A Scalable Computer Architecture for On-line Pulsar Search on the SKA

- Draft Version -

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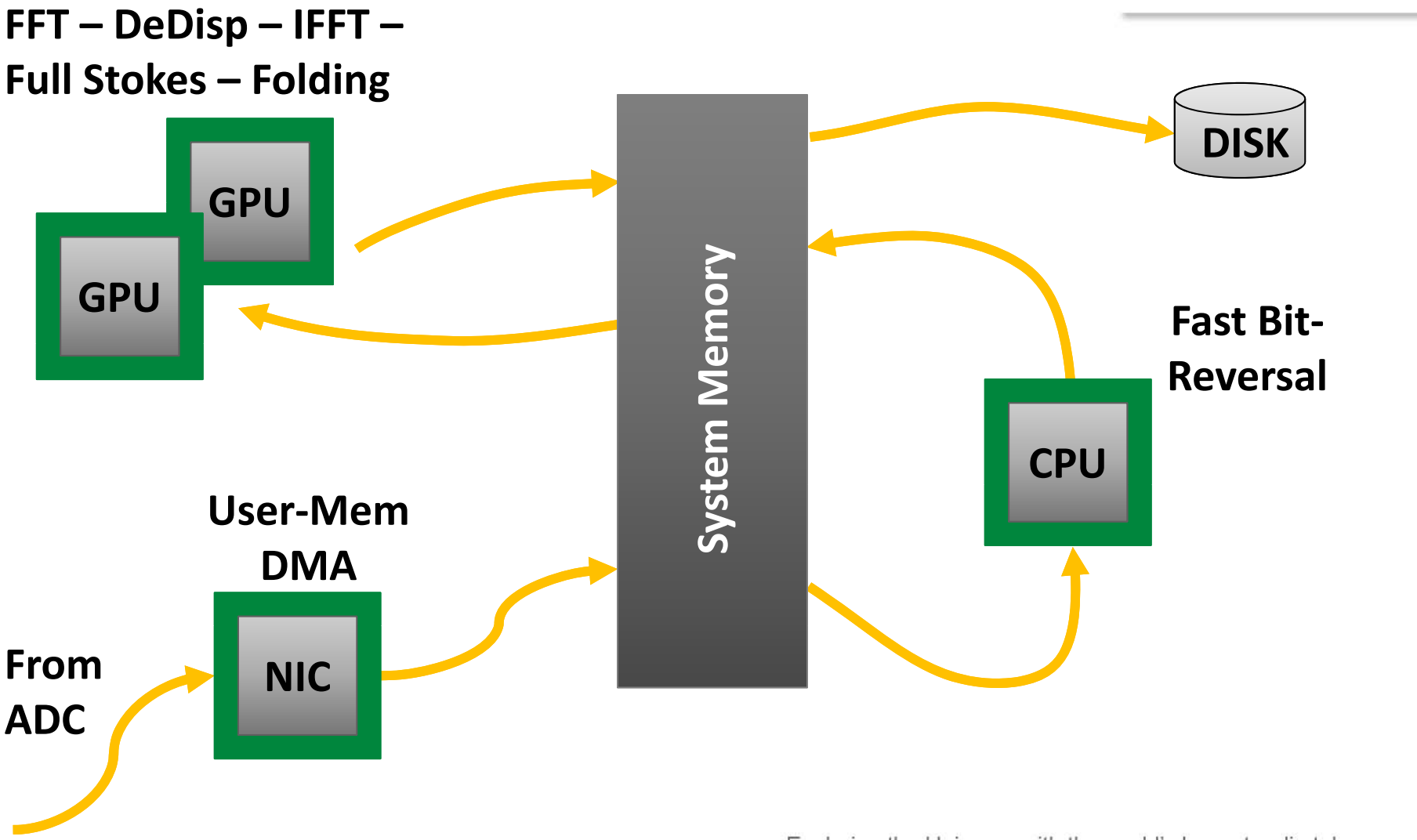
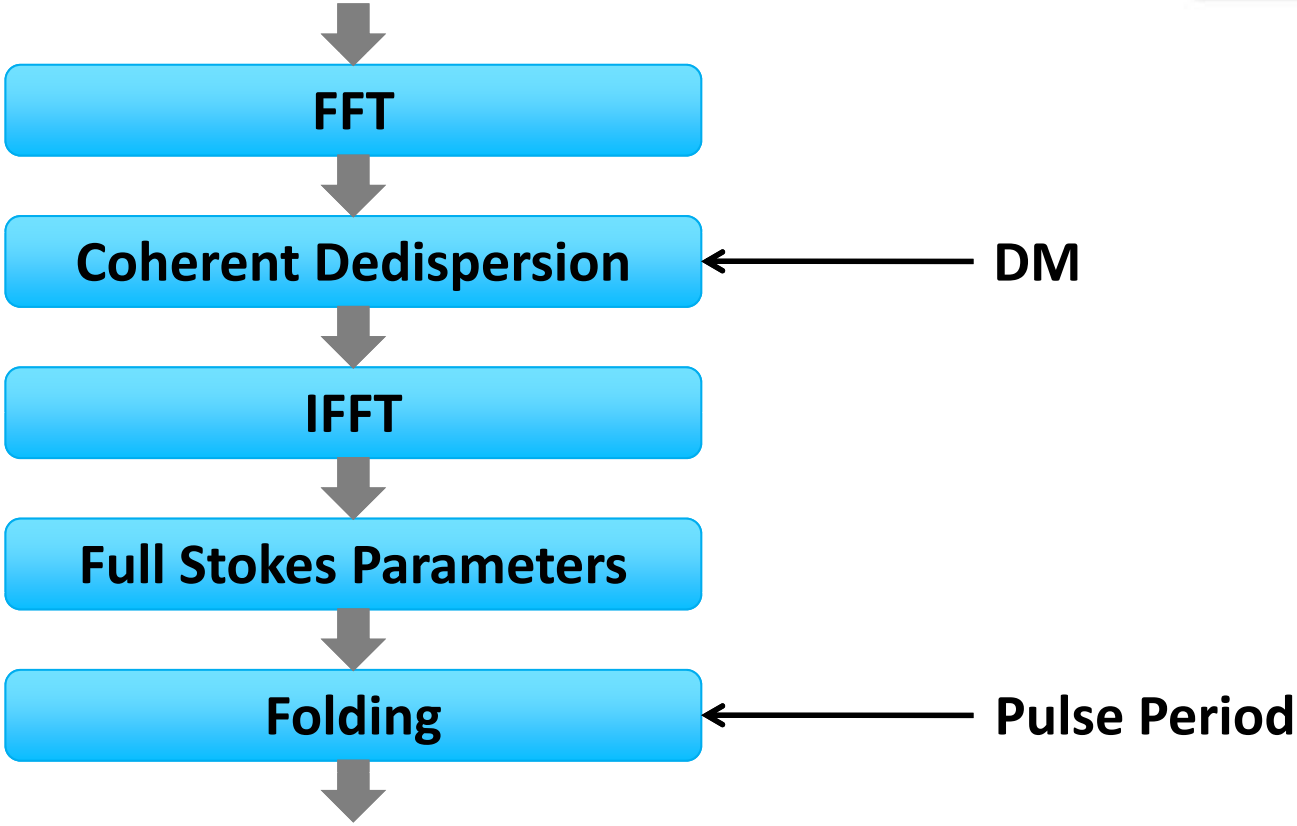
with help from:
M. Kramer, B. Klein, R. Eatough

