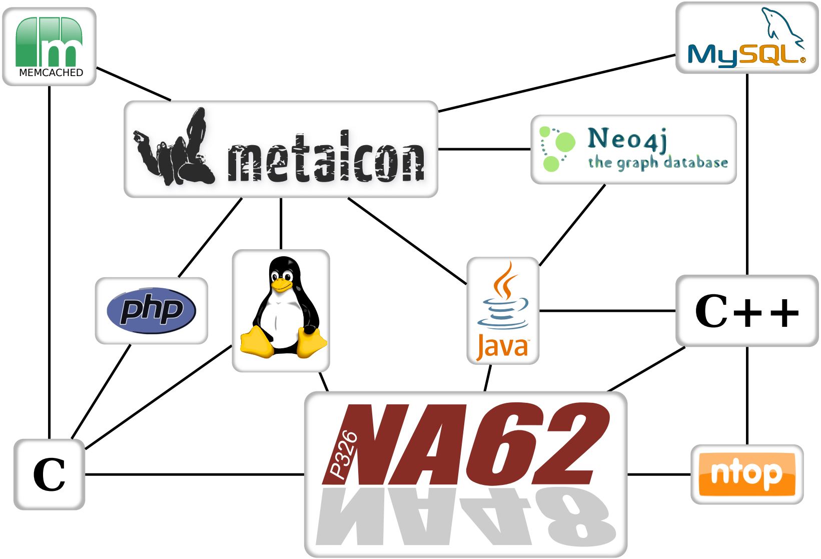
Jonas Kunze: IT affine physicist



How to analyze 12 GBps data online

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1. Motivation
   - The physics
   - The experiment
2. Trigger topology
   - Three level online trigger
   - New proposal
3. Implementation
   - Socket programming
   - Parallel programming
4. Conclusion

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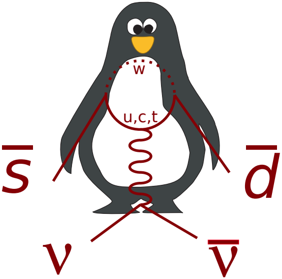
The Kaon K^+

- An elementary particle like Proton, Neutron...
- Decays within 12 ns

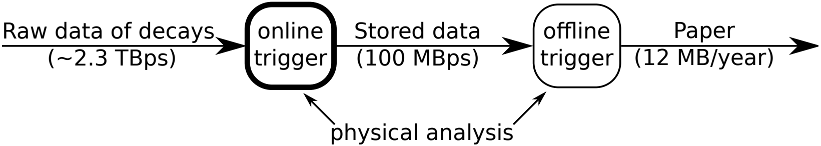


$K^+ \to \pi^+ \nu \bar{\nu}$

Extremely rare: 1 out of 10^{10} decays

What it does mean

1 out of 10^{10} decays is like taking a 227 kB picture of every human being on earth and filtering those with red hair, green-brown eyes, 3 birthmarks at the right cheek, being smaller than 1.50 m . . .



Raw data of decays (~2.3 TBps)

online trigger

Stored data (100 MBps)

offline trigger

Paper (12 MB/year)

physical analysis

The NA62 Experiment at CERN

- About 90 physicists from I, GB, RU, BE, USA, DE . . .
- Will measure about 100 decays within 2 years
- Needs to analyze 10^{13} K^+ decays

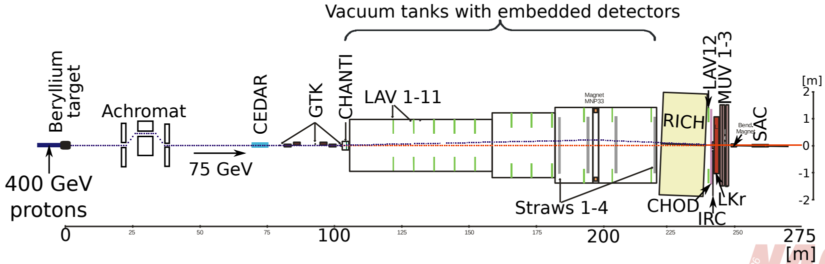
NA62 Experiment at CERN

K^+ production

High energy protons colliding with a beryllium target

Measurement

- 0.8 GHz particles crossing
- 9 “cameras” shooting a picture at every decay (10 MHz)



Data rates

10 MHz event rate or “10 Mio. pictures per second”

Detector	Event size [B]	Data rate [GBps]
CEDAR	216	2.16
GTK	2250	22.50
CHANTI	192	1.92
LAV	160	1.60
STRAW	768	7.68
RICH	160	1.60
MUV	768	7.68
IRC & SAC	576	5.76
LKr	**222 k**	**2220**
Sum	**≈227 kB**	**≈2.3 TBps**

It’s like 10 Mio. users uploading a big profile image every second!

