A PC/Linux Cluster and Feasibility Study of the BES Data off-line Reconstruction and D/Ds Physics Analysis Based on the Cluster[1]

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BES'99, IHEP, Beijing, June 14–17, 1999

INTRODUCTION

- Why need PCs?
  - D Physics Analysis needs more CPU, larger DISK ...
  - PCs/Linux – PC is cheaper and Linux is free software. Easier to get more CPU and Larger Disk.
  - CERNLIBs – have been ported to Linux already. Make to use PC for physics analysis and data off-line processing possible.
- PC/Linux Cluster–A Distributed PCs System
  - A prototype: To try to set a PCs Cluster based on Linux up. To study its stability. To get the first hand information about a Distributed PCs System based on Linux (We called PC/Linux Cluster). These are beneficial to BES/BES-II data off-line reconstruction and physics analysis.
  - The experience for setting up and developing the PC/Linux Cluster is not only helpful for setting up an software environment for BES/BES-II data off-line processing and physics analysis based on the PC/Linux Cluster, but also helpful for setting up and developing the software environment for some others, such as software environment of Babar experiment at IHEP, and ...
- Is it possible to switch from HP/UNIX to PC/Linux?

  Trigger reactions from physicists and experts to pay more attention to the physics analysis and off-line data processing performed on PC/Linux.

  If the result is OK, ⇒ maybe possible to switch the data off-line reconstruction and physics analysis from HP/UNIX to PC/Linux for BES/BES-II ⇒ Save a lot of Money!

[1]The talk was first given at BES Monthly' Meeti IHEP, January, 1999

PC/Linux Cluster, Hardware and Software

- BES software on PC/Linux

  In 1996, the BES Version 8.7 codes were converted from HP/UNIX to PC/Linux by CSU people.[2]

  We need the BES Version 8.6 code to do D physics analysis, since the available DST data taken at 4.03 GeV were reconstructed with the version 8.6 code by UTD people.

  In order to make our physics analysis results obtained based on the PC/Linux platform more reliable, especially for Monte Carlo simulation, we decided to convert the V8.6 code on HP-UX platform to that on PC/Linux. The rule of the code conversion is that *we only change some read, write, open, and equivalent statements to make the code runnable on the* PC/Linux.

  K.L. He of D group at IHEP began to convert the V8.6 code from HP-UX to PC/Linux platform in October, 1998 and run the V8.6 code successfully in November. For detail information about the code conversion, please see a write-up "Summary of the BES V86 Code Porting to LINUX"

  In November and December 1998, people in D Physics Group began to study the Monte Carlo code of Version 8.6 on HP/UNIX and PC/Linux platforms. We began to do the feasibility study of the BES data off-line reconstruction and D/Ds physics analysis based on the PC/Linux in December 1998.

- Our PC/Linux Cluster

  In November another PC was setup. It works well. We set up two PCs system to a PC/Linux Cluster. BES data and Libraries are shared via NFS. By the 15 September, 1999, a new PC (PIII-500) was added into the cluster. All hardware and software can be shared by the three PCs via NIS and NFS. The PC/Linux Cluster works well. It just like the BES HP/UNIX Workstation Cluster at IHEP.

  Through the network, we can read and write the data from and to the BES HP/UNIX Workstation as well.

- PCs and HP Workstation Hardware

  In general, we want to know the consistent of the data reconstructed and results of physics analysis from different platforms. We want to know the CPU power and prices of the machines, and so on ...

- Why want to know the consistent?

  - Hardware: Different CPU processors in PCs and HP Workstations.
  - Software: Different operation system, different compiler, different CERNLIB and some other support software.

[2]L. Lippert, W. Toki, W. Yang "Linux Conversion of BES Programs", The 5th BES Annual Meeting, Zhangjiajie, Hunan, Jun, 1996

In order to answer the question about consistent, we studied the data off-line reconstruction and physics analysis on the different platforms.

