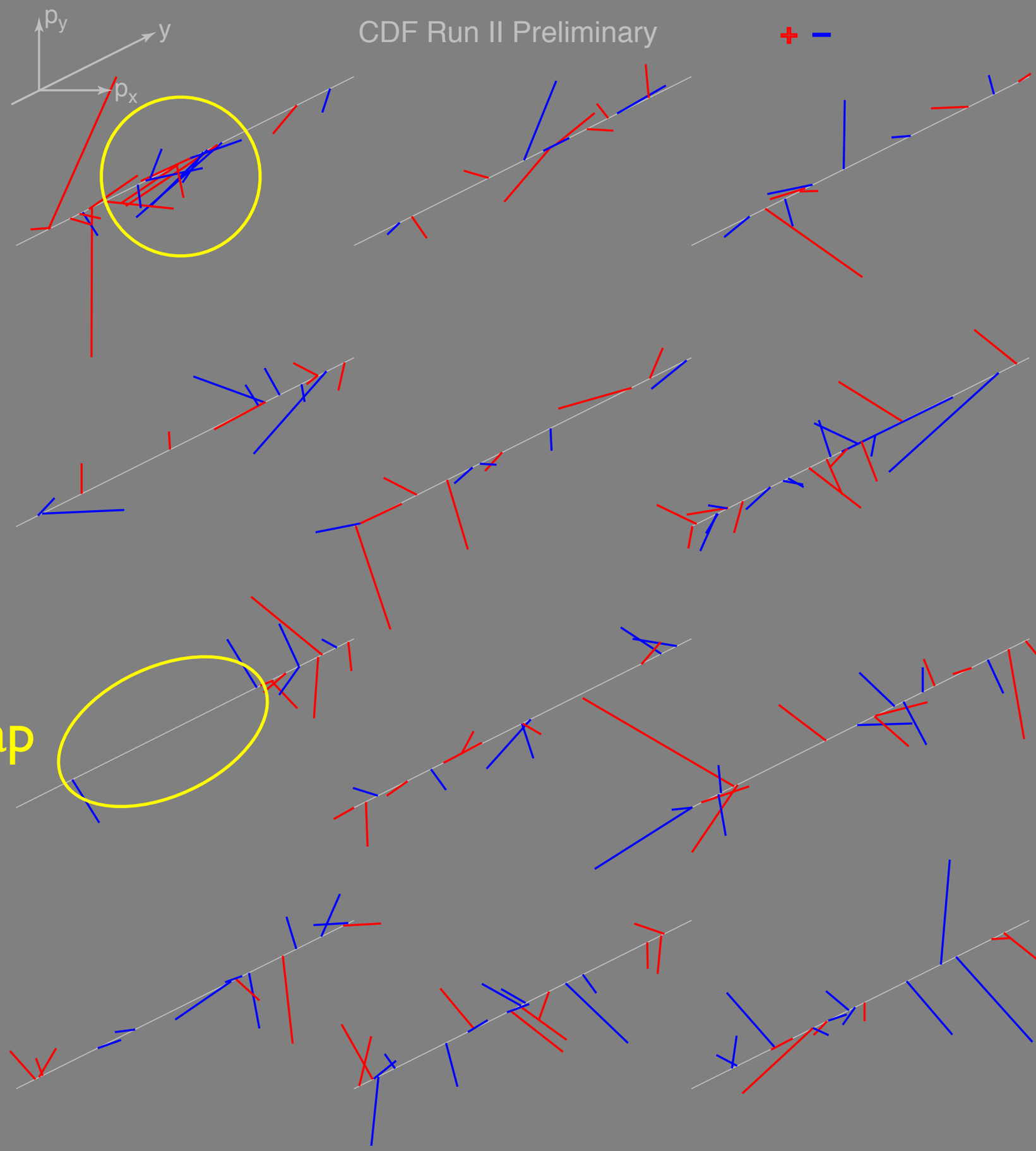
Compare N. Moggi, La Thuile 09


p_y
y
p_x
CDF Run II Preliminary
+ −