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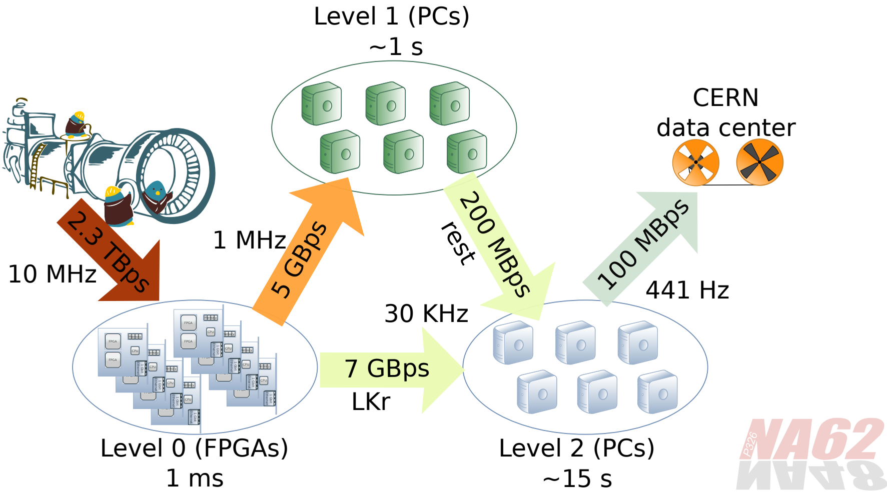
Online trigger system

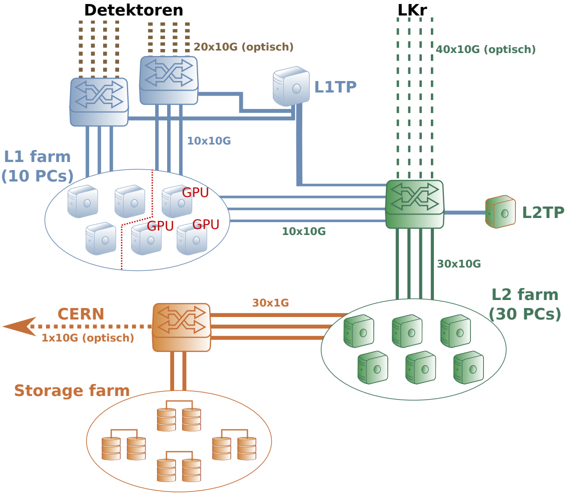
Three levels to filter data

Data transmission via ordinary 10 gigabit ethernet and **UDP/IP**:



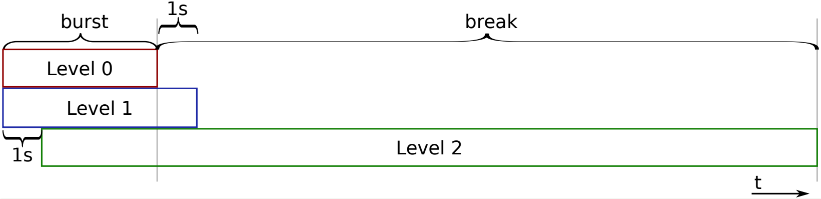
First topology proposal

Original concept:



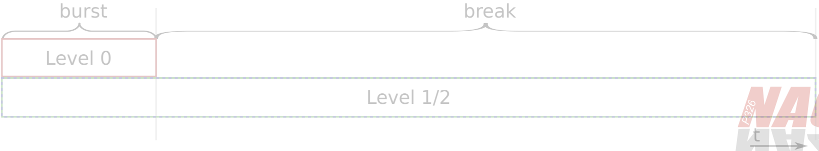
Burst time

Only 3-9 sec. proton burst and long break



My proposal to use resources more efficiently

Combine L1 and L2 to one farm



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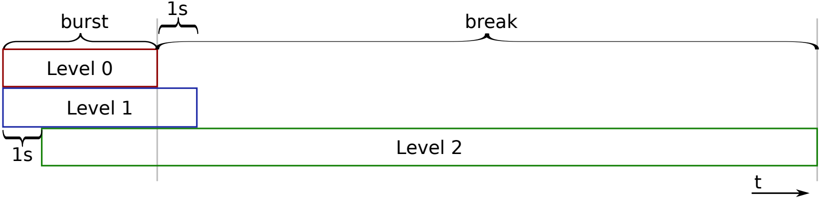

