Front-End Electronics for a Ton-Scale HPGe Experiment - A User Perspective

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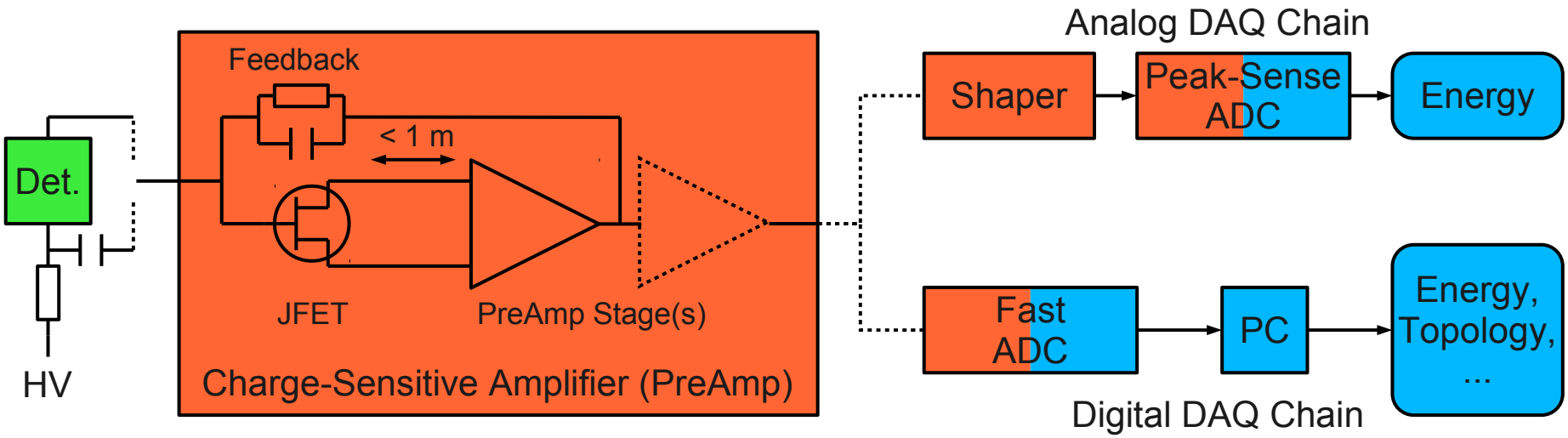
Basic HPGe Readout Chain



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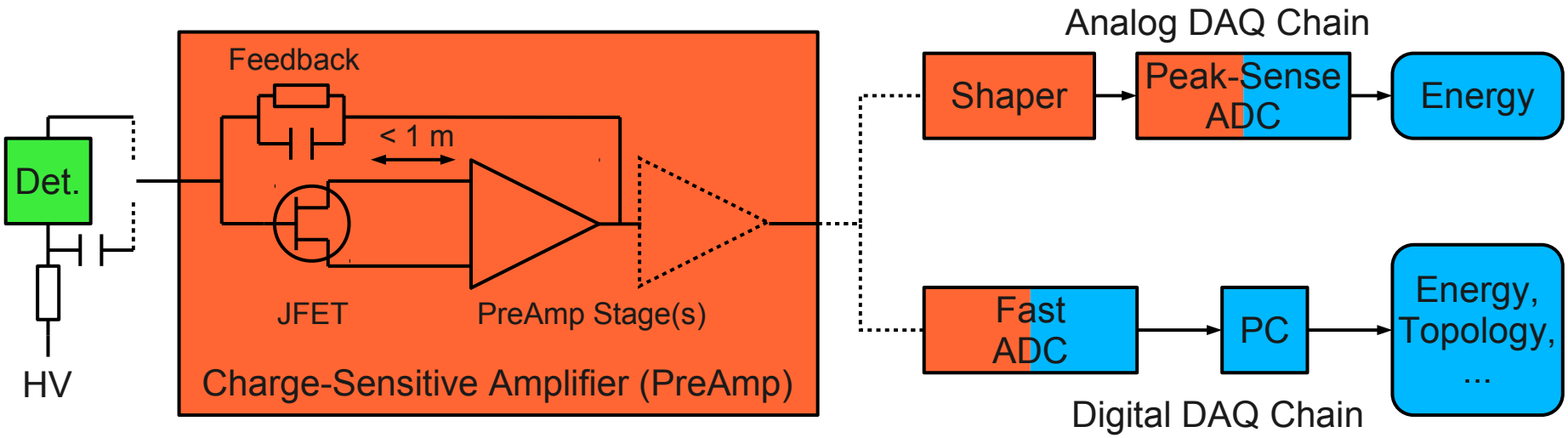
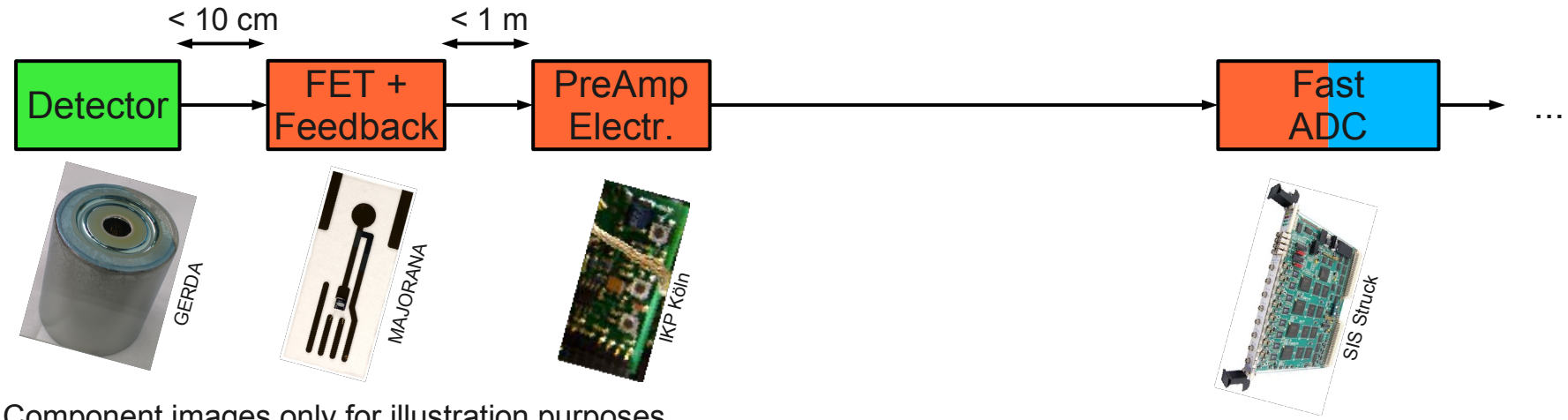