Local $p_\perp$, Q compensation

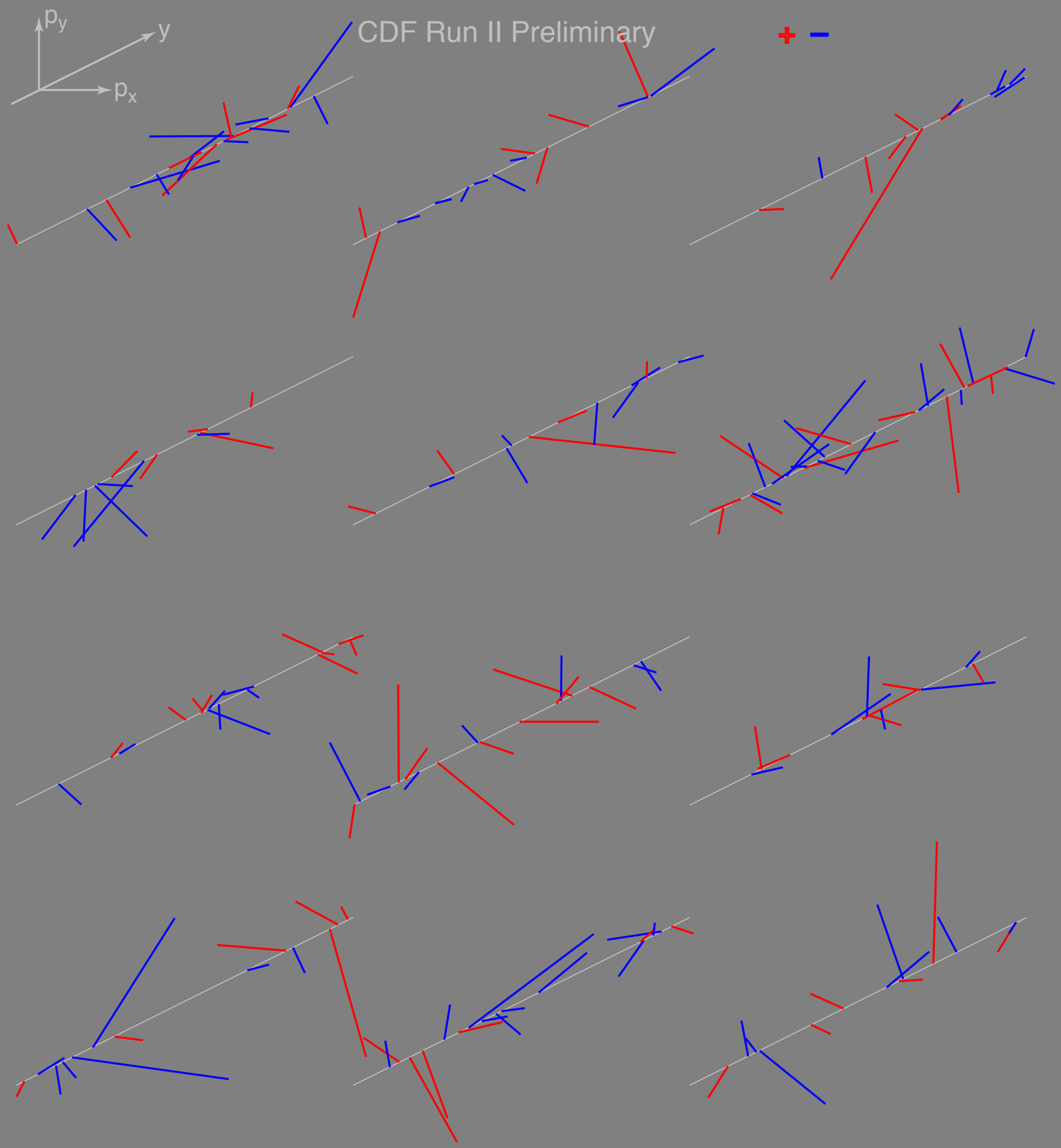

p_y
y
p_x
CDF Run II Preliminary
+ −
$p_\perp$ imbalance

