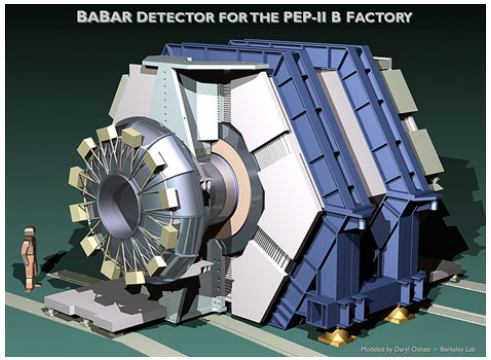
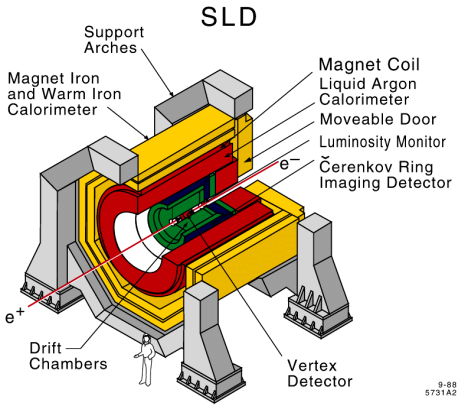
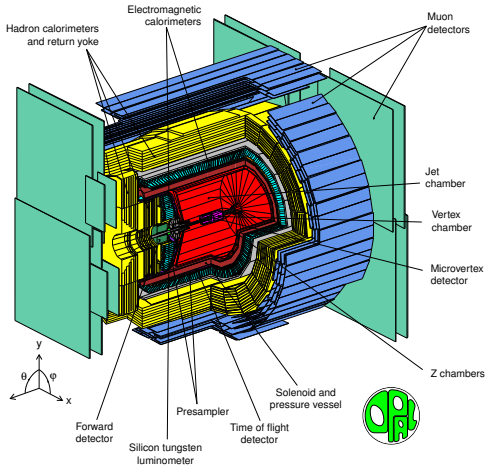
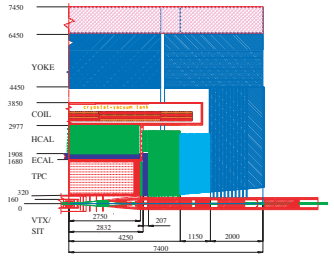
Detectors in Particle Physics





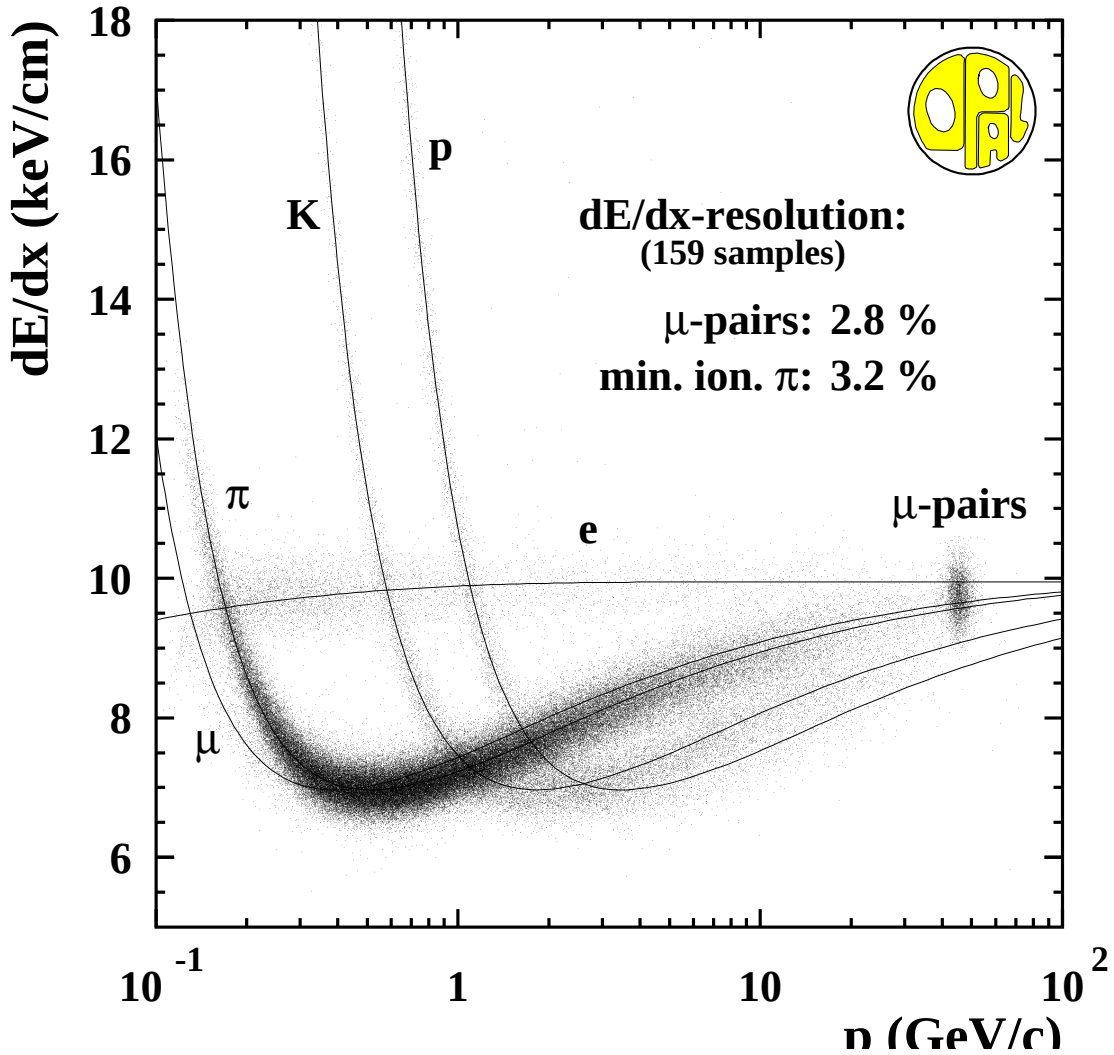
- Interaction of radiation with matter
- Tracking detectors
  - Wire chambers
  - Silicon Detectors
- Calorimeters
  - Electromagnetic calorimeters
  - Hadron calorimeters