My proposal to use resources more efficiently

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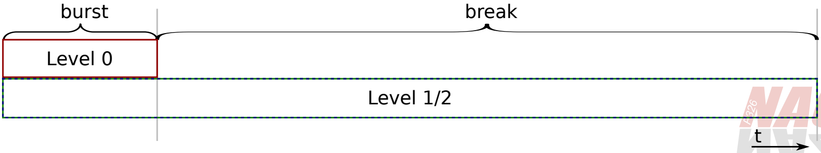
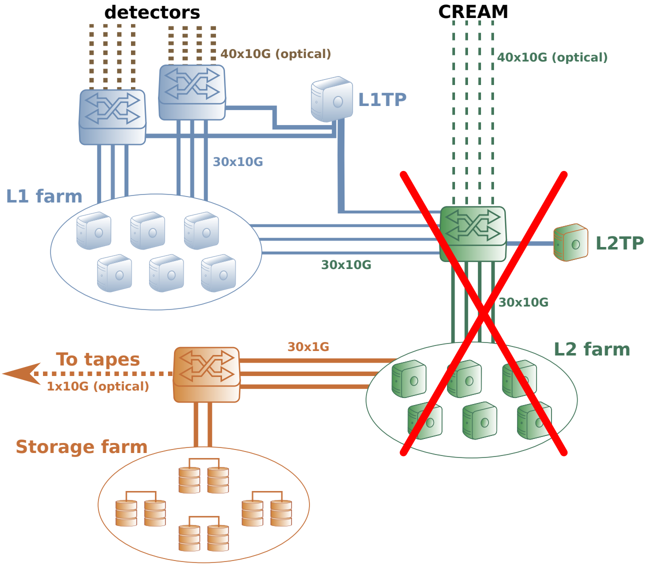
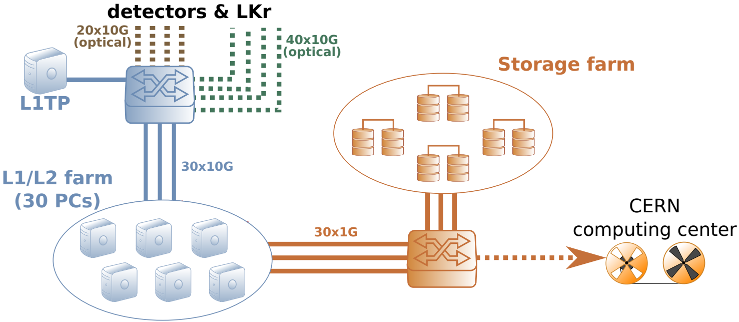


Don't separate L1 and L2!



Combine L1 and L2 to one farm

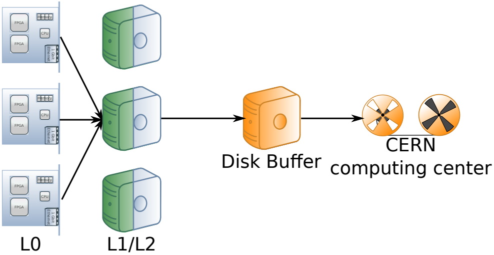


We save about 80k

- No L1 PCs anymore
- Less switches, less network cards

New proposal

Event building @ L1



Every subdetector sends data of one event to the same PC

- ✚ **More physics at earlier state**
- ✚ No broadcast of a L1 decision needed anymore
- ✚ Easier to implement load balancing (self-sustaining PCs)

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Bad performance with interrupts

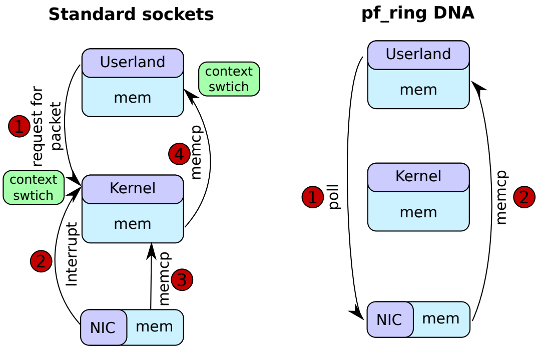
Standard socket programming is interrupt based

Every hardware and software (syscall) interrupt induces a context switch ($\approx$100 ns)

⇨ High packet loss ($> 10^{-5} \Rightarrow$ loose $>$100 Mio. events)

⇨ No problem for web apps but I cannot use kernel sockets!

