PHYS 3446 – Lecture #20

Wednesday, Apr. 20, 2005
*Dr. **Jae** Yu*

- The Standard Model
  - Gauge Bosons
  - Gauge boson decay
  - The Higgs mechanism and the Higgs particle
  - Gauge boson search strategy

Announcements

- Due for your project write up is 4pm next Monday, April 25
  - Your lab finals will be on this Friday as planned
  - Report must have the assigned UTA-HEP note number on the top right corner of your title page
    - Note number format is: UTA-HEP/D0-####.
- We need to make up the order of presentations
  - $Z \rightarrow \mu\mu$: 6. John (0016), 2. Jacob (0007) and 4. Sabine (0009)
  - $Z \rightarrow ee$: 3. Casey (0008), 5. David (0010) and 1. Mathew (0006)
  - $W \rightarrow e\nu$: 5.James (0015), 1. Carlos (0011) and 3. Elisha (0013)
  - $W \rightarrow \mu\nu$: 2. Jeremy (0012) and 4. Jim (0014)

Presentation Evaluation Criteria

- Organization of the presentation
- Relevance of the slide material
- Inclusion of all the necessary plots, results and interpretations
- Presentation manner and skills
- Responses to questions
- Others

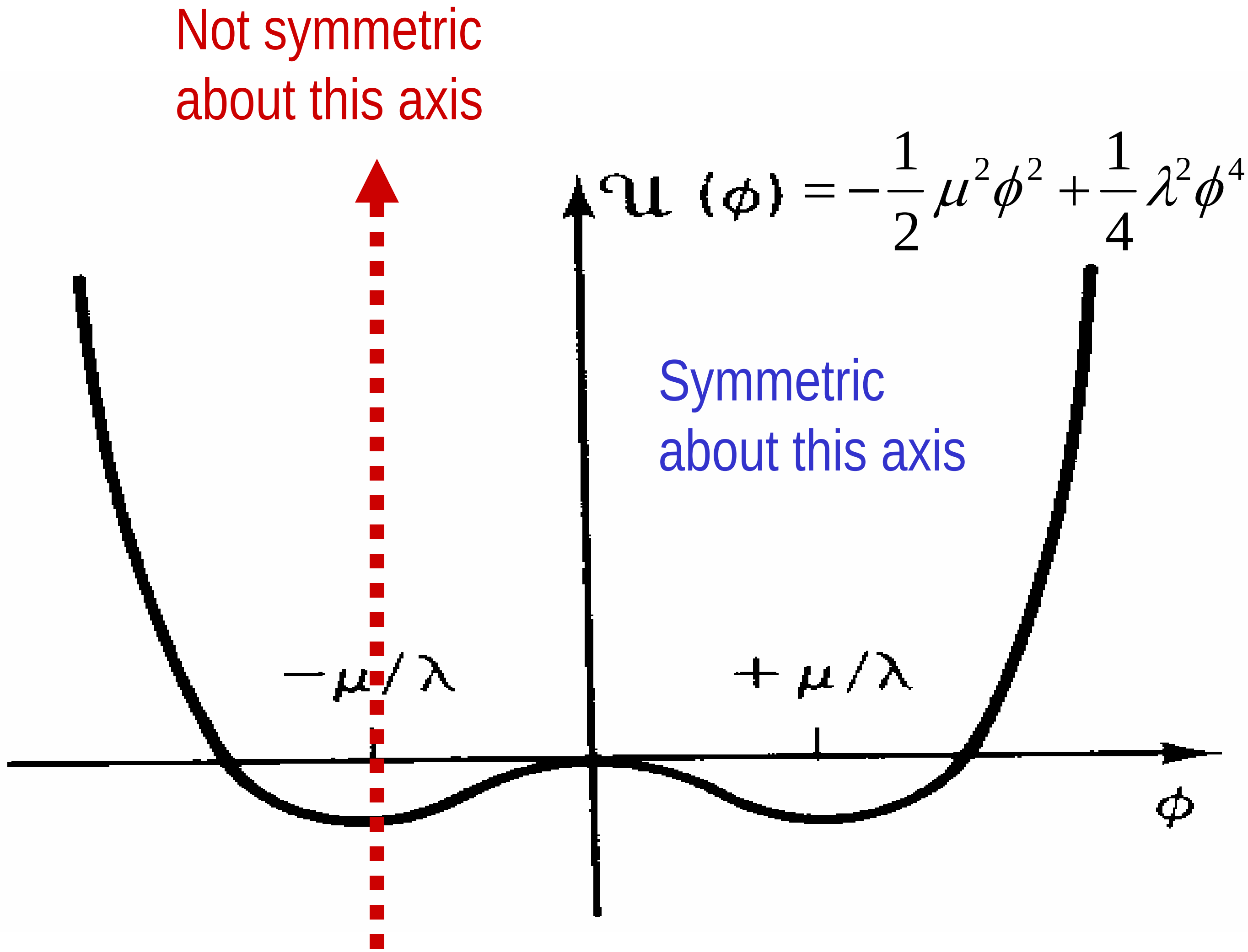
Gauge Bosons

- Through the local gauge symmetry, the Standard Model employs the following vector bosons as force mediators
  - Electro-weak: photon, Z^0, W^+ and W^- bosons
  - Strong force: 8 colored gluons
- The electro-weak vector bosons were found at the CERN proton-anti proton collider in 1983 independently by C. Rubbia & collaborators and P. Darriulat & collaborators

Z and W Boson Decays

- The weak vector bosons couples quarks and leptons
  - Thus they decay to a pair of leptons or a pair of quarks
- Since they are heavy, they decay instantly to the following channels and their branching ratios
  - Z bosons: M_Z=91GeV/c^2
  - $Z^0 \rightarrow q\bar{q} \quad (69.9\%)$
  - $Z^0 \rightarrow l^+l^-$ (3.37% for each charged lepton species)
  - $Z^0 \rightarrow \nu_l\bar{\nu}_l$ (20%)
  - W bosons: M_W=80GeV/c^2
  - $W^\pm \rightarrow q\bar{q}' \quad (68\%)$
  - $W^\pm \rightarrow l^\pm\nu_l$ (~10.6% for each charged lepton species)

EW Potential and Symmetry Breaking



Spontaneous Symmetry Breaking

While the collection of ground states does preserve the symmetry in $\mathcal{L}$, the Feynman formalism allows to work with only one of the ground states. ➔ Causes the symmetry to break.

This is called “spontaneous” symmetry breaking, because symmetry breaking is not externally caused.

The true symmetry of the system is hidden by an arbitrary choice of a particular ground state. This is the case of discrete symmetry w/ 2 ground states.

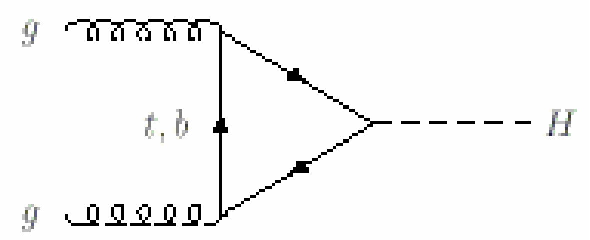
The Higgs Mechanism

The Higgs Mechanism

- Recovery from a spontaneously broken electroweak symmetry gives masses to gauge fields (W and Z) and produce a massive scalar boson
  - The gauge vector bosons become massive (W and Z)
  - The massive scalar boson produced through this spontaneous EW symmetry breaking is the Higgs particle
- In SM, the Higgs boson is a ramification of the mechanism that gives <u>masses to weak vector bosons, leptons and quarks</u>

Higgs Production Processes at Hadron Colliders

Gluon fusion: $gg \rightarrow H$

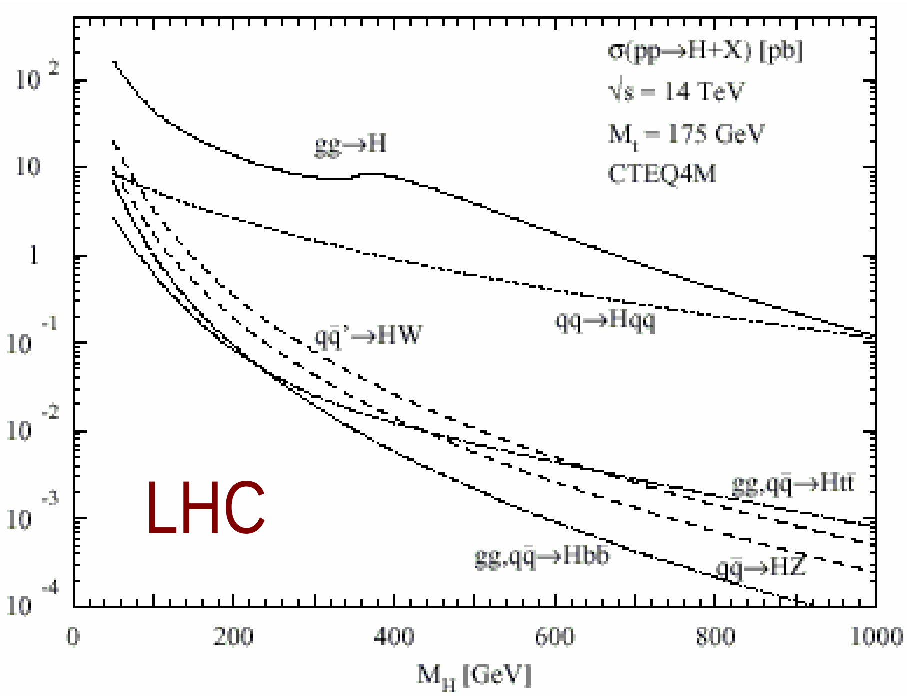


WW, ZZ Fusion: $W^+W^-, ZZ \rightarrow H$

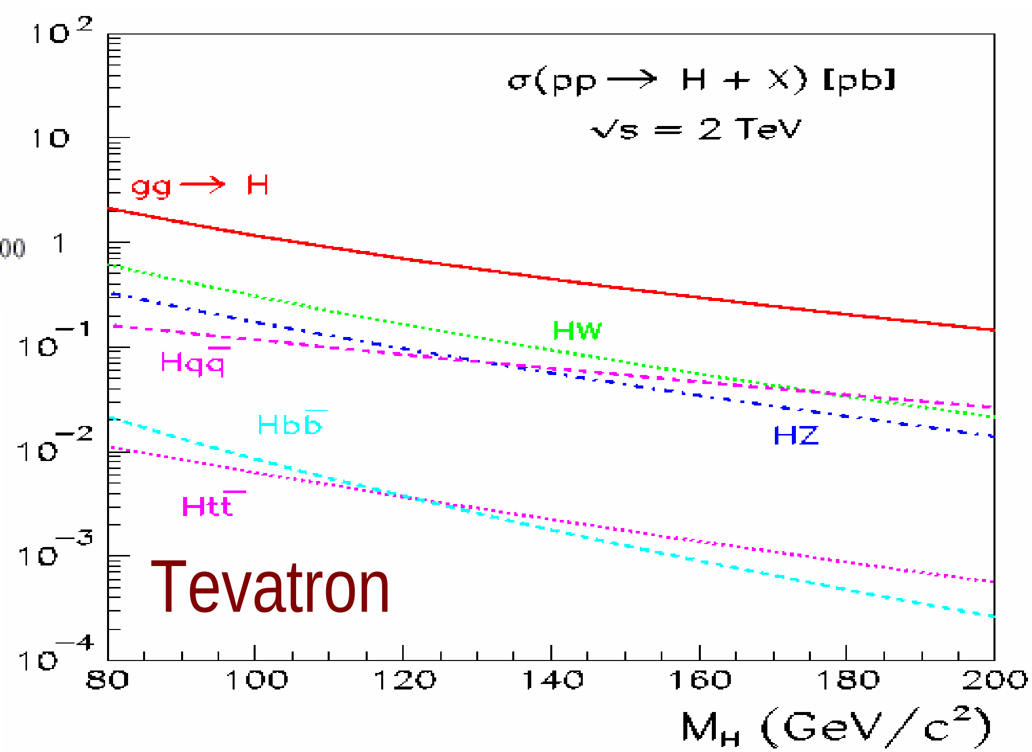
Higgs-strahlung off W,Z: $q\bar{q} \rightarrow W^*, Z^* \rightarrow W, Z + H$