GPU-Based Pulsar Timing

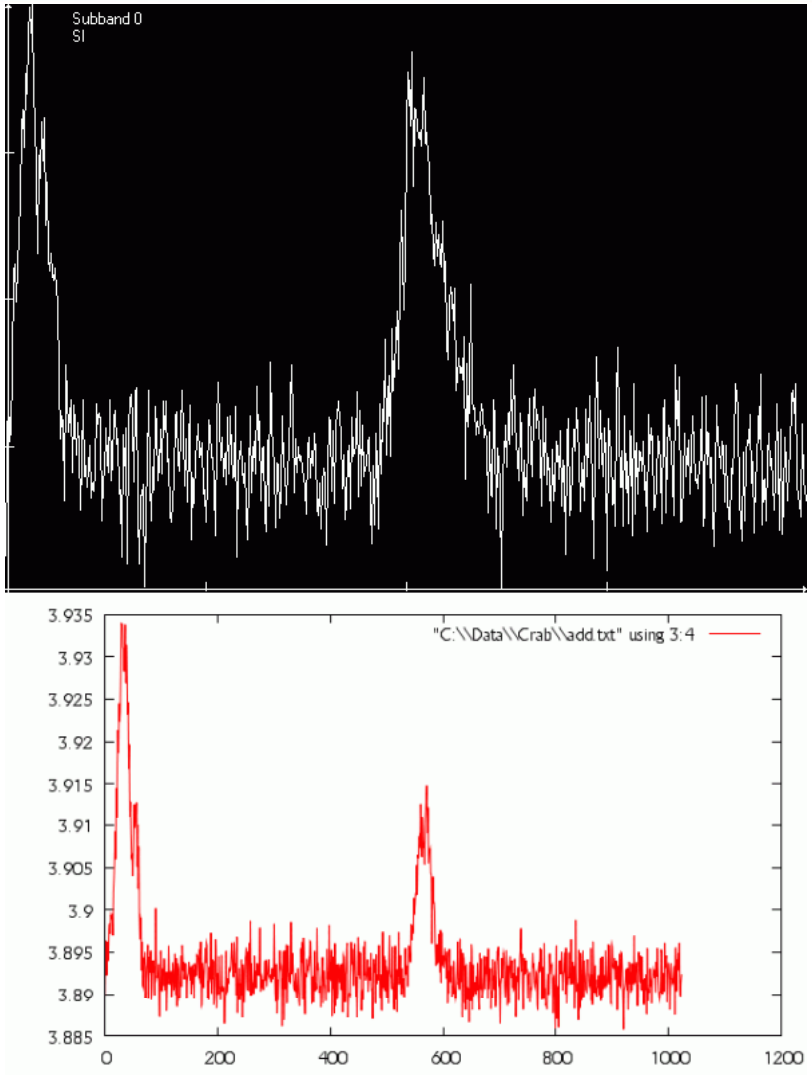


GPU-Processing

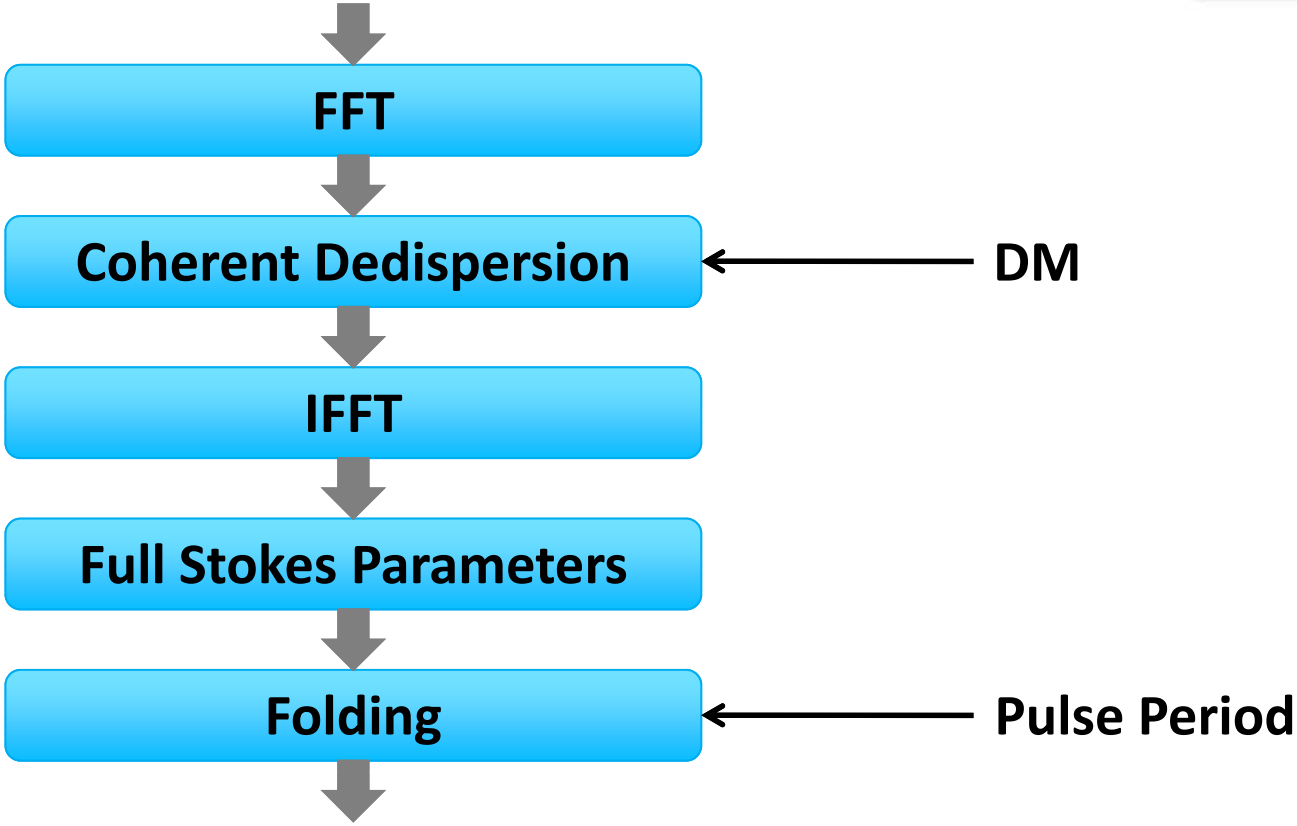


GPU-Based Pulsar Timing

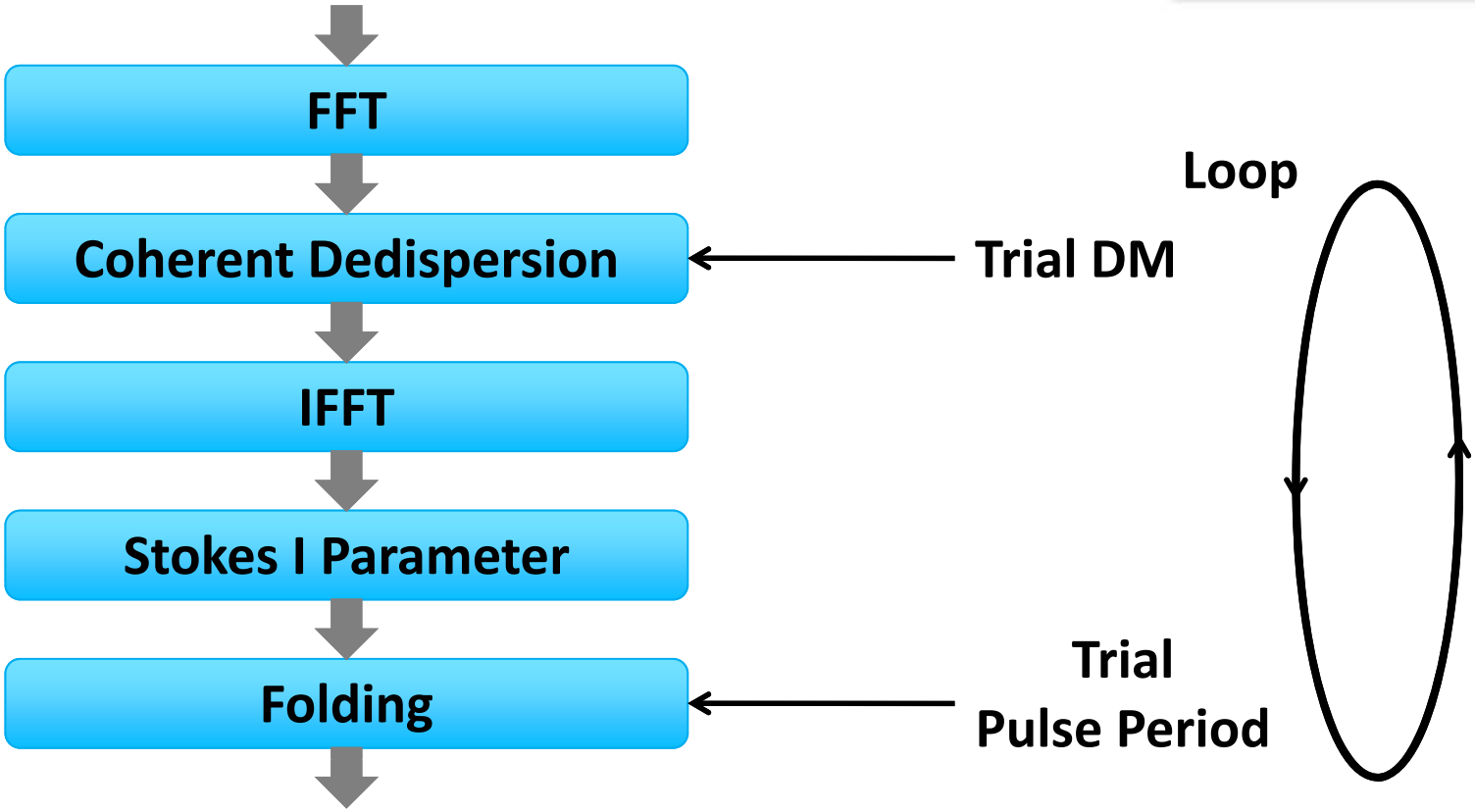
Performance:
610M Samples/s
(2 GPUs)



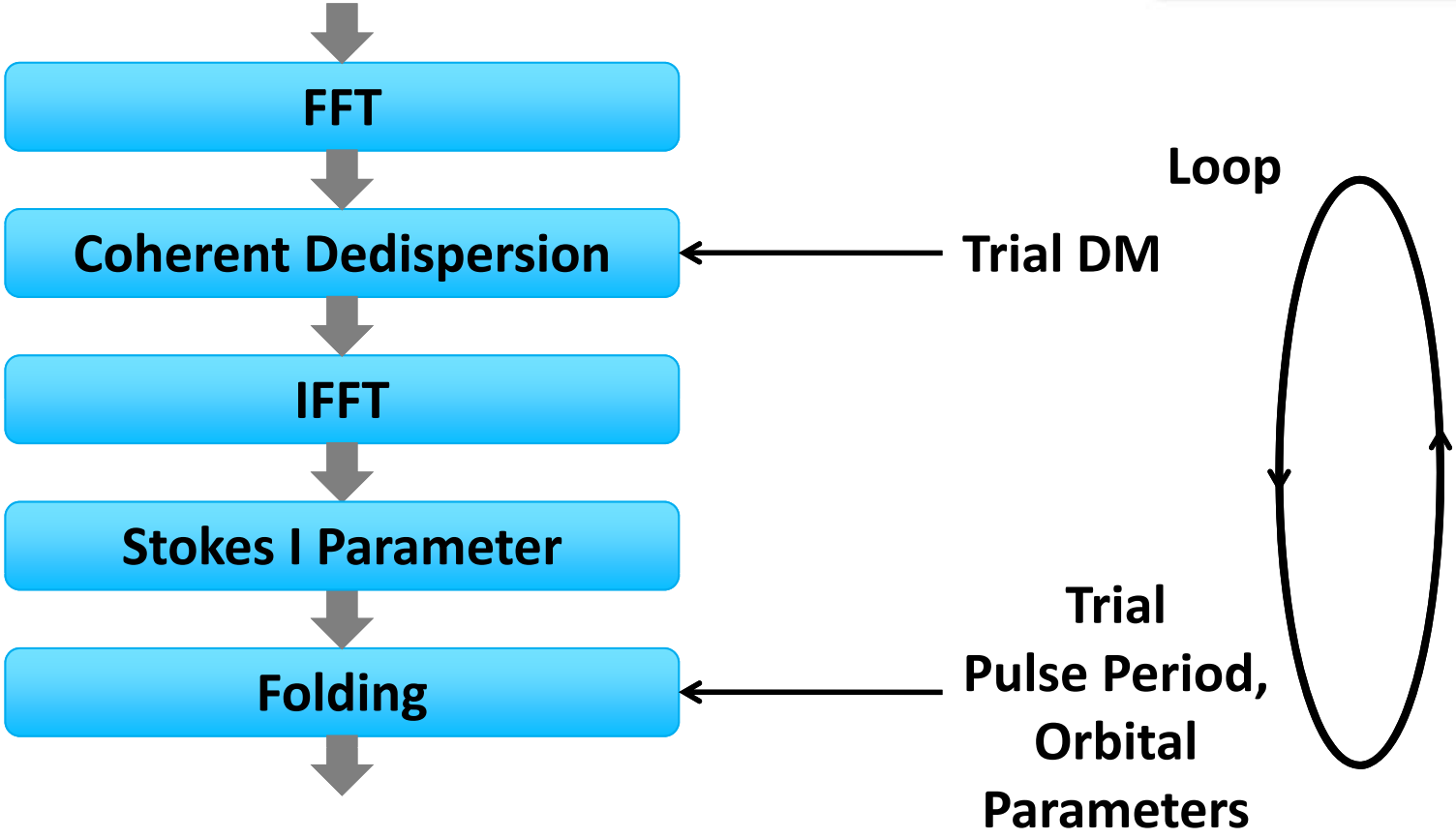
Pulsar Search



Pulsar Search



Binary Systems Search



Pulsar Search

- Idea:
  Pulsar Search by Massively-Parallel Folding (in Time Domain)

Pulsar Search

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  Pulsar Search by Massively-Parallel Folding
- Binary Systems:
  Make Length of Phase Bins variable (similar to Time Sequence Resampling)

Pulsar Search

- Idea:
  Pulsar Search by Massively-Parallel Folding
- Binary Systems:
  Make Length of Phase Bins variable
- High-Dimensional Search Space:
  Complete Coverage not possible.

Pulsar Search

- Frequency Domain:
  Pulsar Search by Massively-Parallel Harmonic Summation
- Binary Systems:
  Process Range of neighboring Frequency Bins
- Use same Hardware!