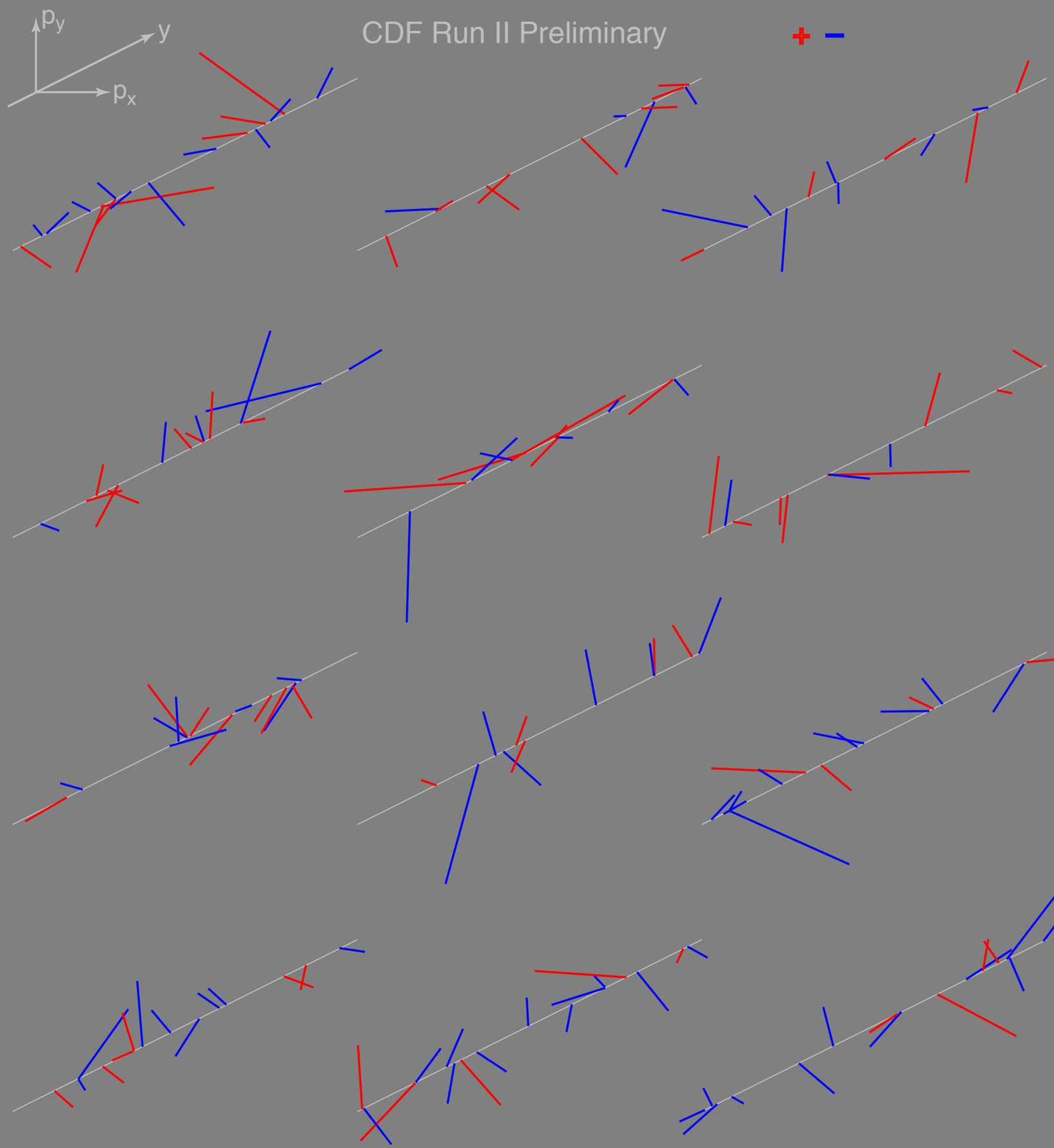

p_y
y
p_x
CDF Run II Preliminary
+ −
charge
separation
Hot spot?

