



Experimental Particle Physics

PHYS6011

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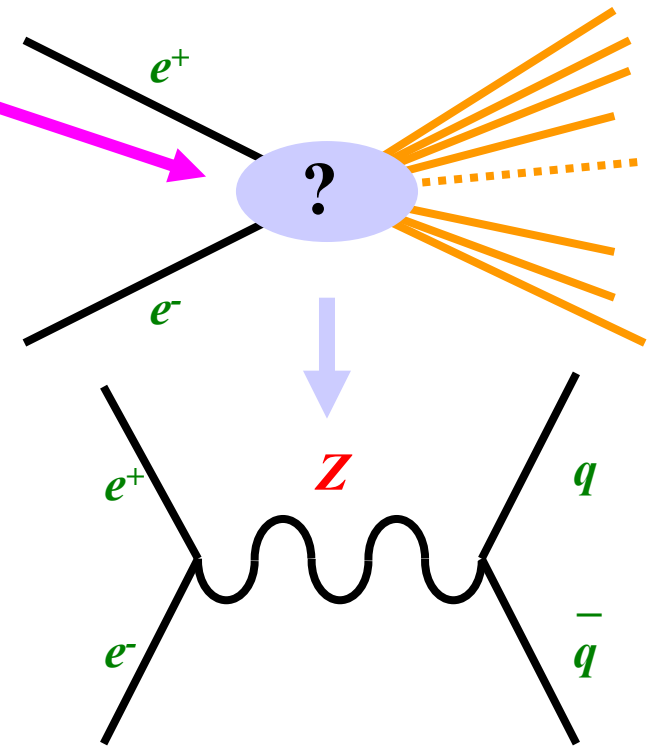
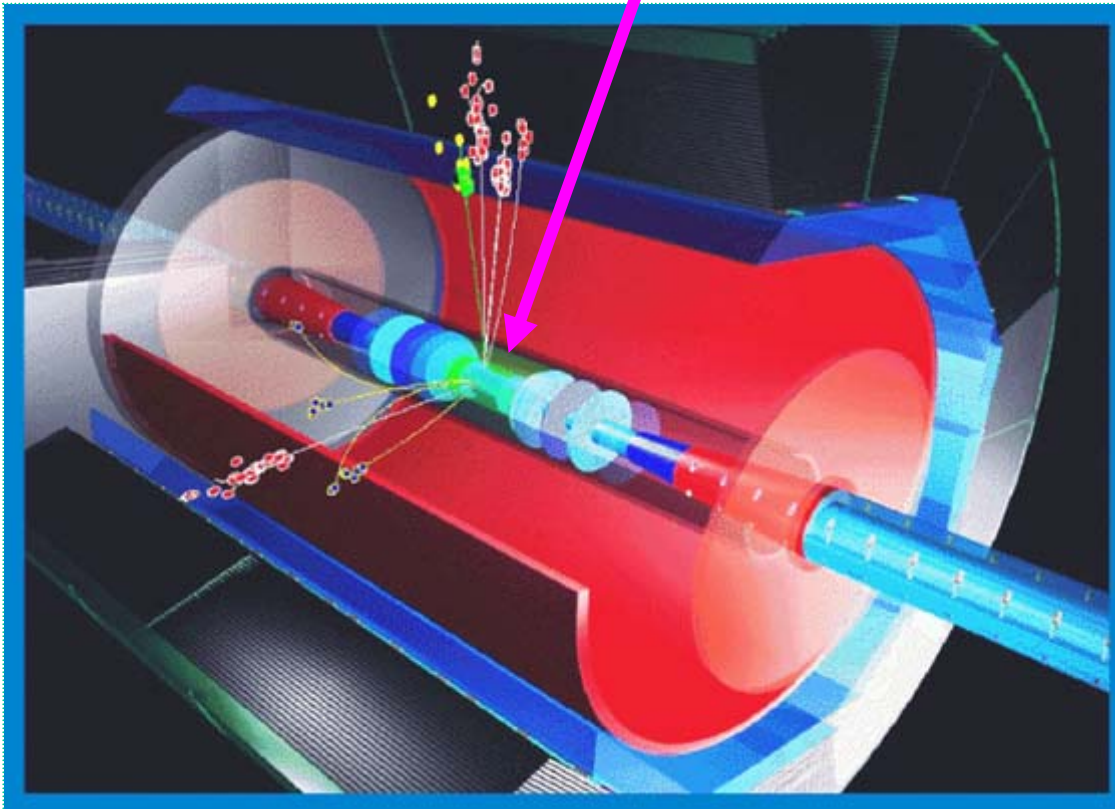
1. Introduction & Accelerators
2. Particle Interactions and Detectors (2)
3. Collider Experiments
4. Data Analysis

Collider Experiments

- **So far:**
 - Accelerators and colliders
 - Particle interactions
 - Types of detectors
- *Combine them to do physics...*
- **Example: CDF at the Tevatron**
 1. Proton-antiproton collisions
 2. Fermilab and the Tevatron
 3. CDF and DØ
 4. Identifying particles
 5. Identifying physics processes
 - *top production*

Reconstructing Collisions

What happened here?

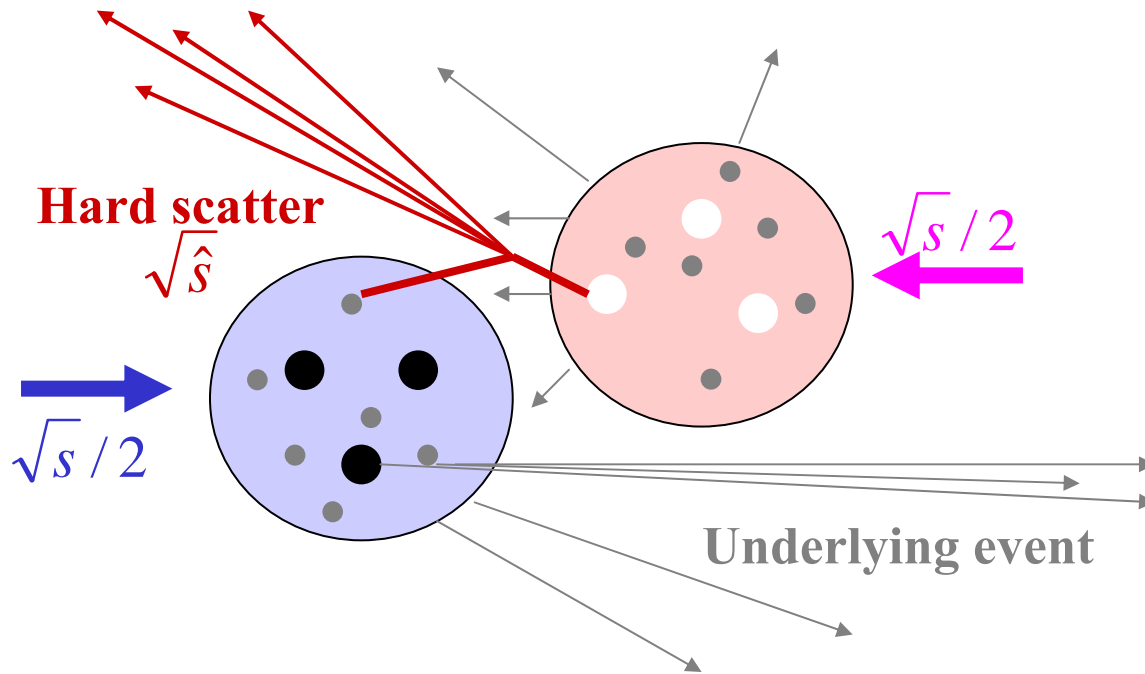


or something more exotic.....

