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The STAR Level-3 Trigger System

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STAR Level-3 Trigger

Online event (helix) reconstruction (input rate 100 Hz)
of high multiplicity Au+Au and p+p collider events
($N_t \approx 8000$ tracks/event, $N_p \leq 45$ points/track)

- STAR experiment @ RHIC
- Example Applications
- Level-3 Cluster Finder
- Level-3 Track Finder
- Level-3 Fast Network (MYRINET, SCI)

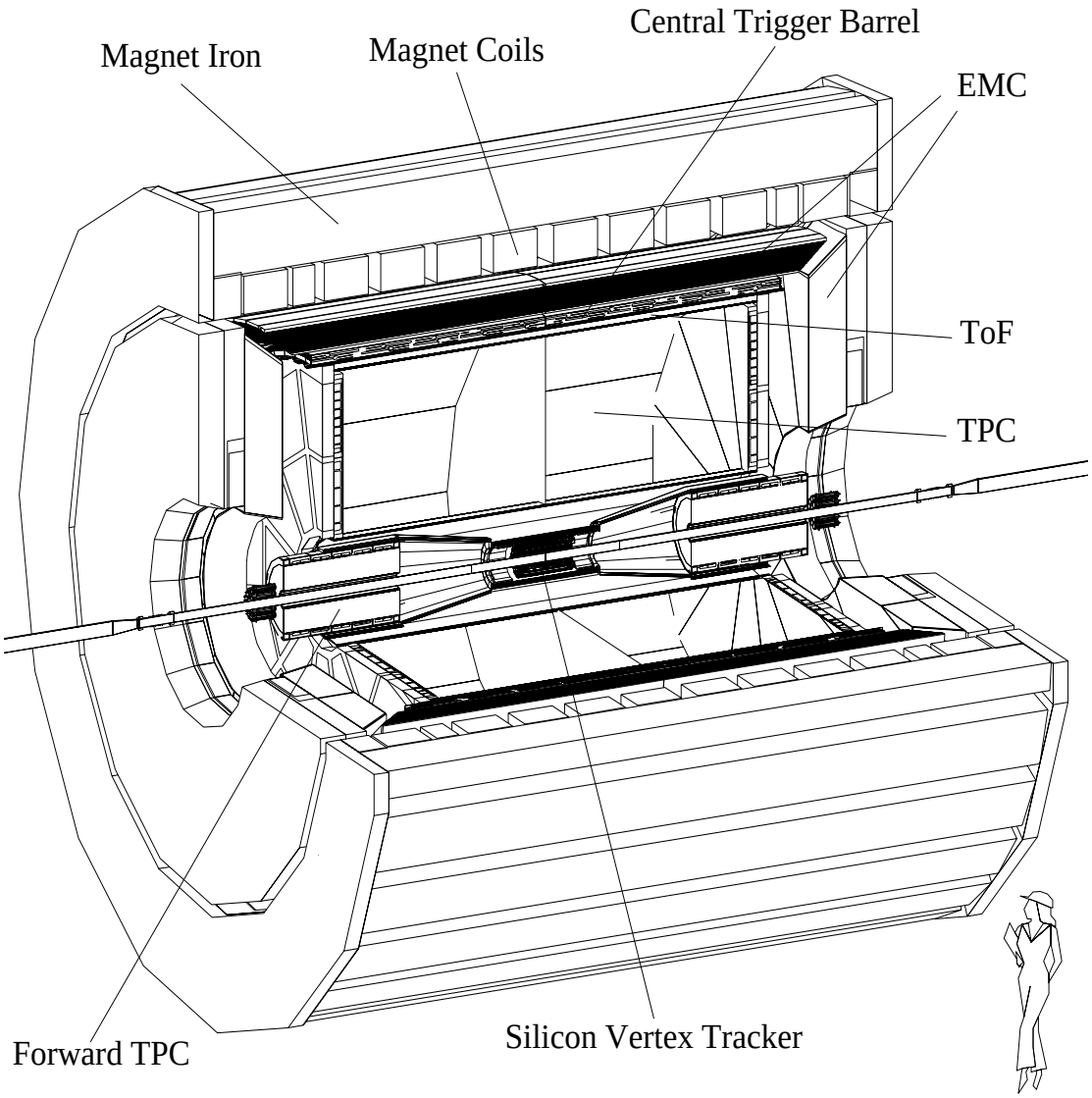
STAR Experiment

Solenoidal **T**racker **A**t **R**HIC

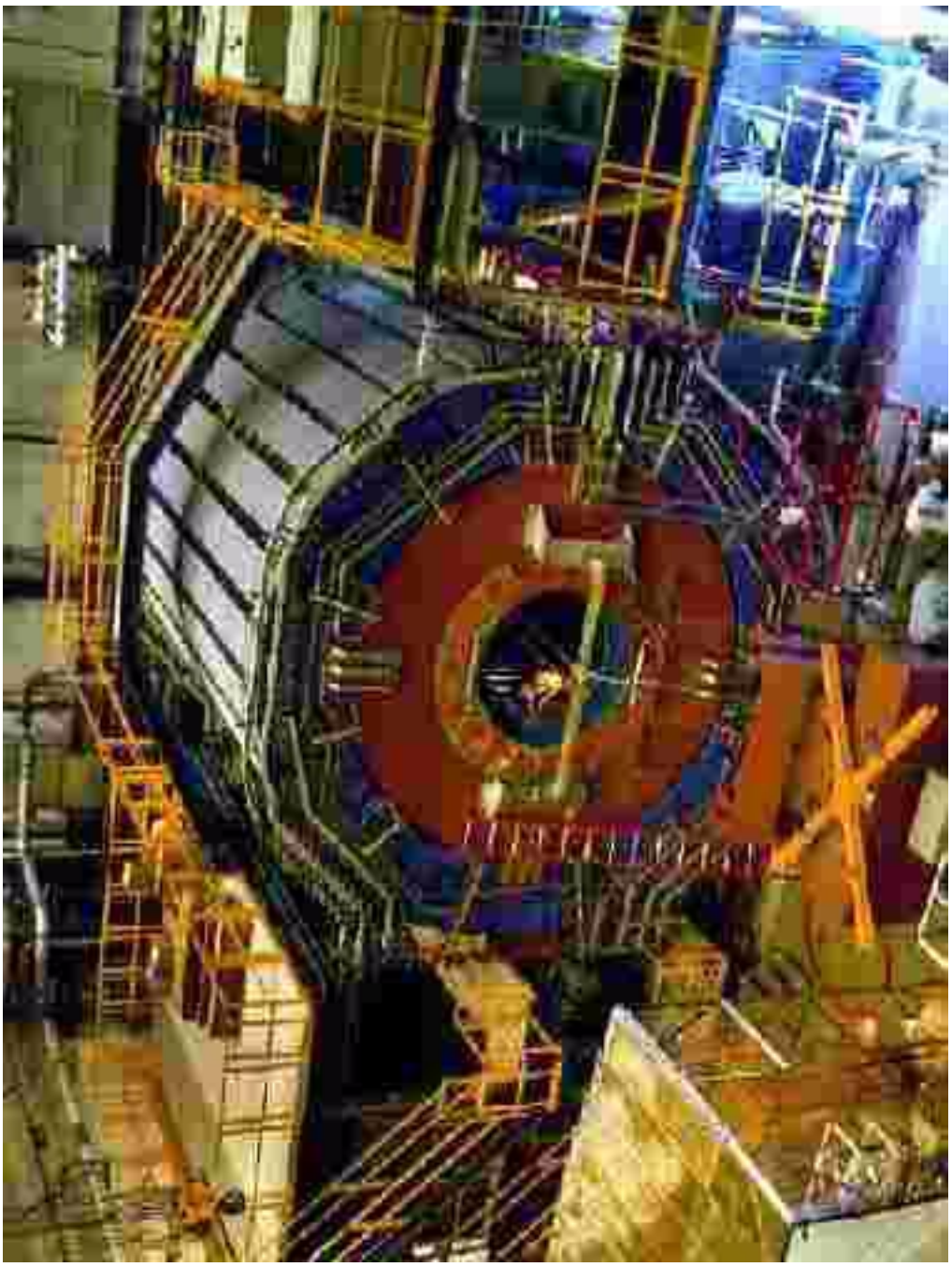
Au+Au at $\sqrt{s} \leq 200$ GeV/N

p+p at $\sqrt{s} \leq 500$ GeV/N

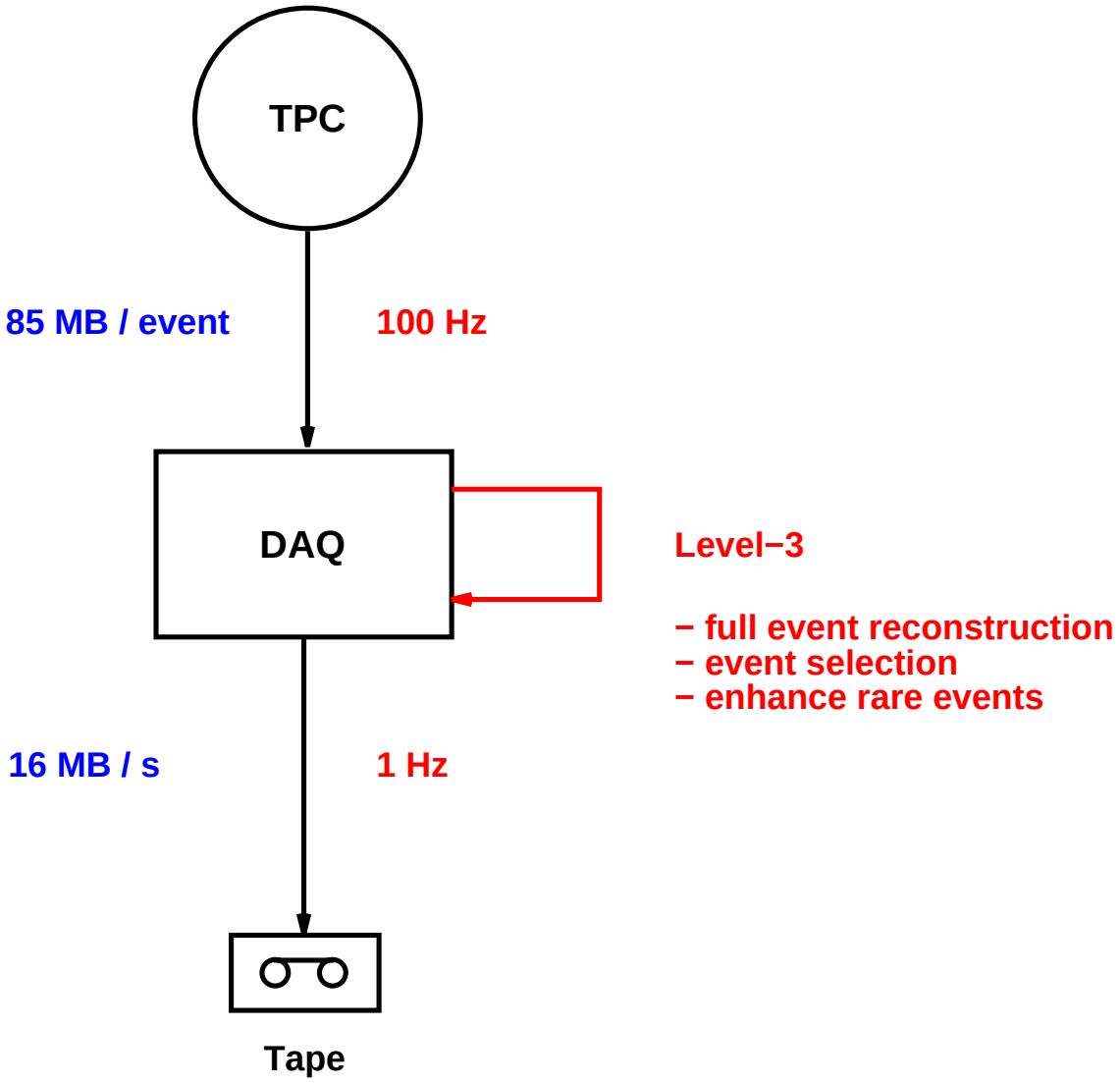