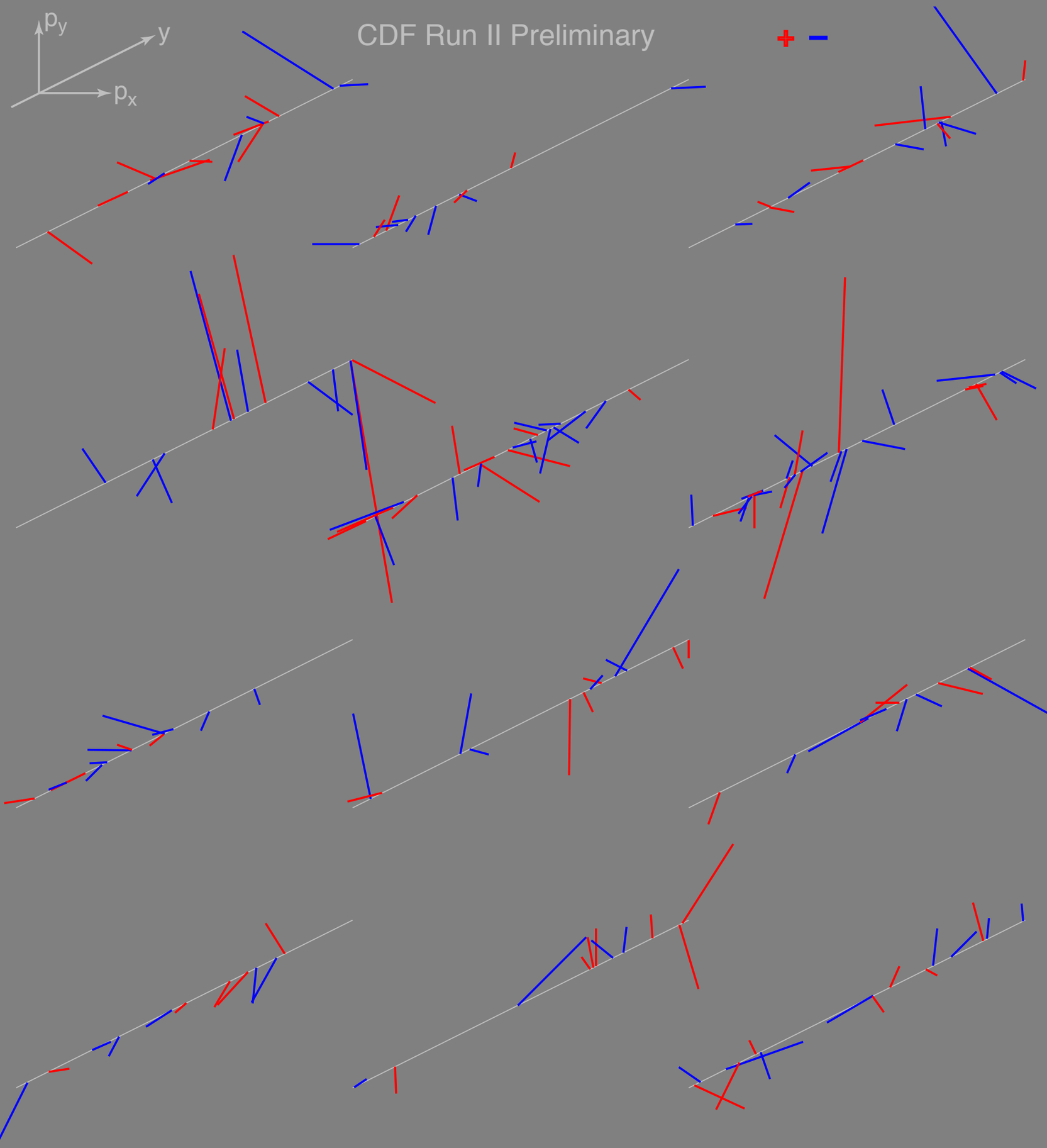
Hot spot?