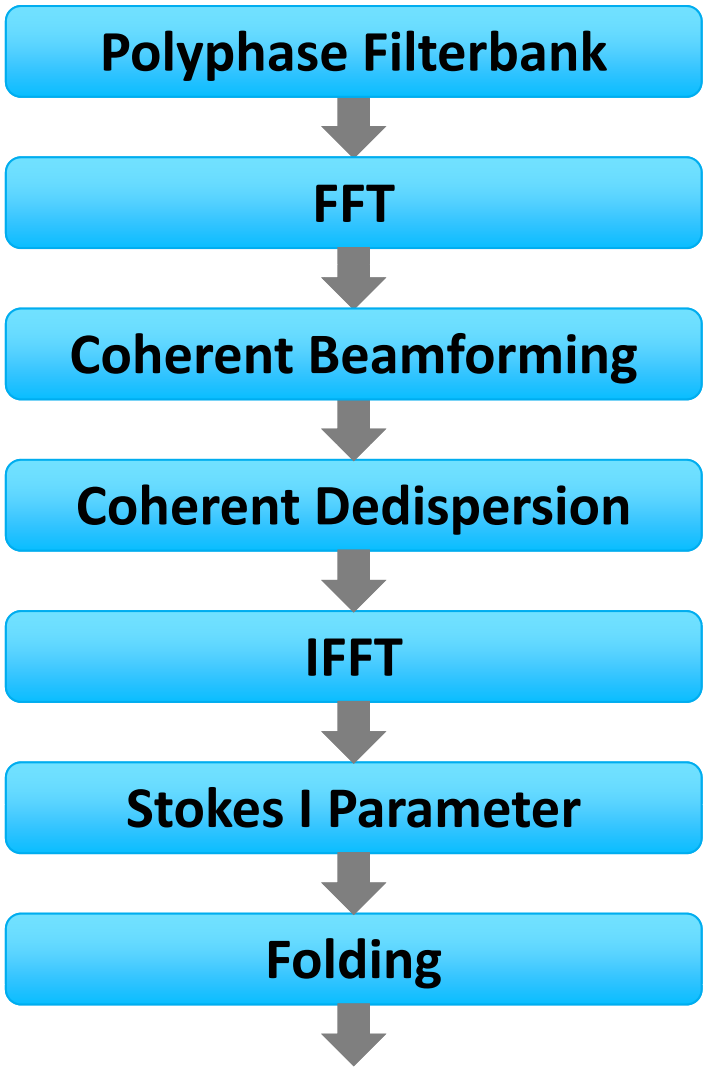
Pulsar Search

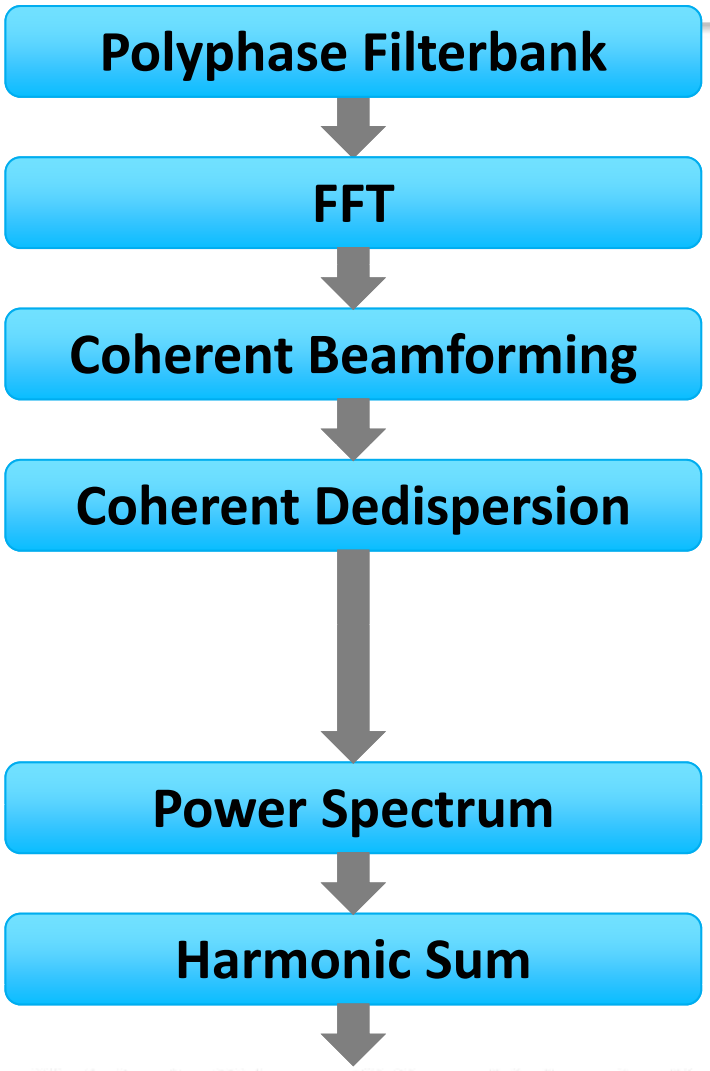
- Frequency Domain:
  Pulsar Search by Massively-Parallel Harmonic Summation
- Binary Systems:
  Process Range of neighboring Frequency Bins
- Use same Hardware!
- Not completely worked out yet.