Hardware Configuration and Network

- CPU type
  HP712/80, HP735/125, HP-J2240, celeron/300, and PII/400

Machine Machine	CPU CPU	Memory (MB)	Data Media
hpws0	hp735/125	144	NFS
hpws6	hp712/80	64	NFS
e781b	celeron-300	64	Quantum(IDE) or NFS
cquark0	PII-400	128	Maxtor(IDE) or NFS

- Network
  - FDDI
  - NIS
  - NFS

Software Environment

- BES Code
  - V8.6 code of HP/UNIX version is available in the BES Lib.
  - V8.6 code was converted from HP/UNIX version to PC/Linux Version.
- Complier
  - C, C++ and FORTRAN were optimized.
  - Others ...

Comparison of Data Off-line Reconstruction on HP/UNIX and PC/Linux

To check and study the consistent, we reconstructed the BES data on the two platforms with the BES V8.6 codes, separately.

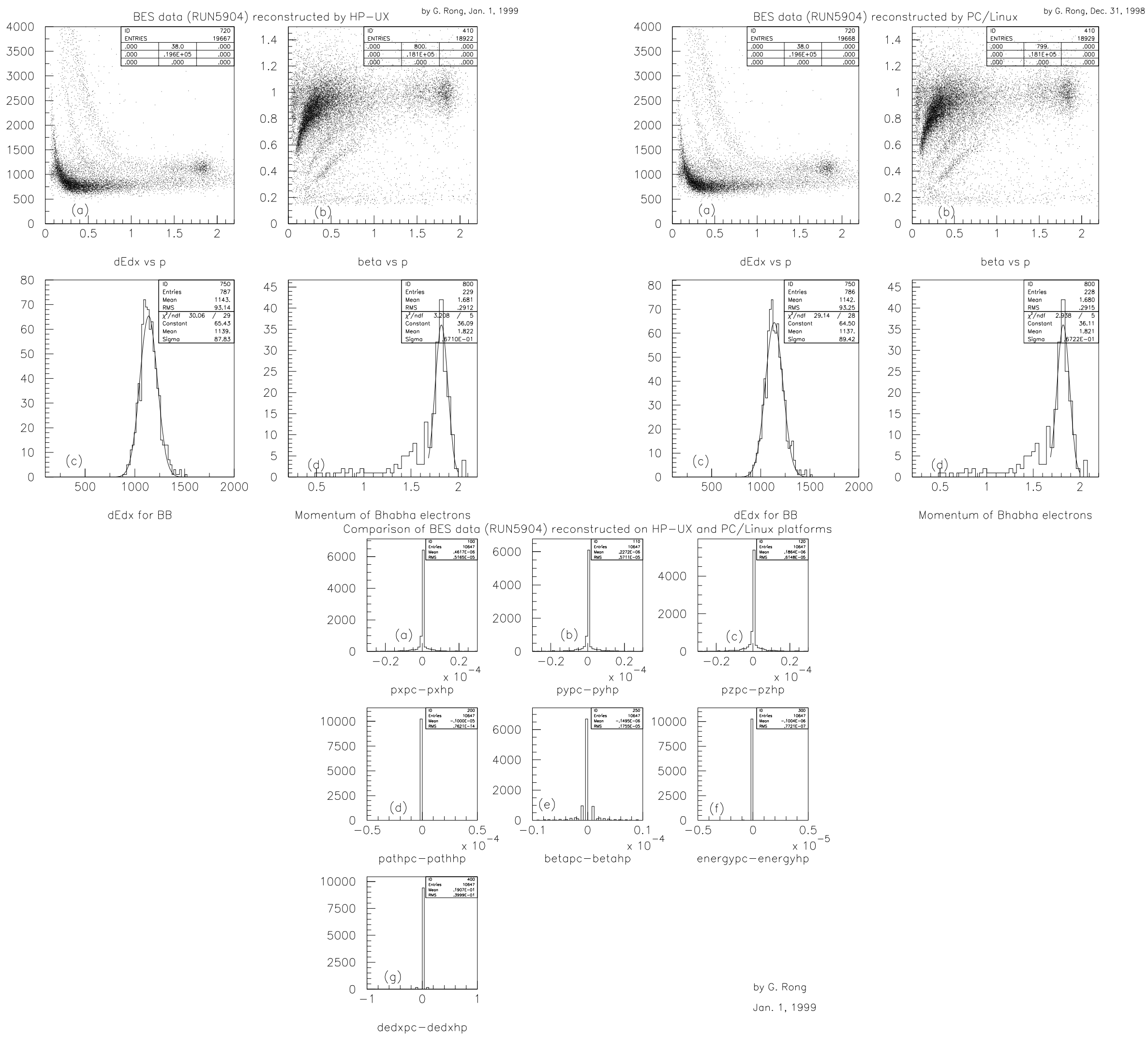
- Data
  One run filtered ψ" data as an input to be used to test the data off-line reconstruction.