Interaction of radiation with matter

- Any high energy particle passing through neutral matter will cause the matter to be ionized and/or "excited"
  - Primary mechanism by which particle detectors work
  - To first approximation independent of particle type
    MIP = minimum ionizing particle
  - Energy loss due to ionization is relatively small


dE/dx (keV/cm)
18
16
14
12
10
8
6
K
p
dE/dx-resolution:
(159 samples)
μ-pairs: 2.8 %
min. ion. π: 3.2 %
π
e
μ-pairs
μ
10 -1
1
10
10 2
p (GeV/c)

Electromagnetic interactions with matter

– If a charged particle undergoes a hard electromagnetic interaction with a nucleus – Brehmstrahlung results:

$$e + Z \rightarrow e + \gamma + Z$$

charcterized by radiation length
1rl = 0.35 cm of W
1rl = 1.76 cm of Fe
1rl = 304 m of air
Chernkov and transition radiation also possible

- High energy γ rays can "pair produce"

$$\gamma + Z \rightarrow e^{+}e^{-}Z$$

- Compton scattering is also possible

$$\gamma + e \rightarrow \gamma + e$$

Hadronic Interactions with matter

- Hadrons (such as $\pi^{\pm}$, K^0_{long}, n, p) can interact via the strong force with the nucleus, e.g.

$$\pi^+ + N \rightarrow N + \pi^+ + \pi^0$$

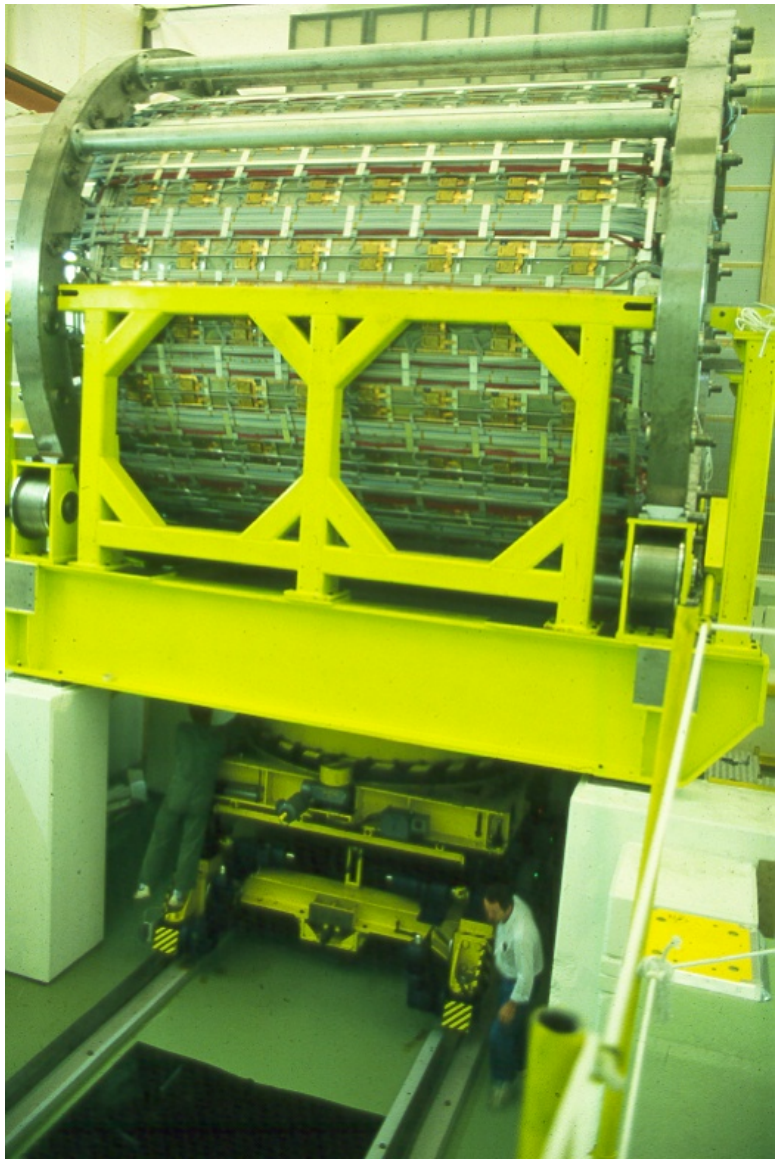
- Characterized by "interaction length"
  (mean free path between inelastic collisions)

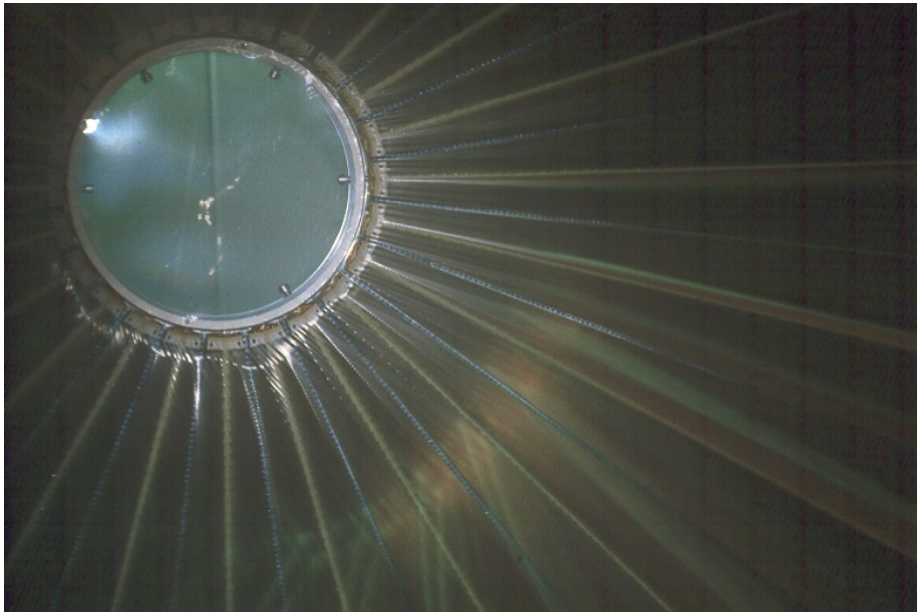
$$\lambda_I = 17 \text{ cm of Fe}$$
$$\lambda_I = 9.5\text{cm of W}$$