Pulsar Search on the SKA

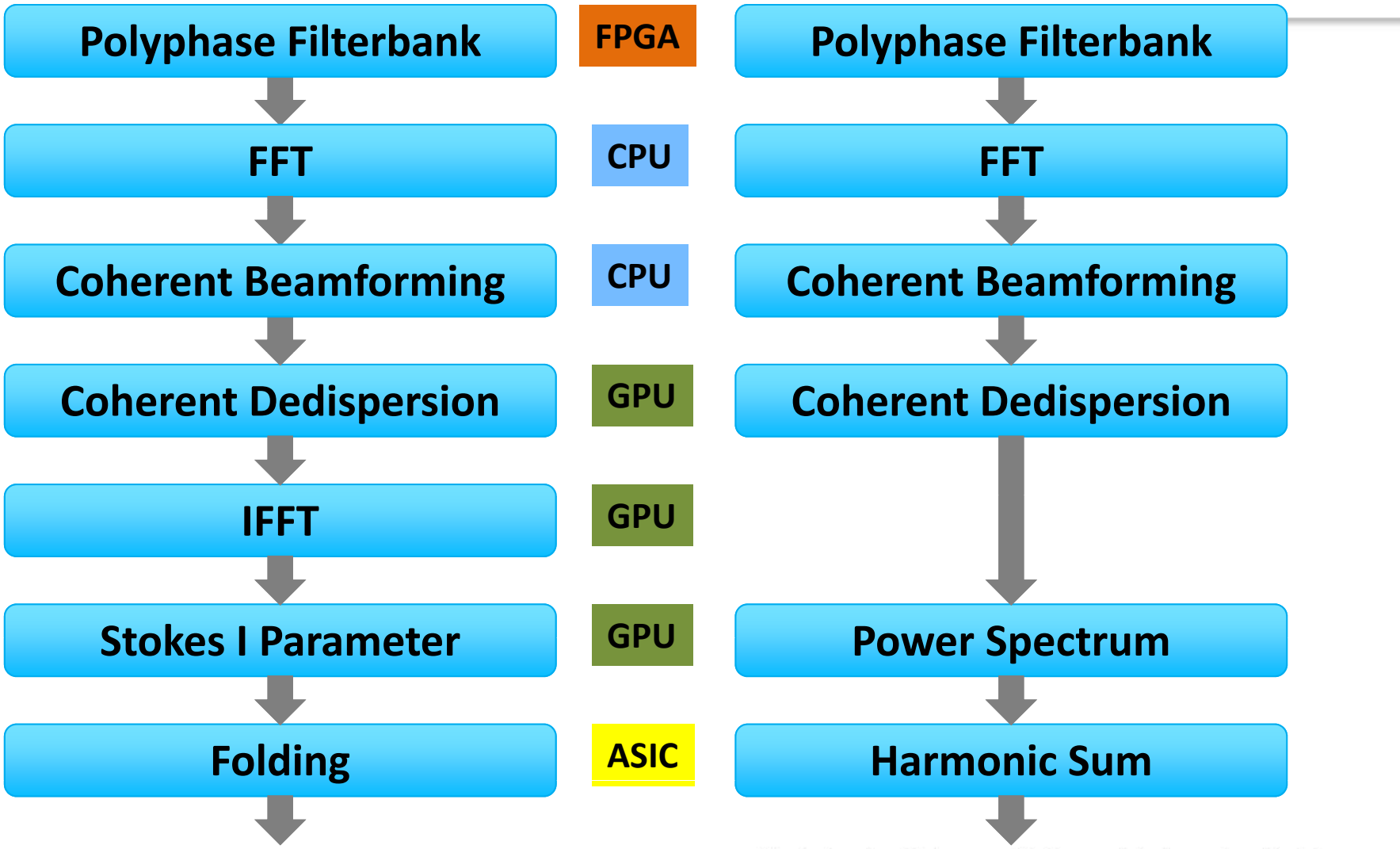
- Add Coherent Beamforming

Pulsar Search on the SKA

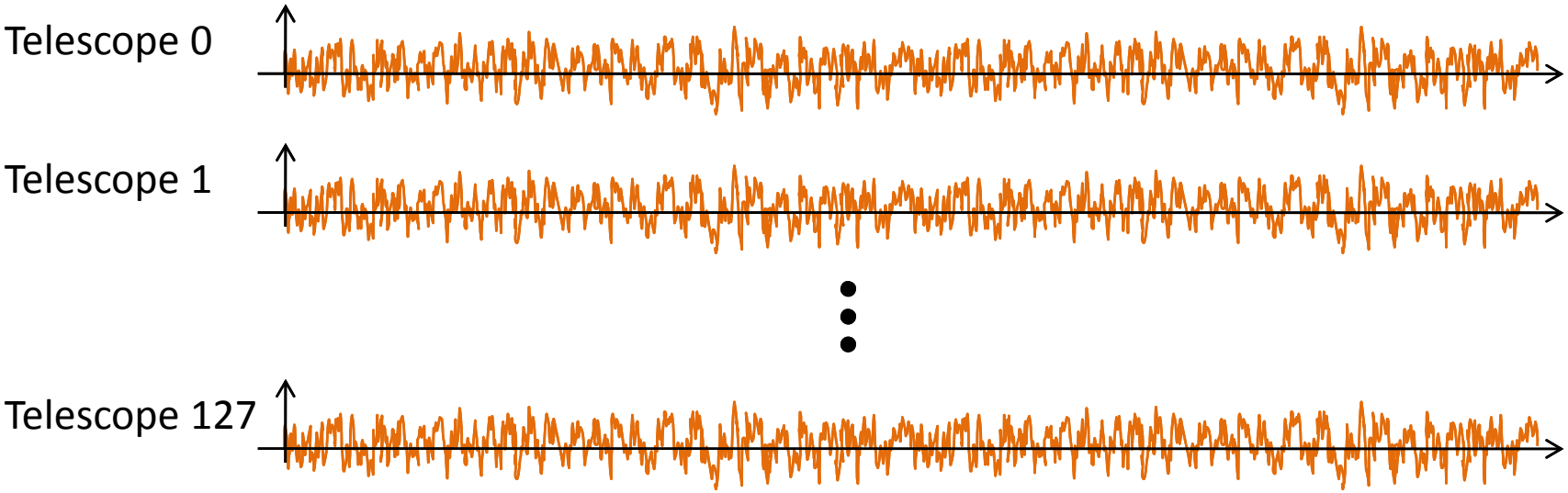




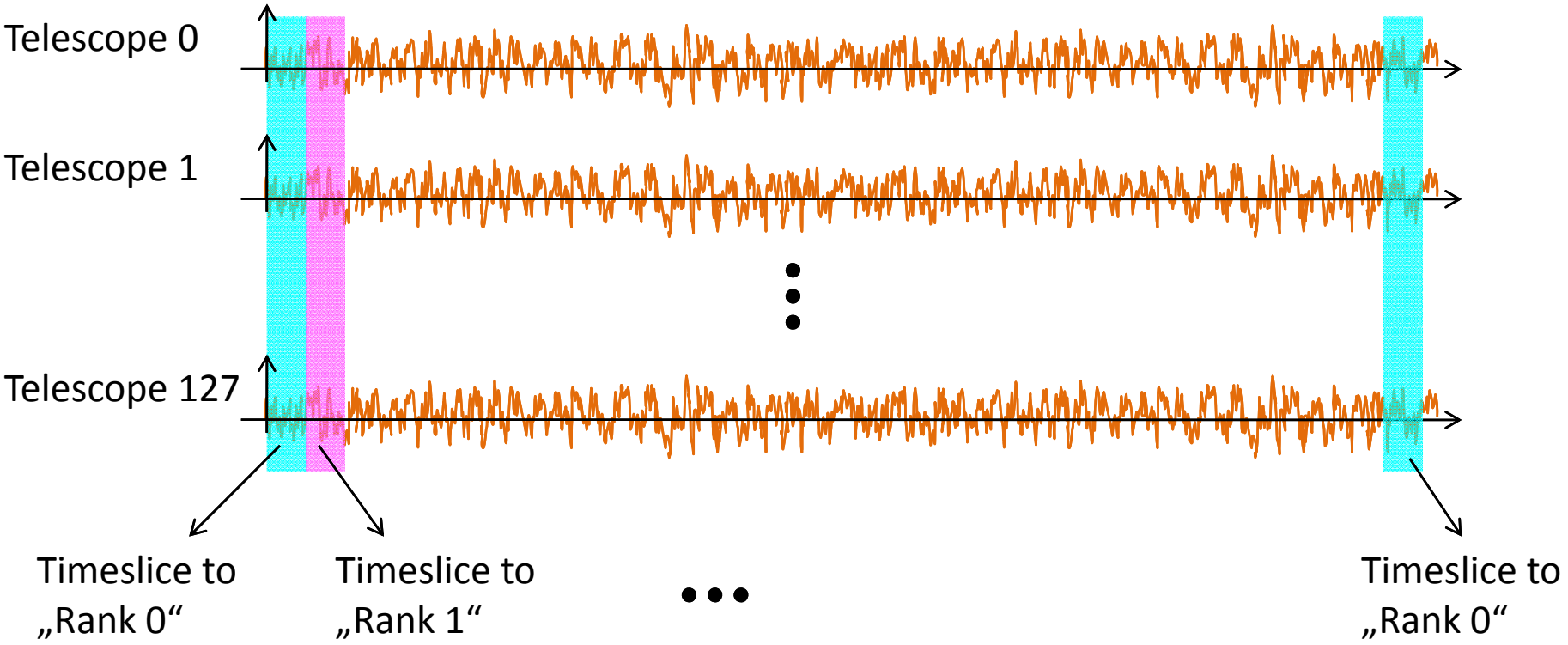
Pulsar Search on the SKA



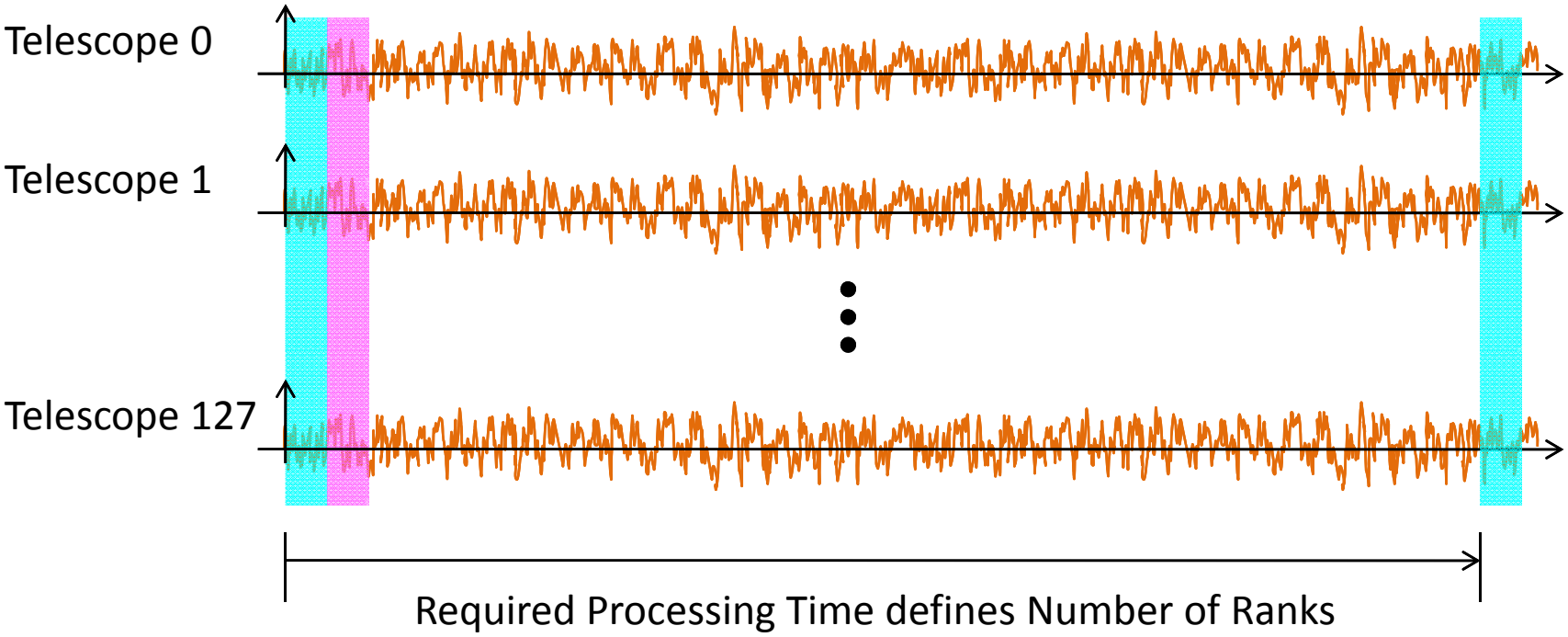
Mode of Operation (Time Domain)



Parallelization: Timeslicing



Parallelization



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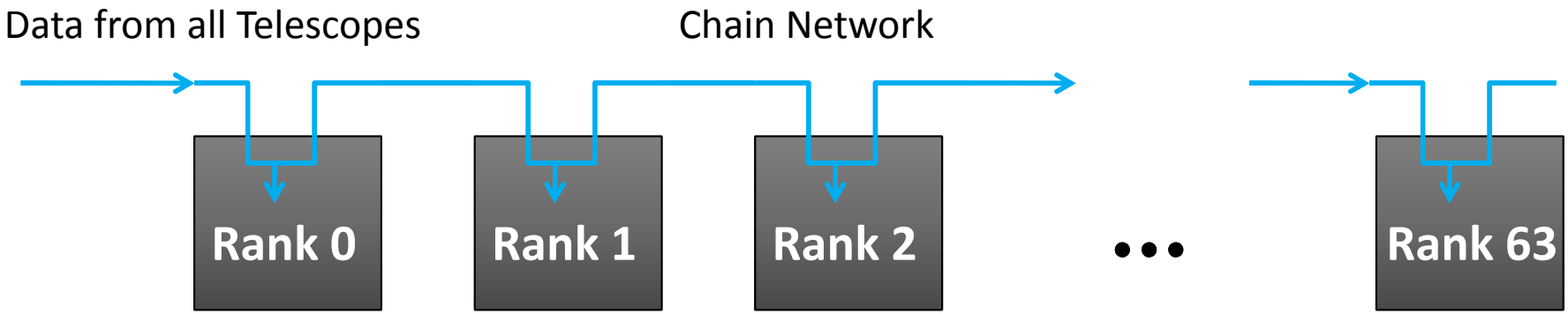
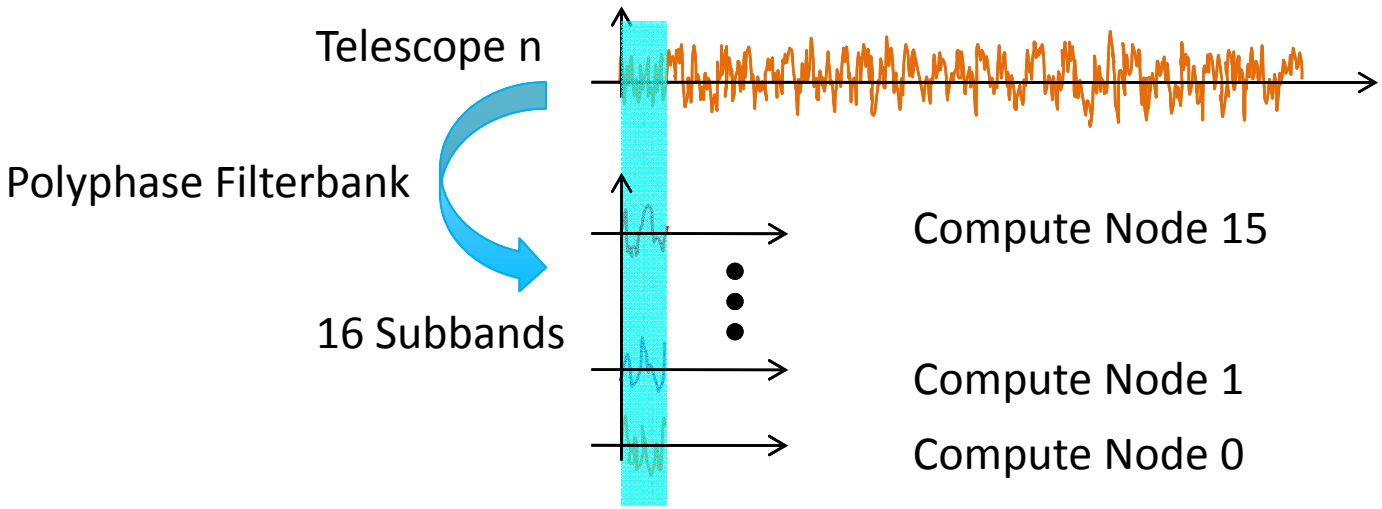


Architecture scales endlessly

Parallelization



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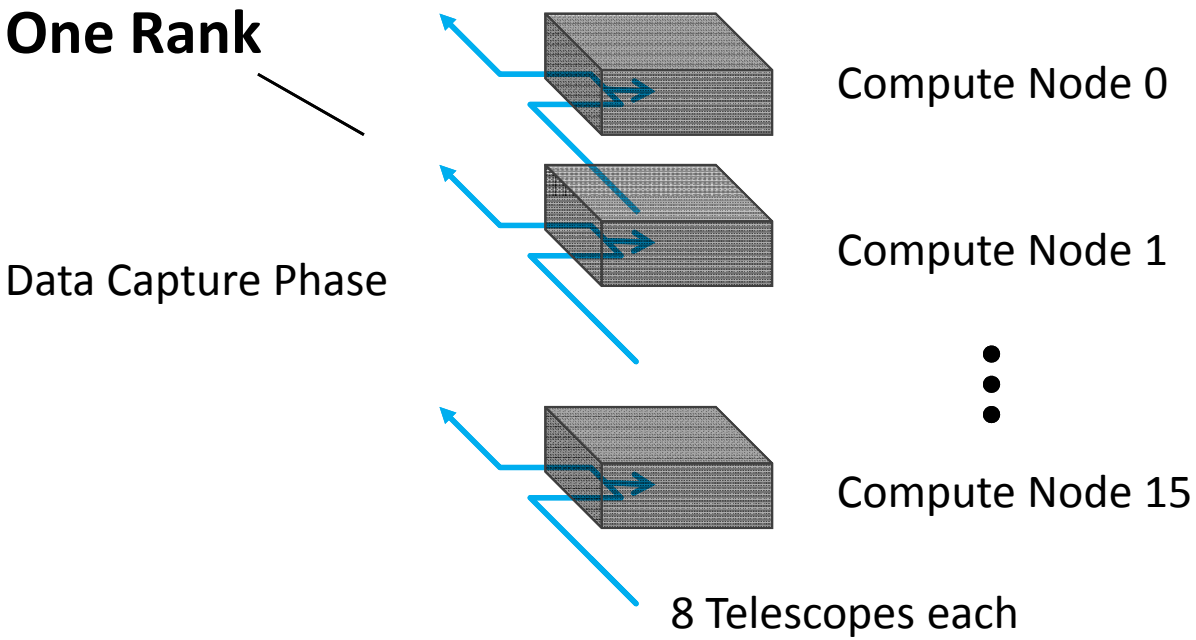