- extract maximum information outgoing particles

Proton-Antiproton Collisions

- Protons are composite objects: valence & sea quarks; gluons
- Really *parton-parton* collisions



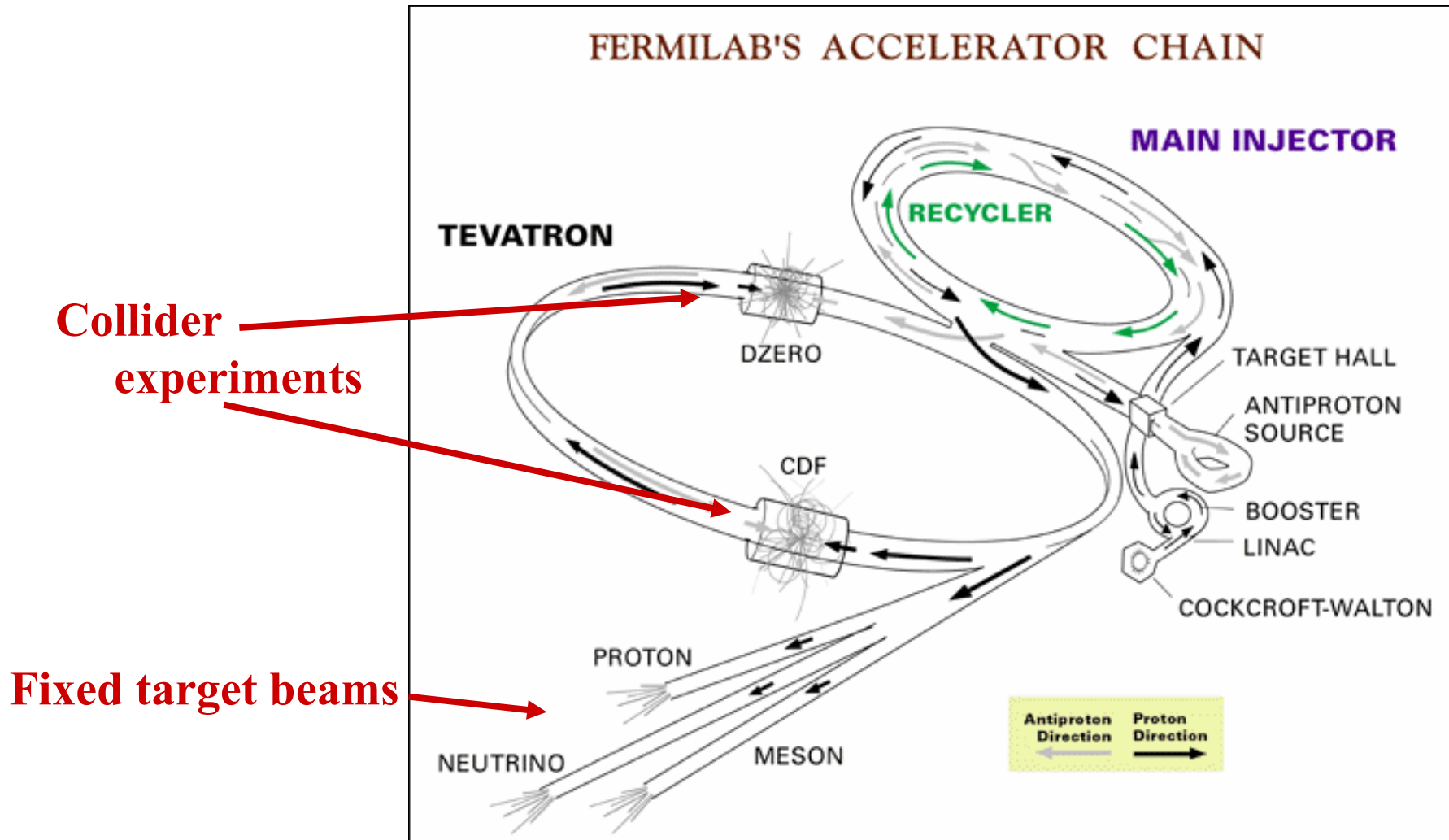
- **Underlying event:**
 - Most lost at low angles
 - Some in detector
- p_z unknown
- Extra detector hits
- Initial partons unknown
- Huge total cross section (*10s of mb*)

Fermilab

- 30 miles west of Chicago
- 10 square miles
- Started operating in 1972
- **Major discoveries**
 - 1977 Bottom quark
 - 1995 Top quark
 - 1999 Direct CP Violation
 - 2000 Tau Neutrino



Fermilab Accelerators



The Tevatron Run II

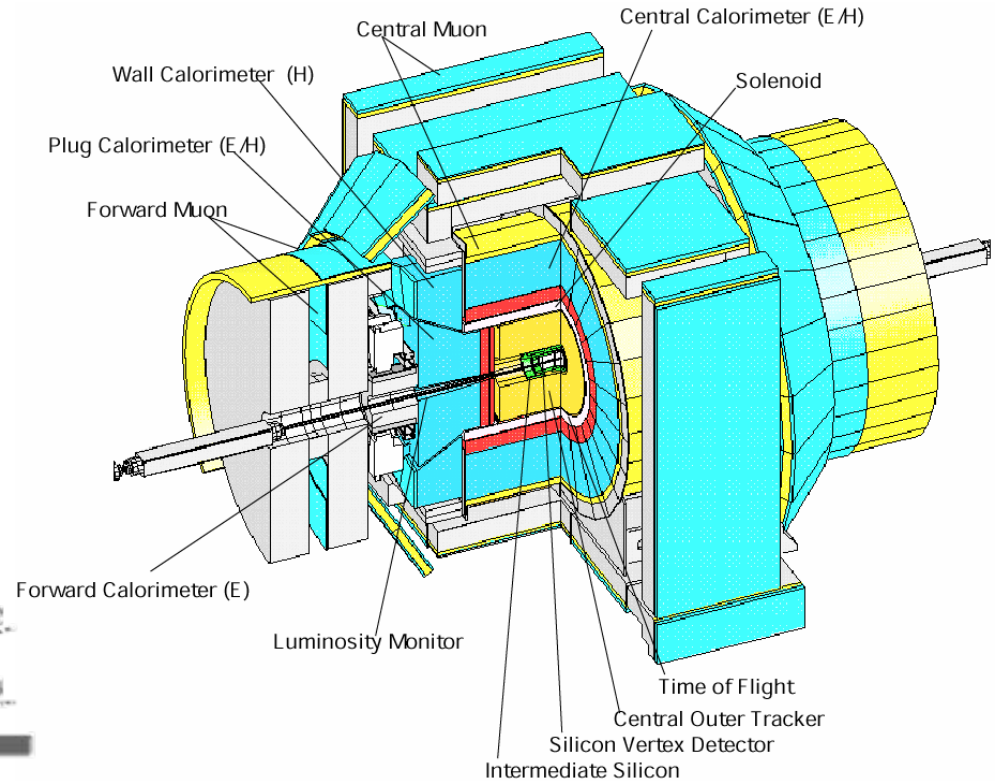
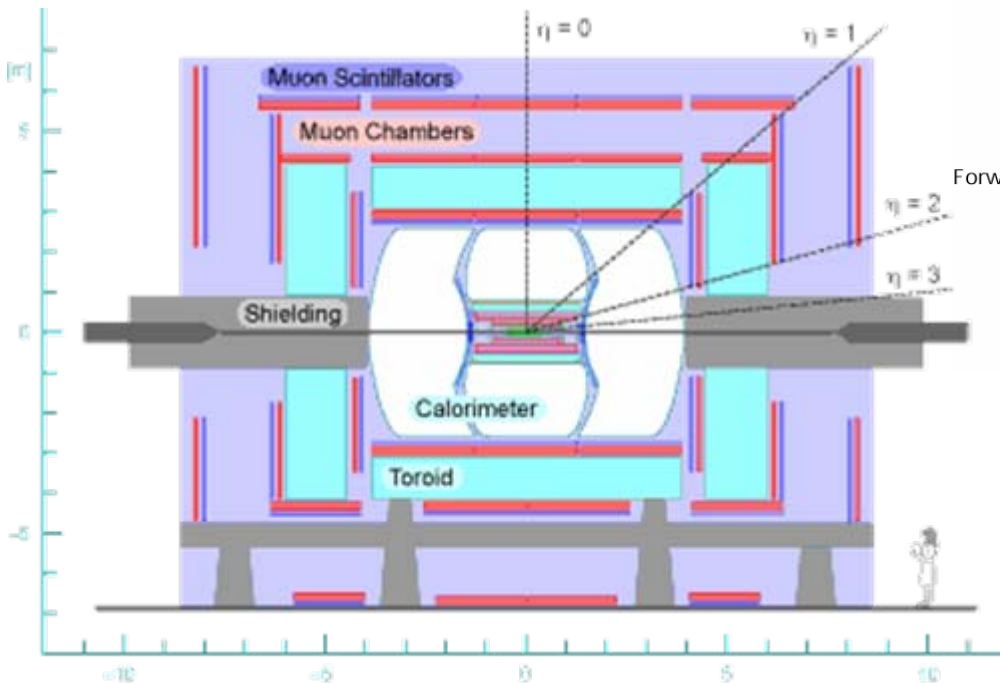
- Upgraded for 2001
- $\sqrt{s} = 1.96 \text{ TeV}$
- proton-antiproton collisions