Solution: pf_ring DNA - new type of network socket



pf_ring DNA

Special socket: pf_ring DNA by ntop (open source)

- Polling the NIC memory directly (avoids system calls)
- Only ≈40% CPU @ full speed 10 G receiving 1 kB packets
- No packet loss at all

pf_ring does not yet support any protocol

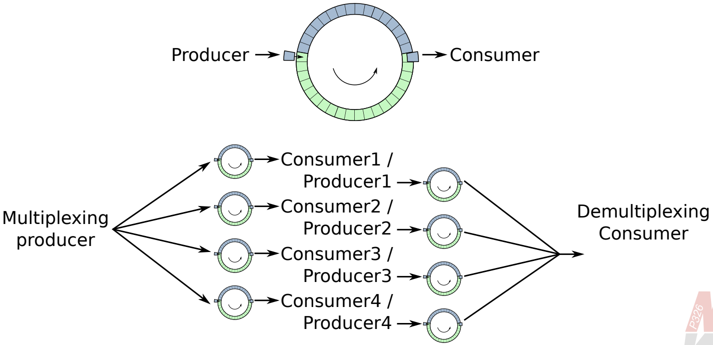
- Every byte has to be moved by the user
- I had to implement Ethernet, IP, UDP, ARP and IGMP

⇨ 270 kHz Eventbuilding rate with ¡5 virtual cores
⇒ ¿19 cores left for L1 and L2 trigger

Same problem with Mutex/Semaphore

Bad performance with Mutexes/Semaphores

Implemented lockless queues based on consumer-producer communications



Producer

Consumer

Multiplexing producer

Consumer1 / Producer1

Consumer2 / Producer2

Consumer3 / Producer3

Consumer4 / Producer4

Demultiplexing Consumer

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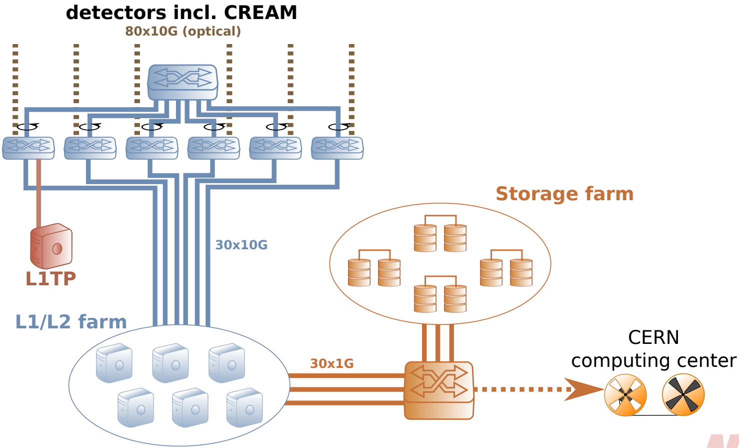
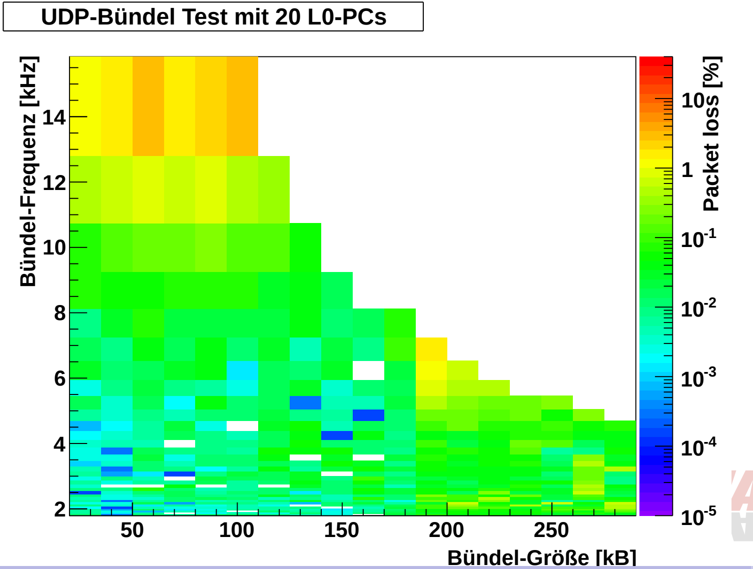
- High energy physics $\hat{=}$ high data rate
- A well planned strategy can save a lot of money
- Using ordinary 10G ethernet saves money but lossless communication only feasible with special software: pf_ring DNA
- High performance parallel programming requires special approaches