Physics run starting in March 1999



1st Year: Level-3 Trigger based on TPC data only



Motivation


TPC
85 MB / event
100 Hz
DAQ
Level−3
− full event reconstruction
− event selection
− enhance rare events
16 MB / s
1 Hz
Tape

Level-3 Trigger Application Examples

Au+Au collisions at $\sqrt{s} = 200 GeV/N$

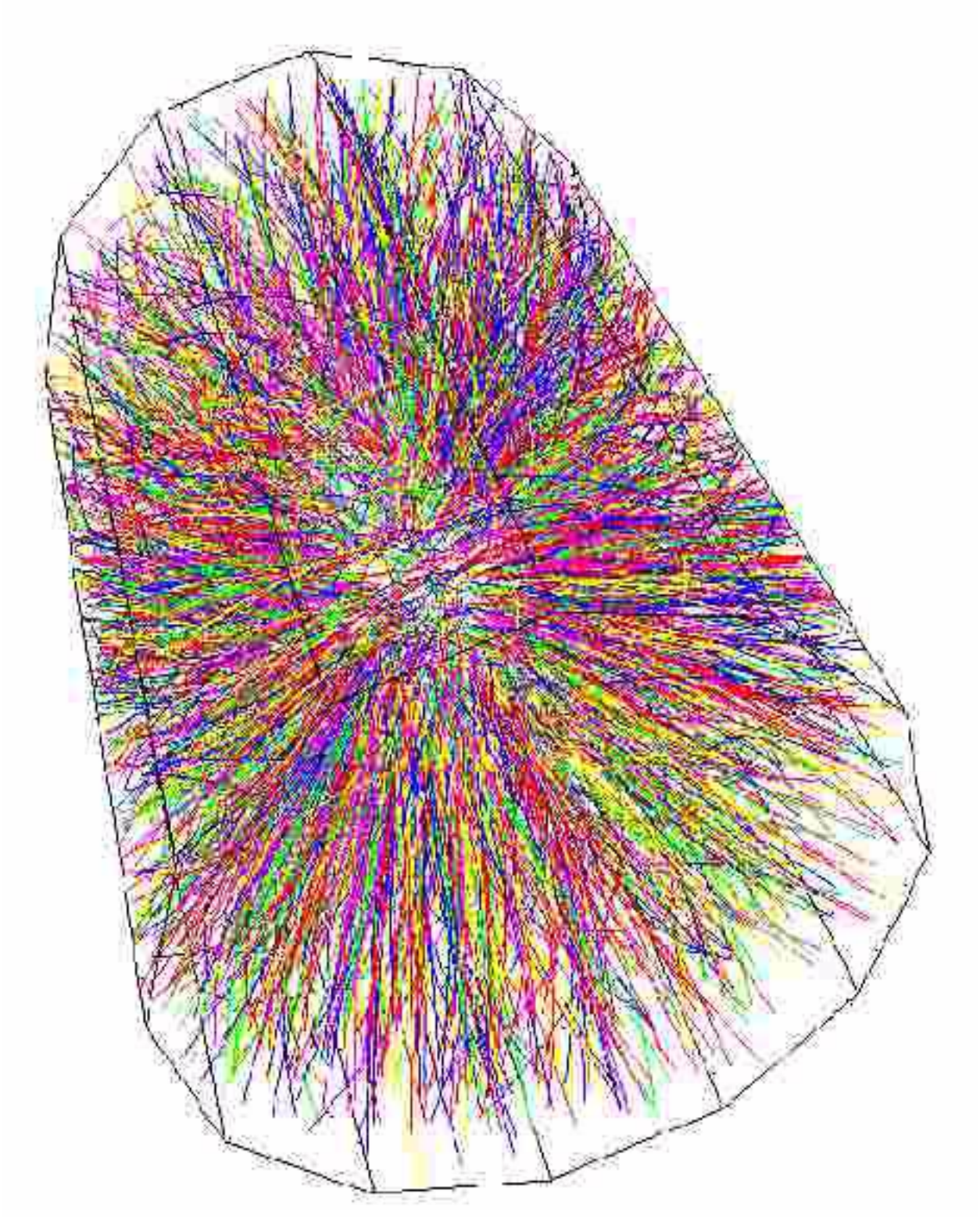
- $J/\psi \rightarrow e^+ e^-$ as probe for the Quark Gluon Plasma
  online high p_T / invariant mass cut

	$N_{J/\psi}$ /day
without L3 Trigger	3.5
with L3 Trigger	330

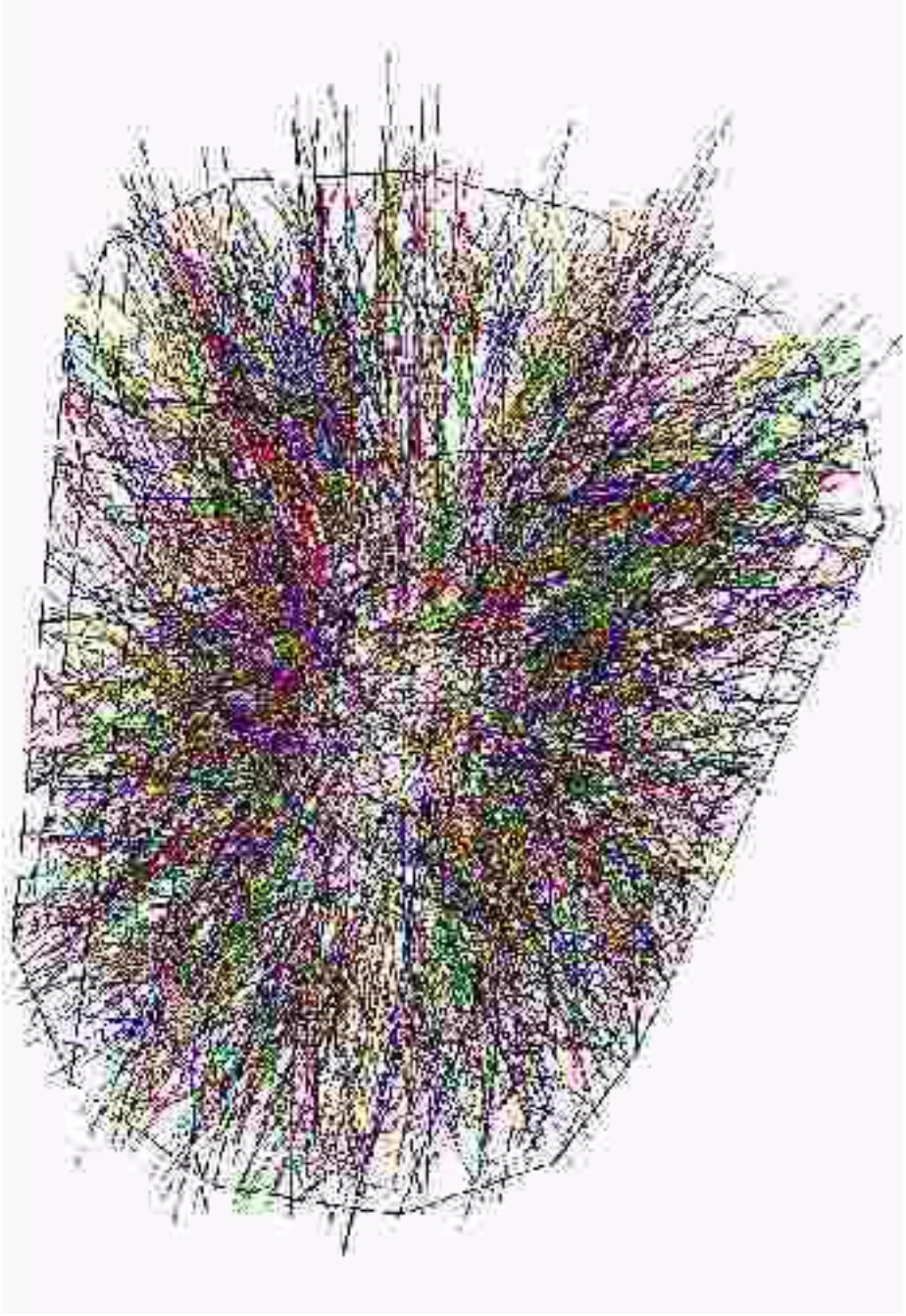
- Heavy (anti-) fragments (e.g. $^4\overline{He}$)
  online high p_T / dE/dx cut
- EMC calibration (high p_T π^-)