- 396 ns bunch crossing
- $L \sim 100 \times 10^{30} \text{ cm}^{-2}\text{s}^{-1}$
 - *3 interactions per crossing*
- 4-8 fb^{-1} by 2009

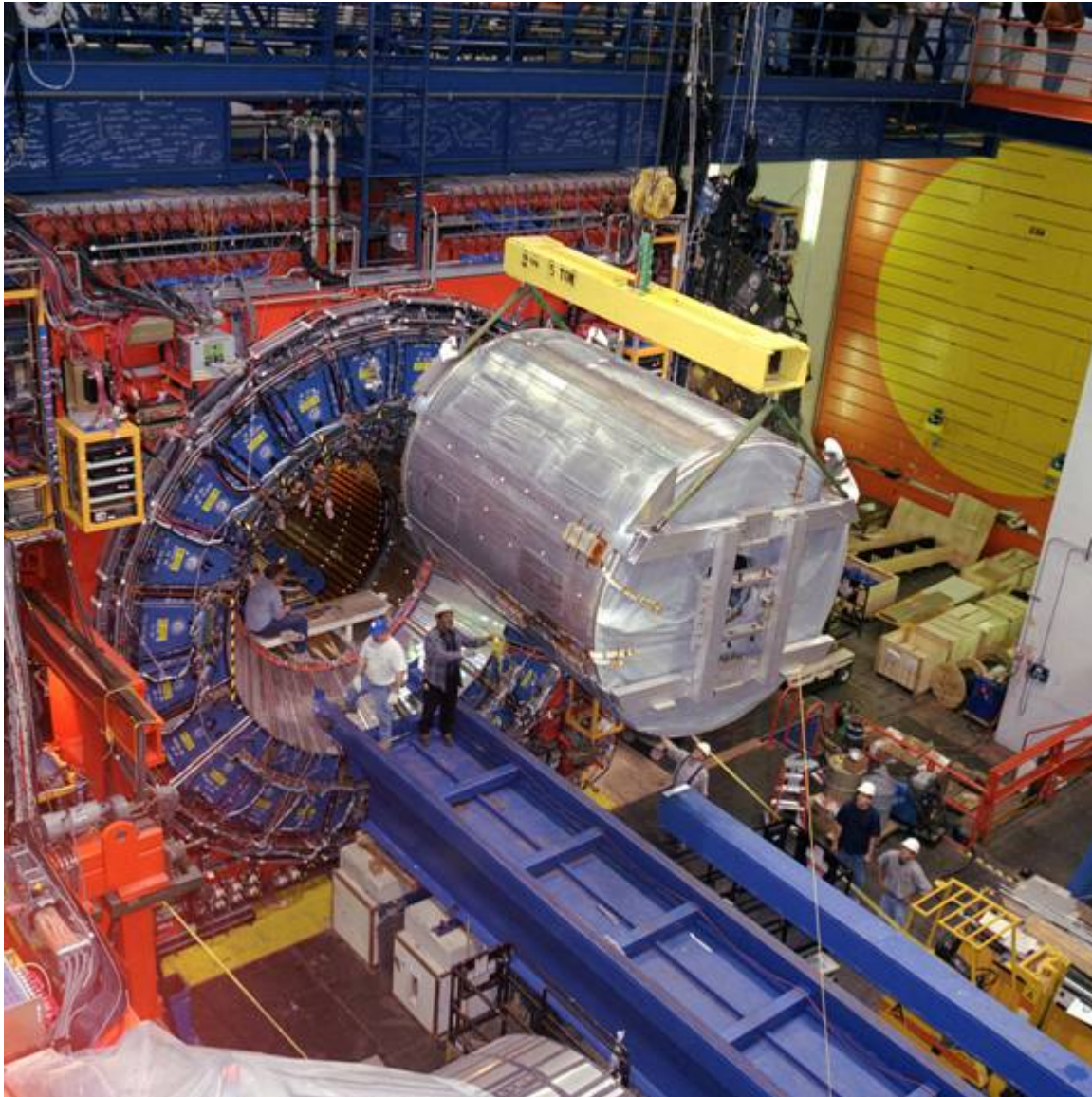
The Experiments

DØ - optimised for calorimetry



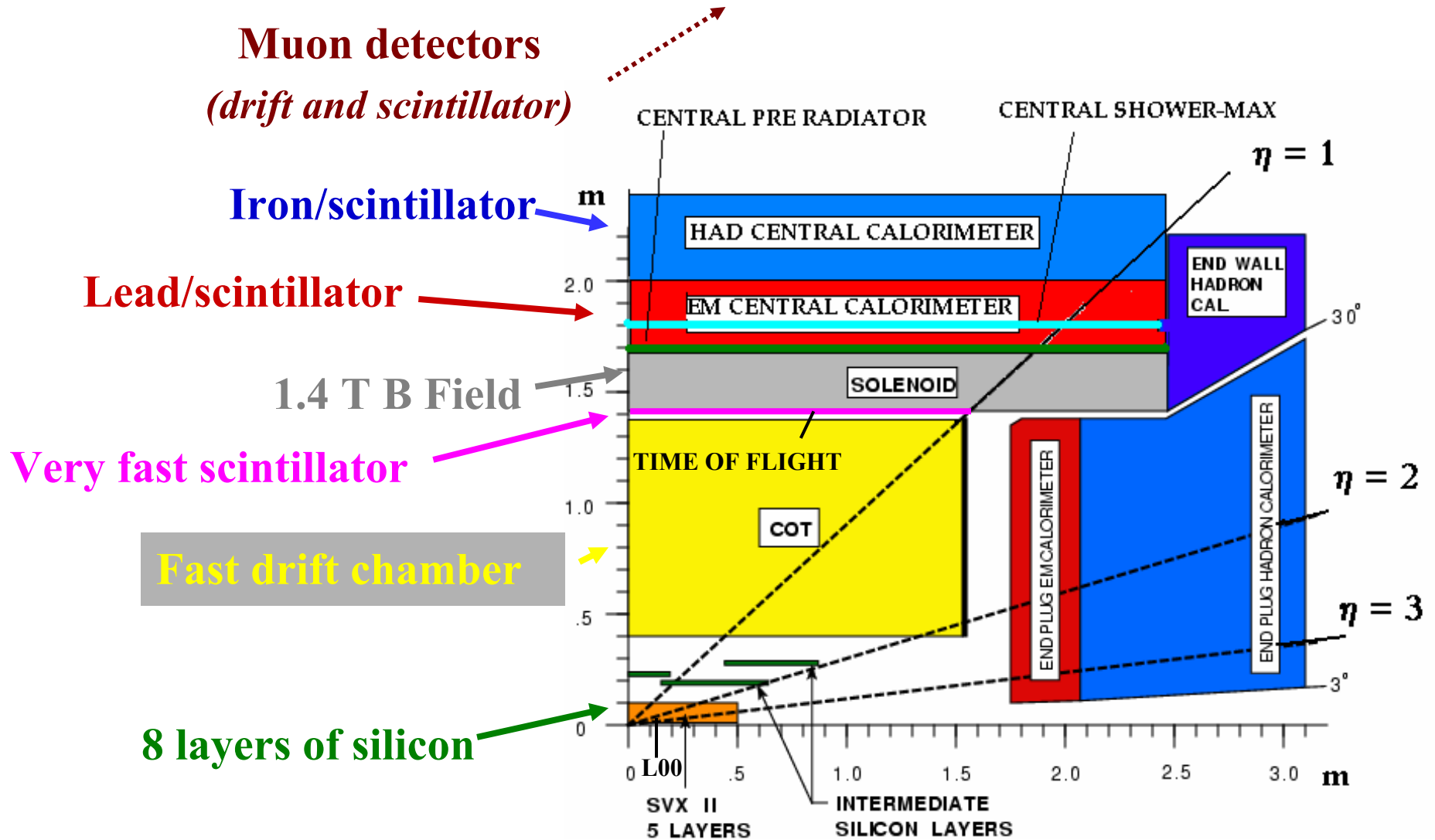
CDF - optimised for tracking

CDF



- **2001 Upgrade**
 - Higher luminosity
 - Newer technology