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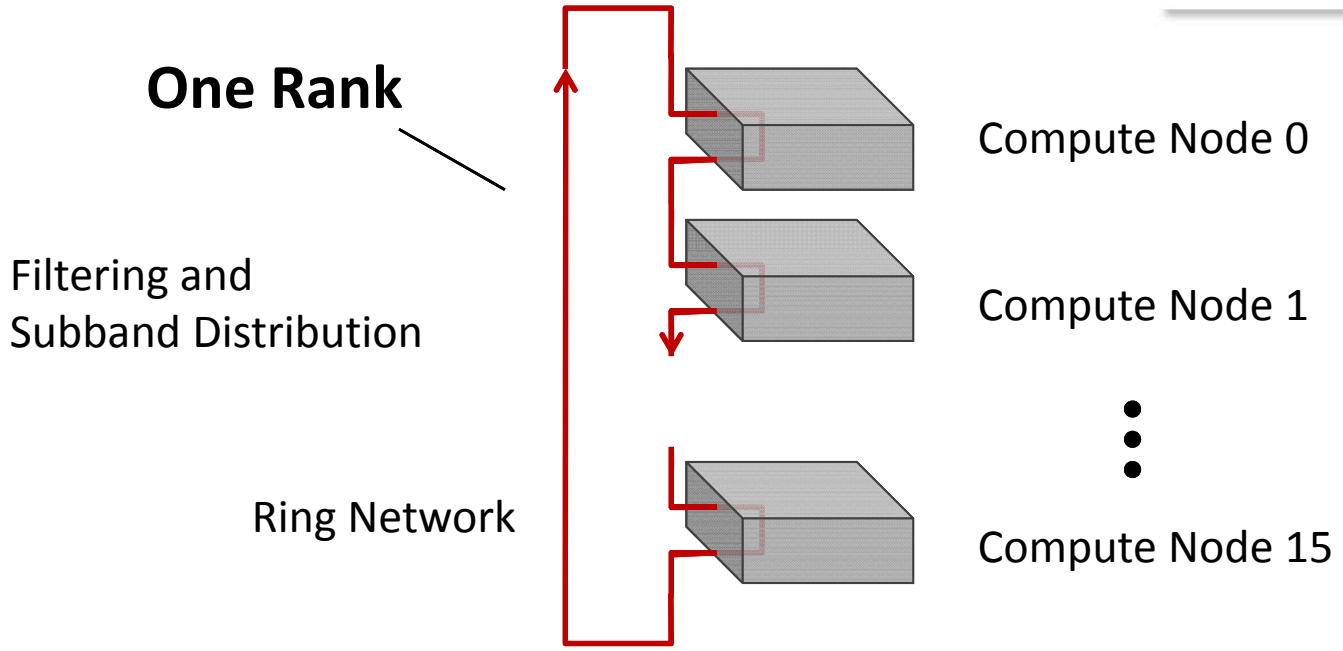
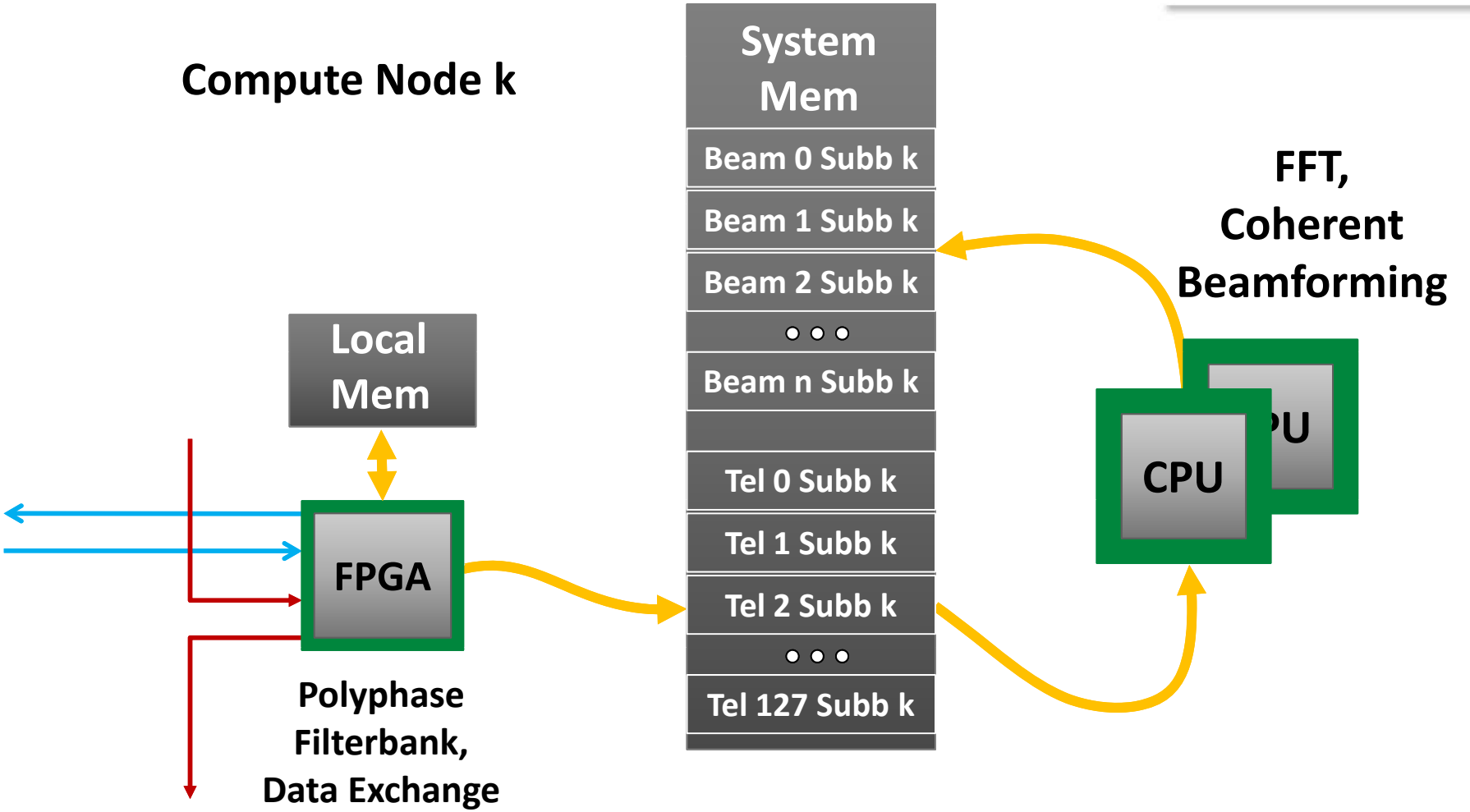


Coherent Beamforming

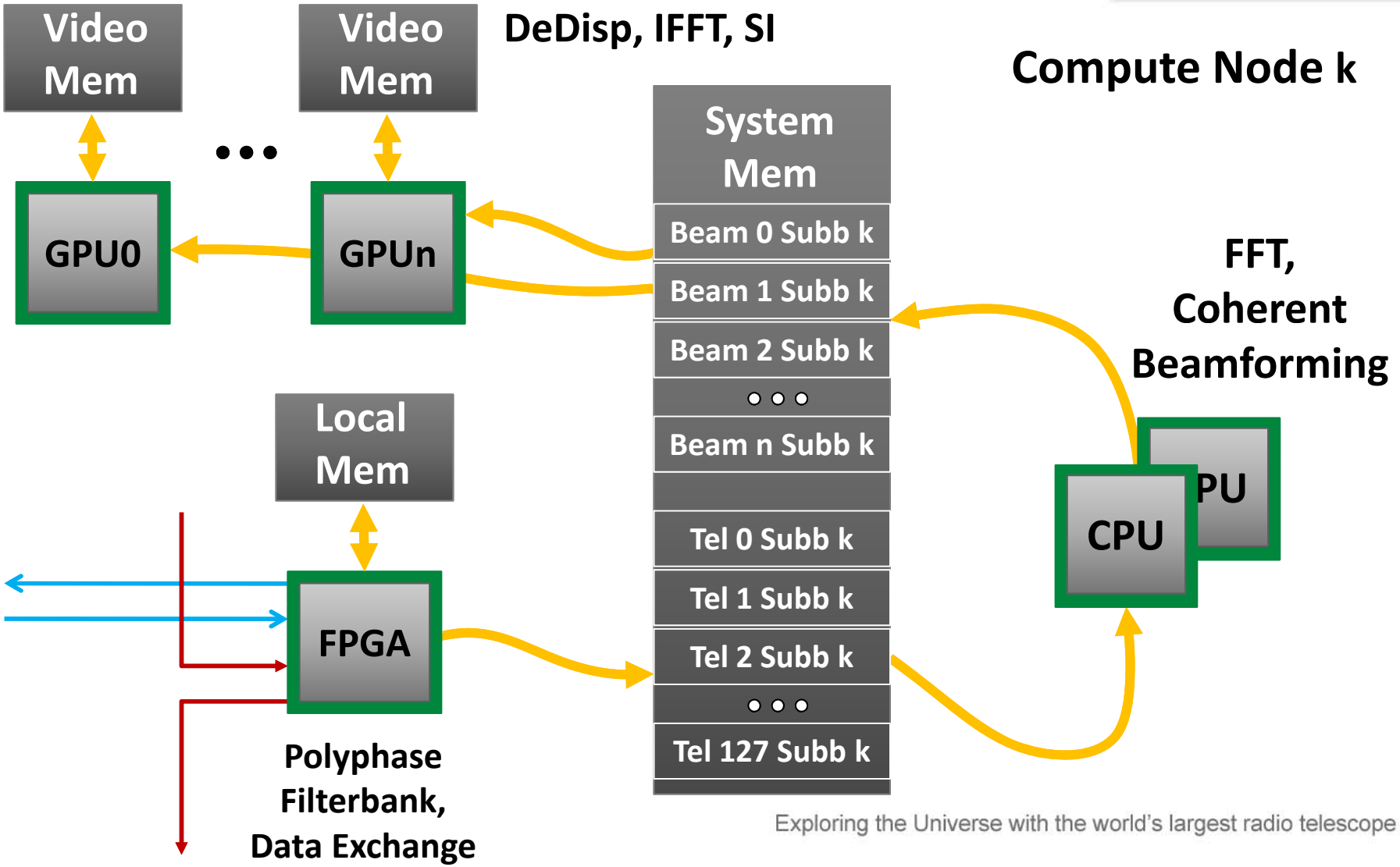


Coherent Beamforming on CPUs

- Performance using AVX:
  128 Input Spectra, single-precision float,
  256k Elements

- 128 Beams of same Size:
  2.1s per Core @ 3.5GHz (prel. Results)

GPU-Processing



GPU-Processing

- Performance:
  2 Spectra, horz/vert, single-precision float,
  4M Elements

- Total Power Time Sequence of same Size:
  5ms

GPU-Processing

- How to output the Results to the ASICs?

GPU-Processing

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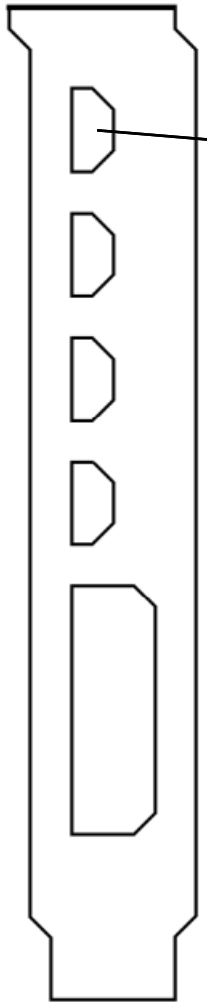
- All PCIe-Slots are already taken (GPUs, FPGAs)

GPU-Processing

- How to output the Results to the ASICs?
- All PCIe-Slots are already taken (GPUs, FPGAs)

- Write to Screen Buffer, to be output via Monitor Cable

GPU-Processing



Mini-DisplayPort
17.28 Gbit/s

~ 70 Gbit/s
Equiv. 1 PCIe x16 Slot

GPU-Processing

- Does it work?

GPU-Processing

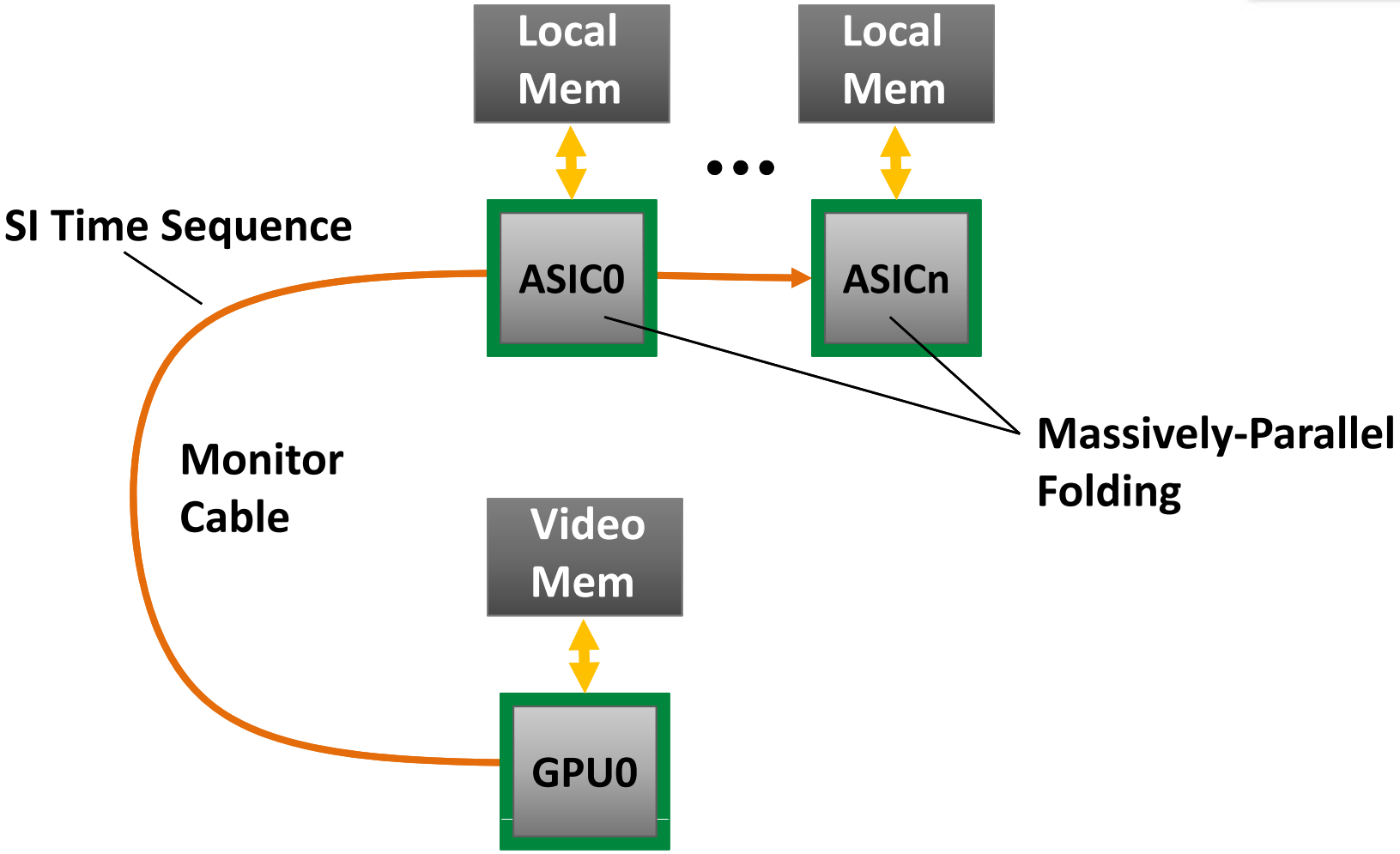
- Does it work? Yes, but...