p+p collisions at $\sqrt{s} = 500 GeV/N$

Filtering of 700 TPC pile-up events per bunch-X

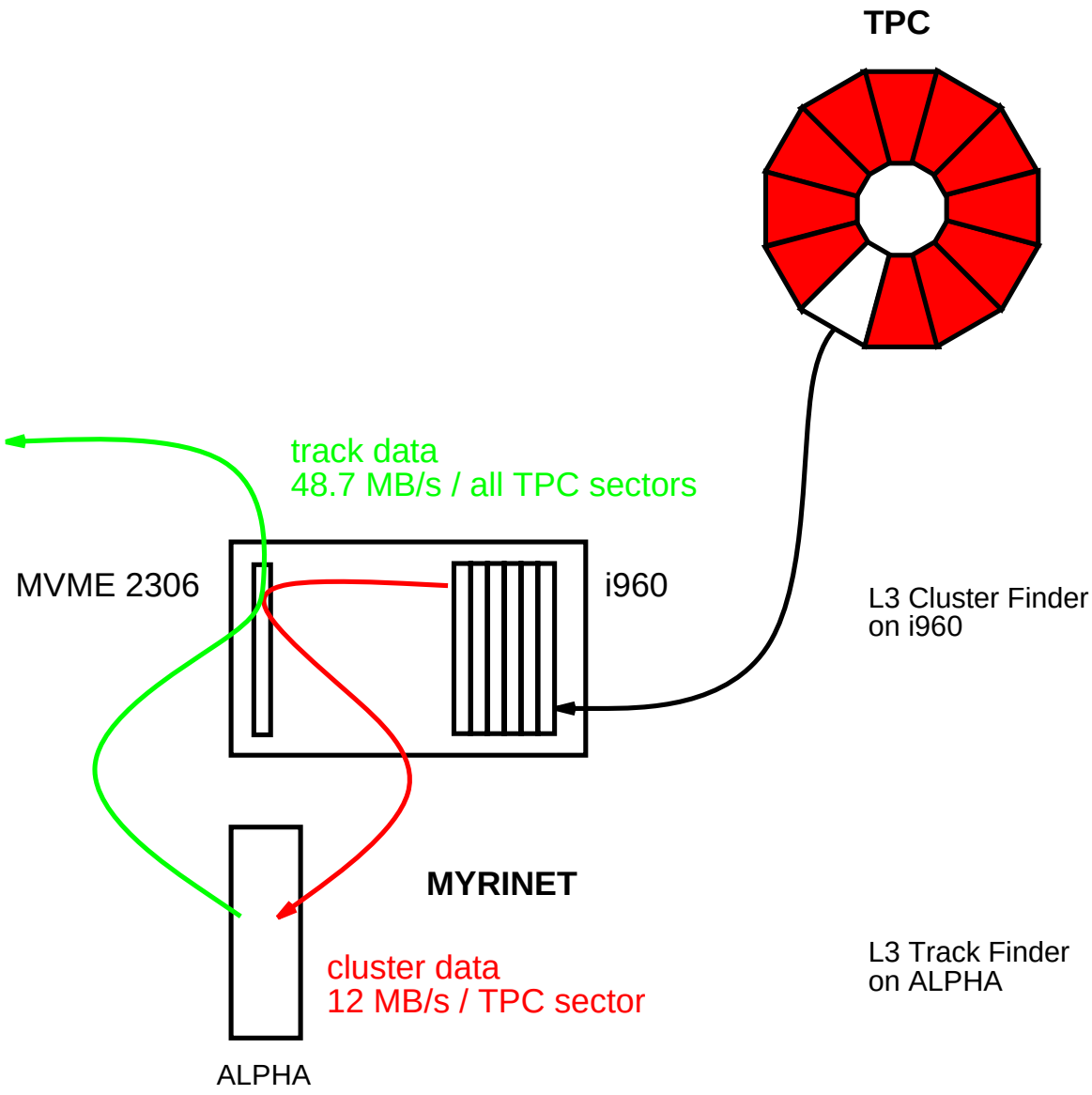


AuAu @ 200 GeV



pp @ 500 GeV

Level−3 Sector



Level-3 Cluster Finder

- **platform**:

  Intel i960 @ 33 MHz (VxWorks)
  (24 sectors *x* 6 receiver boards *x* 3 i960 = 432 CPUs)

- C program + Inline Assembler (600 lines)

- **time constraint**:

  $\tau_{cluster} \leq 10$ ms @ TPC readout rate $R=100$ Hz

- **input:**

  TPC ADC raw data (per sector 6912 pads x 512 time bins)
  (~62 MB/s per sector)

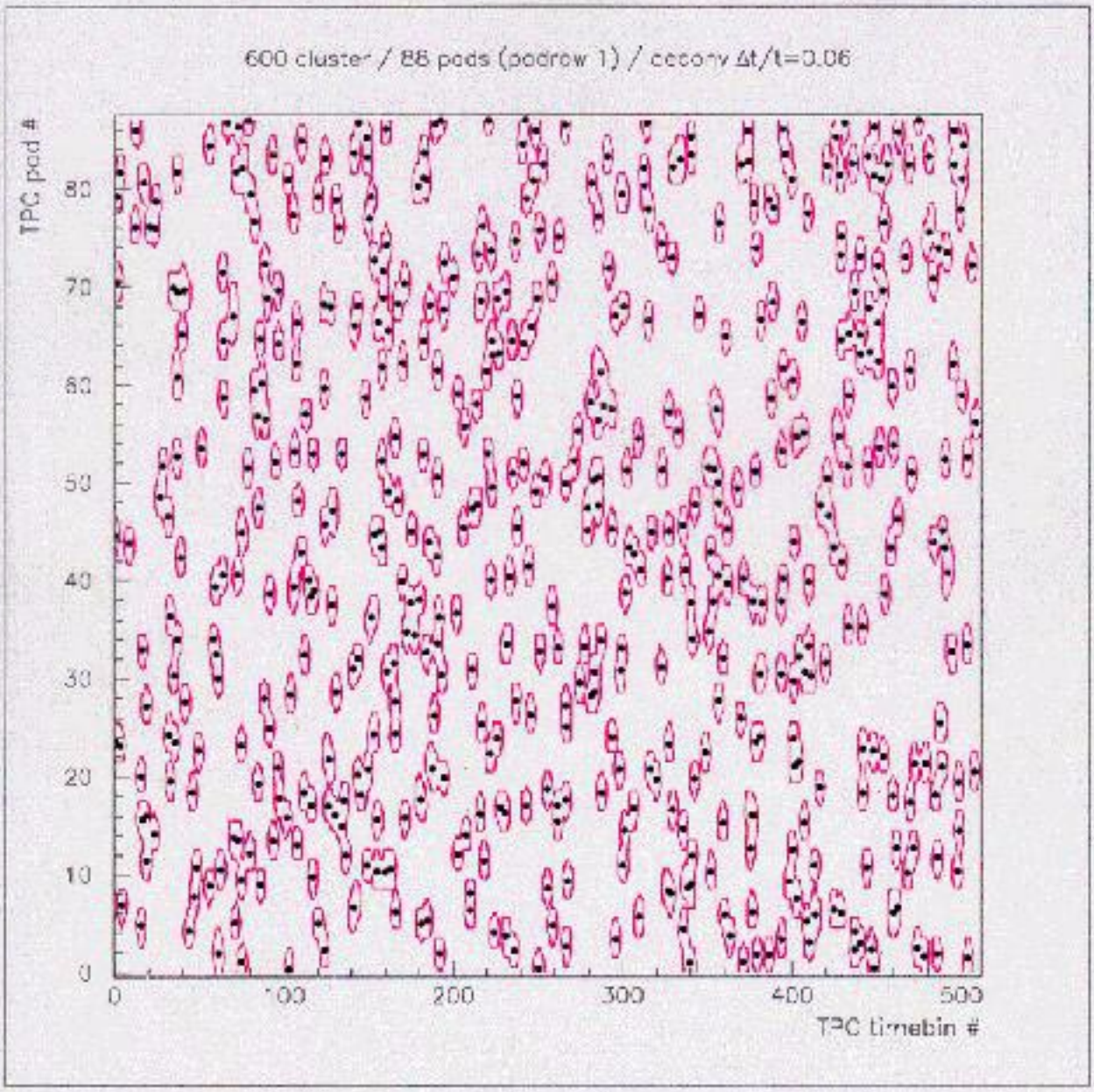
- **output:**

  cluster data (center-of-gravity, ADCsum)
  (~12 MB/s per sector)