- Data Reconstructed by Using HP(735/125)/UNIX
  It caused 4423.0 seconds to reconstruct 17093 events. It caused 0.246 seconds to fully reconstruct one event.

- Data Reconstructed by Using HP(J2240)/UNIX
  It caused 1332.2 seconds to reconstruct 17093 events for the case of using one CPU $\Rightarrow$ corresponding to 666.1 seconds to fully reconstruct one event for the case of using two CPUs.

- Data Reconstructed by Using PC(PII-400)/Linux
  It caused 391.5 seconds to reconstruct 17093 events after optimized the C, C++ and FORTRAN Compilers. It caused 0.023 seconds to fully reconstruct one events.

- Comparison
  See figures.



- Conclusion

  The reconstructed track kinematic variables are **identical within 5 digits after points**. These would give the same physics results for using the same data set but reconstructed on the two different platforms. Our PII-400 PC's CPU speed, in the case of with the optimized compliers, is about 10 times (1.69 times) faster than HP735/125 (HPJ2240 Workstation) in reconstruction of BES data.

Comparison of D/Ds Physics Analysis on HP/UNIX and PC/Linux

- D/Ds single tags (4.03 GeV Data)

  Based on the DST data reconstructed on HP/UNIX workstation with V8.6 code, a set of studies of analysis for tagging the decay process, such as $D^0 \to K^-\pi^+, K^-\pi^+\pi^+\pi^-$, $D^+ \to K^-\pi^+\pi^+\pi^-$, $D^0 \to \overline{K^0}\phi$, $D_S^+ \to \phi\pi^+$, $\overline{K^{*0}}K^+$, $\overline{K^0}K^+$, $K^0K^-\pi^+\pi^+$, $f_0\pi^+$, were made on the both HP/UNIX and PC/Linux platforms. Based on the results from the two platforms, we can check if there are different in the mass spectrum of the $nKm\pi$ (n=1, or 2; m = 1, 2, 3, or 4) combination. Based on these studies we can find out if we can obtain the same physics results from the two platforms. These are an important step before we decide to switch the BES/BES-II data off-line reconstruction and physics analysis from the HP/UINX to PC/Linux platform.

- D single tags

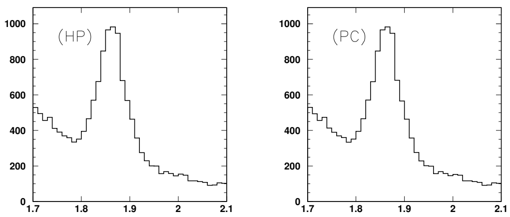
  - Analysis by using HP/UNIX.

    The invariant masses of $nKm\pi$ combination are shown in the first column in the following figures. The analysis was made with V8.6 codes.

  - Analysis by using PC/Linux

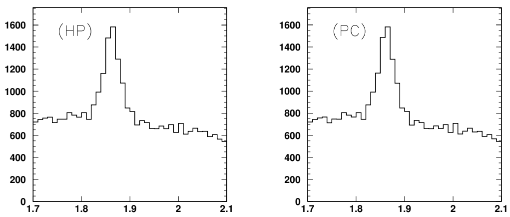
    The invariant masses of $nKm\pi$ combination are shown in the second column in the following figures. The analysis was made with V8.6 codes.