GPU Kernel → **Screen**

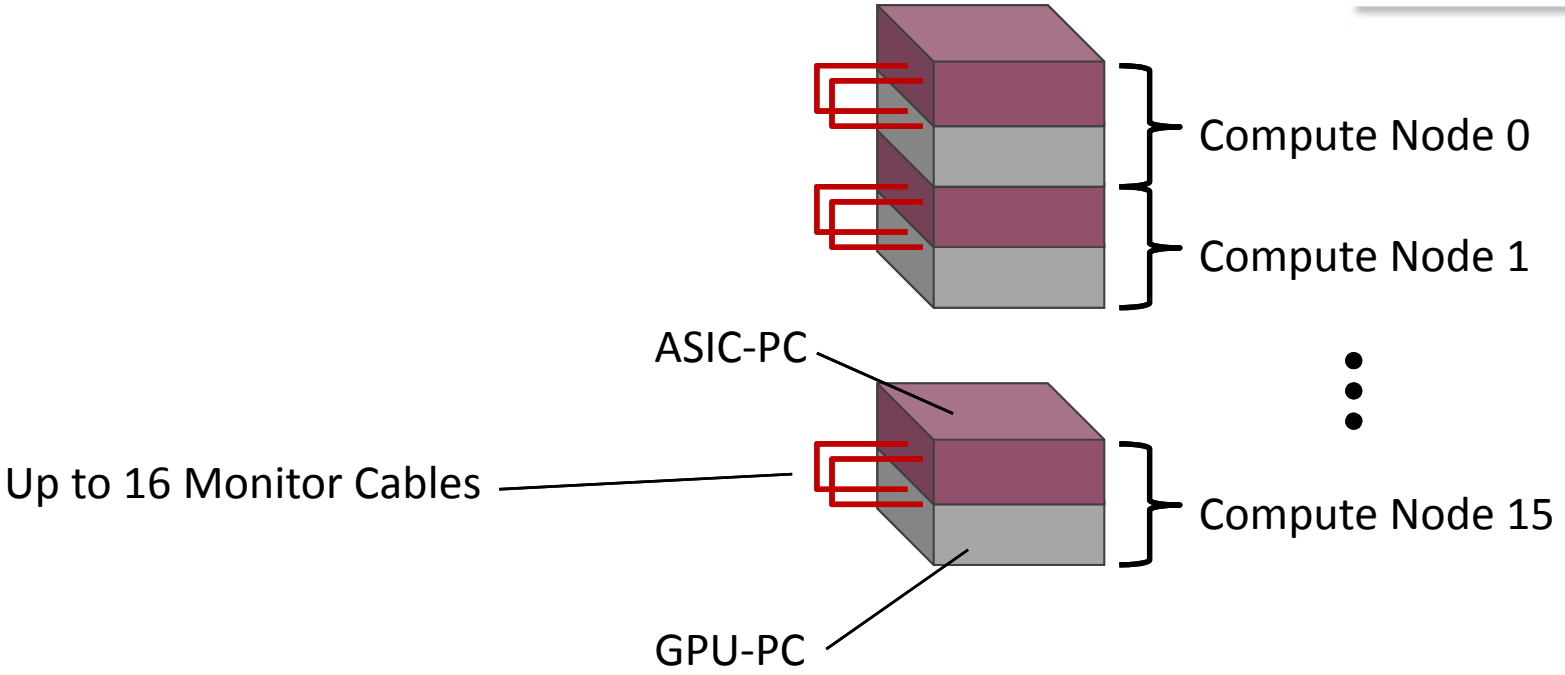
(Video)