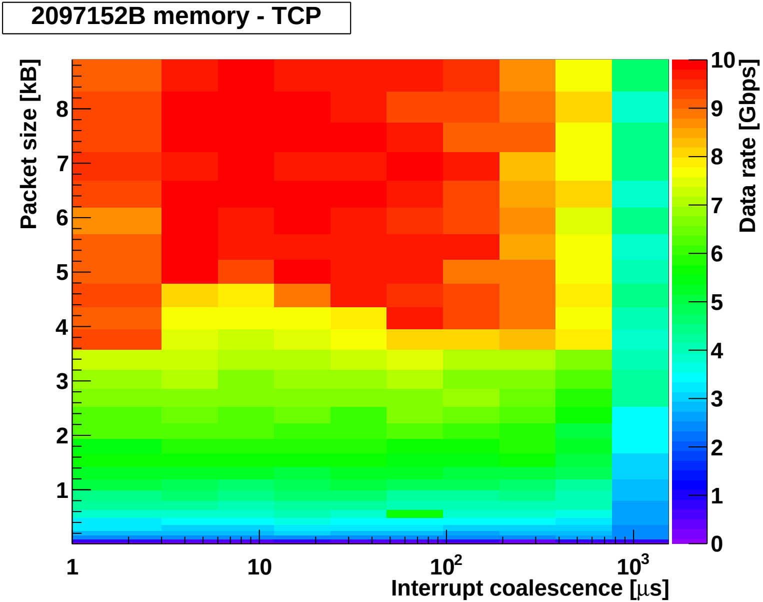
Thank you for the invitation!

Tree topology (Hexapus)

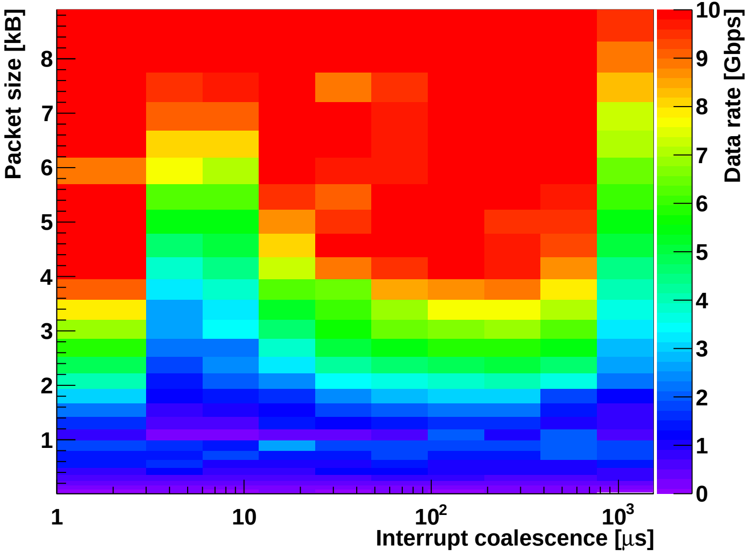


Packet loss


UDP-Bündel Test mit 20 L0-PCs
Bündel-Frequenz [kHz]
2
4
6
8
10
12
14
50
100
150
200
250
Bündel-Größe [kB]
Packet loss [%]
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}


2097152B memory - TCP
Packet size [kB]
1
2
3
4
5
6
7
8
1
10
10^2
10^3
Interrupt coalescence [µs]
Data rate [Gbps]
0
1
2
3
4
5
6
7
8
9
10

2097152B memory - UDP


Packet size [kB]
10^2
10^3
Interrupt coalescence [µs]
Data rate [Gbps]