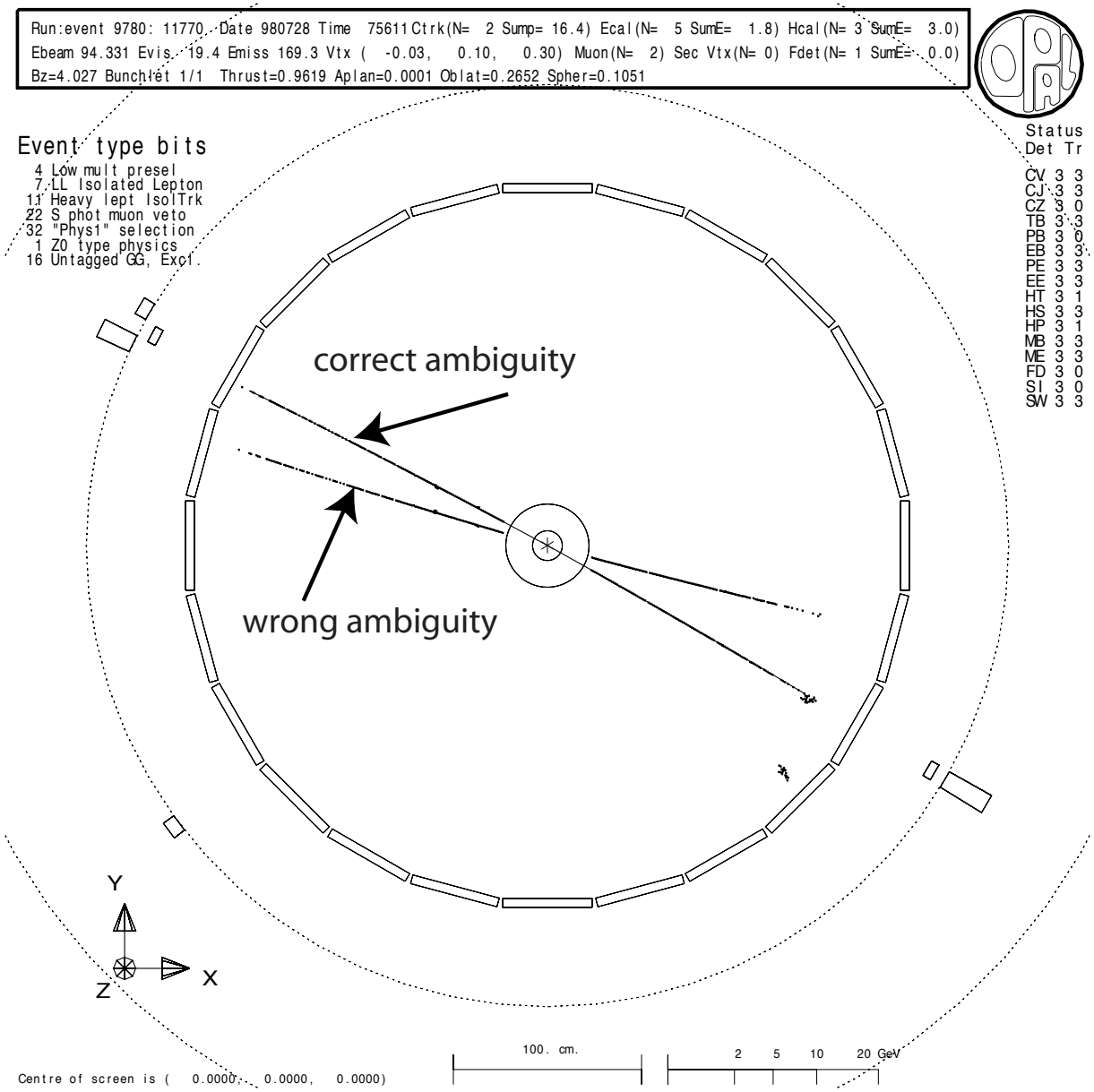
Tracking Chambers

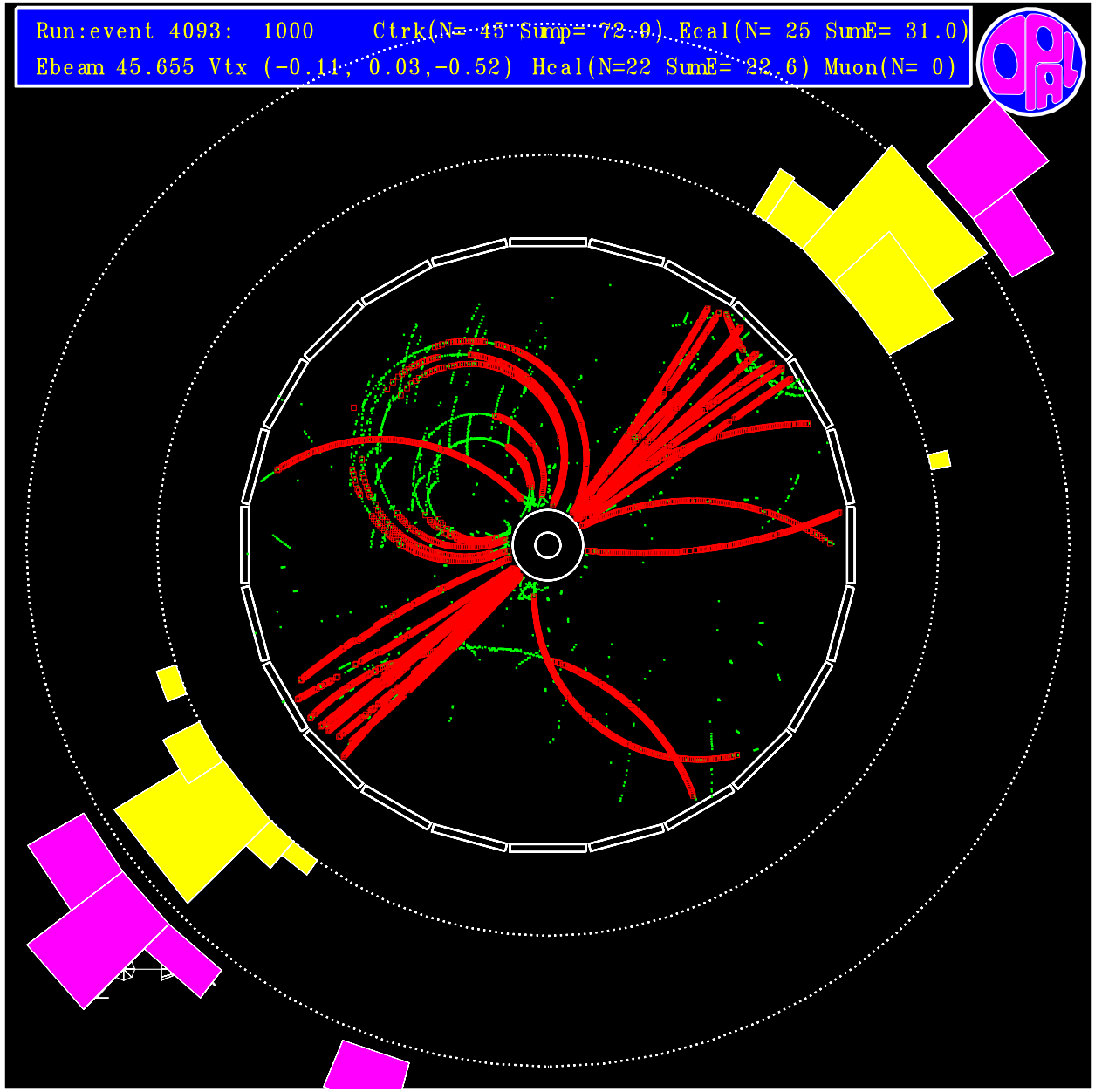
- Wire
  - Ionization (electrons) drifted in an electric field to wires
  - High field at wires cause an avalanche (gain 10^4 to 10^6)
  - Two-fold ambiguity for each "hit"
  - Spatial resolution $\sim$ 100 μm
- Silicon
  - Uses electron-hole pairs formed in
  - Spatial resolution $\sim$ 10 μm