Higgs Bremsstrahlung off top: $q\bar{q}, gg \rightarrow t\bar{t} + H$

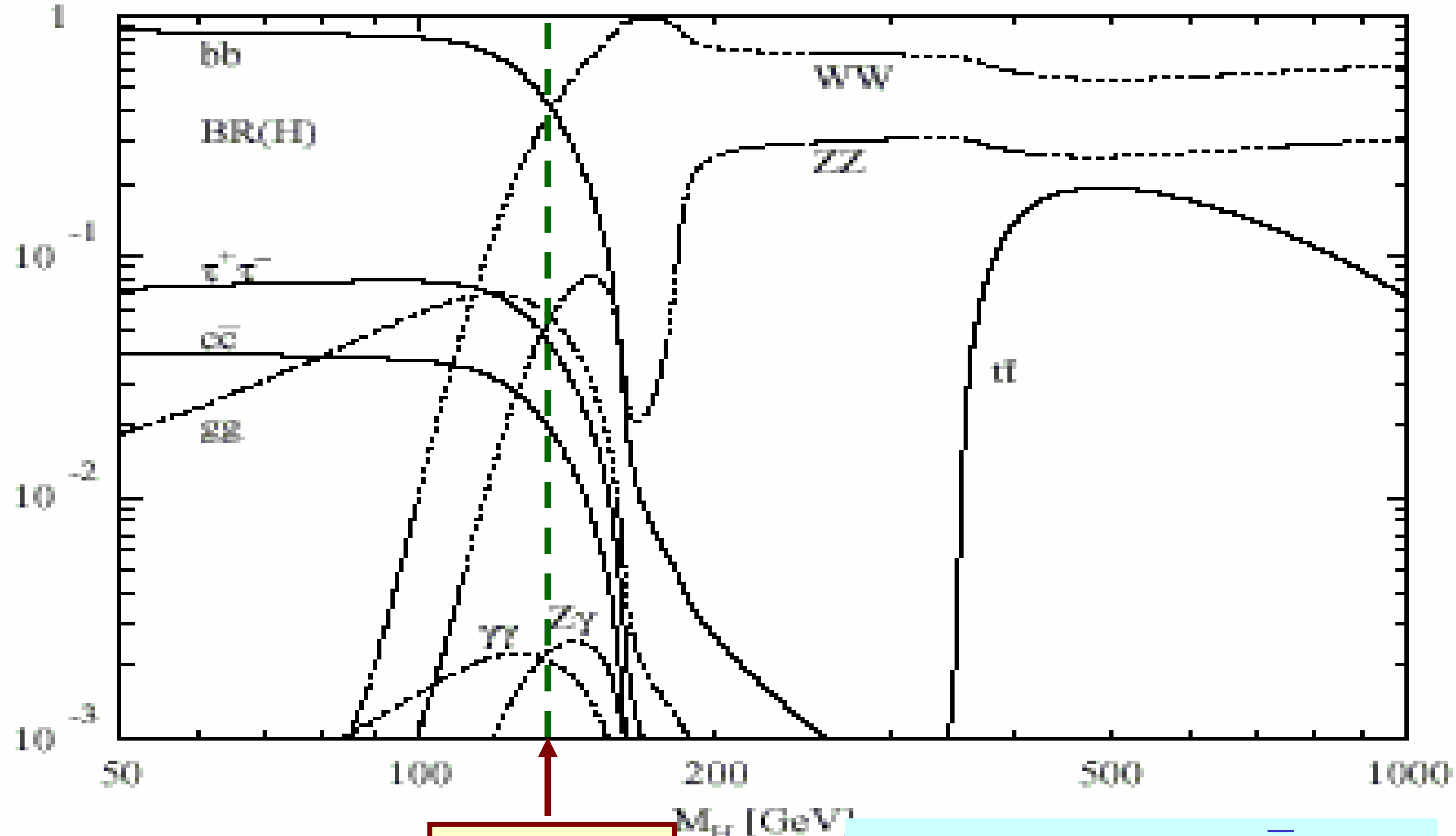
Hadron Collider SM Higgs Production σ



We use WH→eν+b b̄ channel for search for Higgs



SM Higgs Branching Ratio

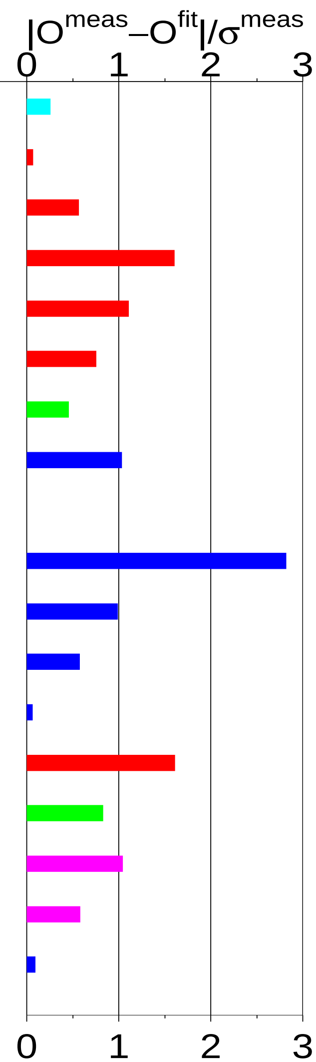


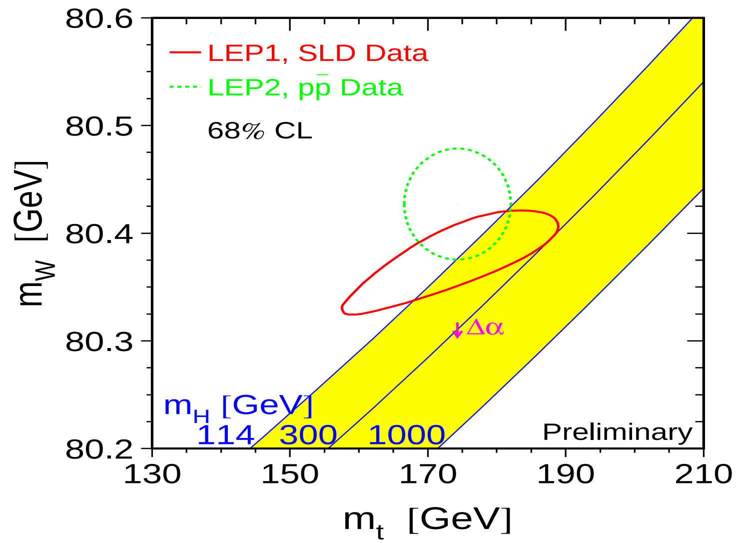
140GeV/c^2

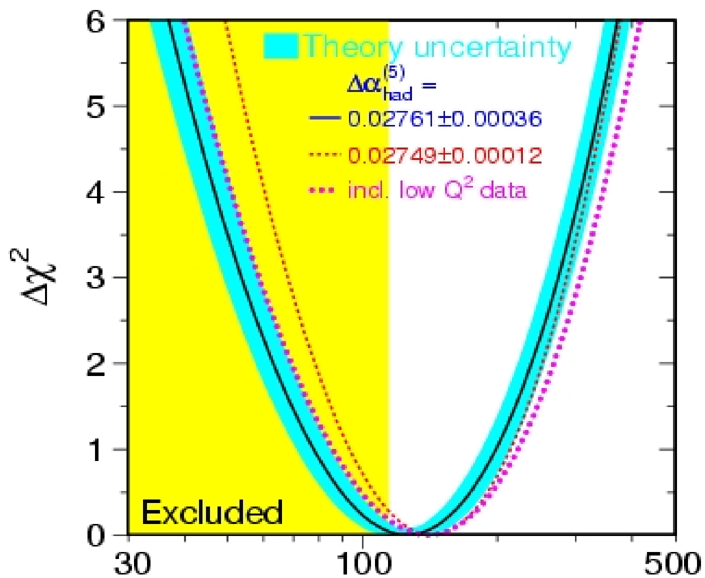
We use WH→eν+b $\bar{b}$ channel for search for Higgs

What do we know as of Winter 05?

	Measurement	Fit
$\Delta\alpha_{had}^{(5)}(m_Z)$	0.02761 ± 0.00036	0.02770
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4965
σ_{had}^0 [nb]	41.540 ± 0.037	41.481
R_l	20.767 ± 0.025	20.739
$A_{fb}^{0,l}$	0.01714 ± 0.00095	0.01642
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21630 ± 0.00066	0.21562
R_c	0.1723 ± 0.0031	0.1723
$A_{fb}^{0,b}$	0.0992 ± 0.0016	0.1037
$A_{fb}^{0,c}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1480
$\sin^2\theta_{eff}^{lept}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.425 ± 0.034	80.390
Γ_W [GeV]	2.133 ± 0.069	2.093
m_t [GeV]	178.0 ± 4.3	178.4