Via DVI:
2.7 Gbit/s

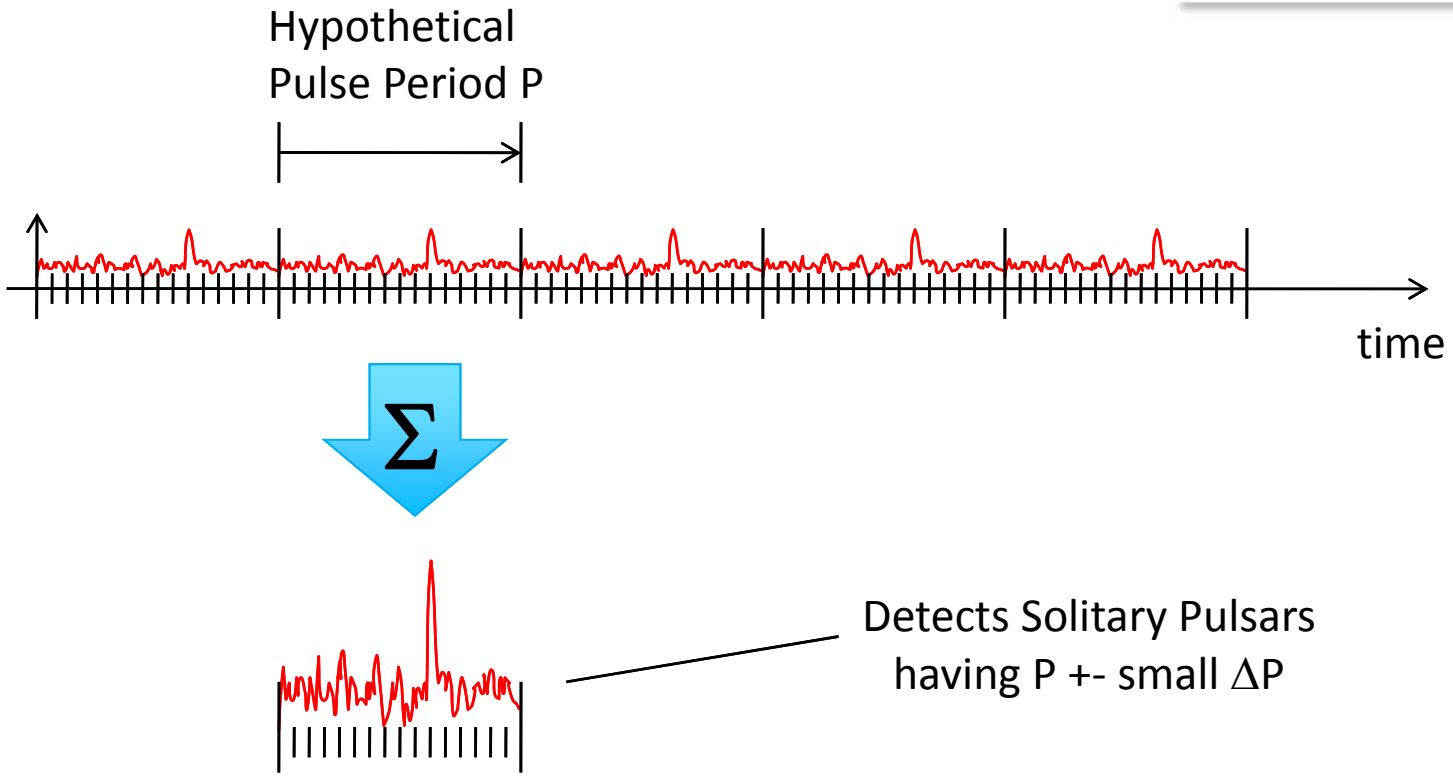
Massively-Parallel Folding



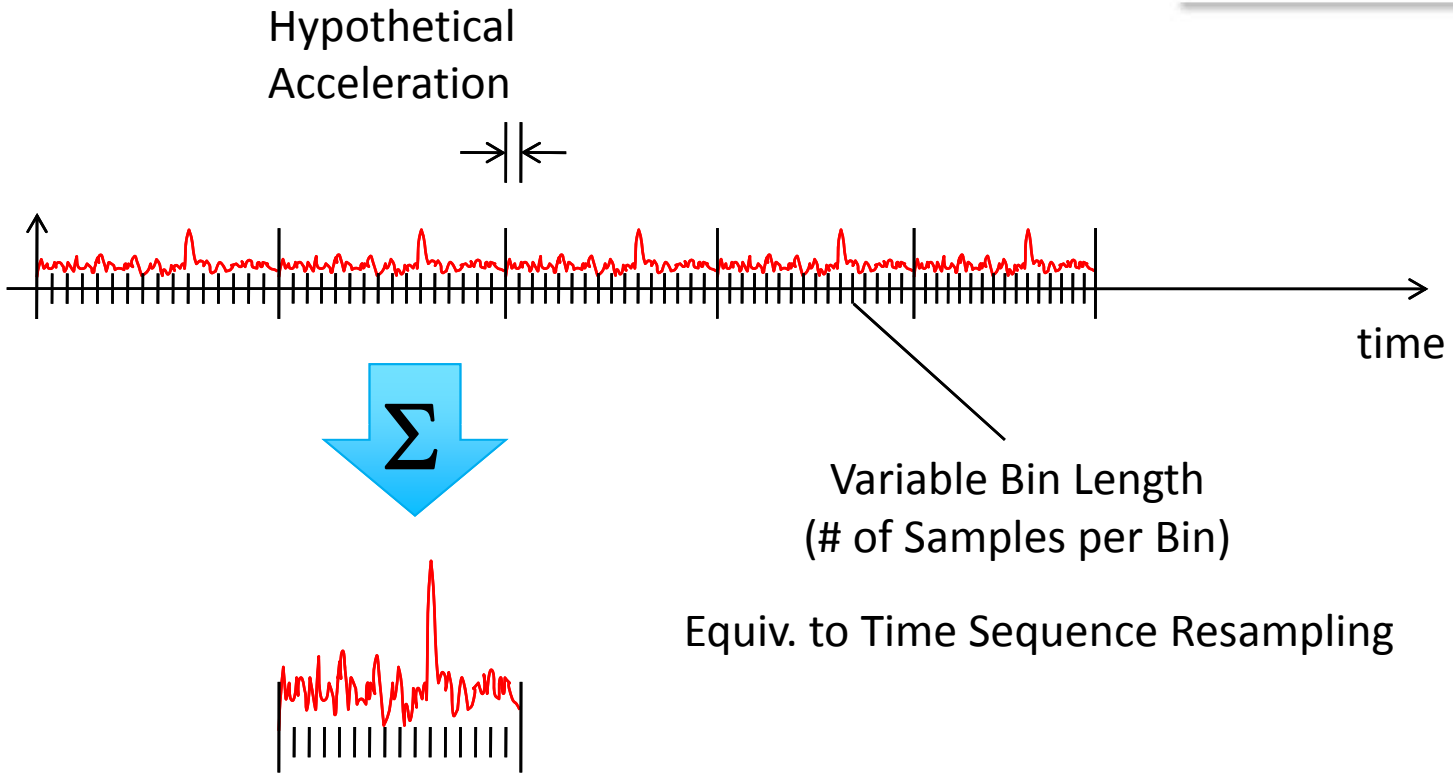
Massively-Parallel Folding



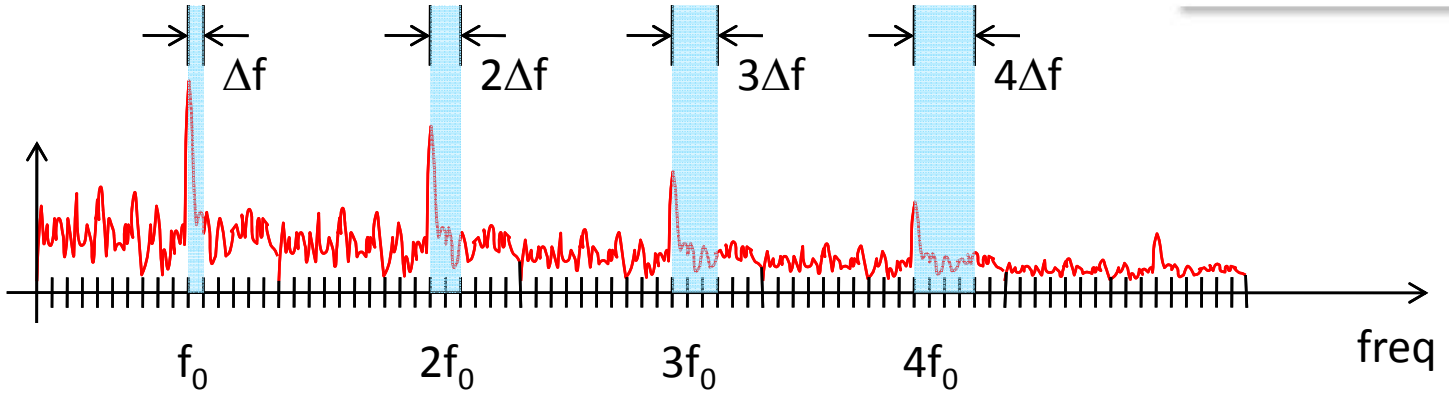
Folding – Time Domain

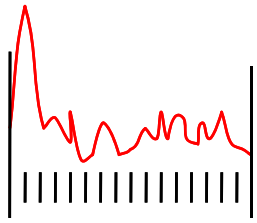


Folding – Acceleration Search



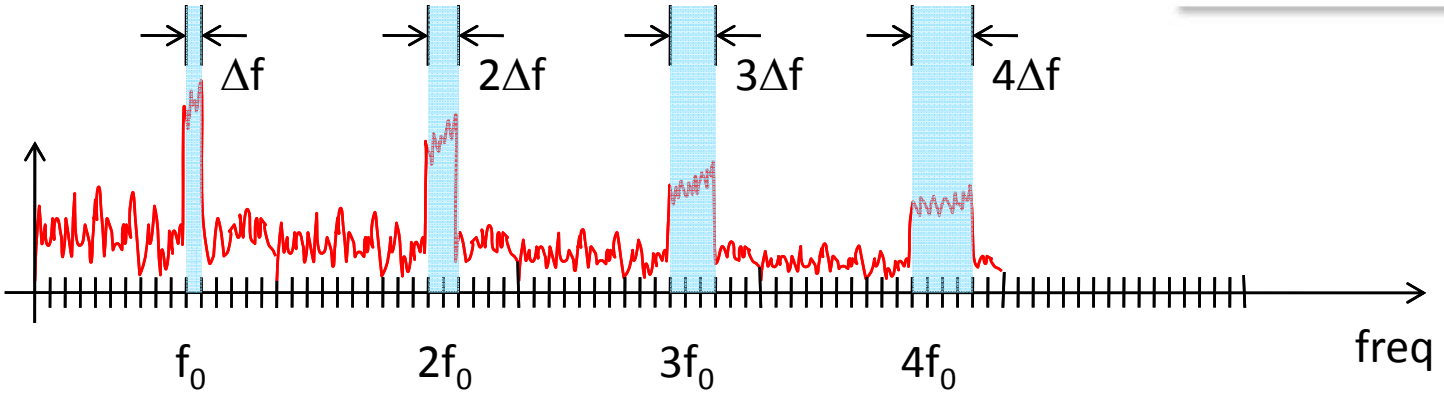
Harmonic Summation

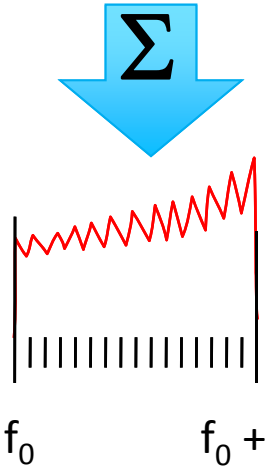




Detects Solitary Pulsars between f_0 and $f_0+\Delta f$

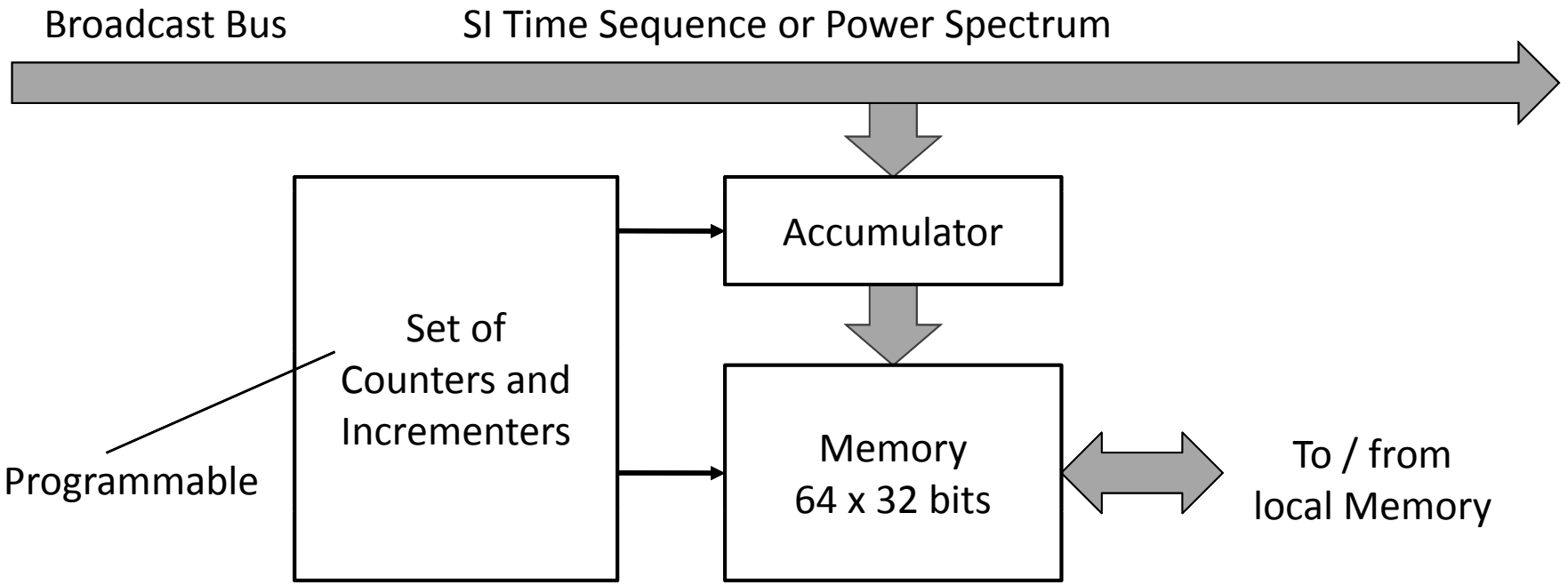
Harmonic Sum - Acceleration Search



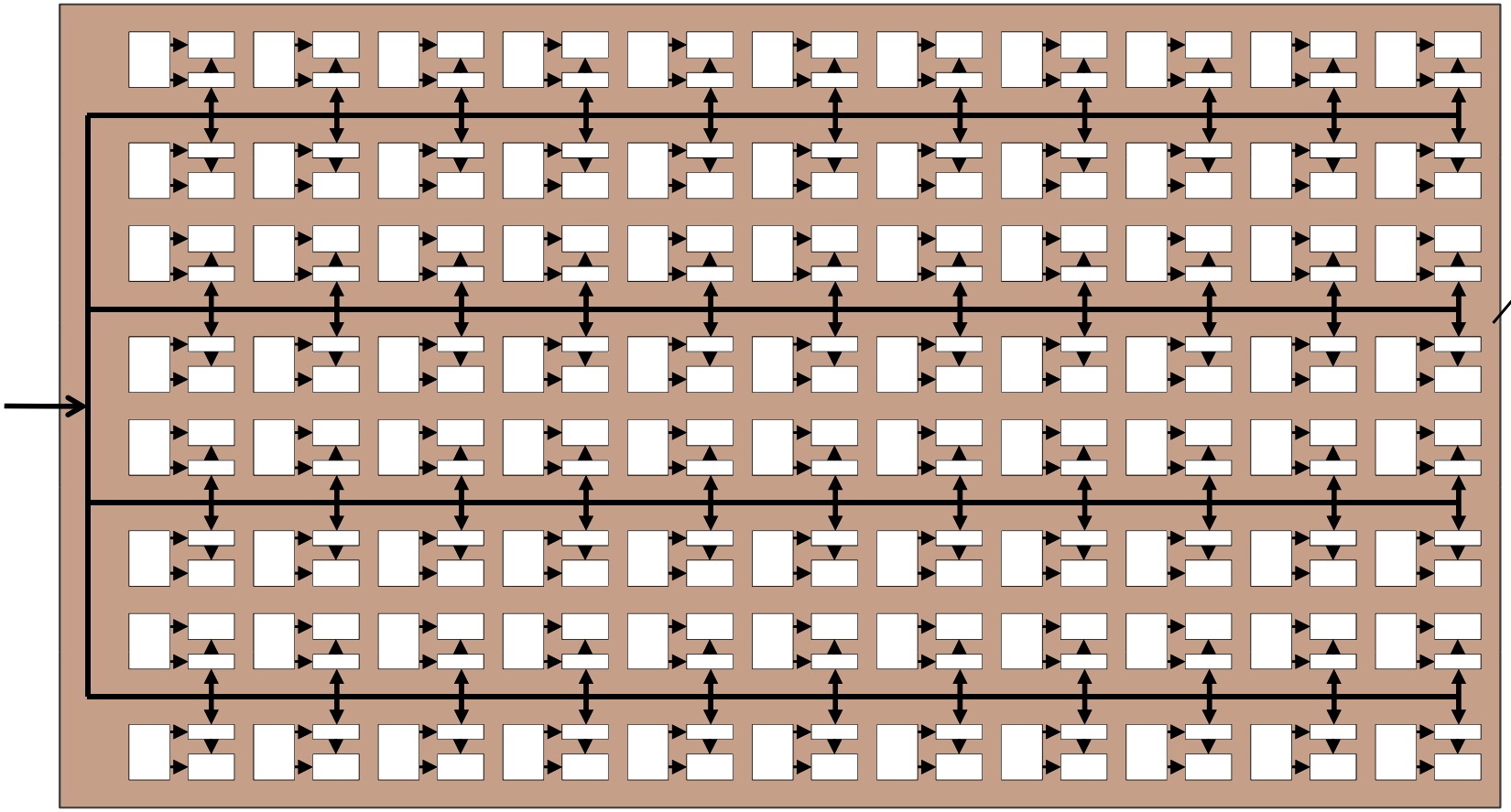


Detects Binary Systems
with max. Acceleration ≙ Δf

Folding Processor

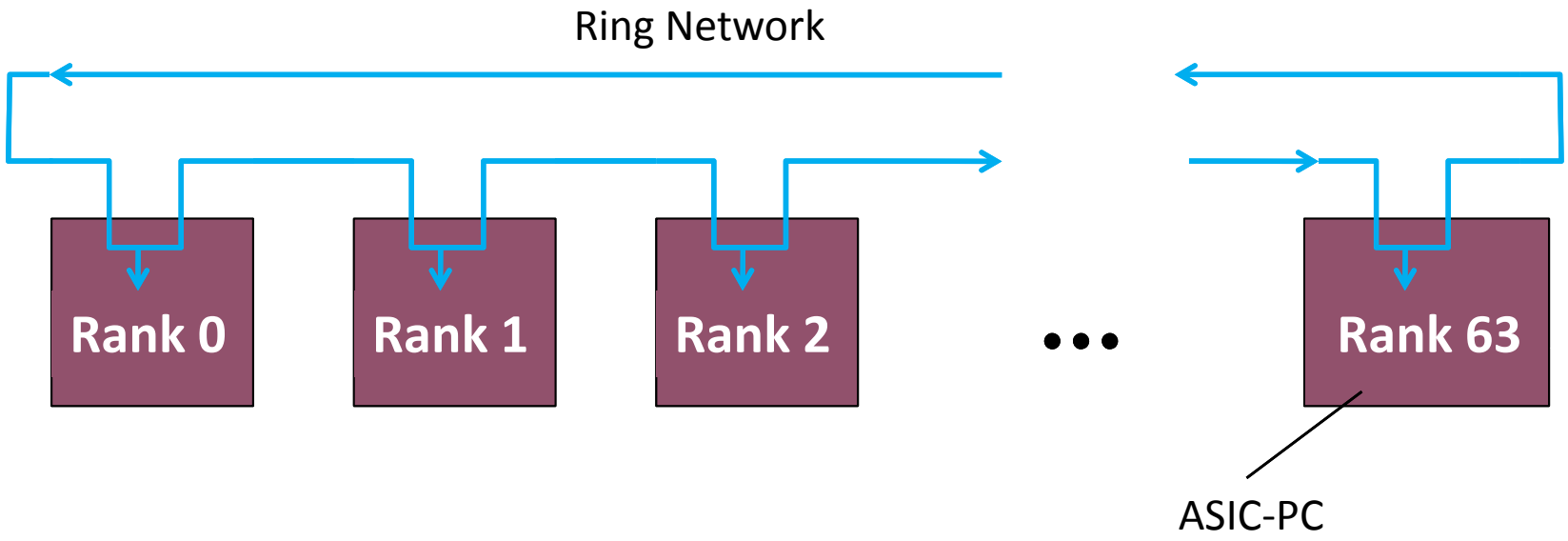


Pulsar Detector ASIC



10^3 - 10^5 Folding Processors

ASIC Network



RFI Mitigation

- Subband-relative:
  Accumulation is per Subband
- Beam-relative

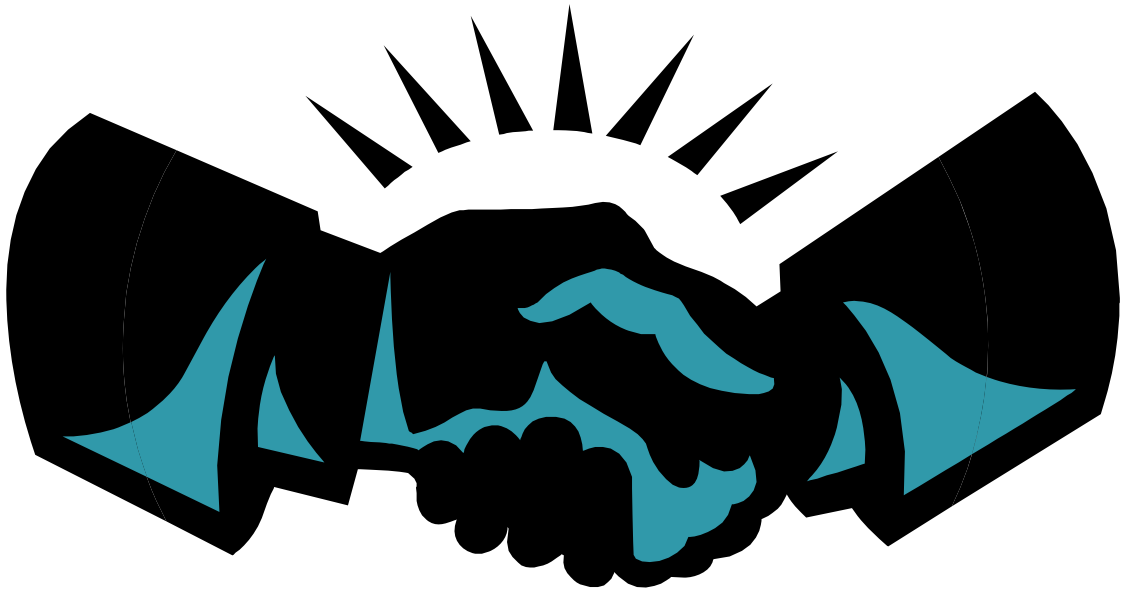
The Pulsar Search Machine

- 128 Telescopes
- 128 Beams
- 100 DMs
- 50.000 Orbits
- 6.4×10^8 hypothetical Pulsars

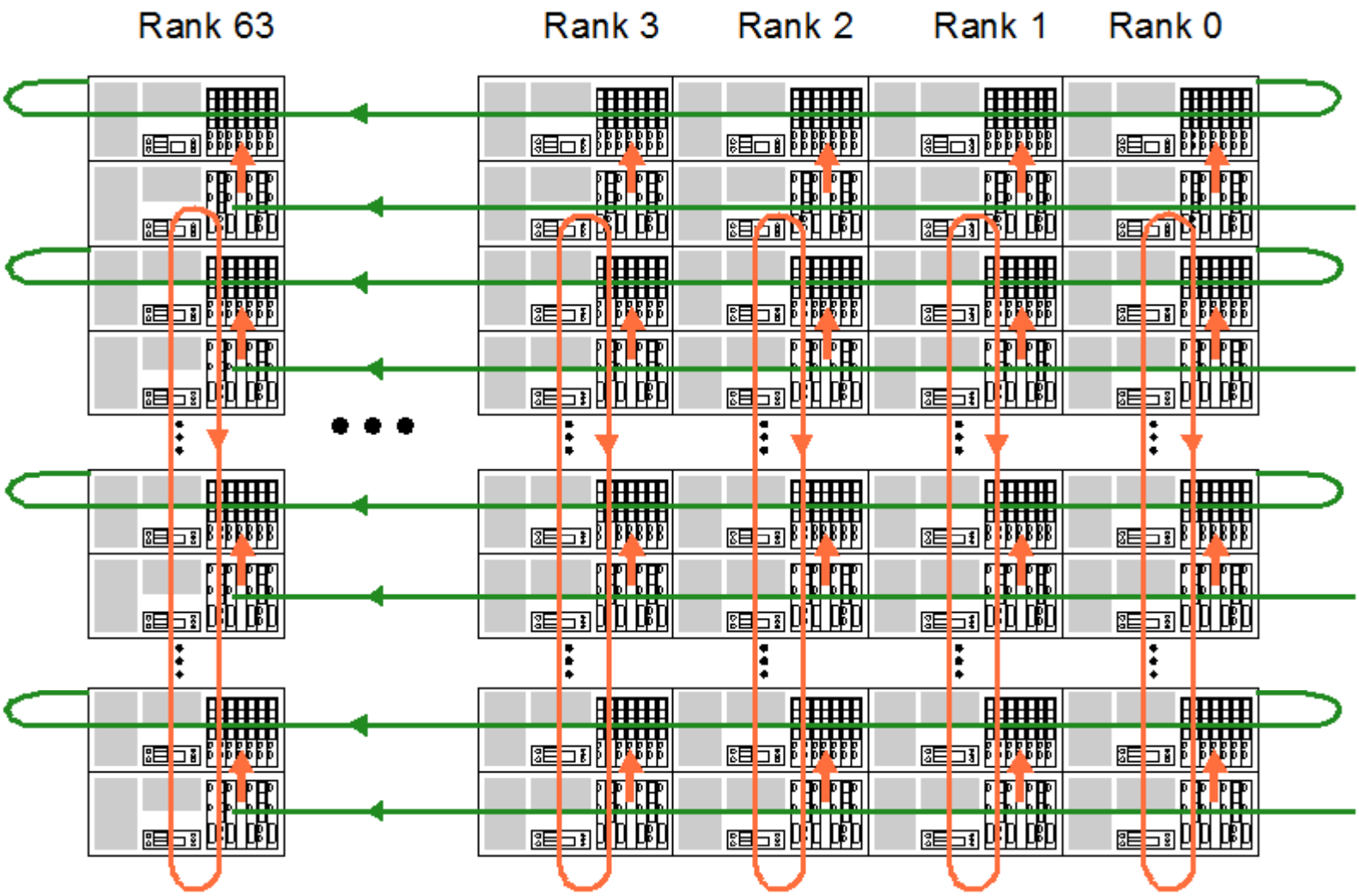
The Pulsar Search Machine

- PC Cluster
- Switch-less Design, helps Scalability