OPAL Jet Chamber



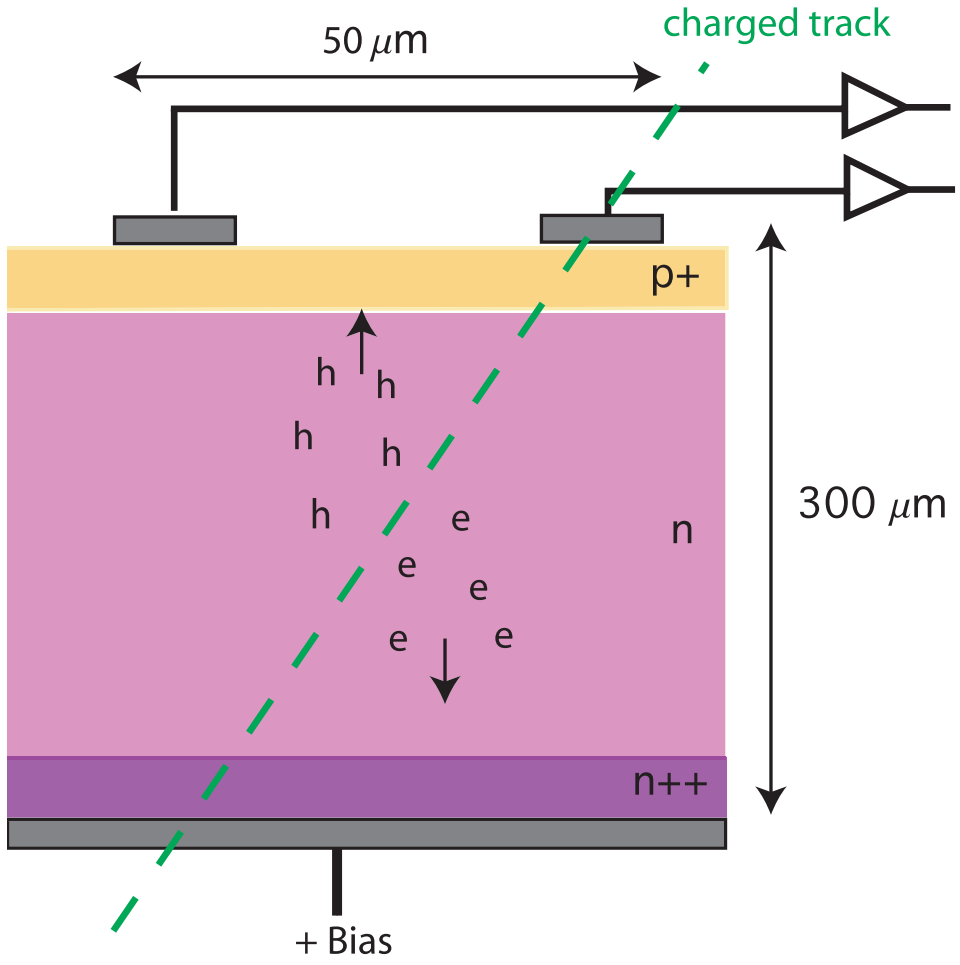


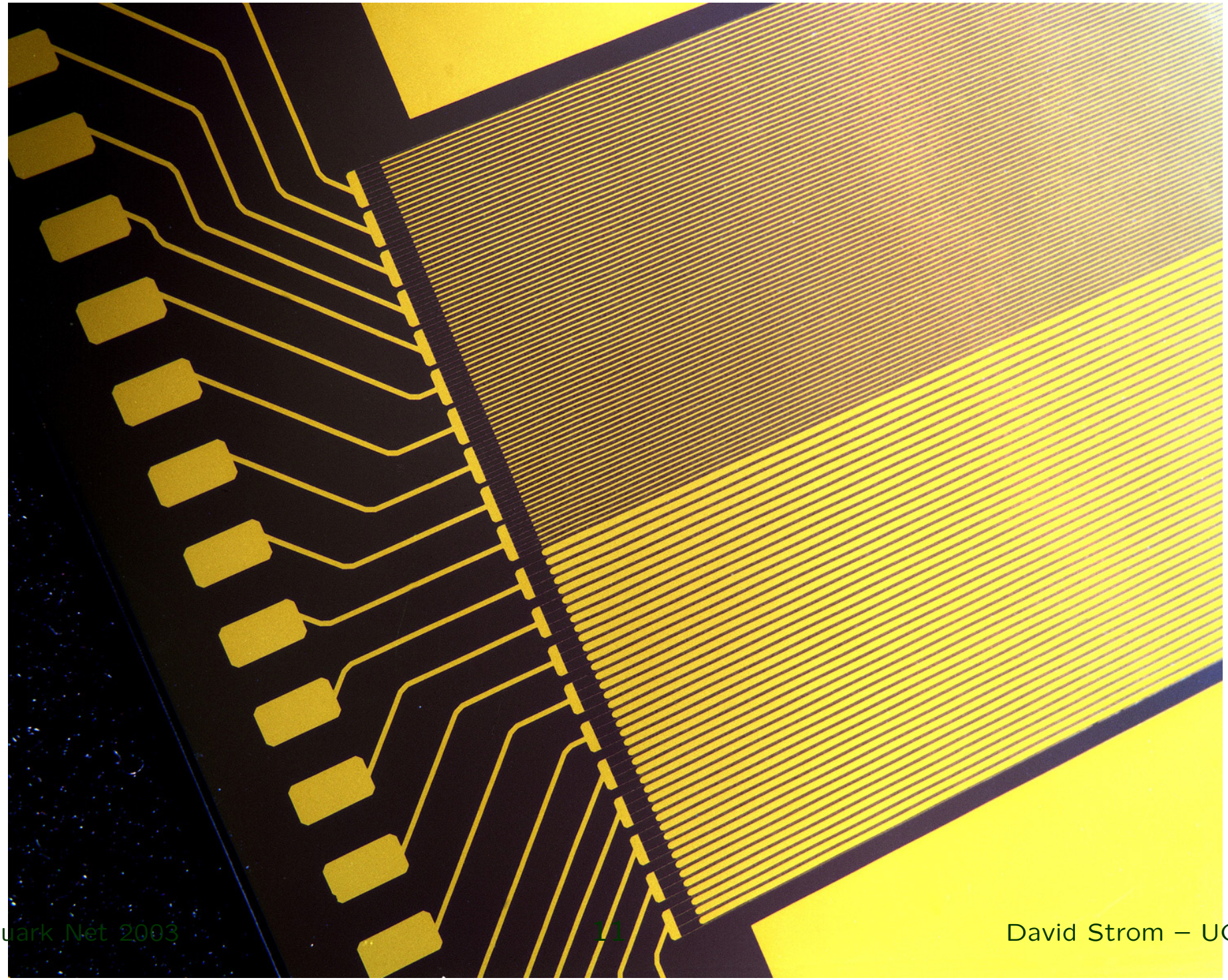

Run:event 9780: 11770 Date 980728 Time 75611 Ctrk(N= 2 Sump= 16.4) Ecal(N= 5 SumE= 1.8) Hcal(N= 3 SumE= 3.0)
Ebeam 94.331 Evis 19.4 Emiss 169.3 Vtx (-0.03, 0.10, 0.30) Muon(N= 2) Sec Vtx(N= 0) Fdet(N= 1 SumE= 0.0)
Bz=4.027 Bunch let 1/1 Thrust=0.9619 Aplan=0.0001 Oblat=0.2652 Spher=0.1051
Event type bits
4 Low mult presel
7 LL Isolated Lepton
11 Heavy lept IsolTrk
22 S phot muon veto
32 "Phys1" selection
1 Z0 type physics
16 Untagged GG, Exc1.
Status
Det Tr
CV 3 3
CJ 3 3
CZ 3 0
TB 3 3
PB 3 0
EB 3 3
PE 3 3
EE 3 3
HT 3 1
HS 3 3
HP 3 1
MB 3 3
ME 3 3
FD 3 0
SI 3 0
SW 3 3
correct ambiguity
wrong ambiguity
Y
X
Z
100. cm.
2 5 10 20 GeV
Centre of screen is (0.0000, 0.0000, 0.0000)