LEP EWWG: http://www.cern.ch/LEPEWWG

$114.4 < M_H < 300+700$ GeV

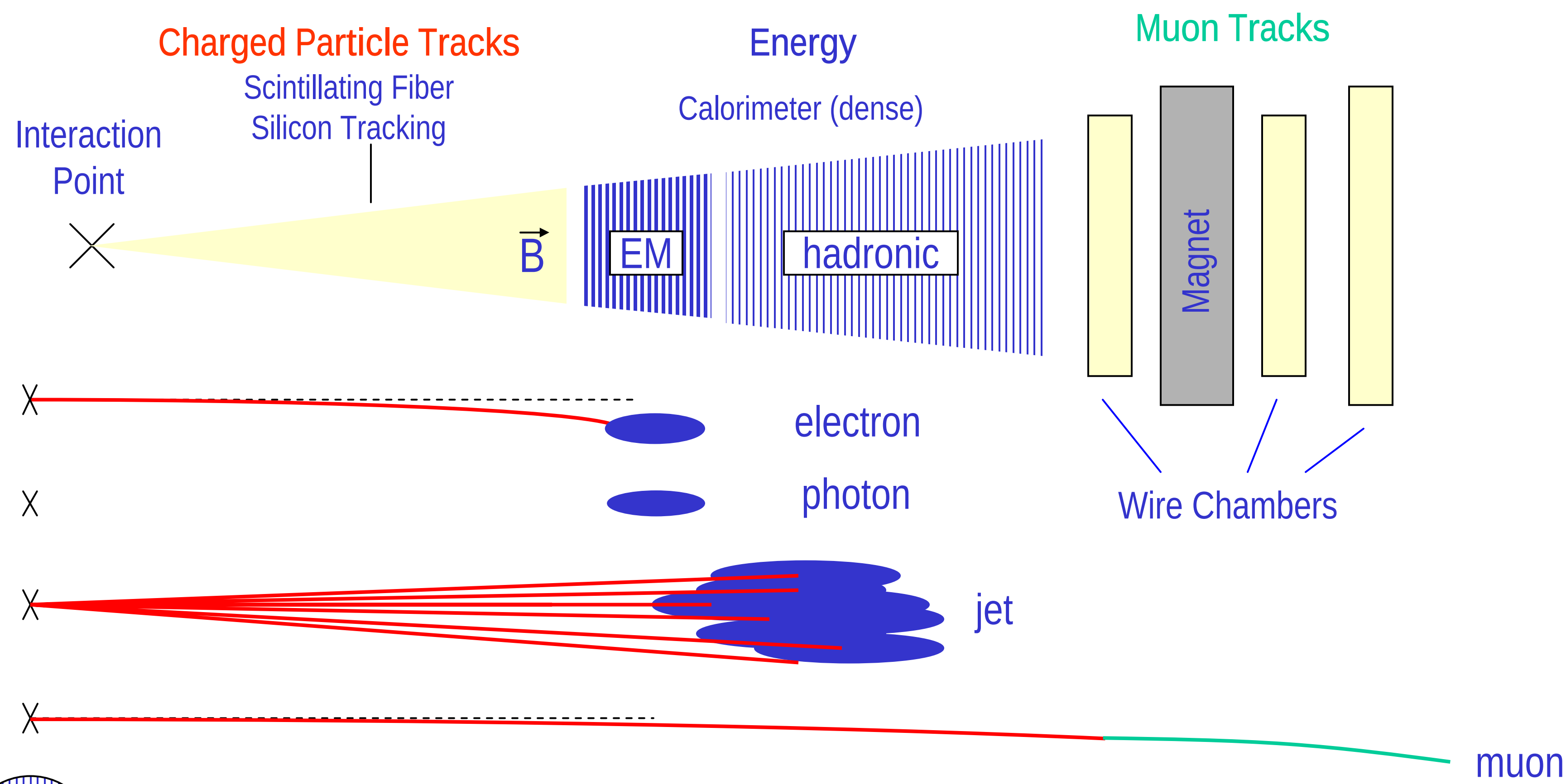
Z and W Boson Search Strategy

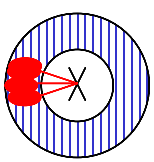
- The weak vector bosons have masses of 91 GeV/c^2 for Z and 80 GeV/c^2 for W
- While the most abundant decay final state is qqbar (2 jets of particles), the multi-jet final states are also the most abundant in collisions
  - Background is too large to be able to carry out a meaningful search
- The best channels are using leptonic decay channels of the bosons
  - Especially the final states containing electrons and muons are the cleanest
- So what do we look for as signature of the bosons?
  - For Z-bosons: Two isolated electrons or muons with large transverse momenta (P_T)
  - For W bosons: One isolated electron or muon with a large transverse momentum along with a signature of high P_T neutrino (Large missing ET).

What do we need for the experiment to search for vector bosons?

- We need to be able to identify isolated leptons
  - Good electron and muon identification
  - Charged particle tracking
- We need to be able to measure transverse momentum well
  - Good momentum and energy measurement
- We need to be able to measure missing transverse energy well
  - Good coverage of the energy measurement (hermeticity) to measure transverse momentum imbalance well

Particle Detection



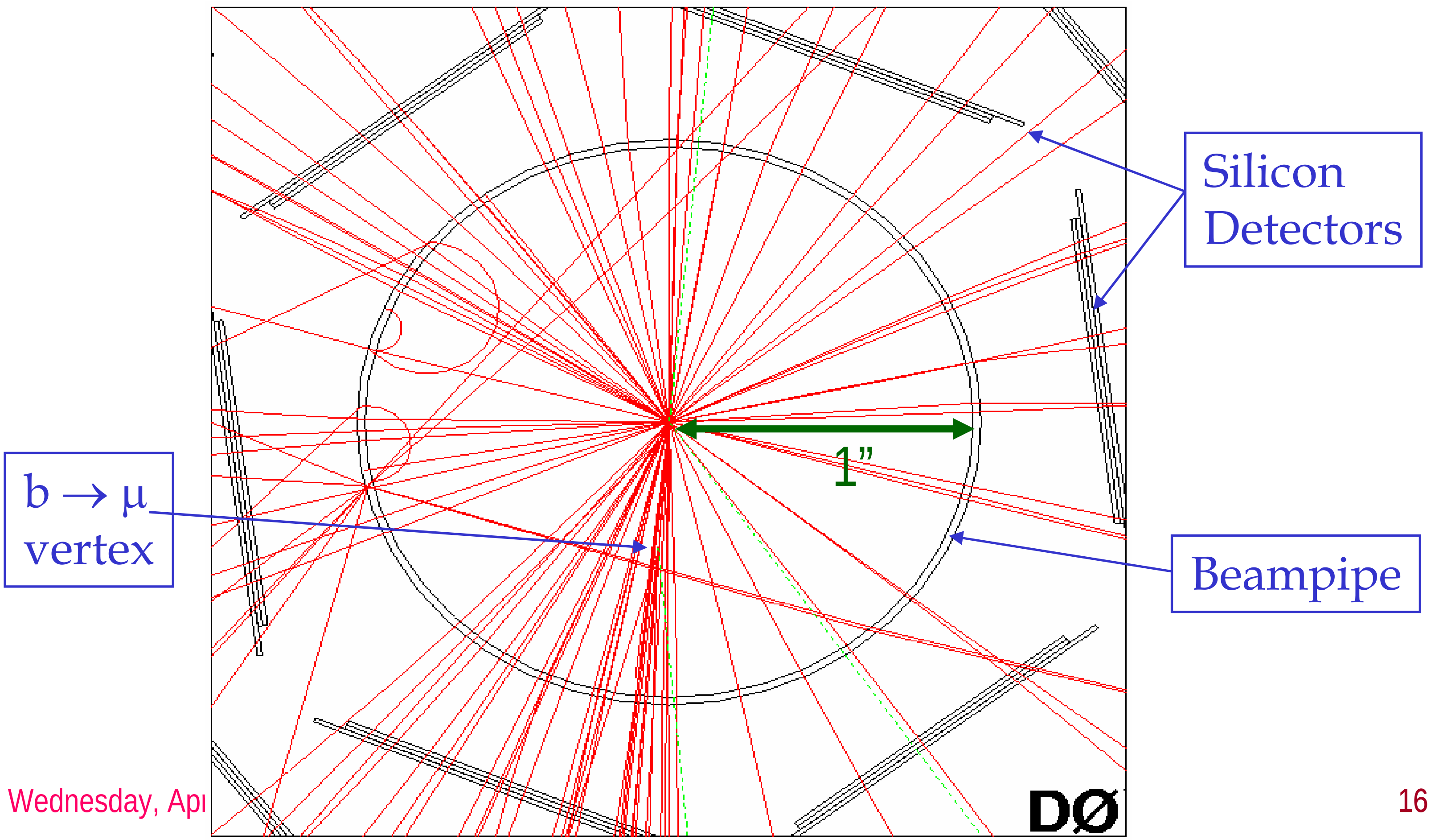


neutrino -- or any non-interacting particle
missing transverse momentum

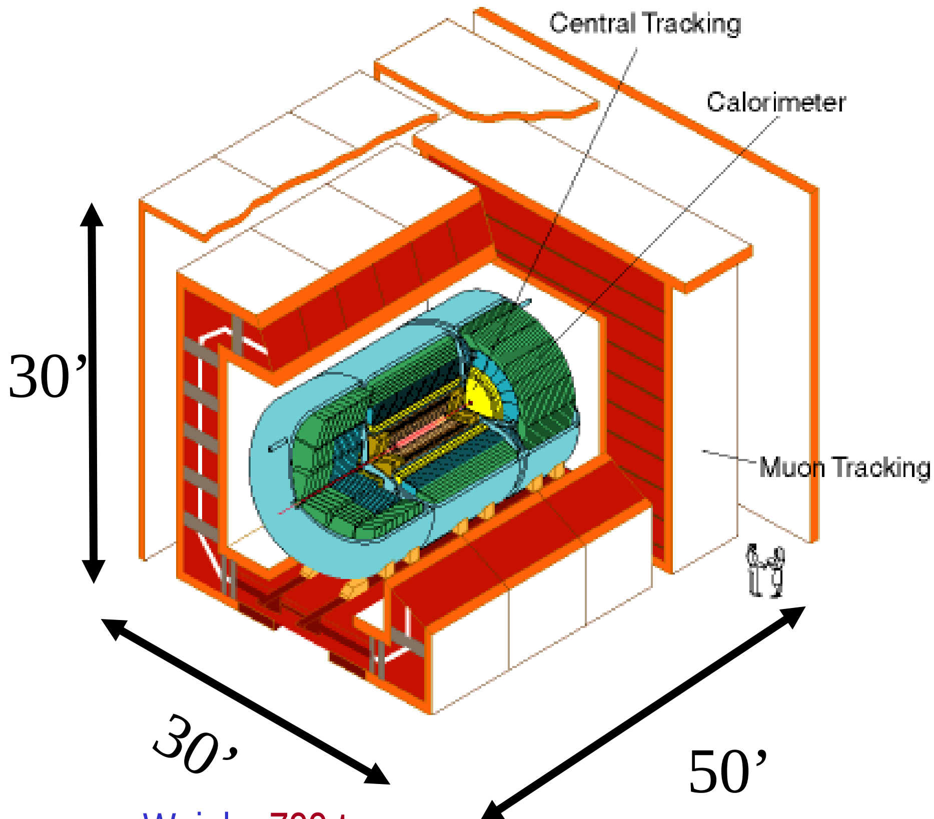
We know x,y starting momenta is zero, but along the z axis it is not, so many of our measurements are in the xy plane, or transverse

How do we find a presence of a b-quark?

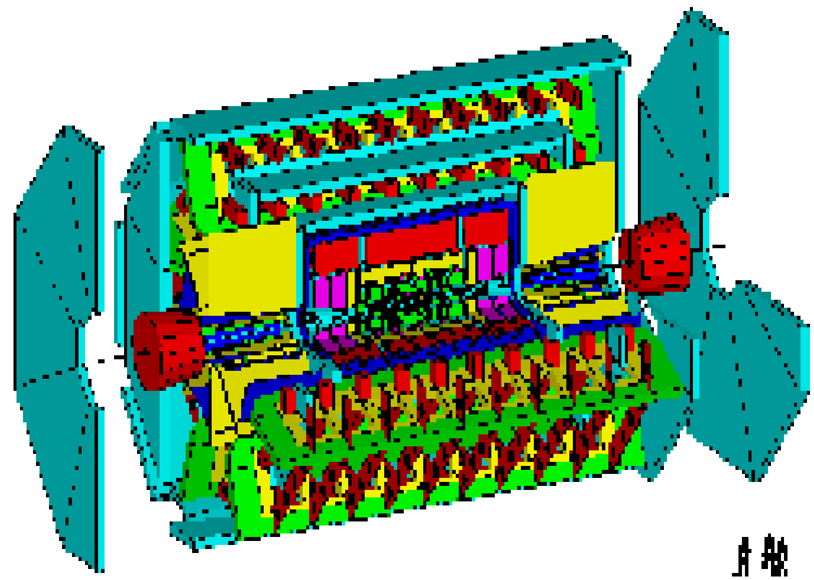
- Use finite lifetime of mesons containing b-quarks within a particle jets.



