Particle Physics
a Techie's dream

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Science, Fiction & Technology
Science
the present state of affairs
Matter is composed of Spin $\frac{1}{2}$ particles

Forces are mediated by Integer Spin particles

- Electroweak: $W, Z, \text{photon}$
- Strong: gluon
- Gravity: “graviton” (not yet observed)

Is there a unifying principle? (SUSY)
Couplings

understanding the way the particles couple to each other.
Weak & Strong Force don't share the same eigenstates

=> Mixing of Quarks & Leptons

Quark mixing matrix. Area proportional to modulus of element.

Mixing matrix for leptons as yet poorly known.

How large is lepton mixing?
Mixing leads to

**Matter - Antimatter Oscillations**

\[ A_{\text{mix}}(t) = \frac{(B - \text{Anti-B})}{(B + \text{Anti-B})} \]

*Shown is the raw yield asymmetry, as well as the fit to the data.*

*Fit function is cosine convoluted with resolution function.*

*Total yield follows exponential decay.*

**Connecting time reversal & Matter – Antimatter Symmetry**
**Simple Example of Matter - Antimatter Asymmetry**

Direct CP Violation

\[ T = |T| e^{-i(\delta - \gamma)} \]

\[ \bar{T} = |T| e^{-i(\delta + \gamma)} \]

\[ \begin{align*}
B^0 & \quad \rightarrow \quad K^+ \pi^- \\
P & = |P| \\
\end{align*} \]

\[ \begin{align*}
\bar{B}^0 & \quad \rightarrow \quad K^- \pi^+ \\
\bar{P} & = |P| \\
\end{align*} \]

\[ \delta = \text{strong phase shift} \]

\[ \gamma = \text{difference in weak phase} \]

\[ \text{CP } \gamma = -\gamma \quad \text{CP } \delta = +\delta \]
Mathematical digression:
simple complex algebra to calculate
matter-antimatter asymmetry

\[ A_{cp} = \frac{\mathcal{B}(B^0 \to K^+\pi^-) - \mathcal{B}(\bar{B}^0 \to K^-\pi^+)}{\mathcal{B}(B^0 \to K^+\pi^-) + \mathcal{B}(\bar{B}^0 \to K^-\pi^+)} \]

\[ = \frac{-2|TP| \sin \gamma \sin \delta}{|T|^2 + |P|^2 + 2|TP| \cos \gamma \cos \delta} \]
Matter - Antimatter Asymmetry is a generic feature of all QFT's

But: Forces we know have only $O(1e^{-3})$ effects.

Why so little?
Forces and their couplings

Coupling Strength is function of Energy

The energy dependence of coupling constants of EWK and strong forces is well understood.

Unification might make sense if one believes in Big Bang Cosmology.

What's needed for couplings to unify?
Open Questions
lead to fiction
Two of many Questions

Do the couplings unify?

Where did all the Antimatter go?
The Story

Grand Unified Theory

Standard Model

QCD

Electroweak

Electrodynamics

Nucleus  Electricity  Magnetism  β-decay  Gravity

Strings, Branes, et al.
Unification of the Coupling Constants in the SM and the minimal MSSM
SUSY scale \( \sim 1 \text{TeV} \) \( (~20 \text{GeV} - 50 \text{TeV} @ 2\sigma) \)

GUT scale \( \sim 1\text{e}12 \) to \( 1\text{e}14 \) TeV
At the beginning there was "light". "stuff" produced via matter-antimatter pair production.

Today's Universe: many orders of magnitude imbalance.

Where did all the antimatter go?
Experiments & Technology
CDF by Numbers

# of crossings/s = 2.5 MHz

# of electr. Channels = 750,000

Total information rate = 7TeraByte/sec

I/O to tape = 20MByte/s

# of events so far = 800 Millions

# of physicists = 800

Custom Hardware Filtering
&
Commodity Computing
My Favorite Technologies

Silicon Tracker
Trigger Electronics
Computing
Computing Hardware

- Code Server
- File Servers
- Worker Nodes
- Linux 8-ways (interactive)
Hardware: Servers

Servers (~300TB total, 110 4U & 5U):
IDE RAID50 hot-swap
old 4U = 2TB, new 5U = 5TB
price today: ~$2.5k per TB
Hardware: Workers

**Workers (1100 CPUs, 1U+2U rackmnt):**

- 16 2U Dual Athlon 1.6GHz / 1.5GB RAM
- 48 1U/2U Dual P3 1.26GHz / 2GB RAM
- 236 1U Dual Athlon 1.8GHz / 2GB RAM
- 224 1U Dual P4 2.60GHz/2GB RAM
A few words about CDF Computing
CDF DAQ/Analysis Flow

CDF

TEVATRON
DZERO
RECYCLER
7MHz beam Xing

0.75 Million channels
L1
L2
300 Hz

Level 3 Trigger
(~250 duals)

Production Farm
(~150 duals)

Robotic
Tape Storage

20 MB/s
80 Hz

Central Analysis Farm
(CAF)
(~550 duals)

User
Desktops

Dat
Analysis

Read/write
Data

CDJ D AQ/Analysis Flow

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CDJ DAQ/Analysis Flow

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CAF Utilization

CPU usage for all

Network throughput for all

20TB/day ->
CAF Utilization

Number of Running Processes

- ceballos
- mikko
- thliu
- sakari
- matthias
- paus
- brianna
- lachman
- lena
- frisch
- pagan
- marjamaa
- masato
- evah
- pauly
- cdfmc
- tsybych
- nigmanov
- paulini
- pounder
- lockwitz
- ikraz
- catalti
- spezziga
- bauerg
- eikoyu
- dsherman
- apollina
- rappocc
- vacavant
- jameseb
- zaw
- tomi
- akorn
- hirokazu
- satoru
- jdeng
- yoshio
- lucchesi
- hcfang
- smwang
- rolli
- yimeih
- menzemer
- litvinse
- max1
- rahaman
- leonardo
- yik
- fernand
- campanel
- djkong
- shapiro
- anantg
- jiank
- jdlee
- finberg
- salaman
- bernd
- tanimoto
- tomohiro
- pt1
- cdfopr
- tmiao
- rakin
- slai
- lungu
- jrsmit
- sdonati
- trj
- issever
- bussey
- cranshaw
- murat
- doraemon
- scuri
- sidoti
- sineadf
- fiori
- ikado
- bolshov
- wittich
- lmiller
- piedra
- canepa
- anikeev
- douglasg
- ptohos
- vjmartin
- angelaw
- jkim
- isamun
- robson
- mhartz
- mattson
- sunh
- luis
- intaeyu
- jslee
- jspark
- azfar
- ischo
- holloway
- mjones
- loginov
- currat
- nord
- jakraus
- jpursley
- ais
- gpope
- gervasio
- martin78
- stuart
- tompkins
- tesarek
- mmap
- dwjang
- bhatti
"Services"

Batch submission from desk/laptop anywhere.

Individual & group based fair share

DH services to desk/laptop & batch.

Metadata catalogue

file transfer (read, working on write)

posix-style file access (read only)

ls,tail,cat,gdb access to running processes.
Future Directions

Fully virtualized multi-site services.
50% of resources outside FNAL by 2005
complete migration to "Grid middleware"

Interactive Grid services.
Prototype for SC03: 5 GB of data in 20s.
scheduling on 3 time scales:
"grid times" ~ hours
"session setup time" ~ minutes
"query times" ~ seconds
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