$D^0 \to K^-\pi^+$



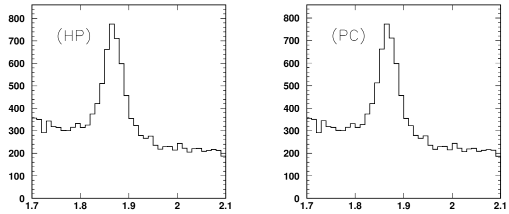
$\mathrm{M}_{K^-\pi^+}$ GeV/c^2

$D^0 \to K^-\pi^+\pi^+\pi^-$



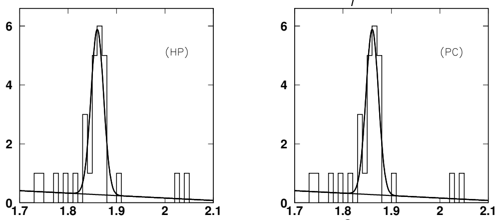
$\mathrm{M}_{K^-\pi^+\pi^+\pi^-}$ GeV/c^2

$D^+ \to K^-\pi^+\pi^+$



$\mathrm{M}_{\mathrm{K}^-\pi^+\pi^+}$ GeV$/c^2$

$D^0 \to \overline{K^0}\phi$

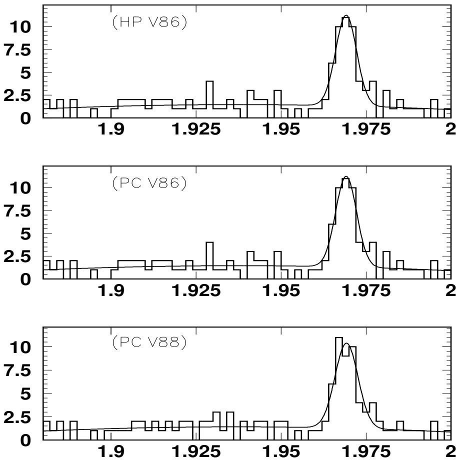


$\mathrm{M}_{\overline{\mathrm{K}^0}\phi}$ GeV$/c^2$

- Ds Analysis

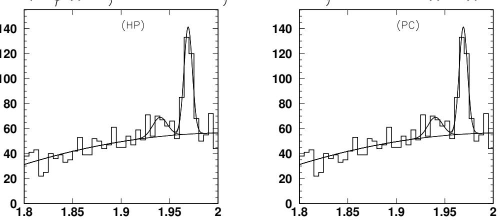
  We use the Kinematic fitting method to search for the Ds decay candidates, and use the fitted momentum vector to calculate the invariant masses of the $nKm\pi$ combination. Since the kinematic fit package calls a lot of subroutines in CERNLIB, the results of the Ds single tag analysis from the two platforms can be used to check the CERNLIB on the two platforms as well.

$D_S^+ \to \phi\pi^+$



$M_{\phi\pi^+}$ GeV$/c^2$

$D_S^+ \to \phi\pi^+, \overline{K^{*0}}K^+, \overline{K^0}K^+, K^0K^-\pi^+\pi^+, f_0\pi^+$

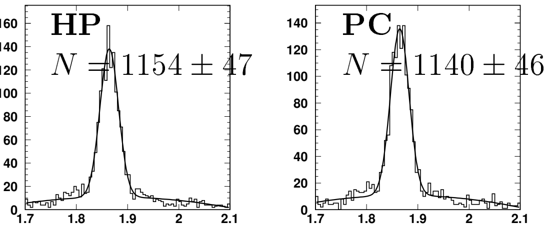


$\mathbf{M}(\phi\pi^+, \overline{K^{*0}}K^+, \overline{K^0}K^+, K^0K^-\pi^+\pi^+, f_0\pi^+)$

The mass spectrum obtained from the two platforms with V8.6 codes are identical (see above figures). These would give the same physics results from the two platforms. These identical results also indicate that the CERNLIB and some other support software on the two platform are same.

- D single tags (Monte Carlo)

$D^0 \to K^-\pi^+\pi^+\pi^-$ **Monte Carlo**



$\mathrm{M}_{\mathrm{K}^-\pi^+\pi^+\pi^-}$ GeV$/c^2$

On the HP/UNIX platform we obtain 1154 ± 47 events for decay $D^0 \to K^-\pi^+\pi^+\pi^-$, while we obtain 1140 ± 46 events for the decay on the PC/Linux platform. This indicates that the Monte Carlo efficiency would be the same within 0.6% on the two platforms.