CDF Components



Trigger and DAQ

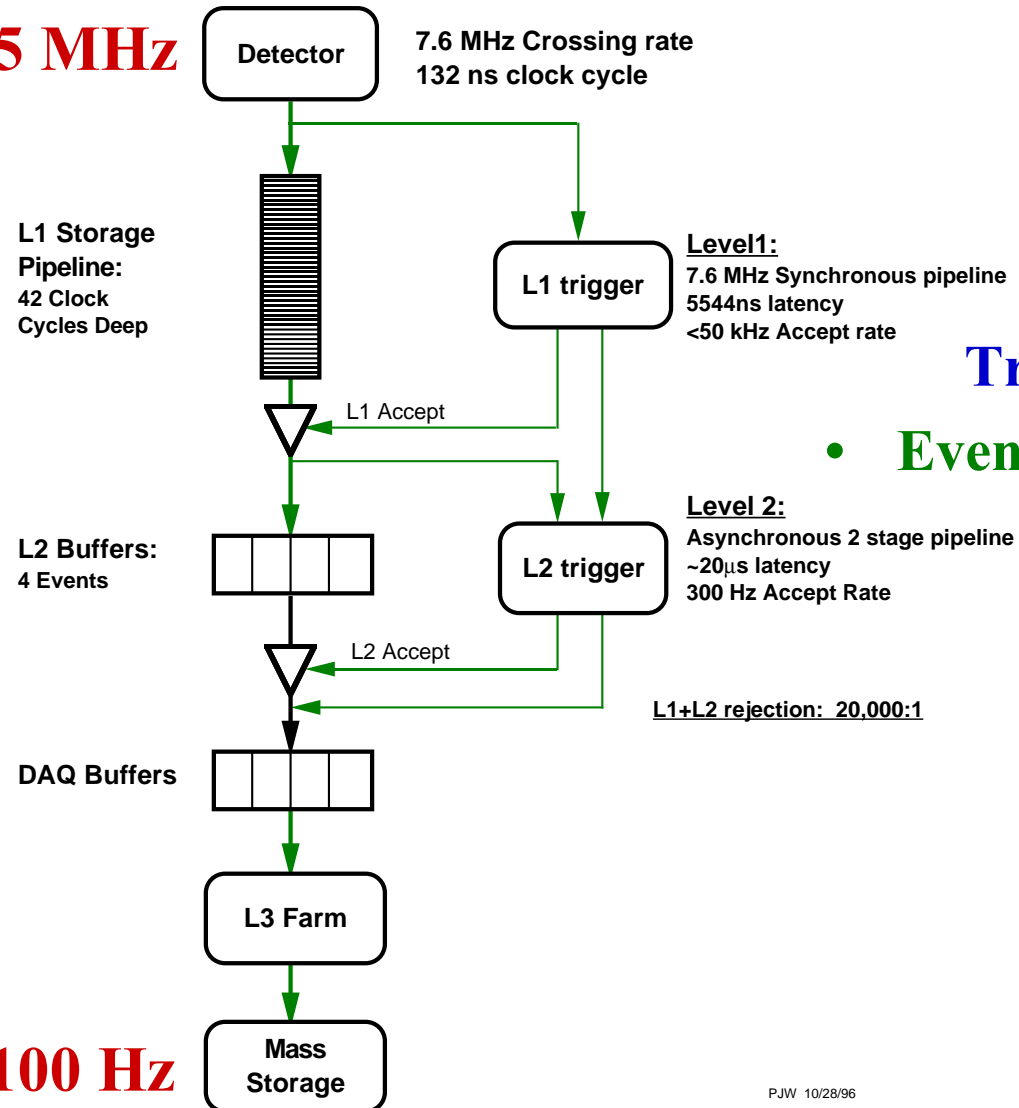
A million channels at 2.5 MHz

DAQ

- Data acquisition
- Processing
- Storage

Trigger

- Event selection

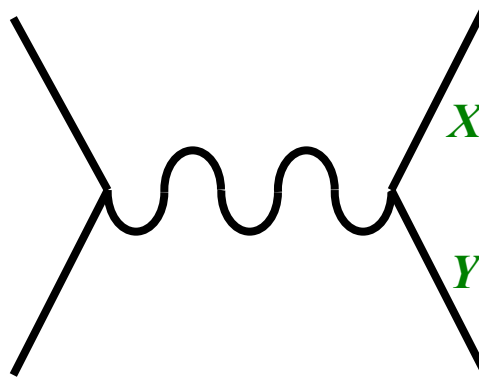


200 kB at 100 Hz

PJW 10/28/96

Feynman Level

- **Hard process with final state X and Y**



Directly observe X and Y if:

Long-lived (> picosecond)