DØ Detector

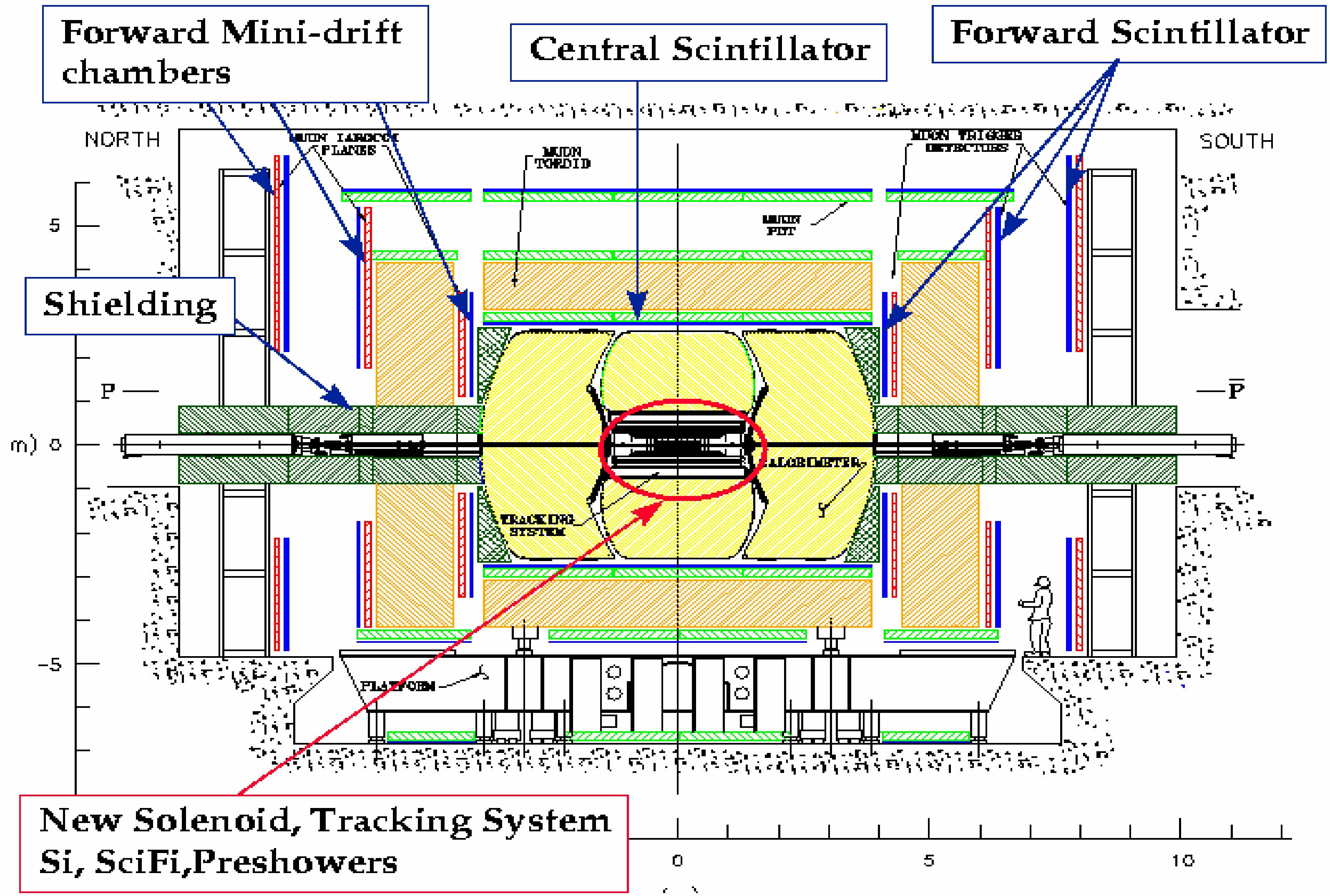


ATLAS Detector



- Weighs 700 tons
- More than 100 million parts
- Can inspect 3,000,000 collisions/second
- Will record 50 collisions/second
- Records approximately 12,000,000 bytes/second
- Will record 5 trillion, 5×10^{15}, (5,000,000,000,000,000) bytes (5 PetaByte).

Run II DØ Detector

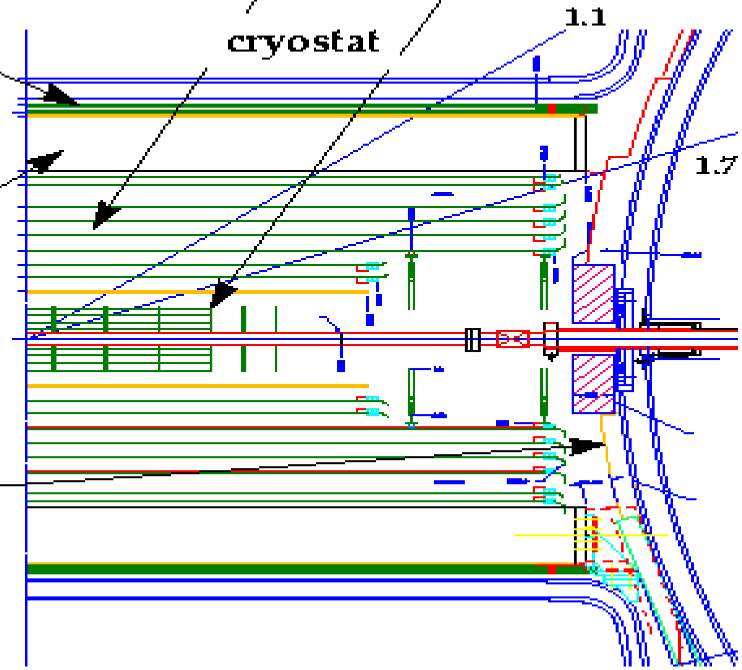


+ New Electronics, Trig, DAQ

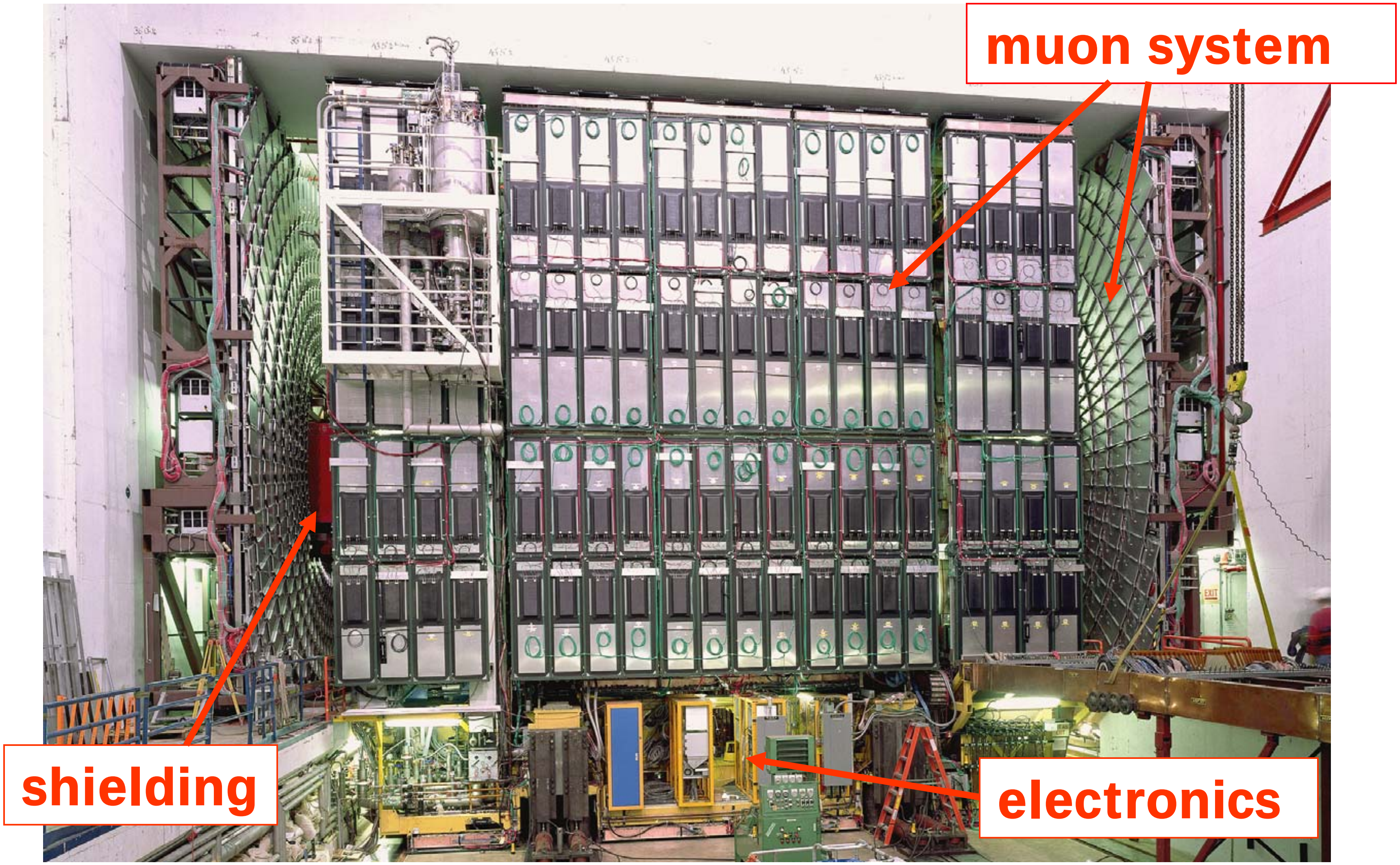
The DØ Upgrade Tracking System

Charged Particle Momentum Resolution
$\Delta p_T/p_T \sim 5\%$ @ p_T = 10 GeV/c

- **Silicon Tracker**
  - Four layer barrels (double/single sided)
  - Interspersed double sided disks
  - 840,00 channels
- **Fiber Tracker**
  - Eight layers sci-fi ribbon doublets (z-u-v, or z)
  - 74,000 830um fibers w/ VLPC readout
- **Central Preshower**
  - Scintillator strips, WLS fiber readout
  - 6,000 channels
- **Solenoid**
  - 2T superconducting
- **Forward Preshower**
  - Scintillator strips, stereo, WLS readout
  - 16,000 channels