- **Level-3 vs. offline analysis**:

  no cluster merging at sector partition boundaries

EFFICIENCY $\varepsilon \approx 93\%$

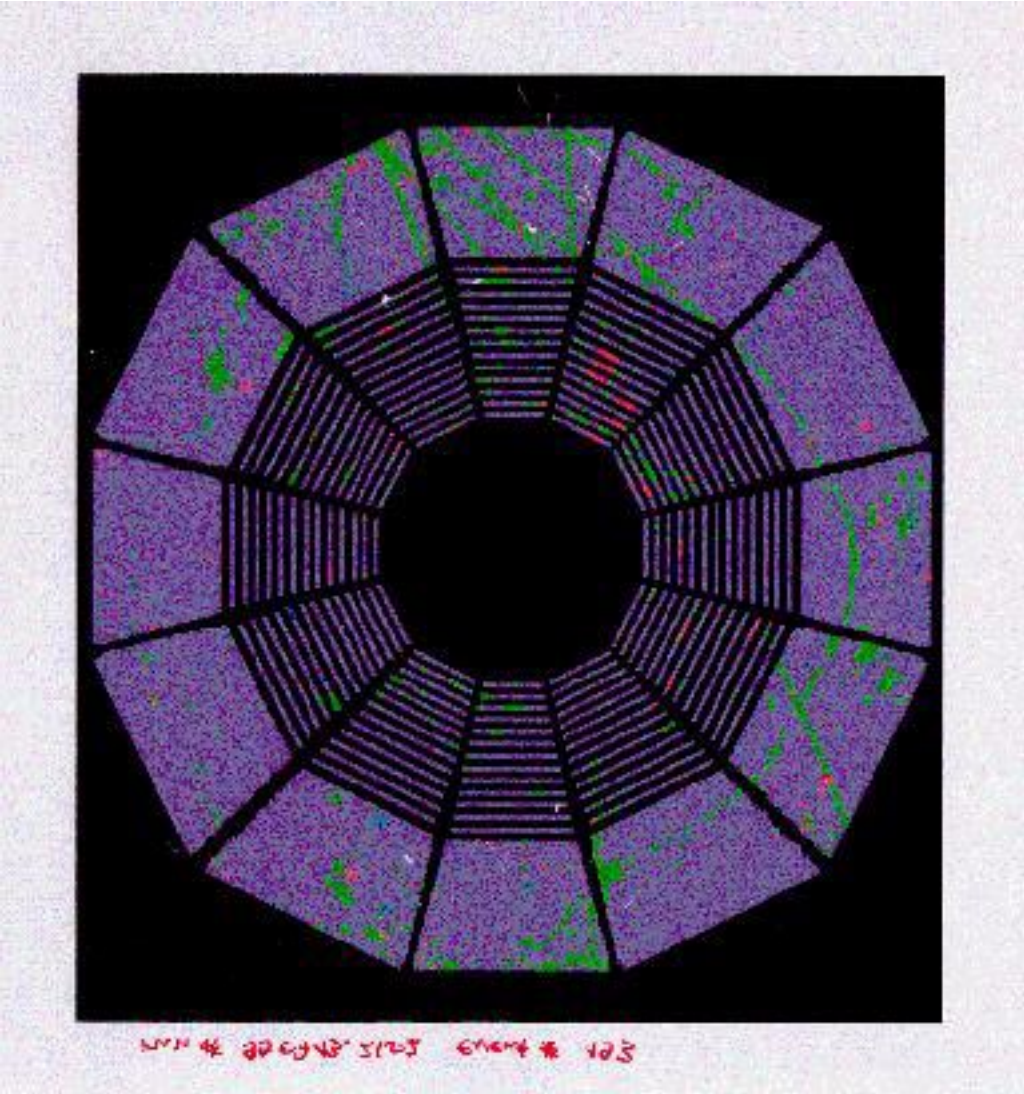


RESOLUTION

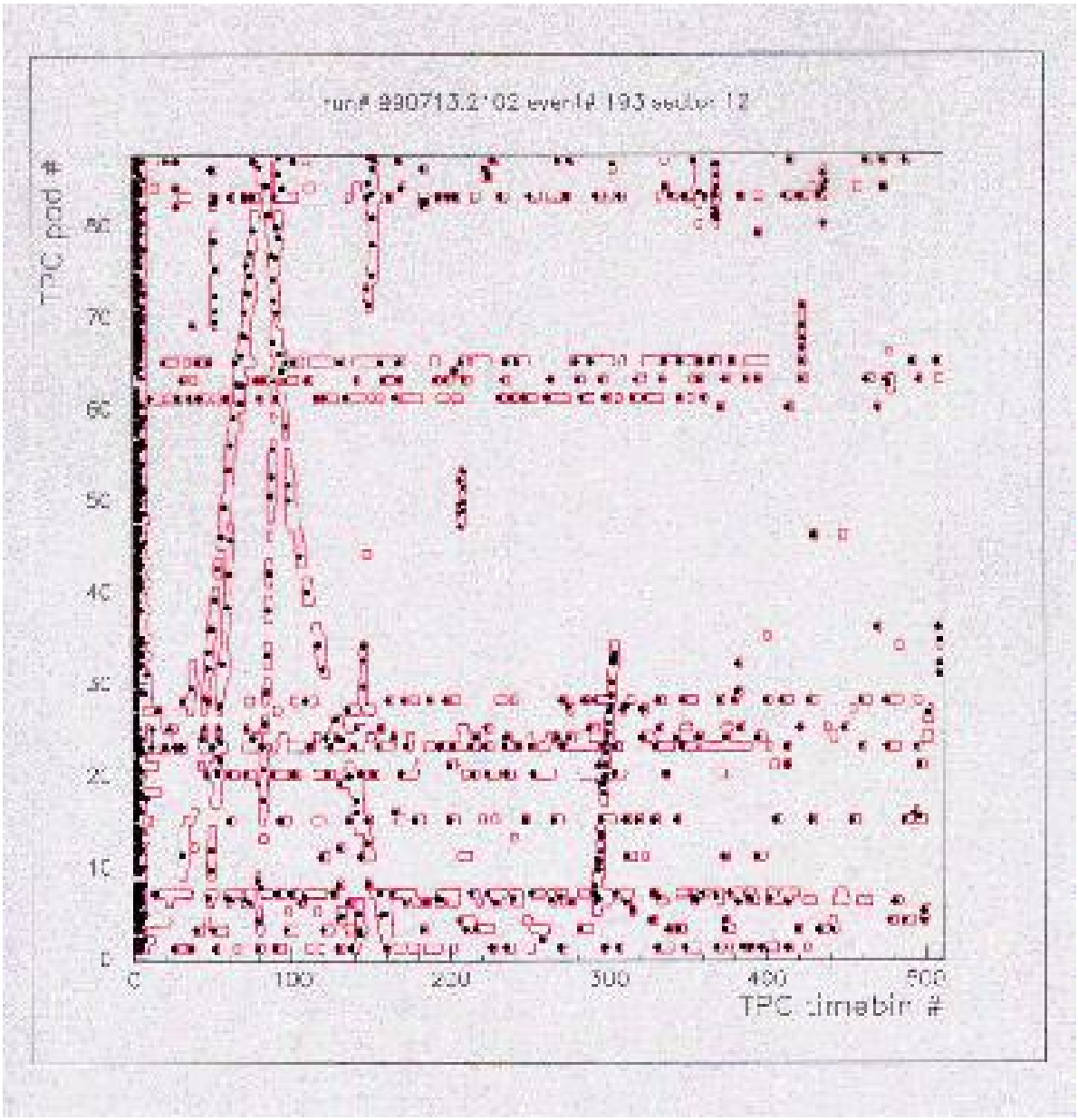
$\Delta r\varphi \approx 37\ \mu m$

$\Delta z \approx 13\ \mu m$

$t \approx 7.5$ ms @ i960 33 MHz per padrow DECONVOLUTION $\frac{\Delta t}{t} \approx 6.0\%$



cosmic event (7/13/1999)
next page shows view through TPC sector (top center)


TPC pad #
TPC timebin #
0
100
200
300
400
500

Level-3 Track Finder

- **platform**: ALPHA DS-10 **(21264, 64 bit, 466 MHz)**
  - hardware sqrt() on chip (~30 sqrt() calls / track)
  - 4MB L2 cache on chip (fast digging on track data)

- Linux 2.2.12

- C++ program (1500 lines)

ALPHA DS-10 466 MHz
t = 87 ms
Pentium II 450 MHz
t = 135 ms

- **time constraint**:

$\tau_{track} < 12 \; x \; \tau_{event} - \tau_{cluster} = 110 \; ms$ phase 1 (now)

$\tau_{track} < \tau_{event} = 10 \; ms$ phase 2 (2002)