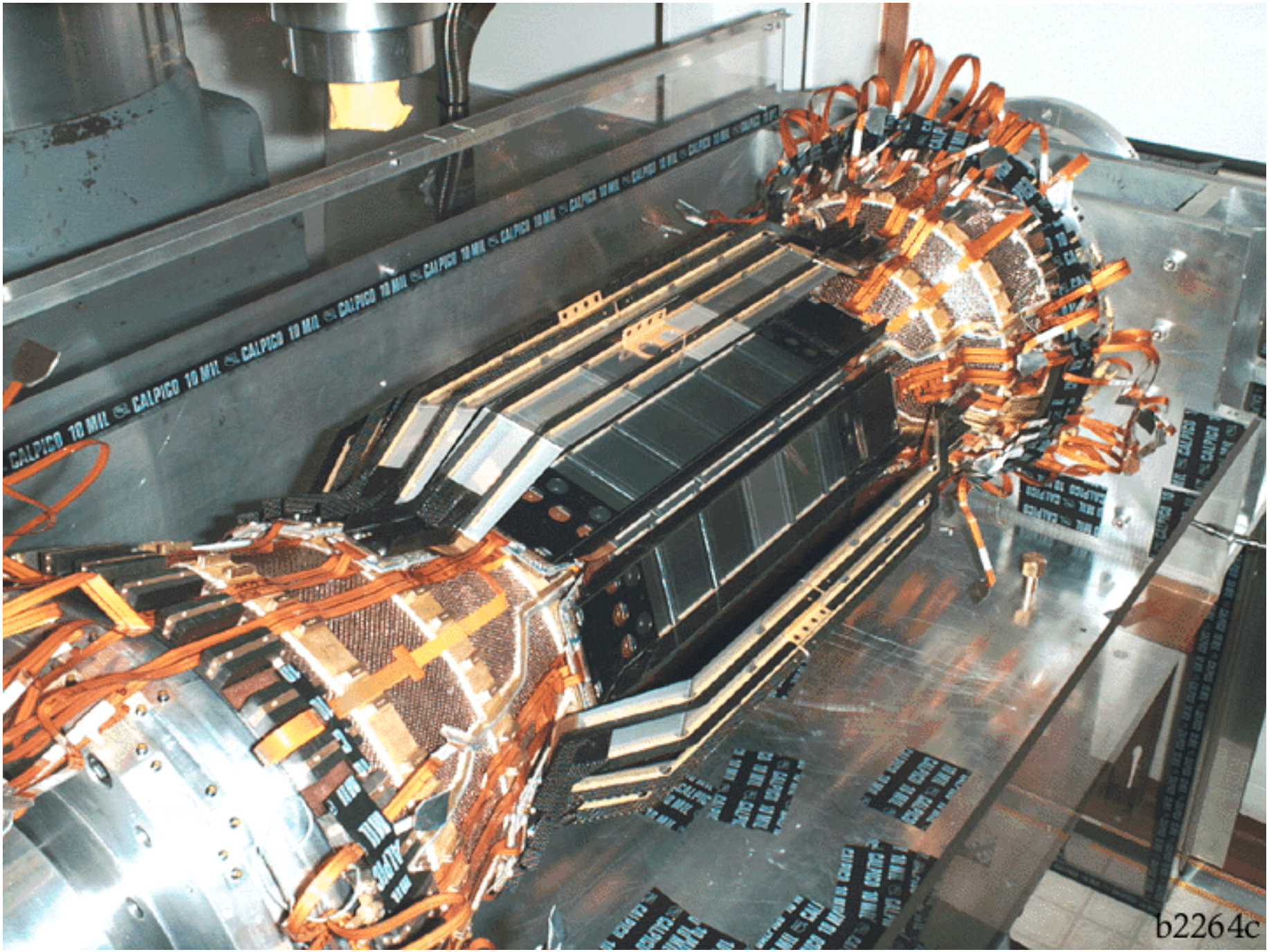

Run:event 4093: 1000 Ctrk(N= 43 Sump= 72.9) Ecal(N= 25 SumE= 31.0)
Ebeam 45.655 Vtx (-0.11, 0.03,-0.52) Hcal(N=22 SumE= 22.6) Muon(N= 0)
OPAL

Silicon Detectors

- $\sim$ 24,000 electron hole pairs are produced by a MIP
- Electrons drift to anode and are detected by low-noise amplifier
- Holes are collected at cathod
- Complicated geometry is needed for double-sided readout