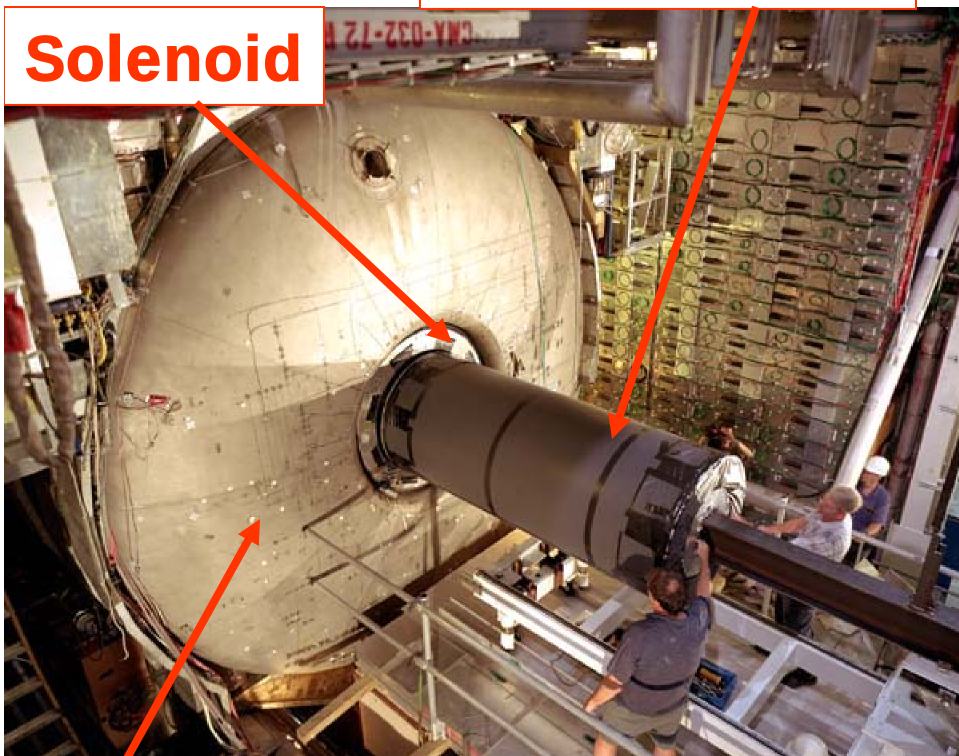
DØ Detector

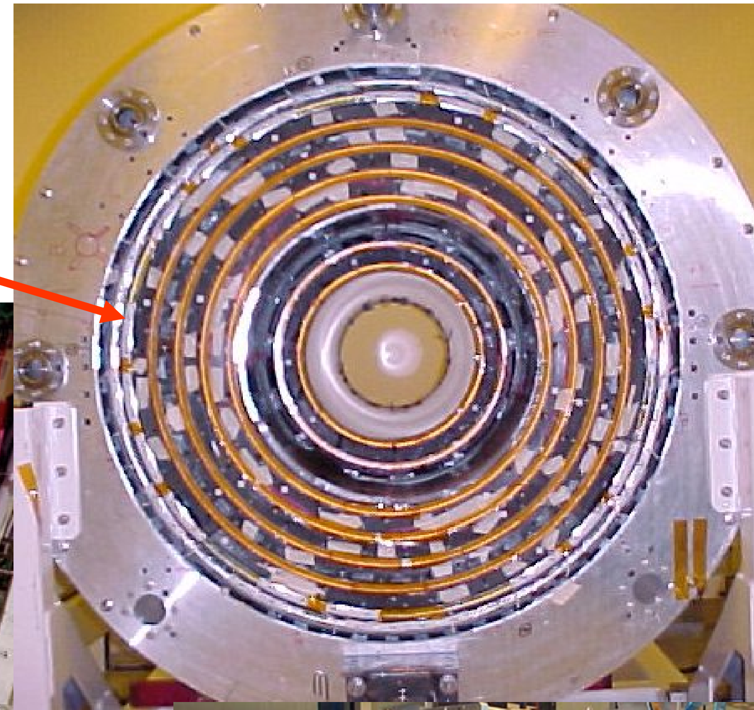


DØ Detector

Fiber Tracker

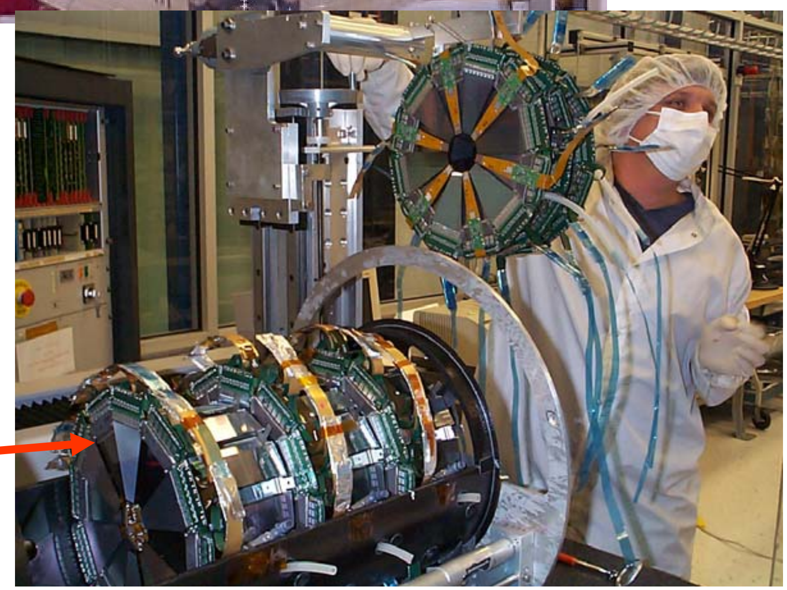
Solenoid





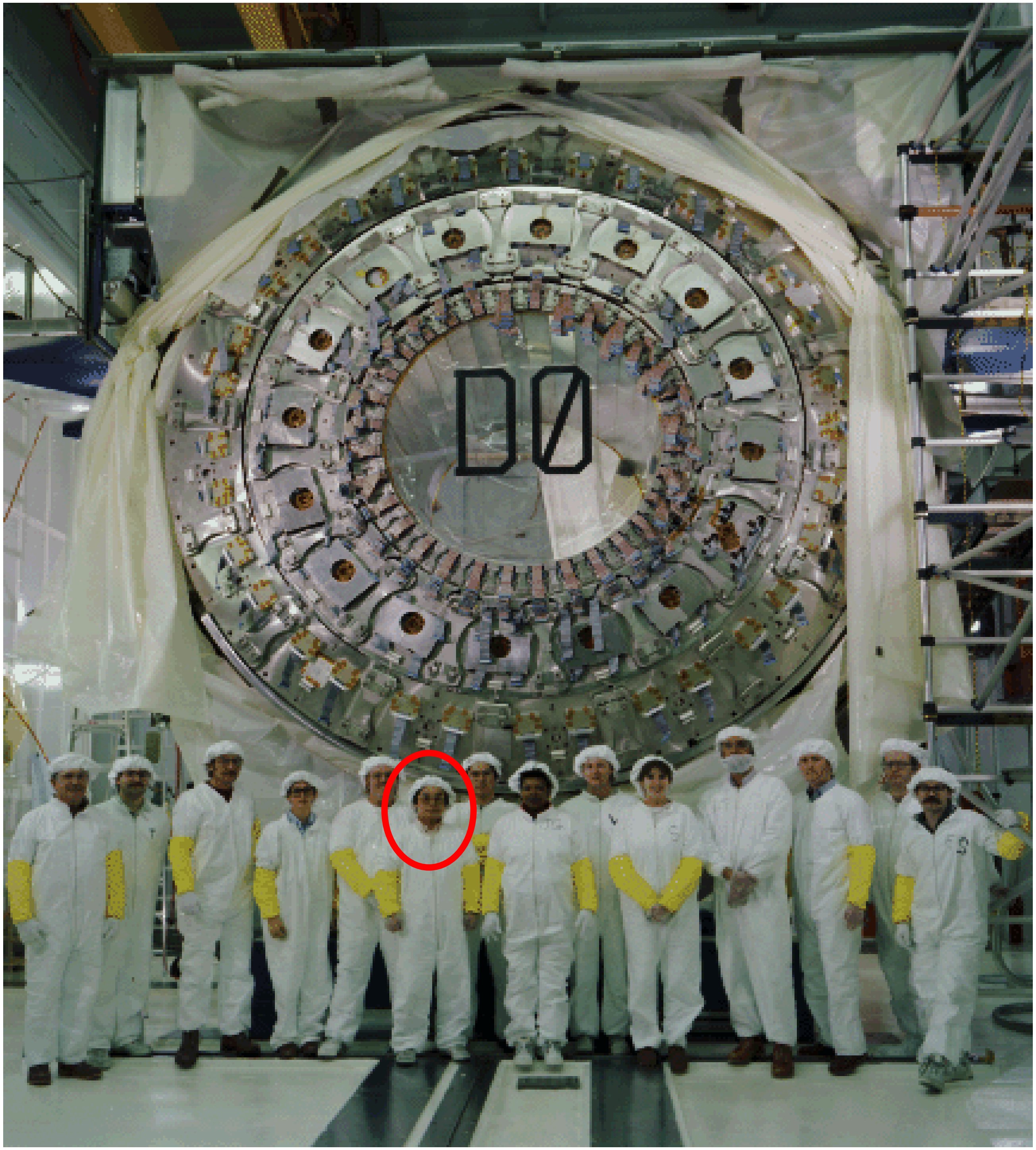
Central Calorimeter

Silicon



DØ Central Calorimeter 1990

Quiz: Where is Dr. Yu?



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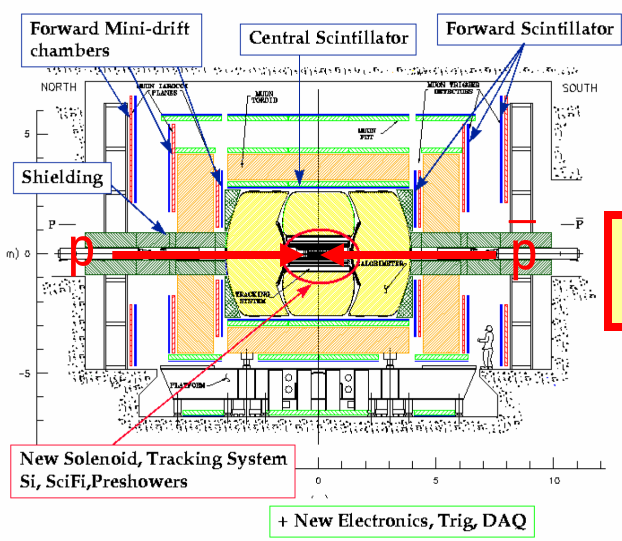
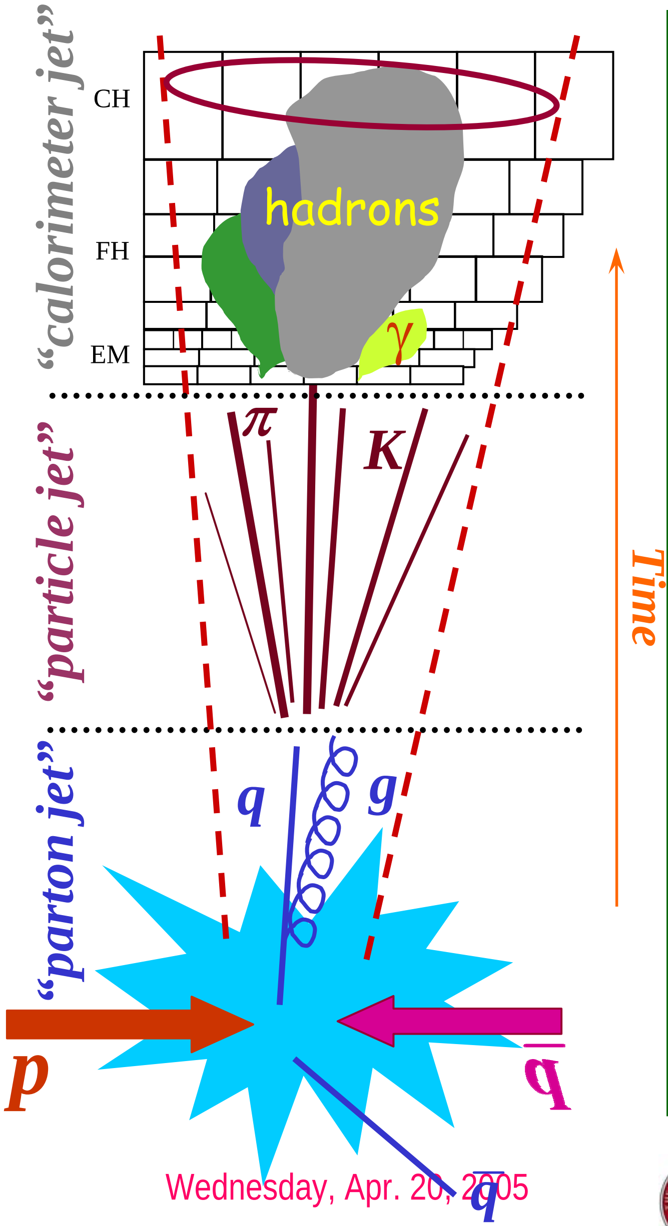
How are computers used in HEP?