Interact with detectors

Not confined

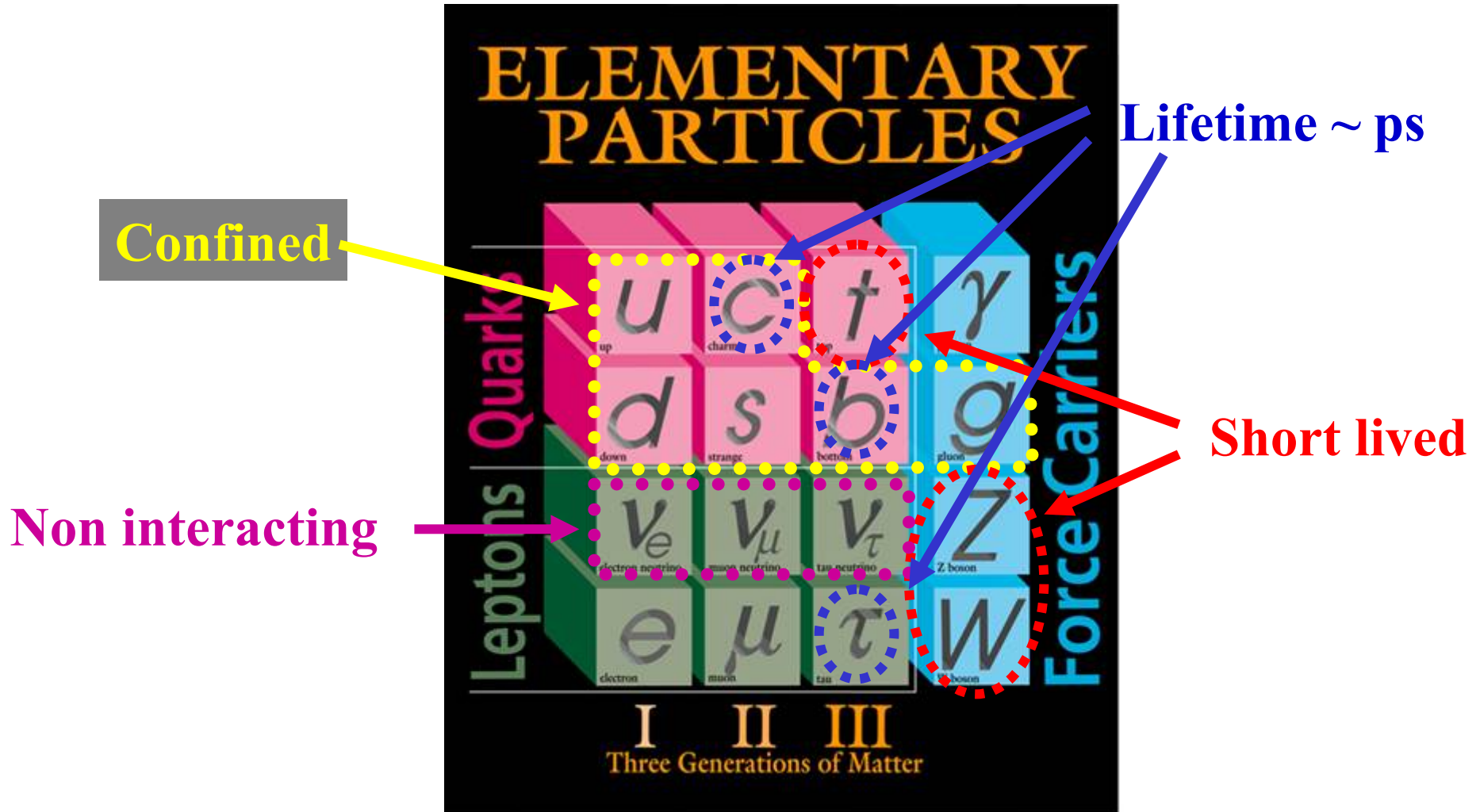
If not:

Reconstruct from decay products

Reconstructed from “missing” p_T

Produce jets

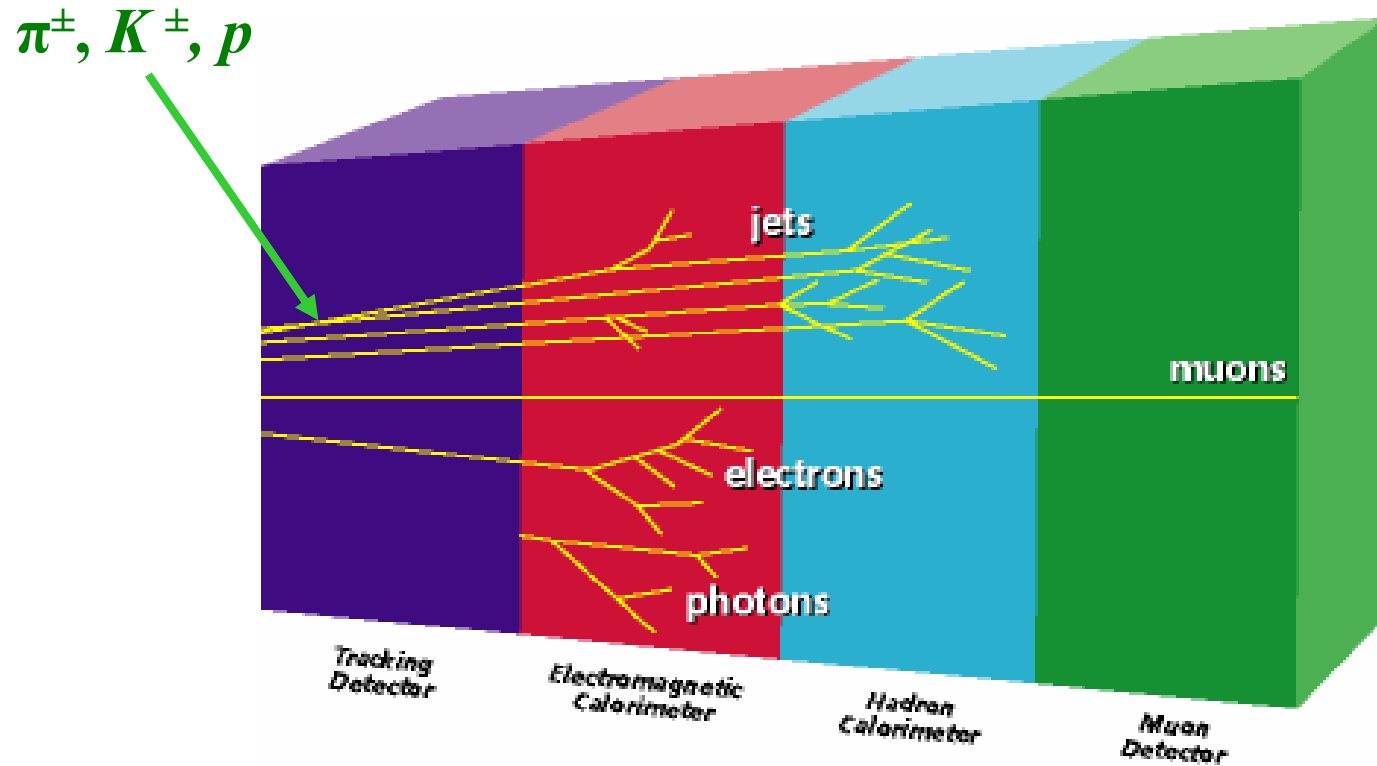
Standard Model Particles



Fermilab 95-759

Particles Signatures

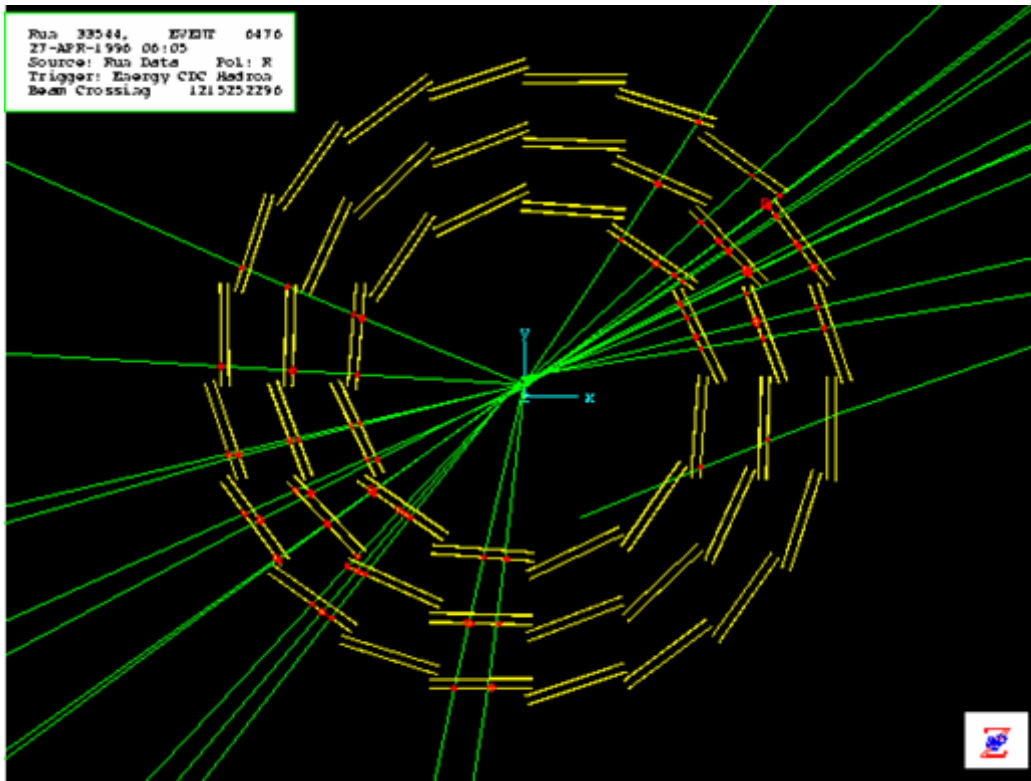
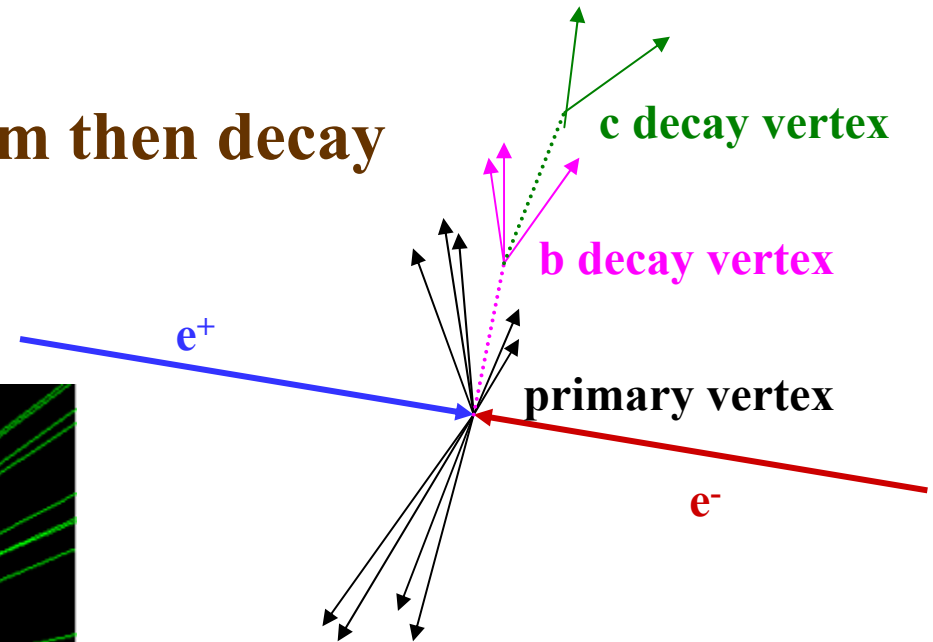
- Electron, photons, muons and jets