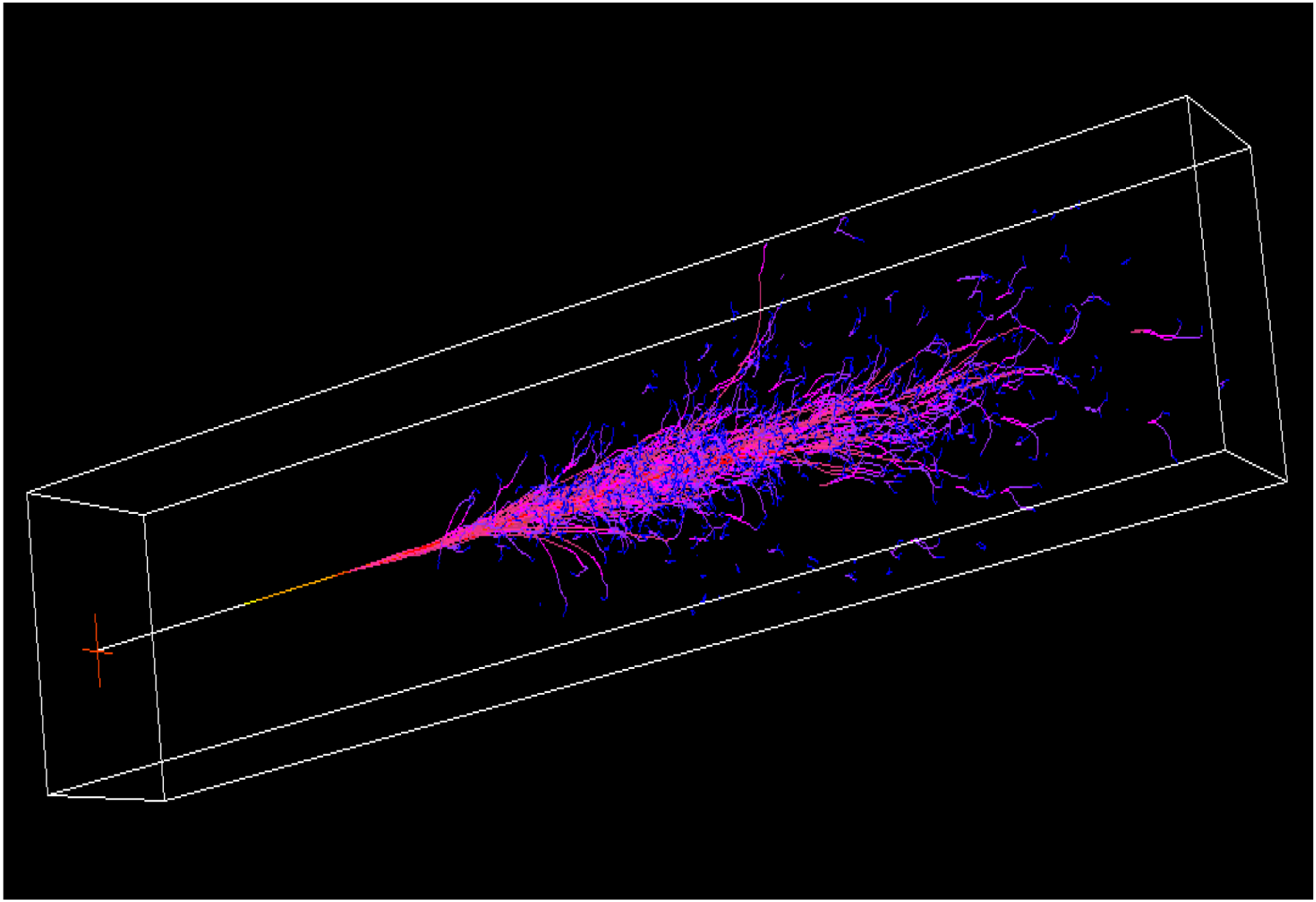

CALPICO 10 MIL
b2264c

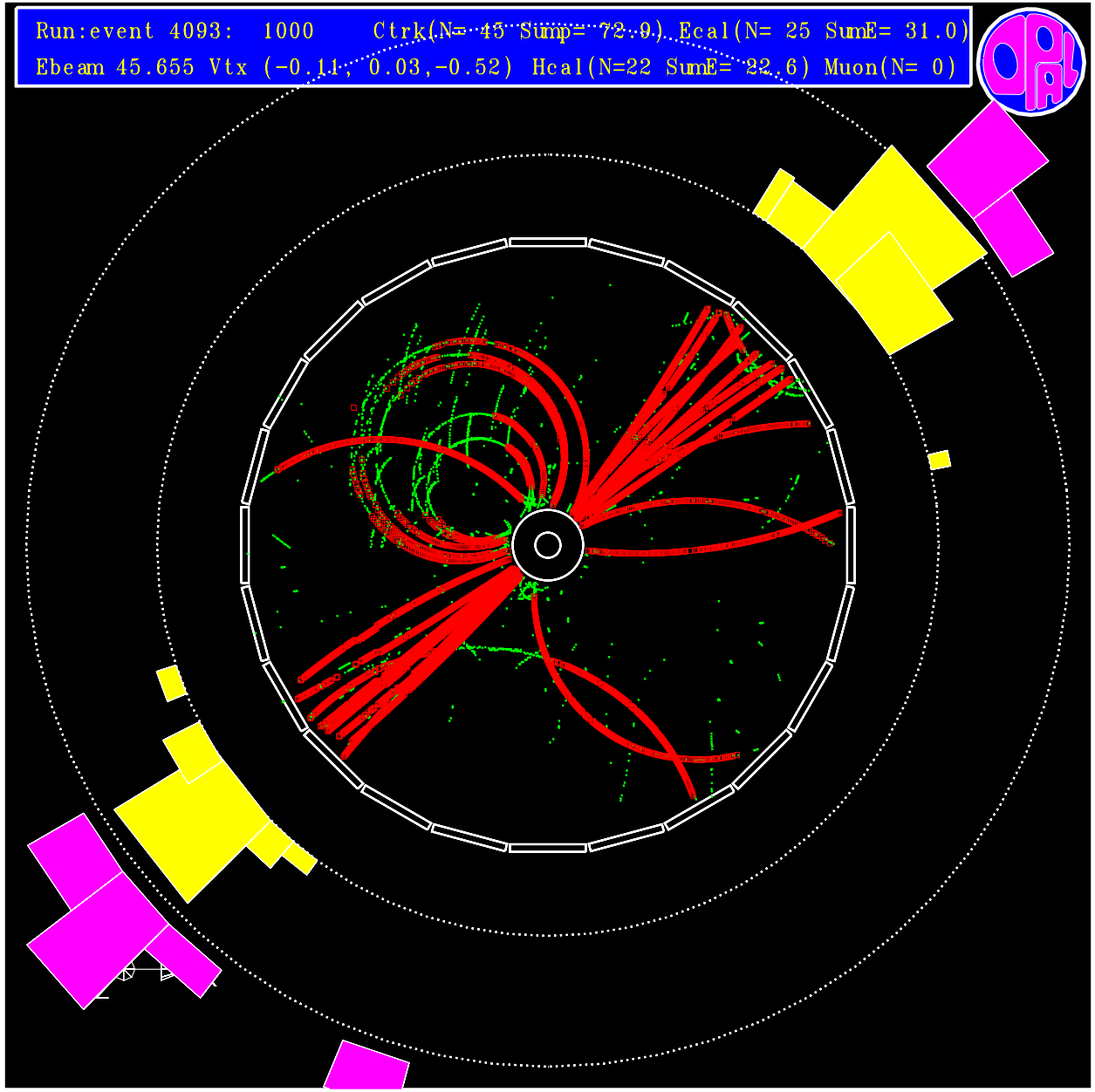
Electromagnetic and hadronic calorimeters