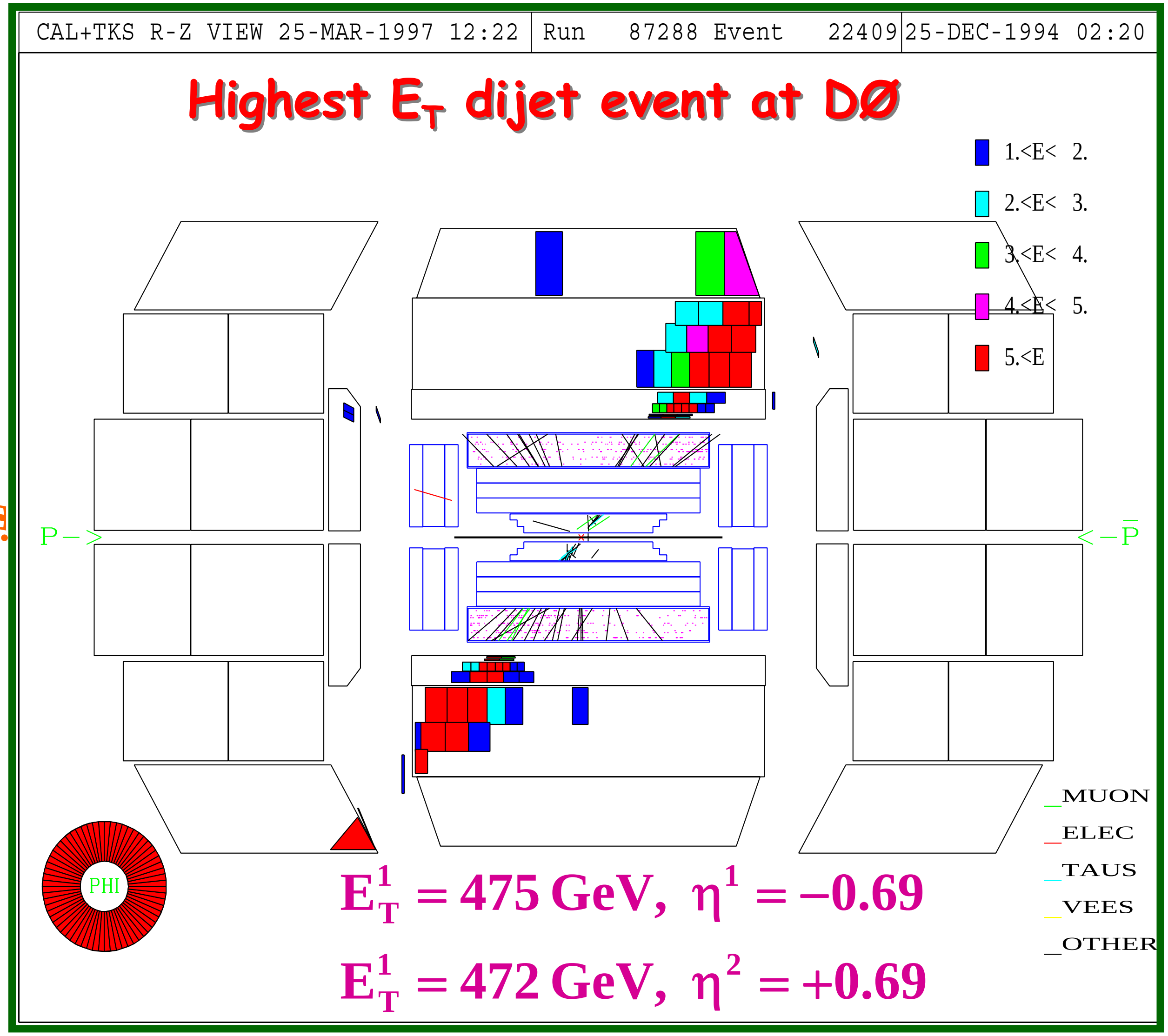


Digital Data

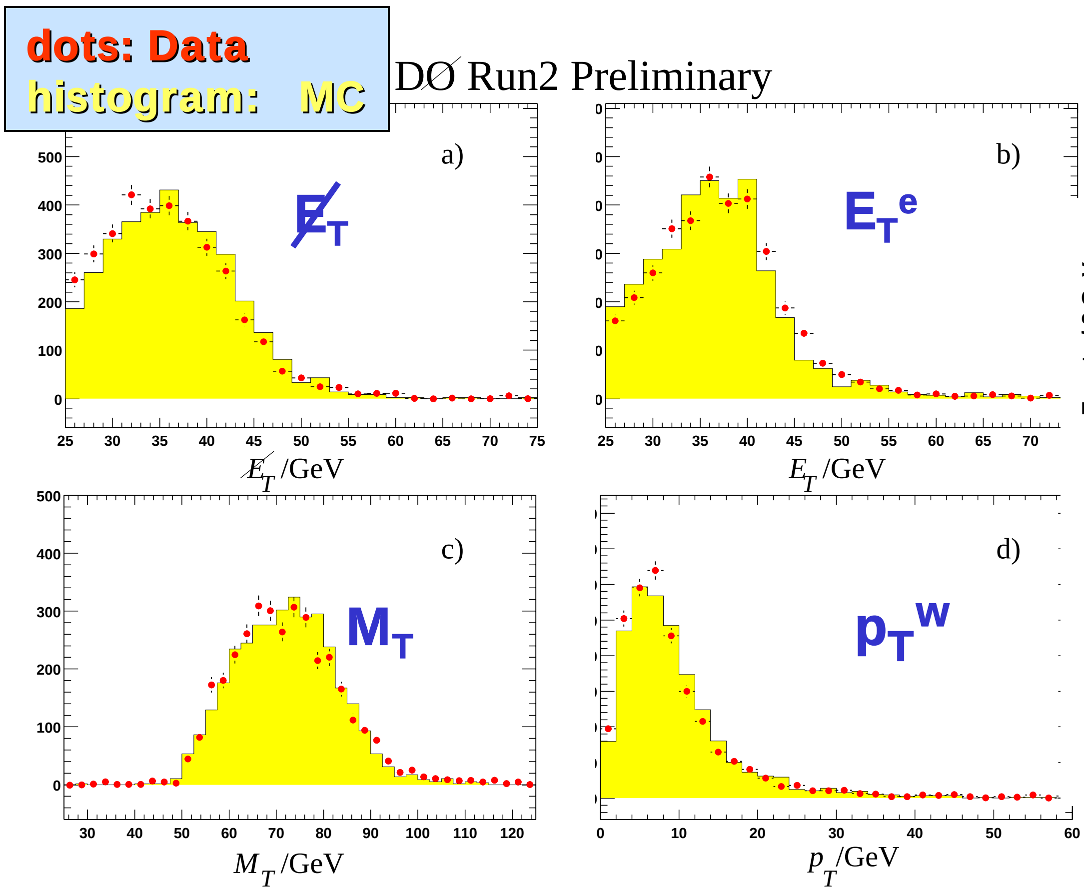
Data Reconstruction

How does an Event Look in a HEP Detector?