- Conclusion

  The invariant mass of $nKm\pi$ (n=1, or 2; m = 1, 2, 3, or 4) combination for D^0, D^+ and D_S^+ decays analyzed with the V8.6 codes from the both HP/UNIX and PC/Linux platforms are identical. But the mass spectrum obtained with the V8.6 on HP/UNIX and the mass spectrum obtained with the V8.8 on PC/Linux are not identical. For these reasons we had better to use the V8.6 code of Linux version to do physics analysis with the DST data, reconstructed by using HP/UNIX with version 8.6 code, on the PC/Linux platform instead of the Version of 8.8 code.

Comparison of CPU Power and Prices of PCs and HPWS

- Data off-line Reconstruction

  Reconstructed filtered data

$$\text{one events} = \begin{cases} \text{PII/400} & 0.023 \text{ seconds} \\ \text{HP735/125} & 0.246 \text{ seconds} \\ \text{HPJ2240 for 2 CPUs} & 0.039 \text{ seconds} \end{cases}$$

- $D_S^+ \to \phi\pi^+$ Analysis

  Kinematic Fitting

- $D^0 \to K^0\phi$ Analysis

  Without Kinematic Fitting

- Prices

Machine	Price	Date
PII/400	18 K RMB	November 98
HPJ2240 for 2 CPUs	350 K RMB	February 99

- Conclusion

  PII-400 CPU speed is much faster than HP735/125, and the prices of the PC is much much cheaper than that of HP Workstation.

Machine Name	CPU Data REC	CPU MC Simulation	CPU D Phy. Analy.	CPU Ds Phy. Analy.
hpws0	1.0	1.0	1.0	1.0
hpws6	0.6	0.6	0.6	0.6
hpws8	6.3	–	–	–
e781b	7.5	6.0	6.1	6.5
cquark0	10.0	8.0	8.2	8.7

Summary, Conclusion and Suggestion

- Converted V8.6 code from HP/UNIX to PC/Linux and the code has been running successfully.
- Using the V8.6 code of PC/Linux Version, we made a "Feasibility Study of the BES Data Off-line Reconstruction and D/Ds physics Analysis". The results show that PC/Linux can does data off-line reconstruction, Monte Carlo simulation and Physics analysis very well as HP/UNIX does.
- Kinematic variables from the data reconstructed on HP-UX and PC/Linux are identical within 5 digits after point. Physics Results would be the same from the both platforms.
- We have set a PC/Linux Cluster up, which consists of three PCs. It works well. Its running is very stable. No problem was found at all during time period of last 7 months (last 11 months by the end of September, 1999) running. The disk files (BES data, LIBs and user accounts and so on...) can be shared by each other. The PC/Linux Cluster works just like BES HP/UNIX Cluster.
- A PII-400 CPU power[3] are equal to that of "4 HP735/175 + 10 HP715/80" for data off-line reconstruction. But the price of the PII-400 is only a few percent of the HP Workstations. The PII-400 CPU power are equal to that of "1.66 HPJ2240", But the price of the PII-400 machine is only about 7% of the HPJ3340 Workstation.
- It is better to use V8.6 code on the PC/Linux platform to do D and Ds physics analysis with data taken at 4.03 GeV and reconstructed with the V8.6 code on HP-UX workstation.
- The Feasibility Study shows that the PCs based on Linux can do BES data off-line reconstruction and physics analysis as good as HP Workstations based on UNIX. The PC system is much much cheaper than HP Workstation system. The PC Cluster–"Distributed PCs System" works well. Based on the Network, the PCs hardware and Software within the cluster can be shared. Also the PCs and HP Workstation hardware and software environment can be shared by each others.
- Suggestion
  We suggest that the "Distributed PCs System Based on Linux" would be a good choice for BES/BES-II physicists and software experts to develope and/or upgrade the BES/BES-II data off-line processing system in the future, since the system is not only cheaper, but also powerful.

[3]Measured based on the V8.6 BES software of PC/Linux version with the optimized C, C++ and FORTRAN Compilers.