- **algorithm**: conformal map **NIM A380(96) 582**

(a) transformation circle -> straight line
(b) “follow your nose” fit

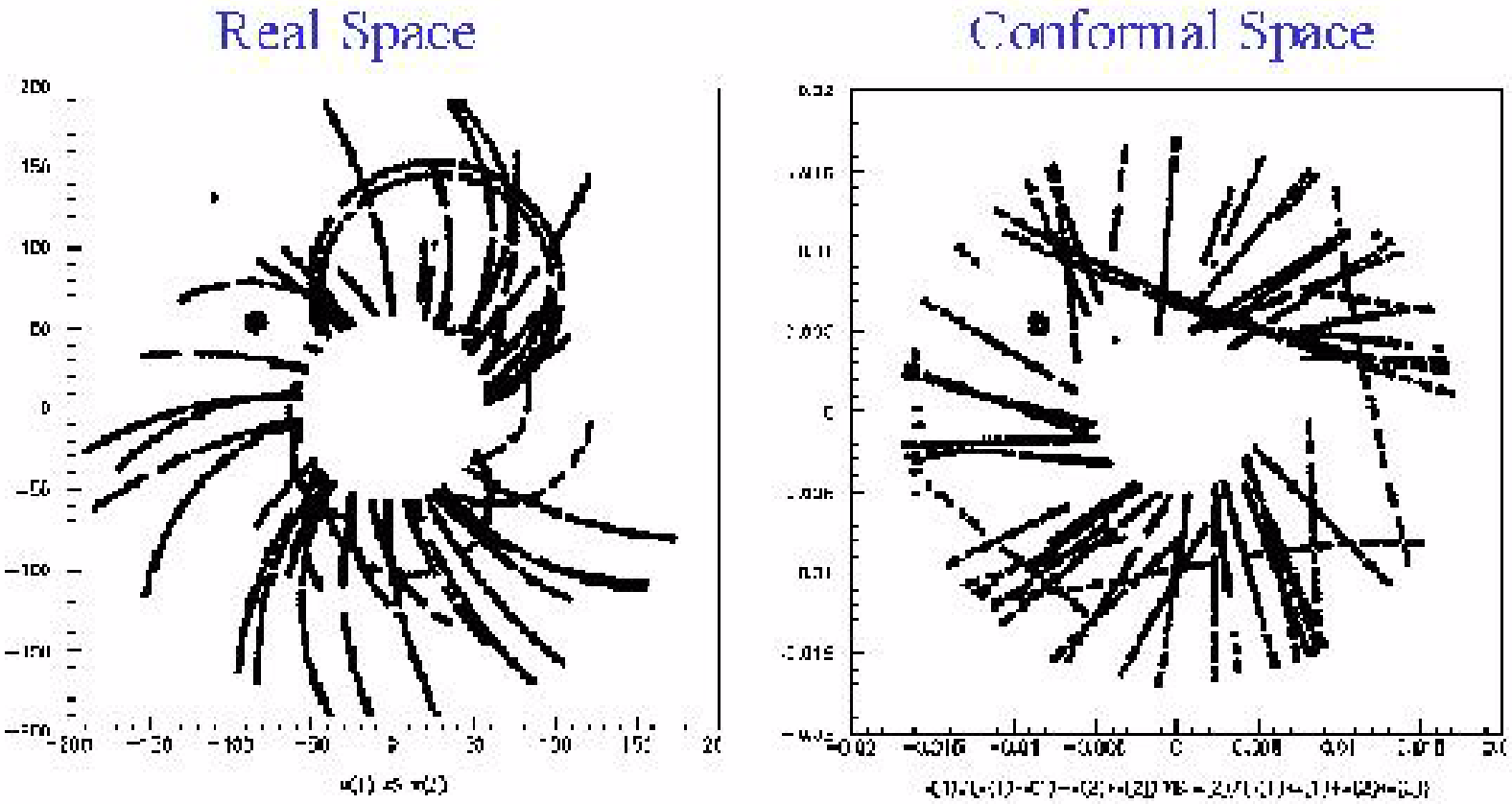
- **Level-3 vs. offline analysis**:

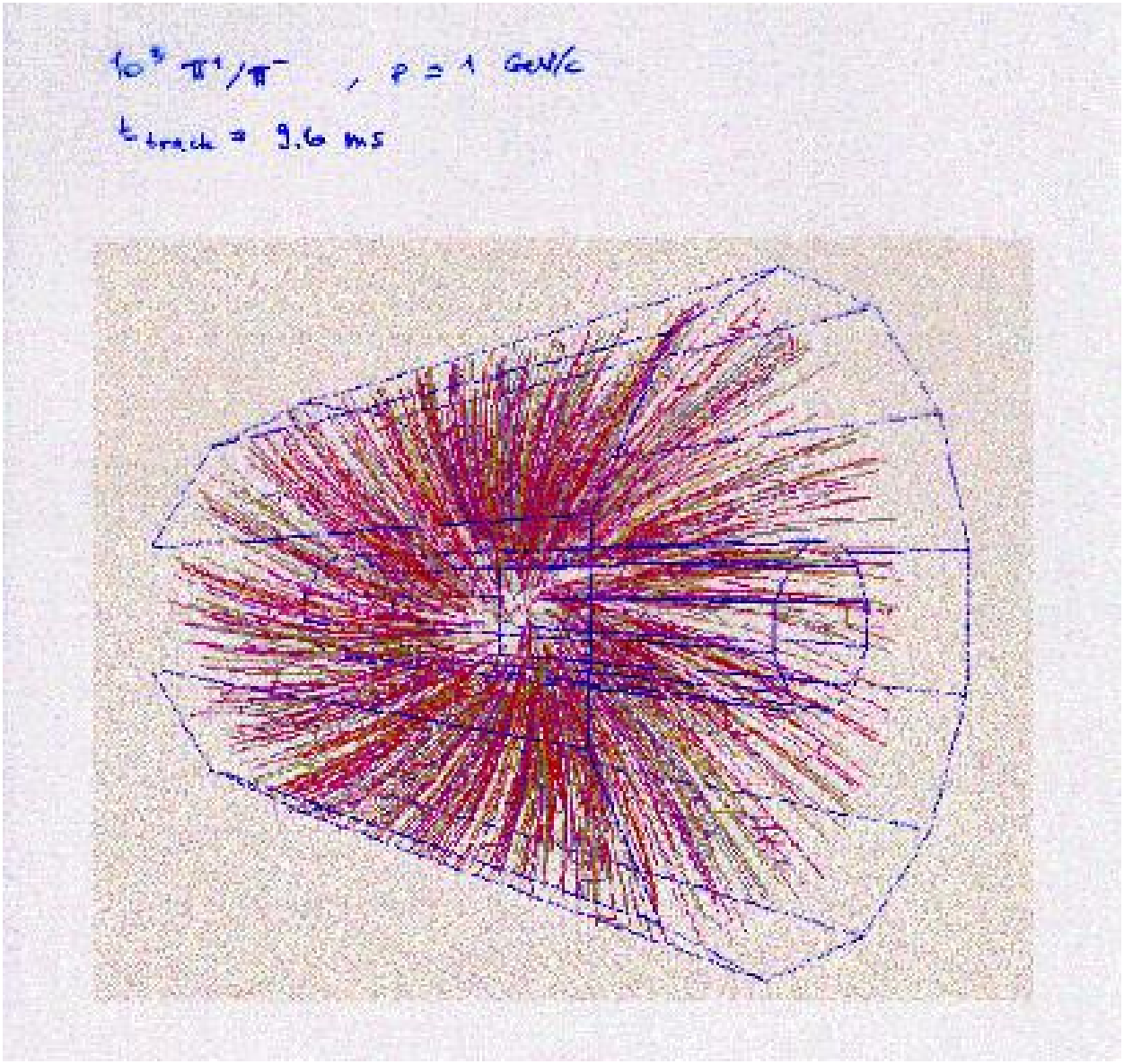
- no track merging at sector boundaries (low p_T spirals)
- vertex constraint (conformal space)

- **input**: cluster data (~12 MB/s per sector)

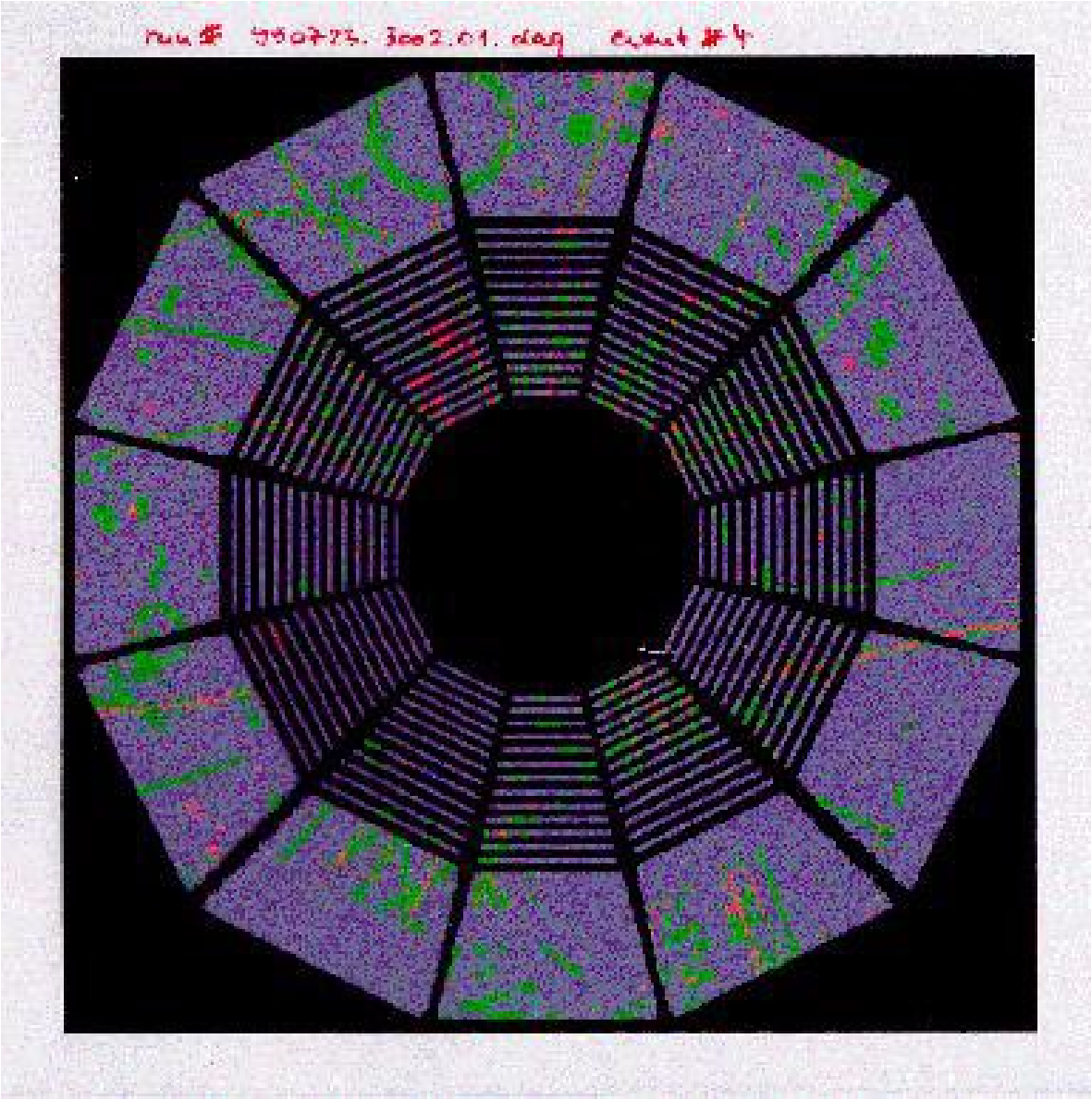
- **output**: track data (~48 MB/s whole TPC)