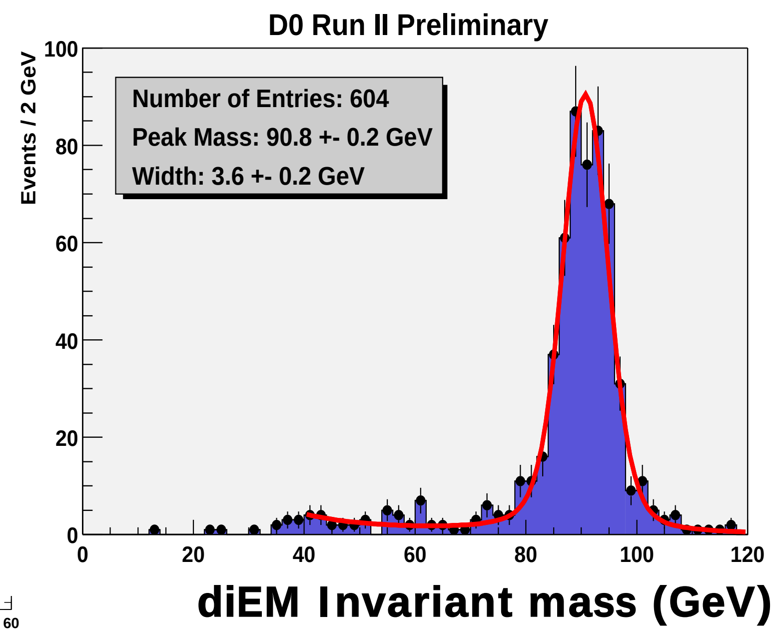




W and Z event kinematic properties

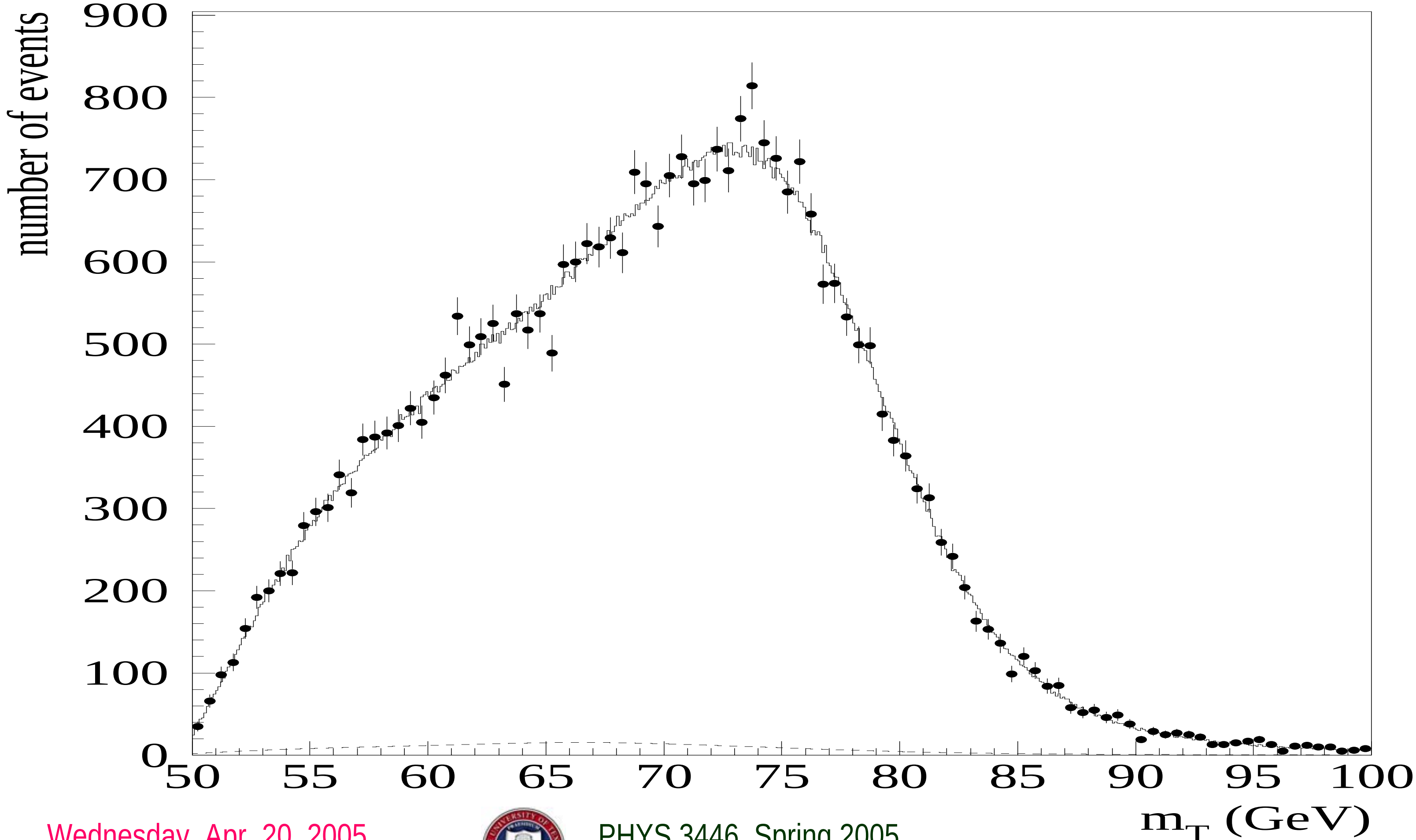


- $Z \rightarrow e^+e^-$ cross-section

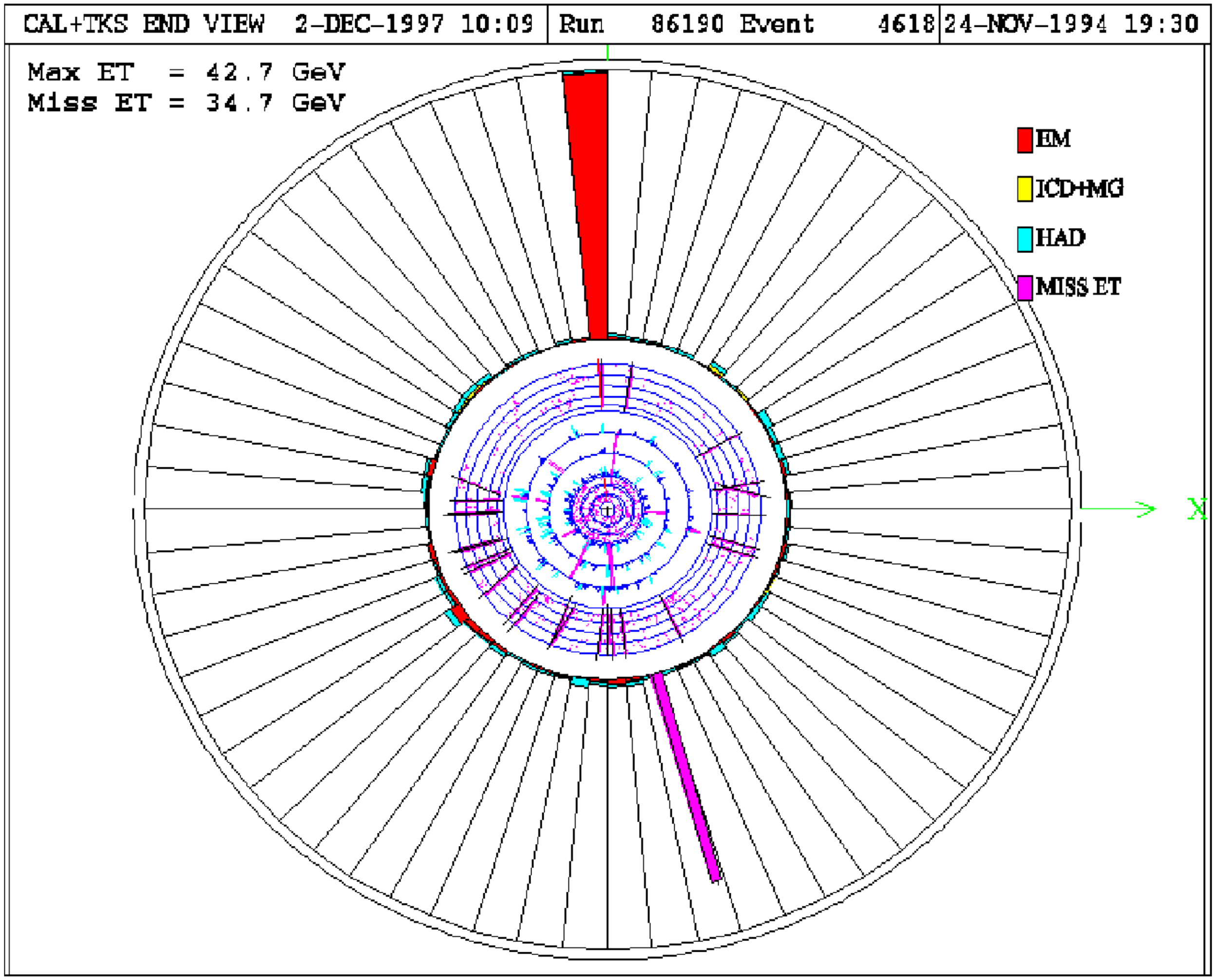


W Transverse Mass Distribution

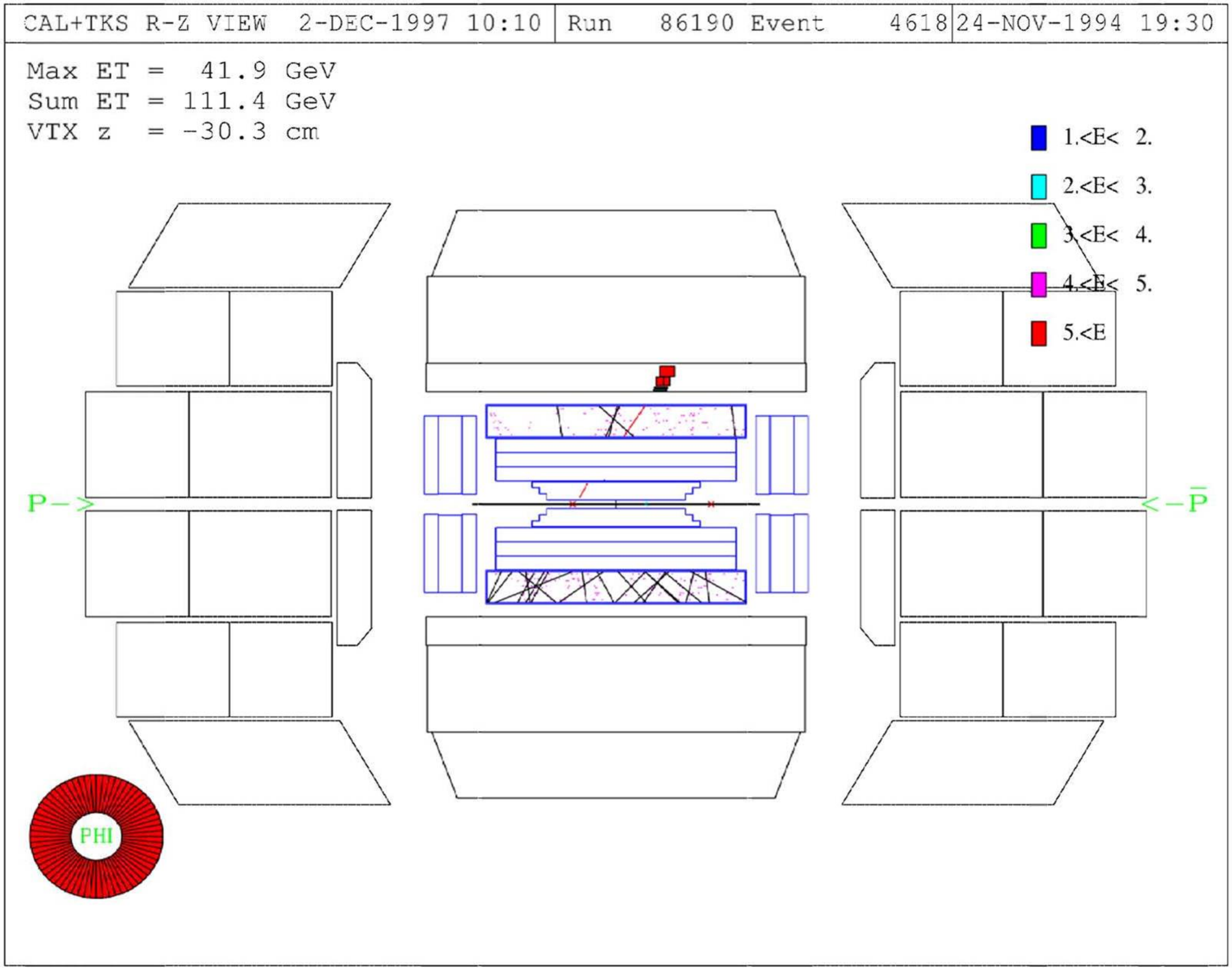
- Transverse mass is defined as $M_T = \sqrt{2E_T^l \not{E}_T \left(1 - \cos\Delta\varphi_{l\nu}\right)}$