- GPU-PC + ASIC-PC = Compute Node
- 64 Ranks of 16 Compute Nodes
- 2048 PCs, 4096 CPUs, 8192 GPUs, 16384 ASICS
- 32.5 M€

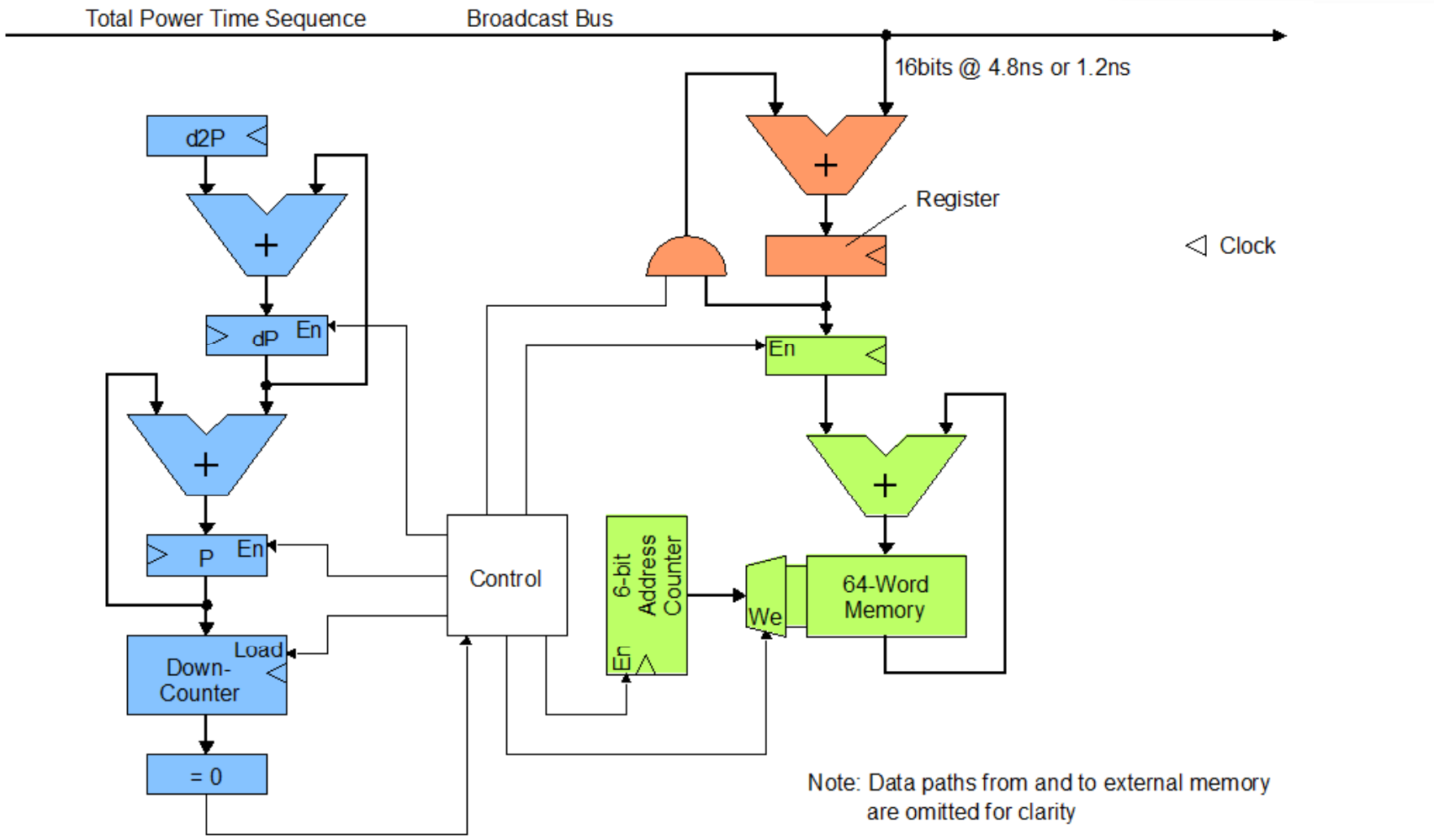
Thanks!



The Pulsar Search Machine



Folding Processor



Costs

Item	# of Units	Unit Price	Total Costs
Server Case	2048	300	614,400
Power Supply 1500W	2048	300	614,400
Harddisks 3TB	8192	180	1,474,560
Mainboard	2048	400	819,200
Multicore CPU	4096	1,400	5,734,400
Main Memory 12GByte	6144	180	1,105,920
Dual-GPU-Card watercooled	4096	800	3,276,800
Watercooling Accessories	1024	300	307,200
FPGA Virtex-6 XC6VHX250T	2048	2,100	4,300,800
CFX: Memory 2GByte SODIMM	8192	25	204,800
CFX: Optical Transceivers	8192	150	1,228,800
CFX-Board	2048	200	409,600
PD: ASIC	16,384	300	4,915,200
PD: Memory 4GByte SODIMM	65,536	40	2,621,440
PD: Optical Transceivers	16,384	150	2,457,600
PD-Board	8192	300	2,457,600
Total Costs Computing Hardware			32,542,720

Supercomputer Costs 2005

- Sandia National Laboratories Red Storm: $90 million
- Los Alamos National Laboratory ASCI Q: $215 million
- Earth Simulator Center, Japan: $250 million
- IBM Blue Gene/L: $290 million

various (unreliable) Internet Sources