Conformal Mapping

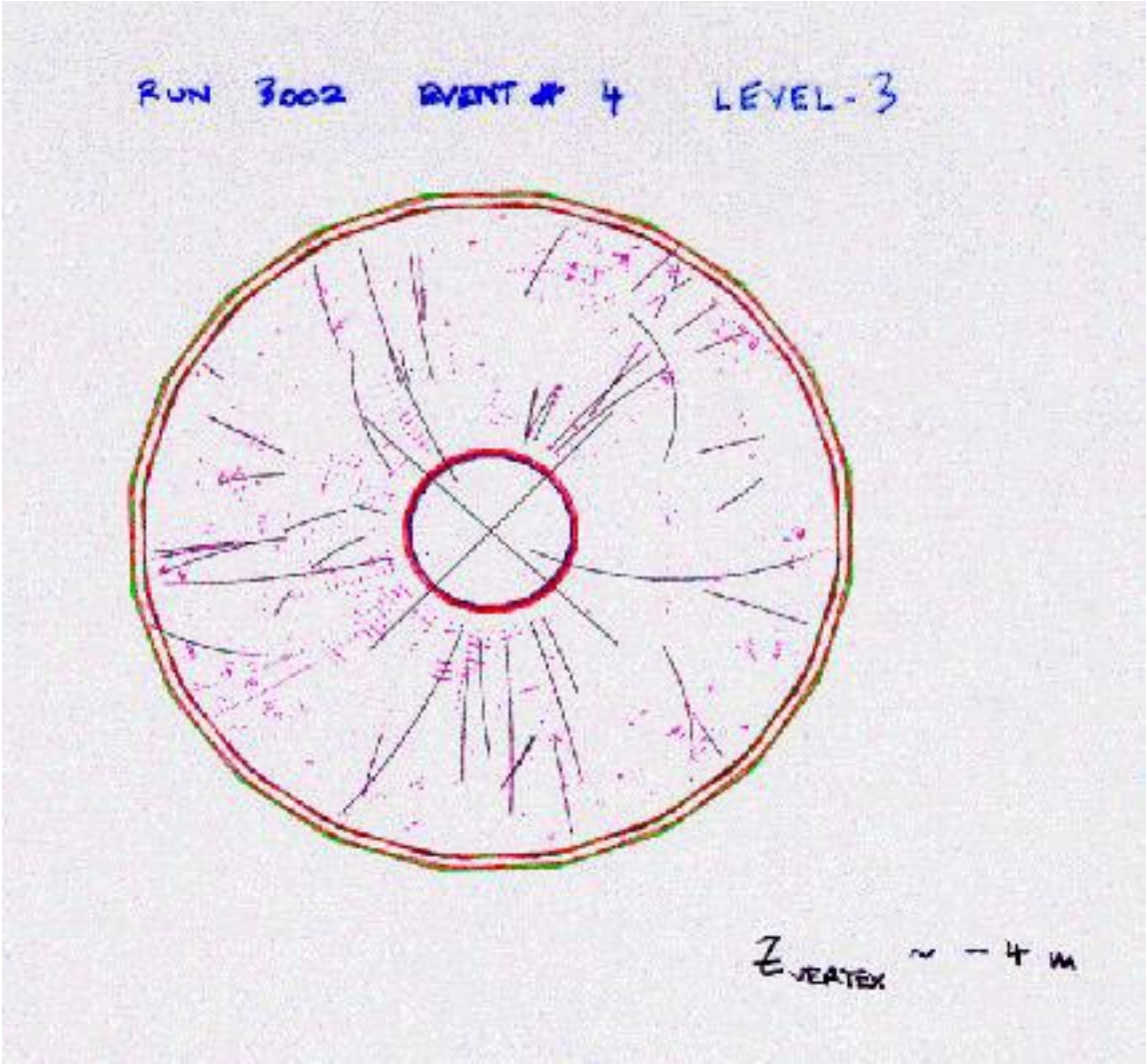



10^3 π^+/π^- , $p = 1$ GeV/c
$t_{track} = 9.6$ ms

cosmic, single tracks, optimized ε_{Track} , not N_{Track} (χ^2 loose)



beam-gas event (7/23/1999)

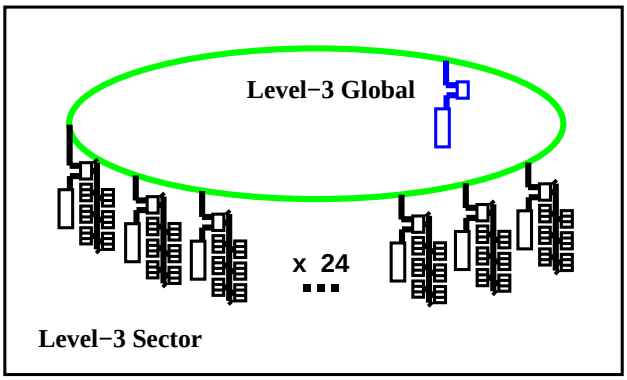


same beam-gas event tracked offline using L3 Track Finder
(not reconstructed tracks due to z_{vertex} outside TPC,
i.e. η/ϕ slice mismatch)

Level−3 Fast Network

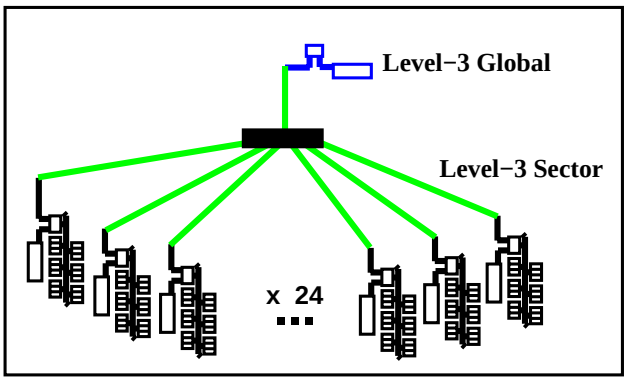
- different from (Gigabit−)Ethernet
  - point−2−point
  - DMA (CPU not busy)
    consumption ~ 12 %