- Tau ID depends on decay mode

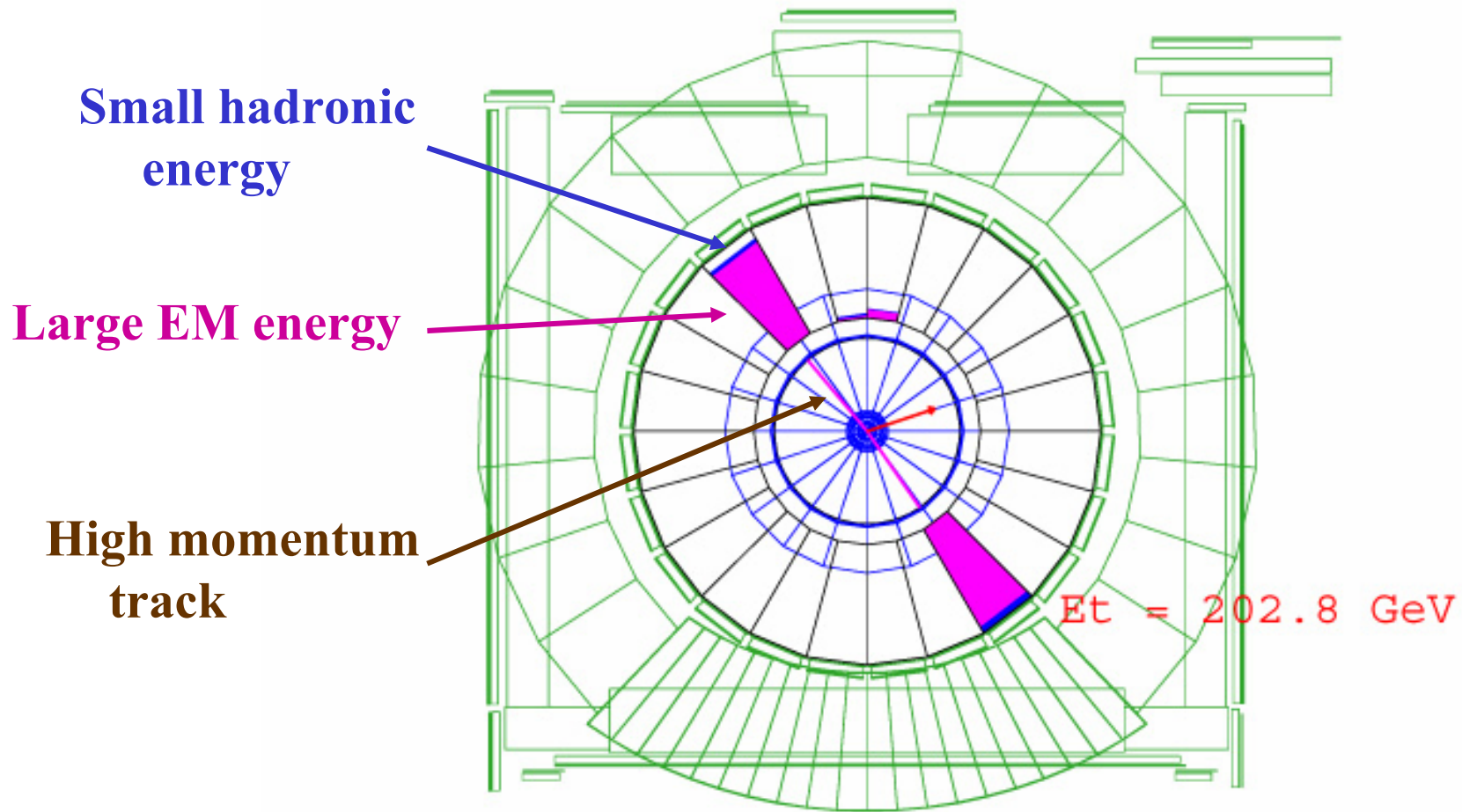
Vertex Tagging

- b, c, τ will travel a few mm then decay



- Precise tracking shows “displaced vertices”
- Easiest for b hadrons

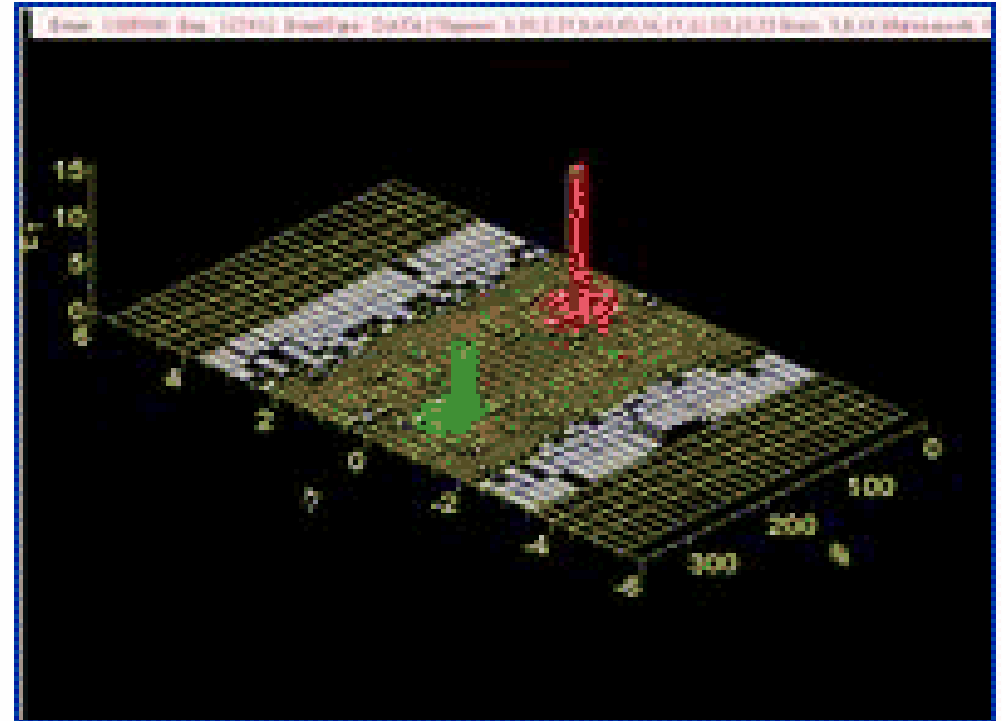
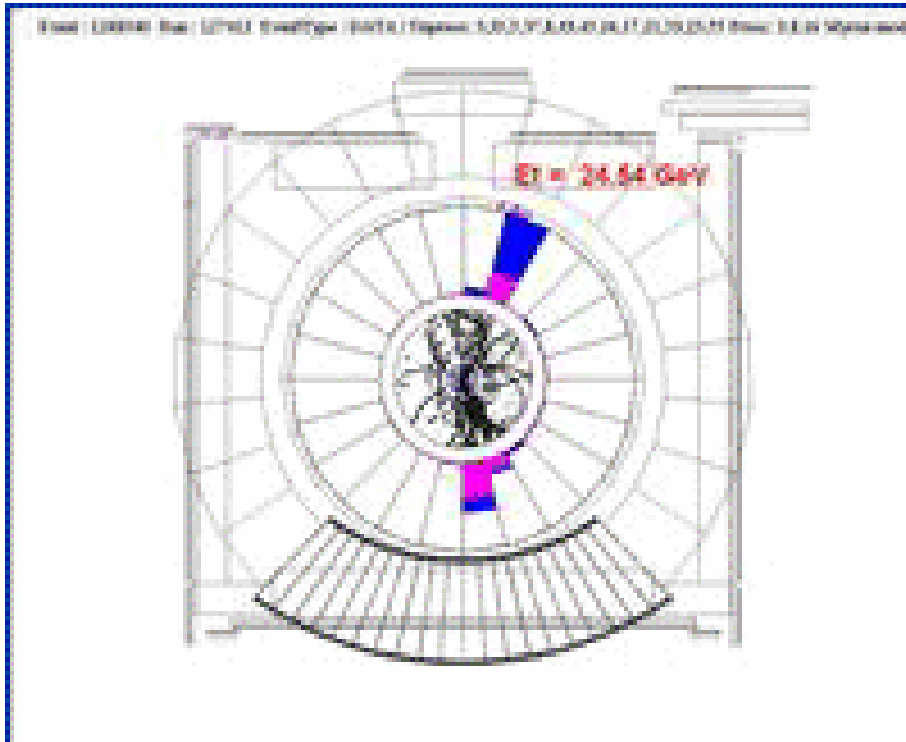
Two Electron Event



- Tracks and energies below a threshold not shown!

Dijet + MET

- Two jets
 - energy in EM and hadron
 - many tracks



Alternate view of calorimeter

- p_T not balanced
 - *undetected particles*

Finding Top Quarks

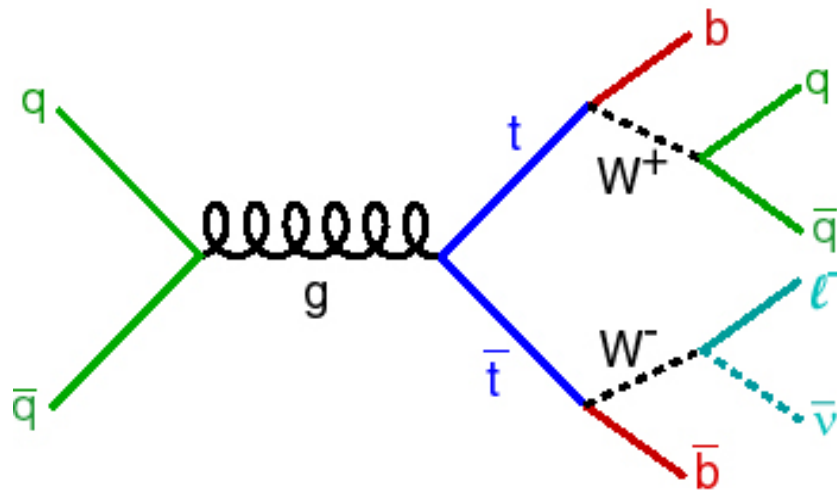
- Top quark discovered at **CDF** and **DØ** in 1995
- Need to identify top pair production