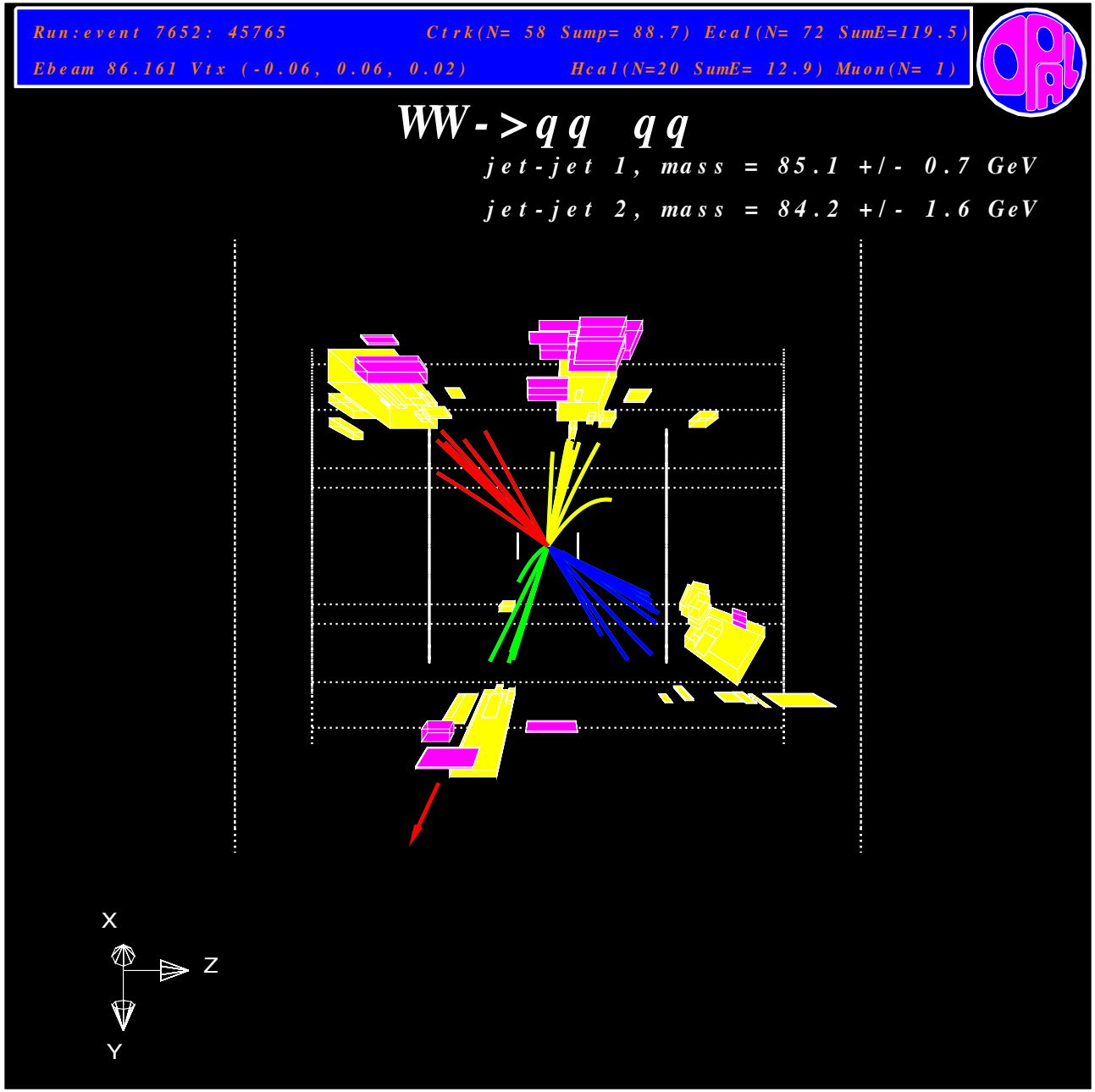
- Calorimeters are designed to completely stop particles and measure all of their energy
  This causes electromagnetic and hadronic showers