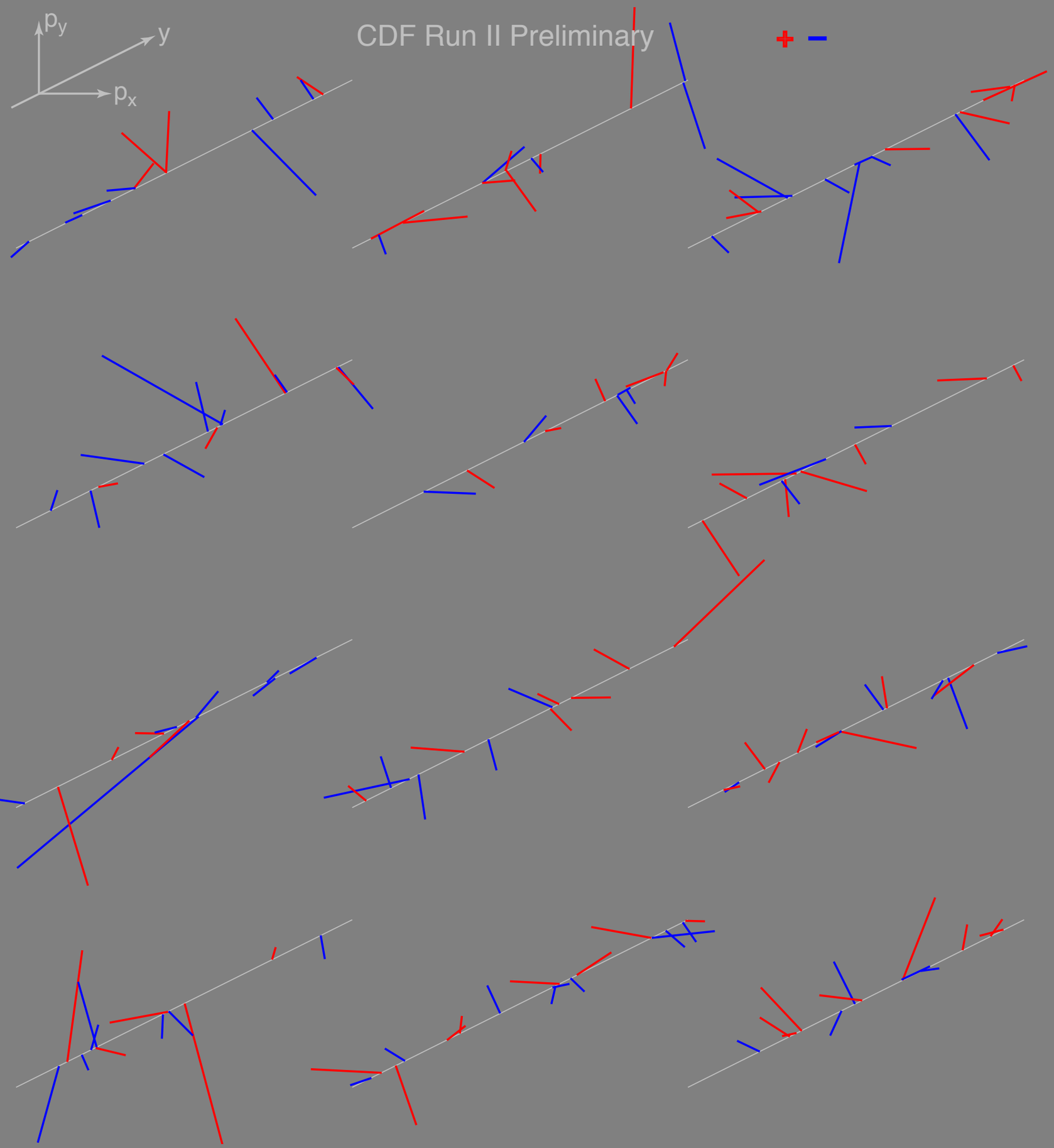


Rapidity gap


p_y
y
p_x
CDF Run II Preliminary
+ −


p_y
y
p_x
CDF Run II Preliminary
+ −


p_y
y
p_x
CDF Run II Preliminary
+ −


p_y
y
p_x
CDF Run II Preliminary
+ −

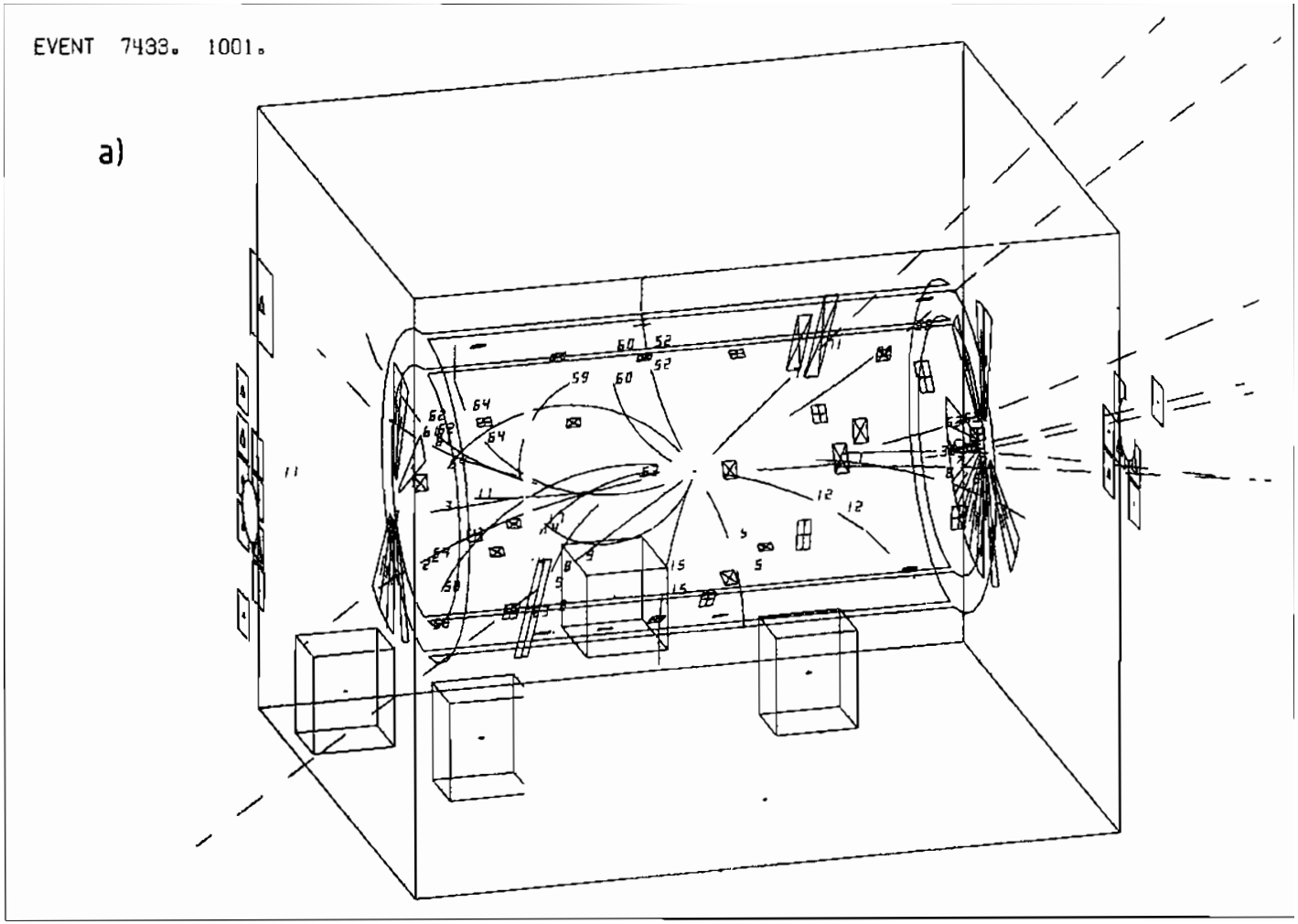
A Modest Proposal

I encourage LHC collaborations to produce live streams of $(y, \vec{p}_\perp)$ representations, along with the online displays of events that show the structure in terms of detector elements in ordinary space.