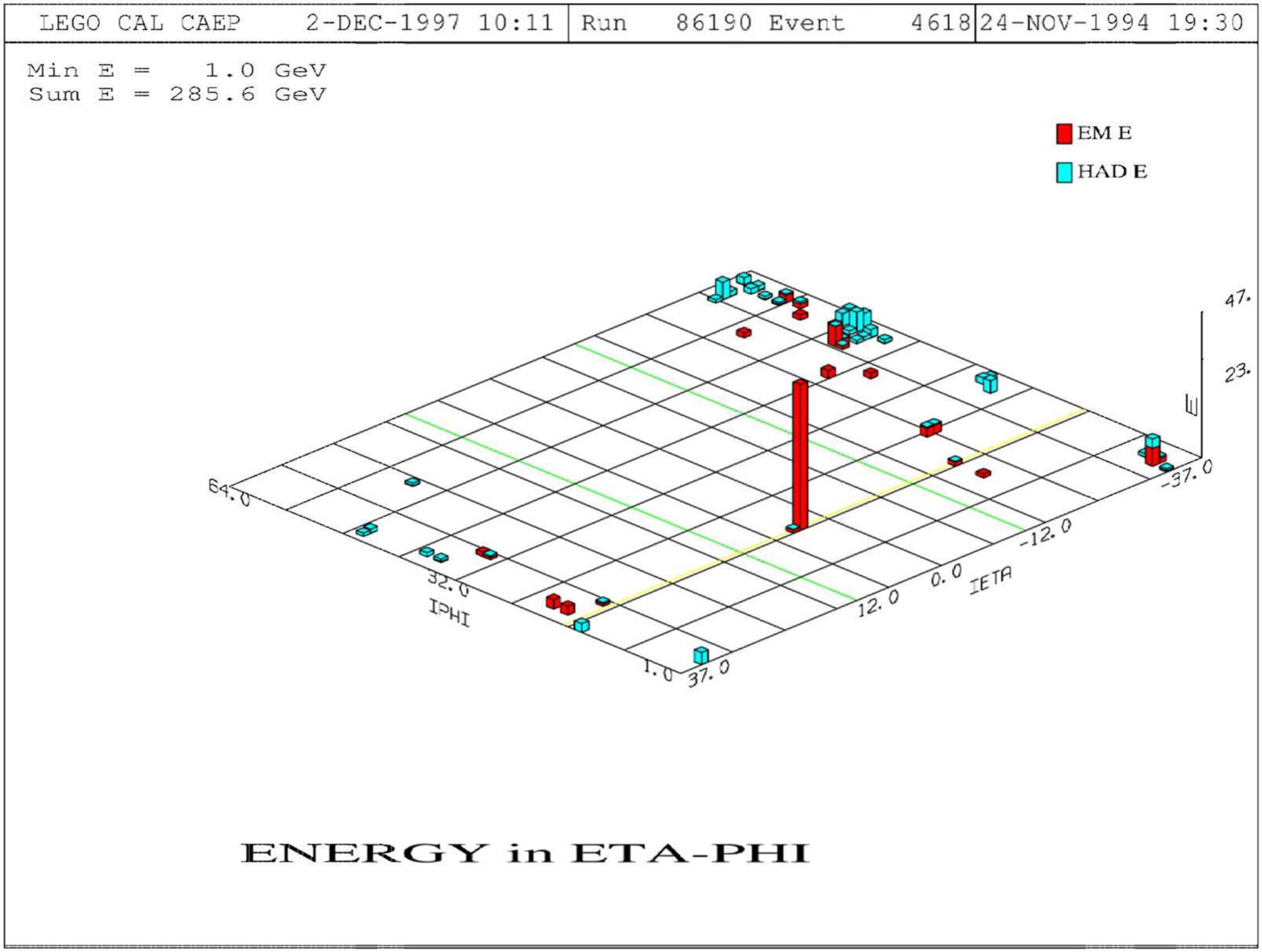
A W → e+ν Event, End view



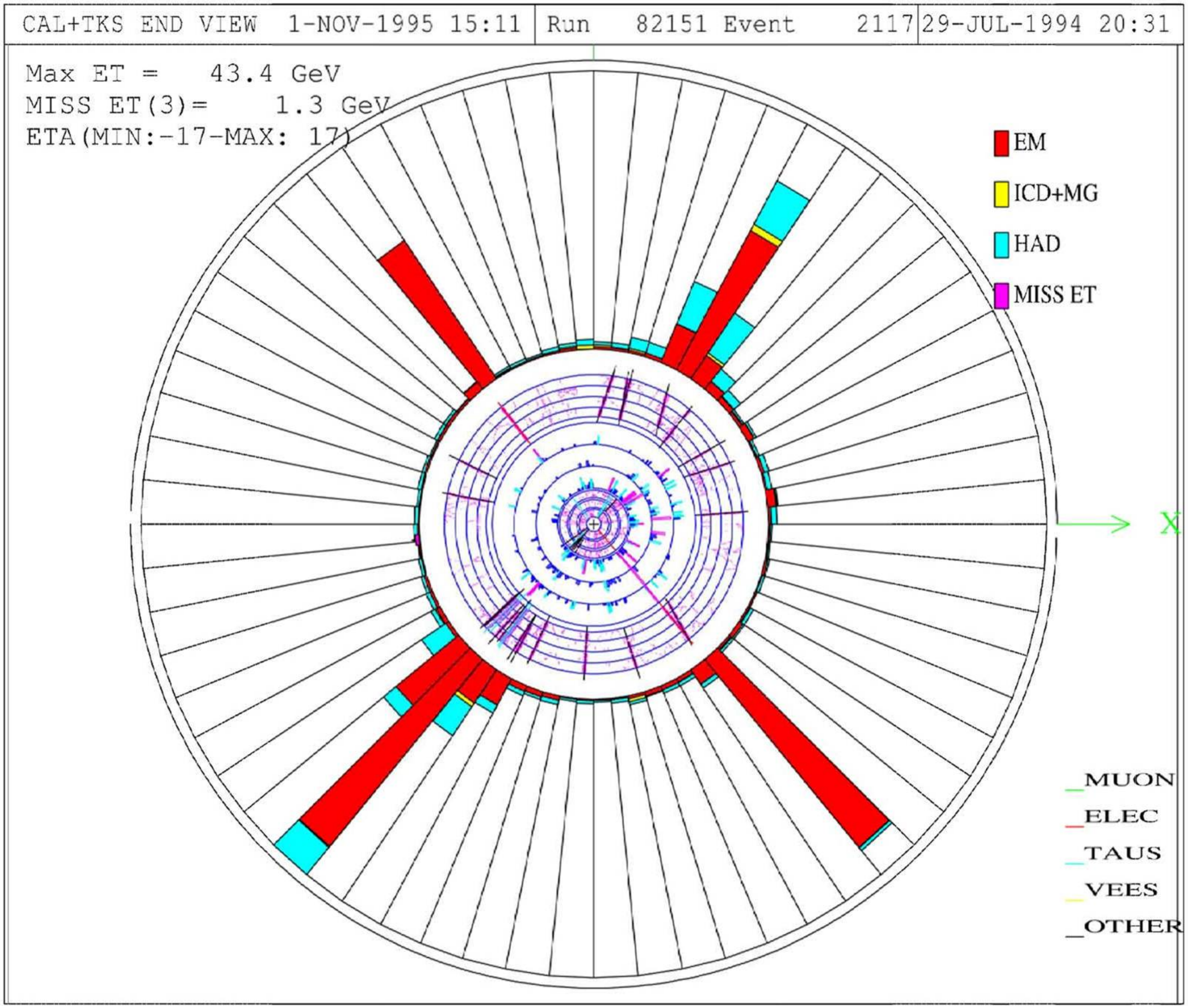
A W → e+ν Event, Side View



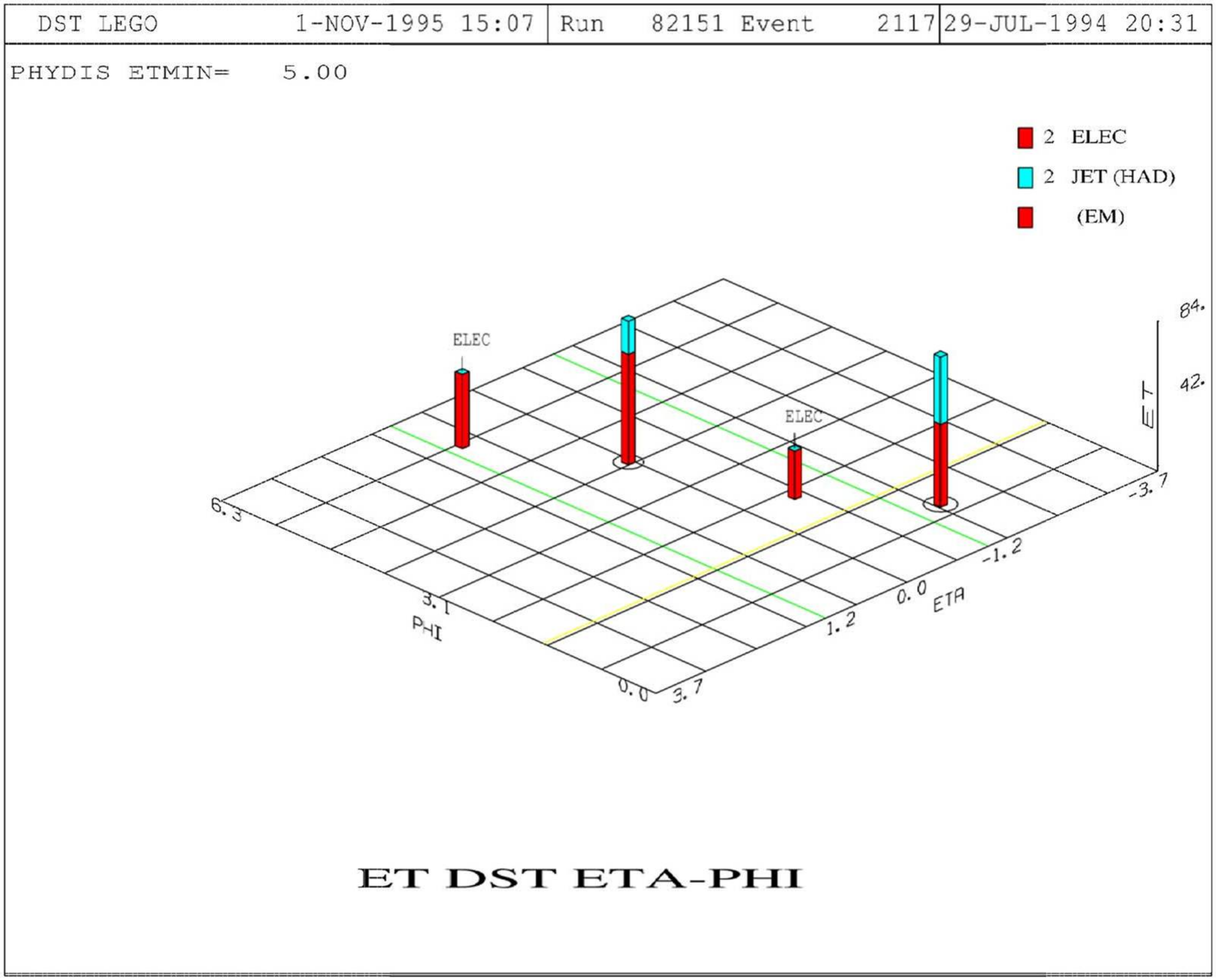
A W → e+ν Event, Lego Plot



A Z → e^+e^-+2jets Event, End view



A Z → e^+e^-+2jets Event, Lego Plot



Assignments

1. No homework today!!!