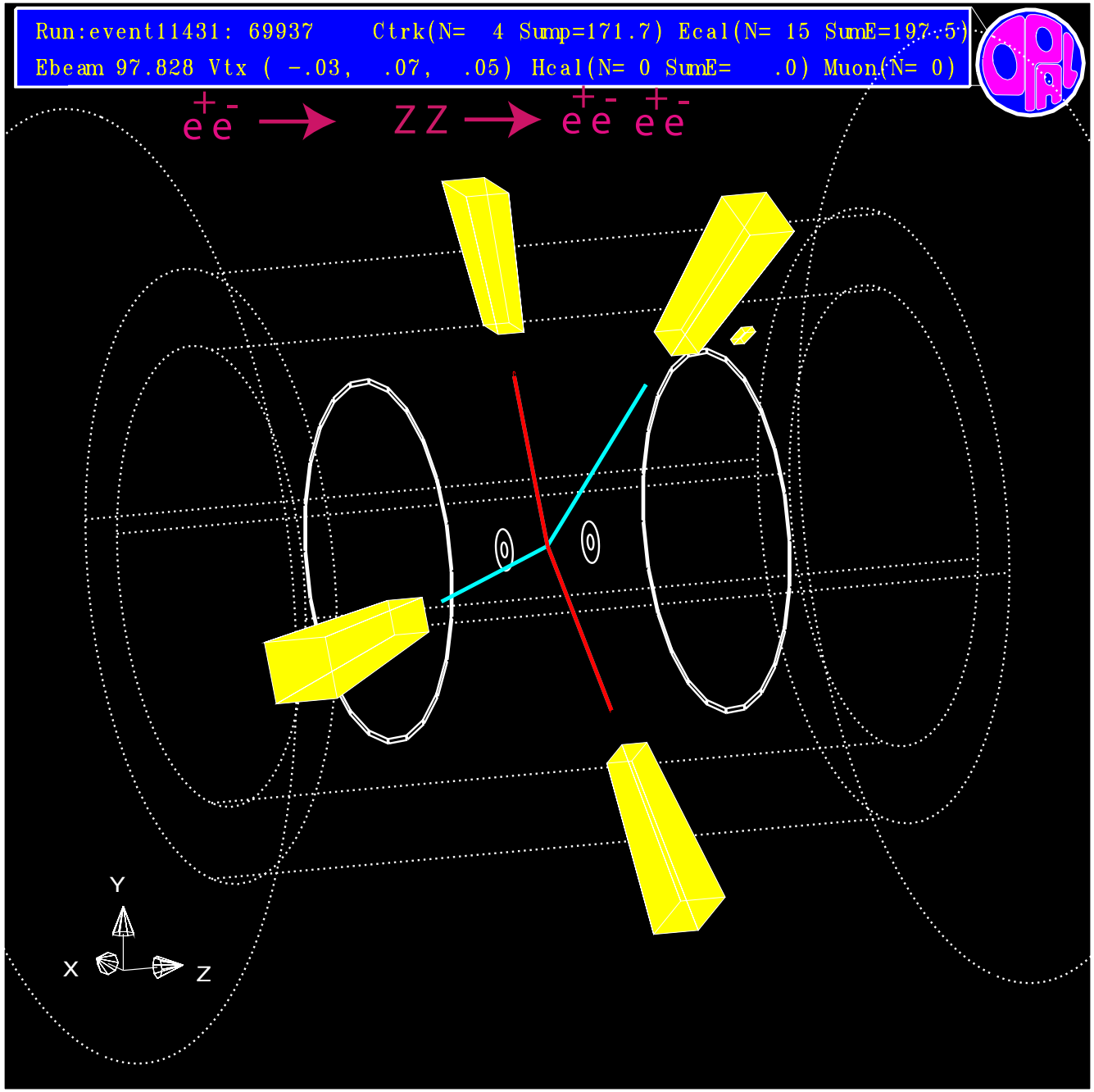
- Detector of finite size $\Rightarrow$ use dense materials

- There are two main types:
  - Sampling
  - Crystal




Run:event 4093: 1000 Ctrk(N= 43 Sump= 72.9) Ecal(N= 25 SumE= 31.0)
Ebeam 45.655 Vtx (-0.11, 0.03,-0.52) Hcal(N=22 SumE= 22.6) Muon(N= 0)
OPAL


Run:event 7652: 45765
Ctrk(N= 58 Sump= 88.7) Ecal(N= 72 SumE=119.5)
Ebeam 86.161 Vtx (-0.06, 0.06, 0.02)
Hcal(N=20 SumE= 12.9) Muon(N= 1)
WW->qq qq
jet-jet 1, mass = 85.1 +/- 0.7 GeV
jet-jet 2, mass = 84.2 +/- 1.6 GeV
X
Z
Y


Run:event11431: 69937 Ctrk(N= 4 Sump=171.7) Ecal(N= 15 SumE=197.5)
Ebeam 97.828 Vtx (-.03, .07, .05) Hcal(N= 0 SumE= .0) Muon(N= 0)
e+e- → ZZ → e+e- e+e-
Y
X
Z

Try your hand at identifying events on your own at

`http://www.hep.man.ac.uk/u/wyatt/events/home.html`

which was produced by Terry Wyatt at Manchester University

(May not work well with internet explorer)