$$p\bar{p} \rightarrow t\bar{t}$$

$$\text{Br}(t \rightarrow bW^+) \approx 100\%$$

$$\text{Br}(W \rightarrow qq) \approx 70\%$$

$$\text{Br}(W \rightarrow lv) \approx 10\% \text{ per } l$$



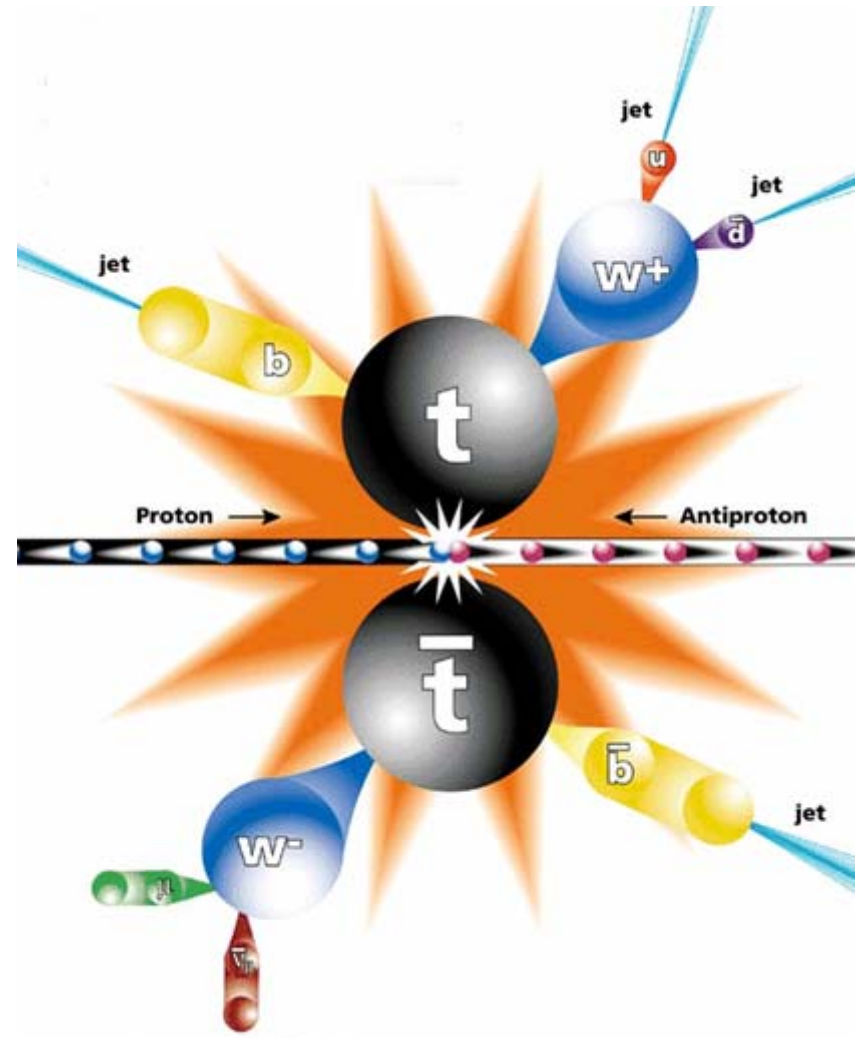
- **Semileptonic channel**

- l is electron or muon
- easy to identify
- only one neutrino

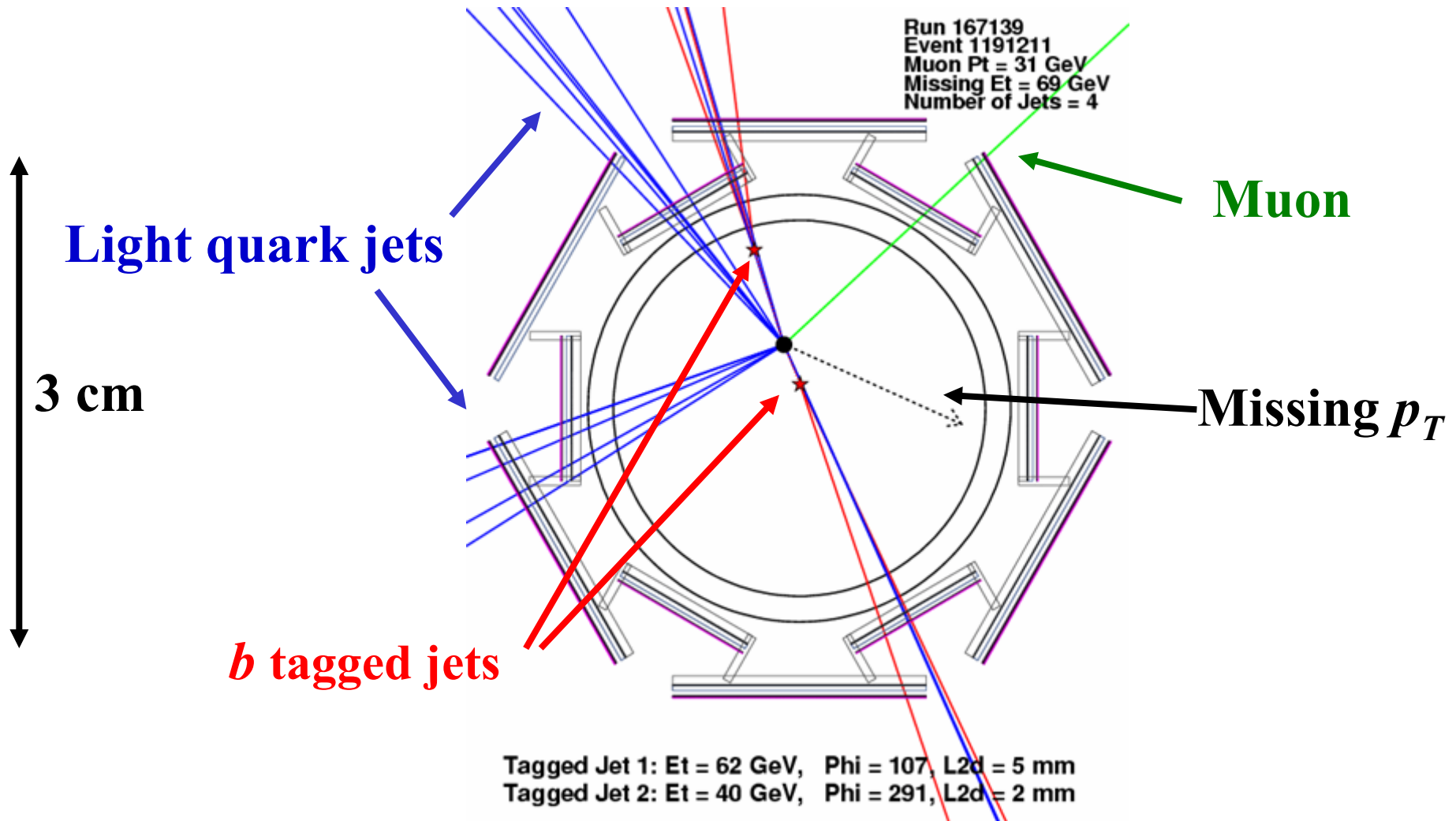
NB may be higher order effects

Top Pair Production

- **Electron or muon 30% of the time**
- **Signature:**
 - 2 light quark jets
 - 2 bottom jets
 - One electron or muon
 - Missing transverse momentum
- **Extras:**
 - Underlying event
 - Higher order processes
 - Multiple interactions



Top Event



Next Time...

Doing physics analysis

(<http://www-cdf.fnal.gov>)