- SCI
  (Scalable Coherent Interface)
  very low latency ~ 3 µs
  DMA 1−step



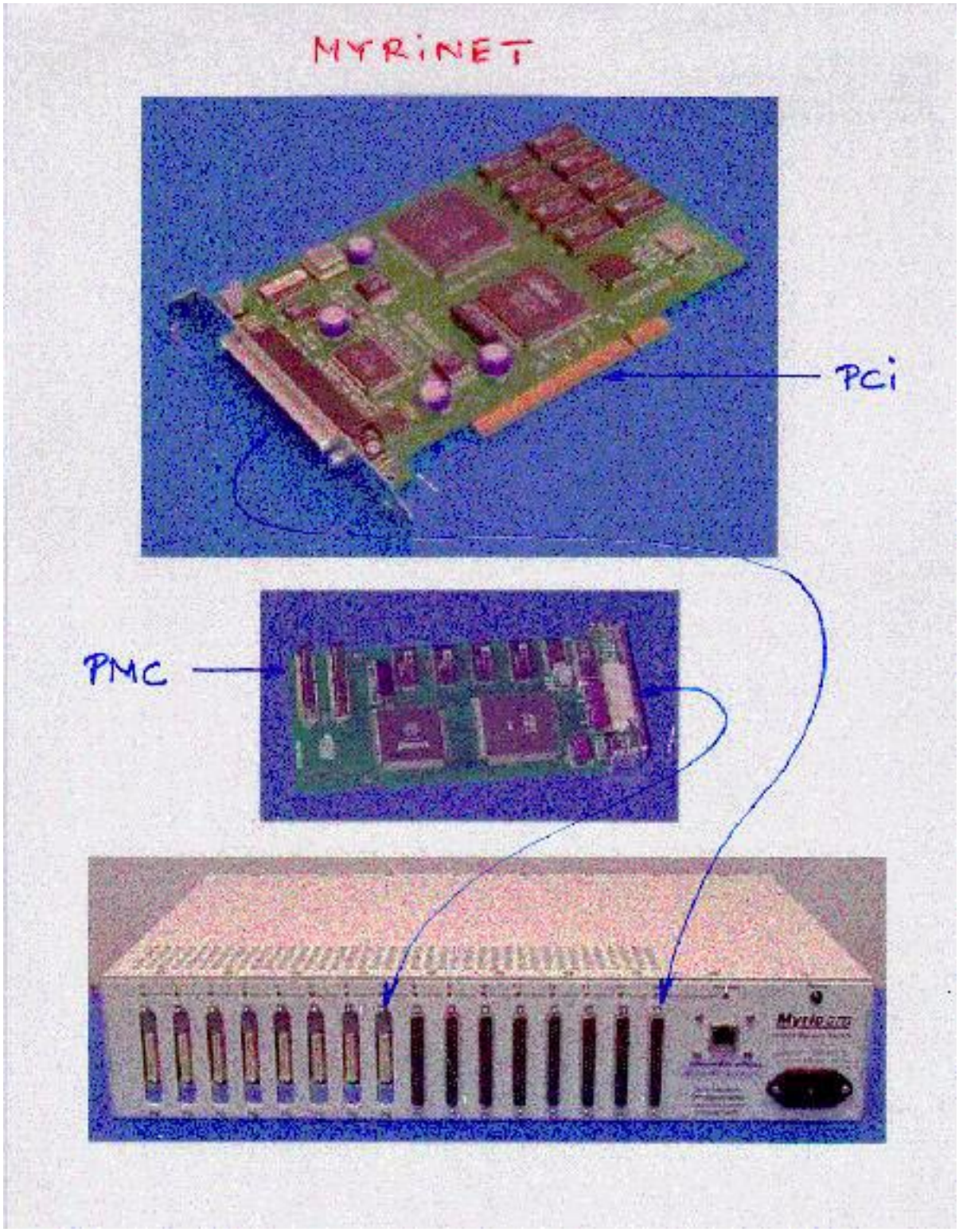
Ring Topology / SCI

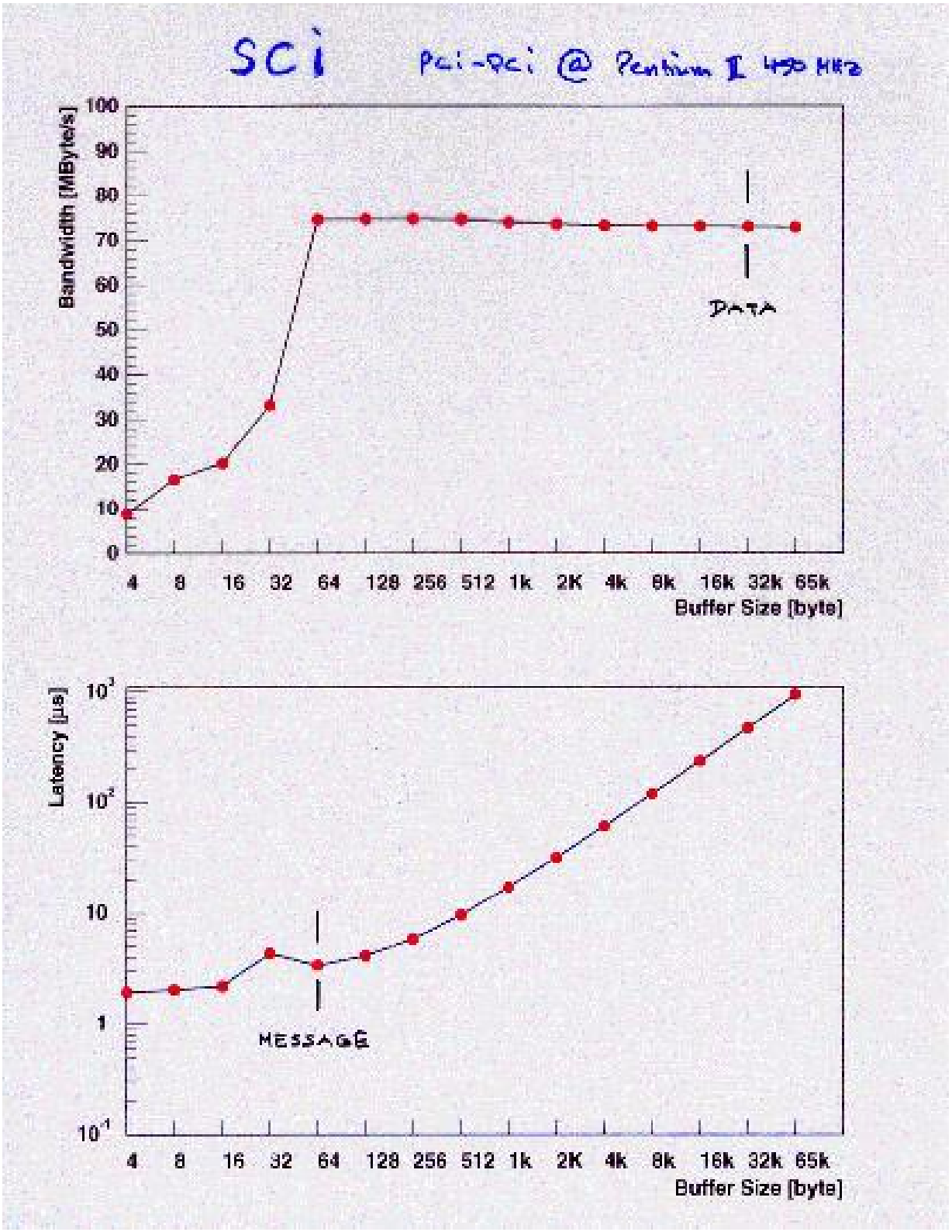
- MYRINET
  low latency ~ 30 µs
  DMA 2−step (via SRAM)