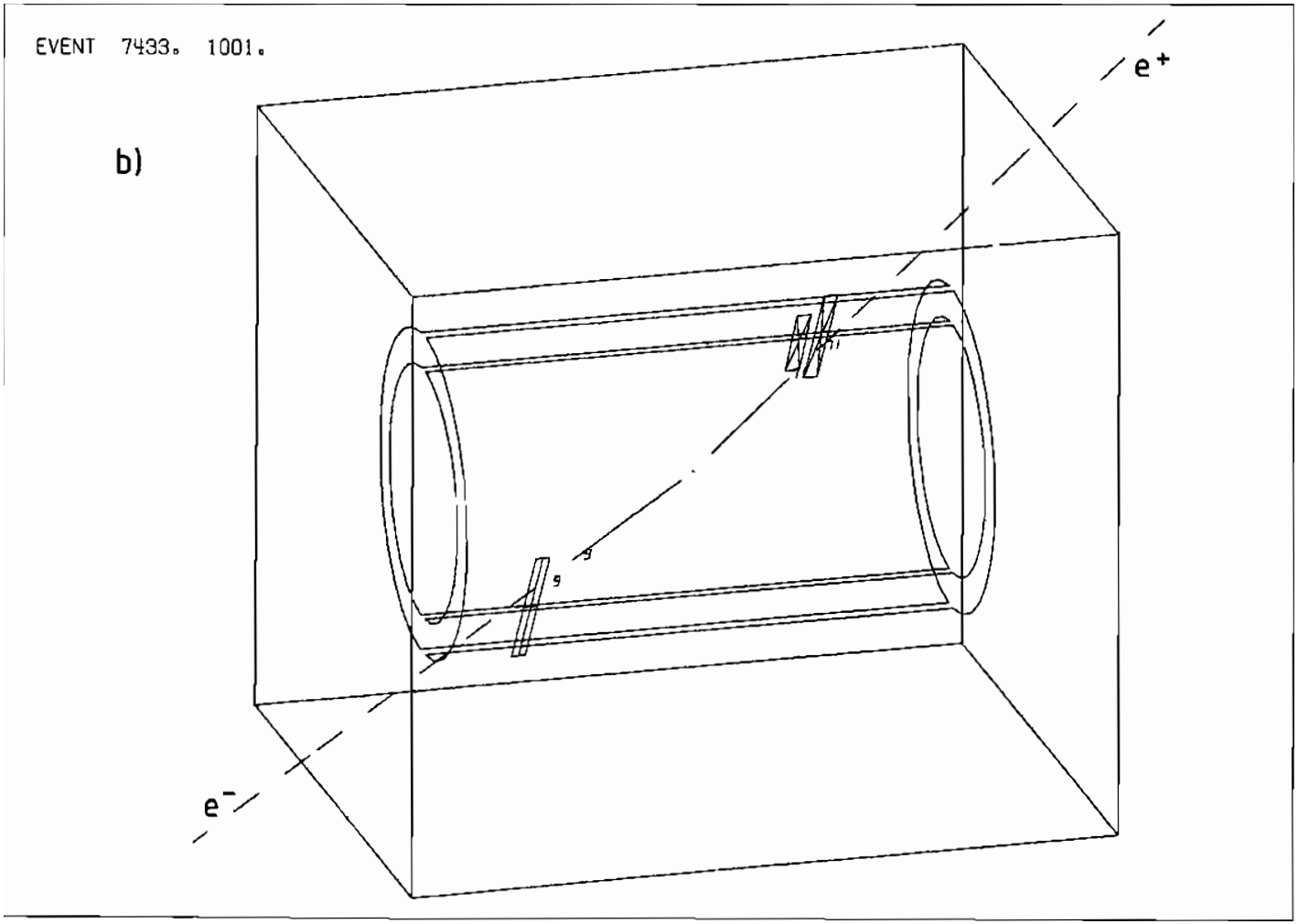
More is to be learned
from the river of events
than from a few specimens!

Changes in event structure vs. $\sqrt{s}$, or the onset of new features, might raise important questions.