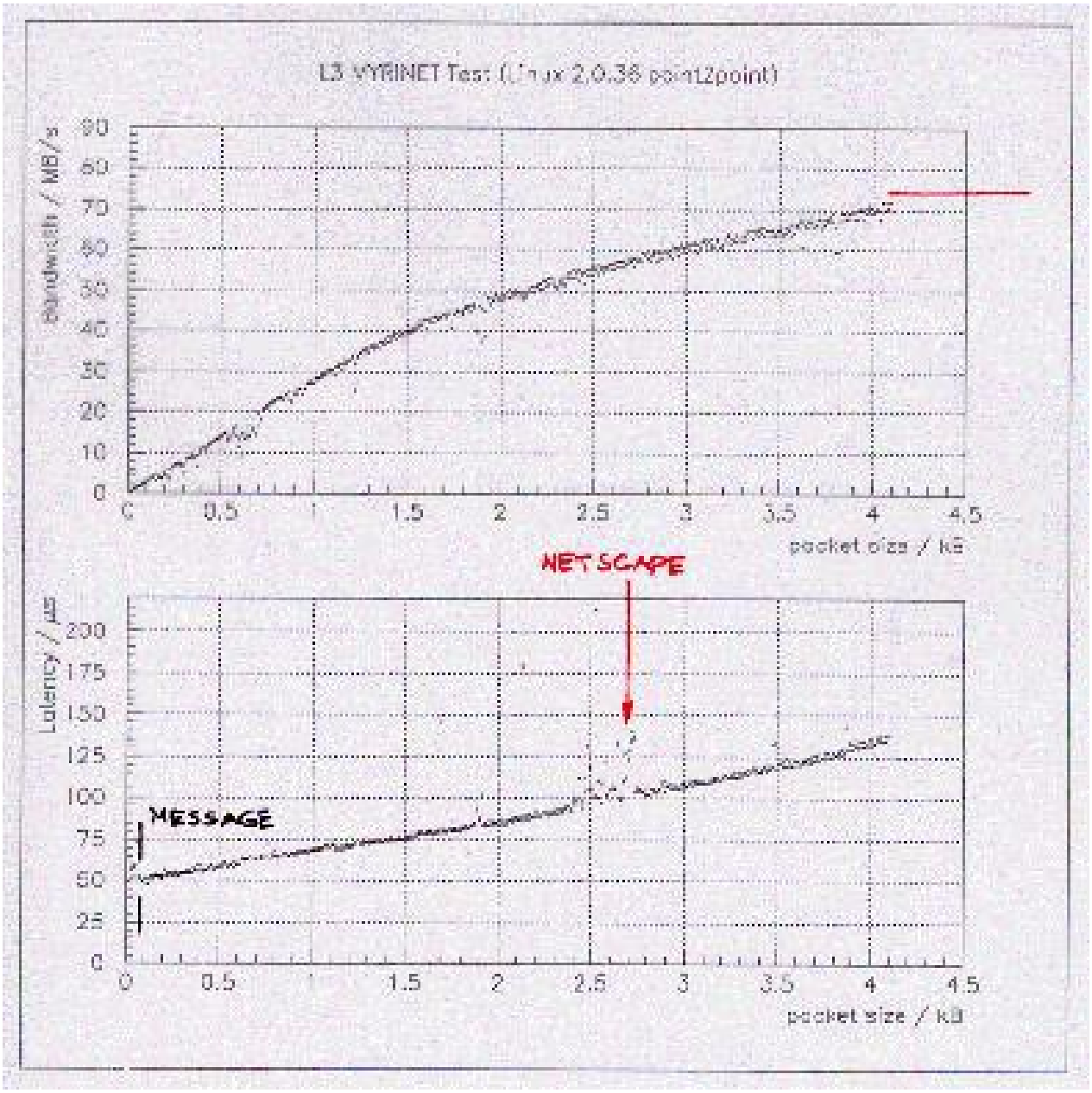


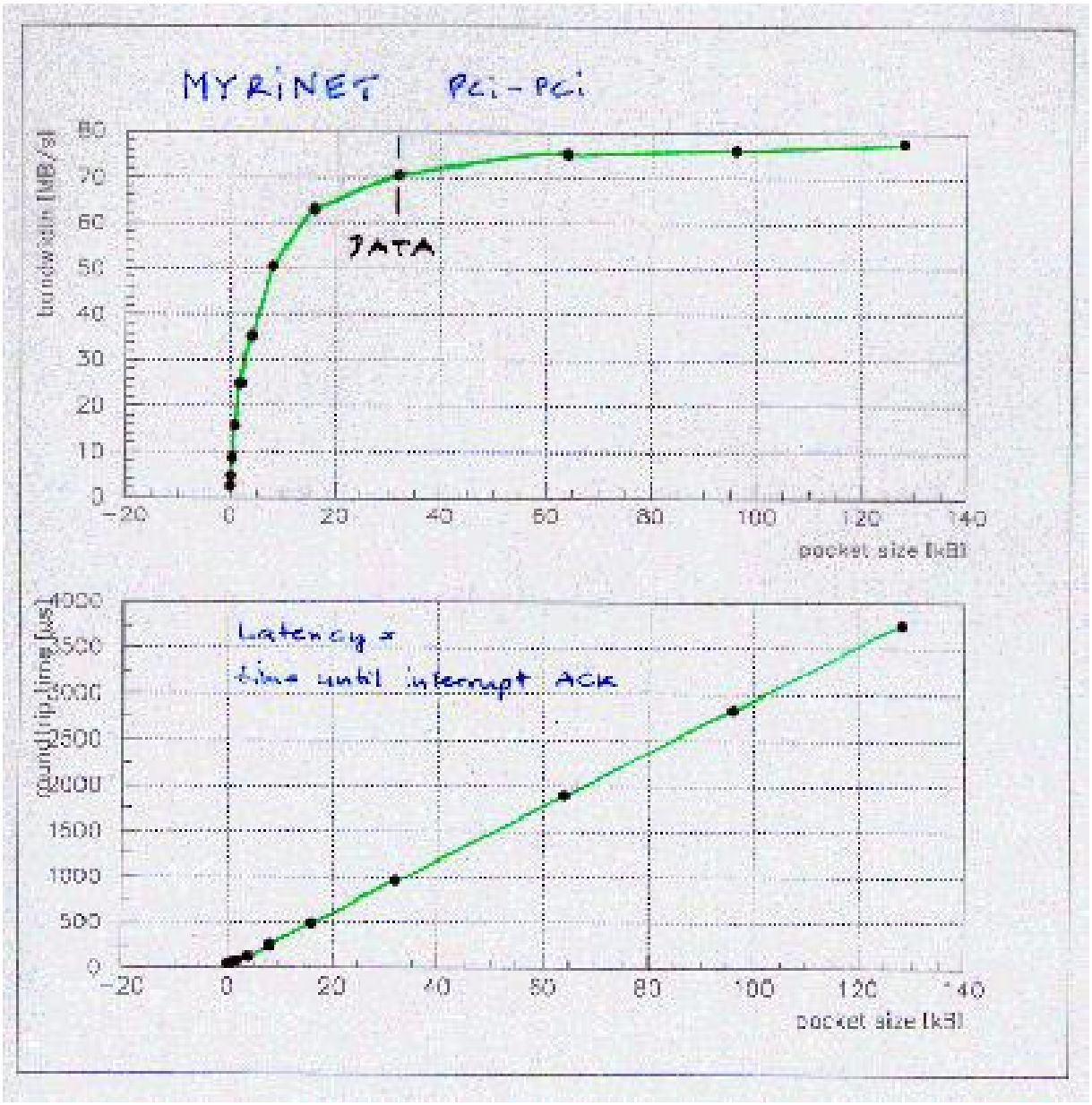
Switch Topology / MYRINET

- Decision for MYRINET
  - no further hardware modification necessary (EPROM)
  - ready−for−use driver for ALPHA/Linux and VxWorks

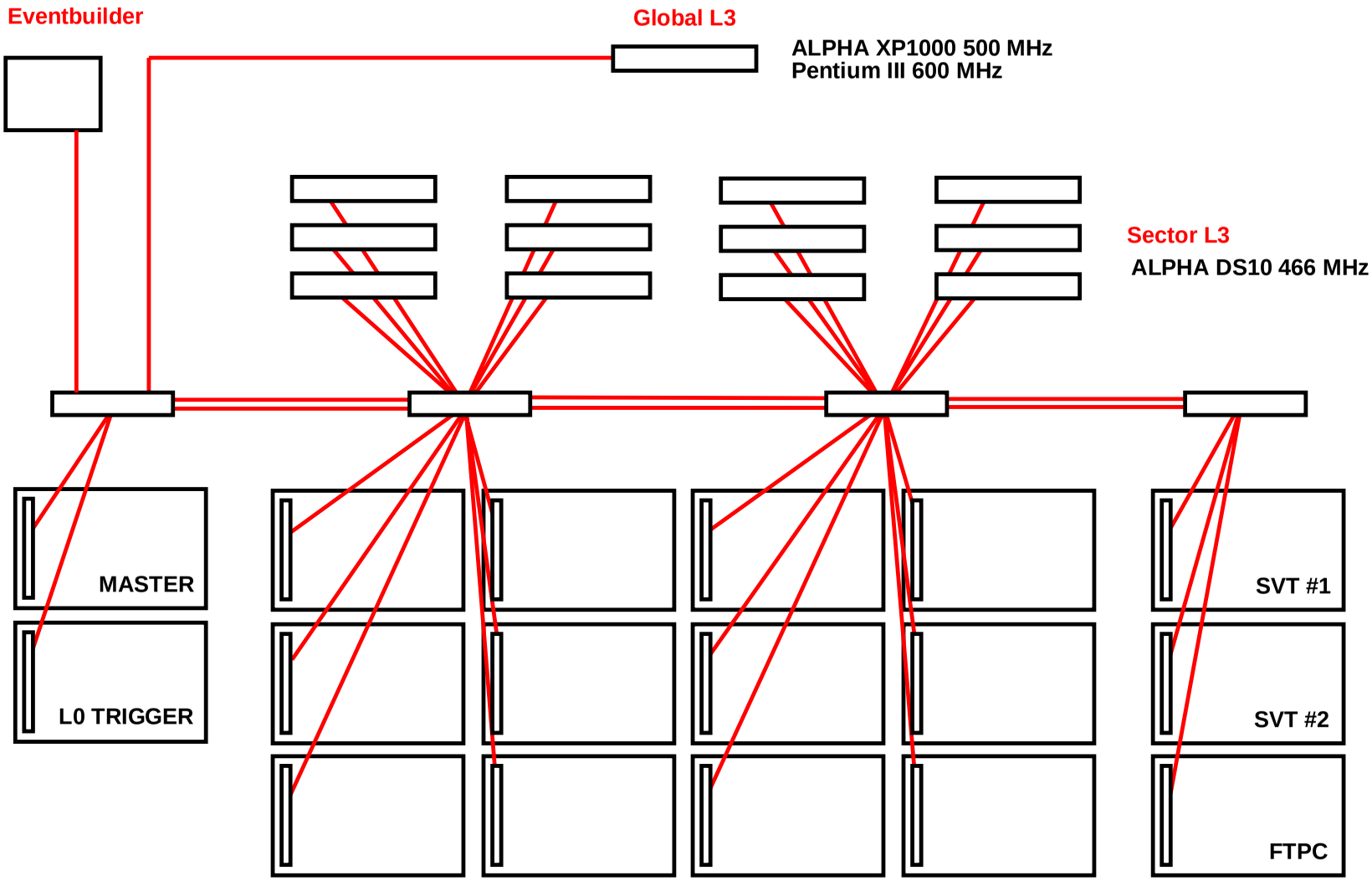

MYRINET
PCI
PMC


SCI
PCI-PCI @ Pentium II 450 MHz
Bandwidth [MBytes/s]
100
90
80
70
60
50
40
30
20
10
0
DATA
4 8 16 32 64 128 256 512 1k 2K 4k 8k 16k 32k 65k
Buffer Size [byte]
Latency [µs]
10^2
10^1
10
1
10^{-1}
MESSAGE
4 8 16 32 64 128 256 512 1k 2K 4k 8k 16k 32k 65k
Buffer Size [byte]


L3 VYRINET Test: (Linux 2.0.38 point2point)
bandwidth / MB/s
packet size / kB
latency / µs
NETSCAPE
MESSAGE
packet size / kB


MYRINET PCI-PCI
bandwidth [MB/s]
80
70
60
50
40
30
20
10
0
-20
0
20
40
60
80
100
120
140
packet size [kB]
DATA
round trip time [µs]
4000
3500
3000
2500
2000
1500
1000
500
0
Latency =
time until interrupt ACK
packet size [kB]

STAR Level−3 Setup 12/99



Apex

STAR Level-3 Trigger =

- ALPHA 21264 / Linux processor farm
  MYRINET interconnected
- first “real” data processed
  (cosmics, beam-gas events)
- prototype 12/99

  1 track finder CPU / 2 TPC sectors
  R=20 Hz (design goal R=100 Hz)
- envisaged start RHIC physics program
  3/01/2000