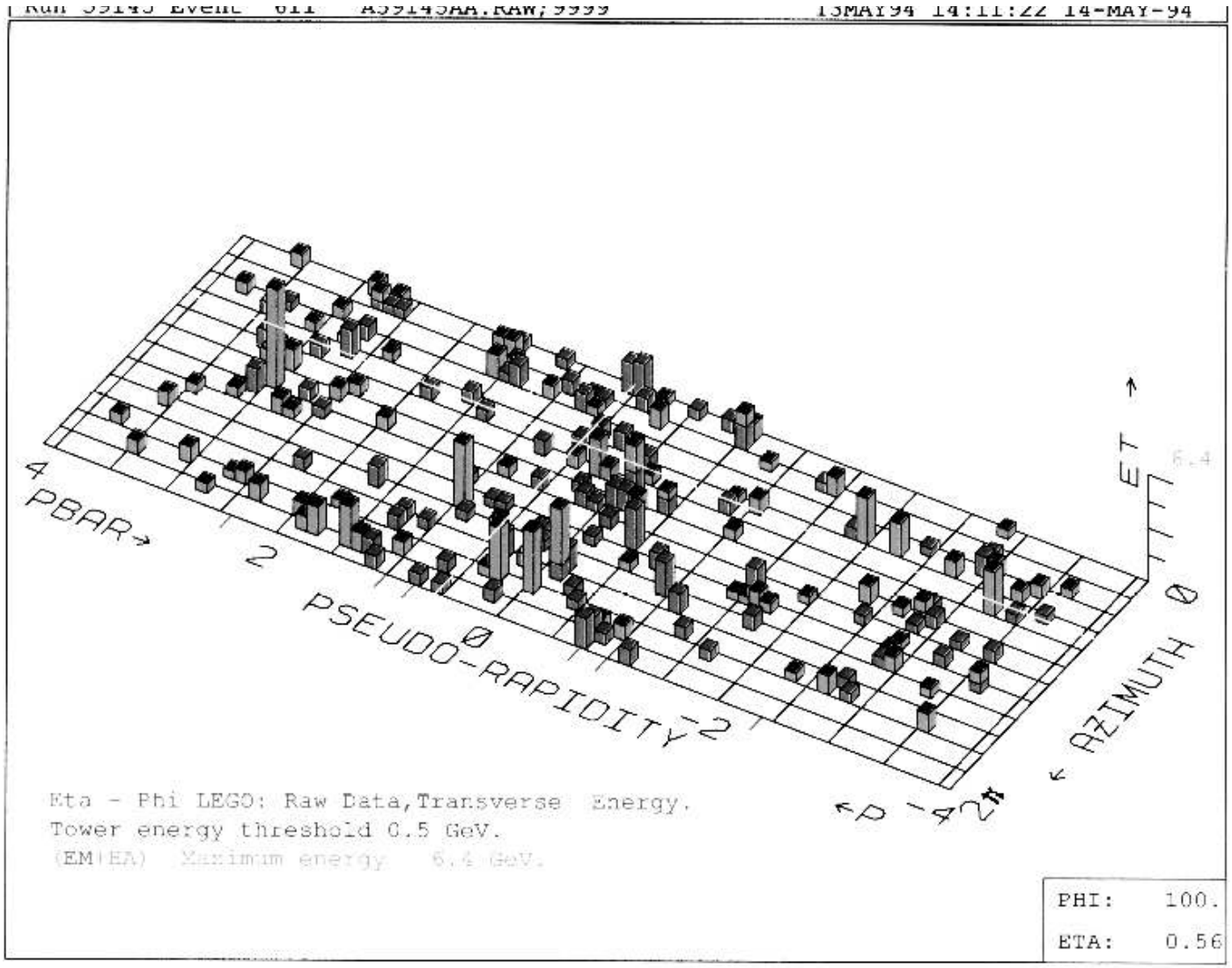
UA1: $Z \longrightarrow e^+e^-$: all tracks, calorimeter hits



UA1: $Z \longrightarrow e^+e^-$: track $p_\perp > 2$ GeV, calo $E_\perp > 2$ GeV



Physics in the Weeds: Atypical Event from CDF Run I



> 100 towers above 0.5 GeV, $\sum E_\perp = 320$ GeV

Opportunity for Exploration and Discovery

- Minimum-bias, triggered (underlying event) samples
- Revisit early multiple-production studies (particles): multiplicity distributions, (semi-)inclusive correlations, charge-transfer across hemispheres or rapidity intervals
- *For some classes of events,* bulk properties: elliptic flow, thermodynamic parameters as at RHIC
- Looking at events, in appropriate coordinates, may identify new event classes (new studies), point to shortcomings in the Monte Carlo programs

Each step in energy is a new world!

Thanks to

- William Wester & Niccolò Moggi
- Christina Mesropian & Sasha Pranko
- Drasko Jovanovic for the Hedgehog event
- James Bjorken