- Large scale integration should be considered from beginning
- Front end design tightly coupled to detector design

State of the Art



Component images only for illustration purposes

- Excellent discrete pre-amplifier designs available, detector can perform with near-theoretical threshold and resolution
- CDEX: Ultra-low threshold preamp (switched reset on PPC)
- MAJORANA: Ultra low-background preamp with 500 eV threshold (PPC detector, short cabling)
- Gerda: Ultra-low background preamps with long cabling, new design (GeFro) with FET/preamp separation of $\sim$ 10 m

What do We Have to Instrument?

- Active mass $\sim$ 1000 kg
- Multi-purpose experiment: dark matter + double-beta
  $\rightarrow$ need excellent energy resolution and very low threshold
  $\rightarrow$ BeGe or Point-Contact geometry, mass $\sim$ 1 kg

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- Multi-purpose experiment: dark matter + double-beta
  $\rightarrow$ need excellent energy resolution and very low threshold
  $\rightarrow$ BeGe or Point-Contact geometry, mass $\sim$ 1 kg
- Extreme low-background requirements
  and rejection of non-physics effects
  $\rightarrow$ Some segmentation would help
  $\rightarrow \sim$ 4 electrodes / detector

$\rightarrow \sim$ 1000 detectors, $\sim$ 4000 read-out channels

Cables are Troubles

Lessons from GERDA and others:

- Very hard to find good low-background cables
- Long cables troublesome $\rightarrow$ noise
- Cable temperature affects calibration (1 K range)
- Single-ended signaling troublesome $\rightarrow$ noise

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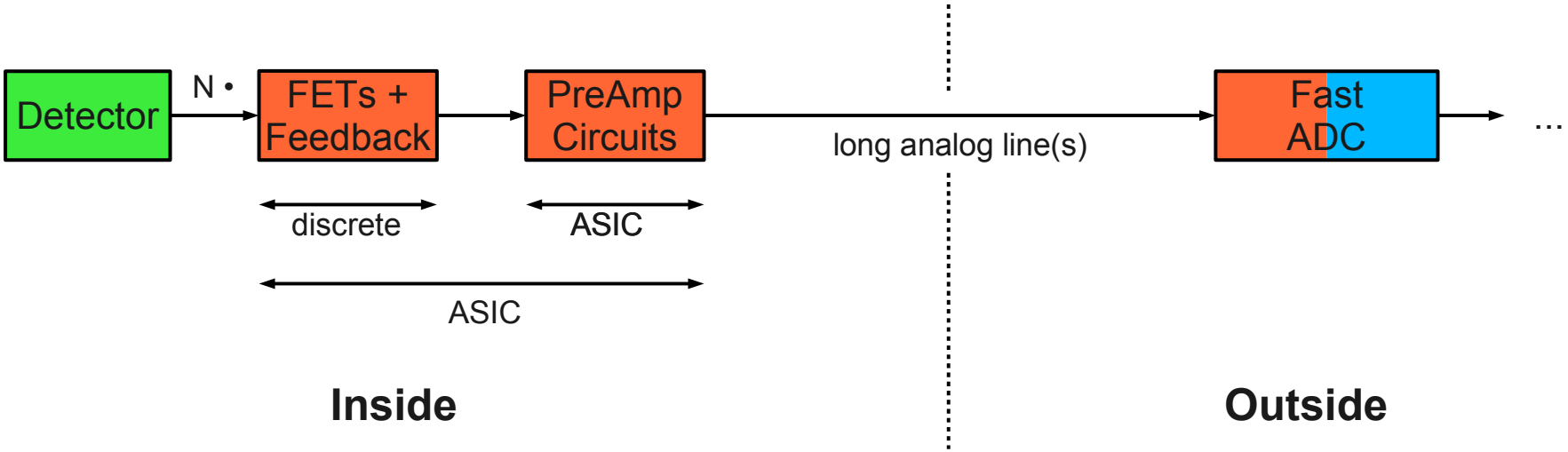
  Ideally combinations of these
- N channels per cable instead of N cables per channel

Integration / ASICS



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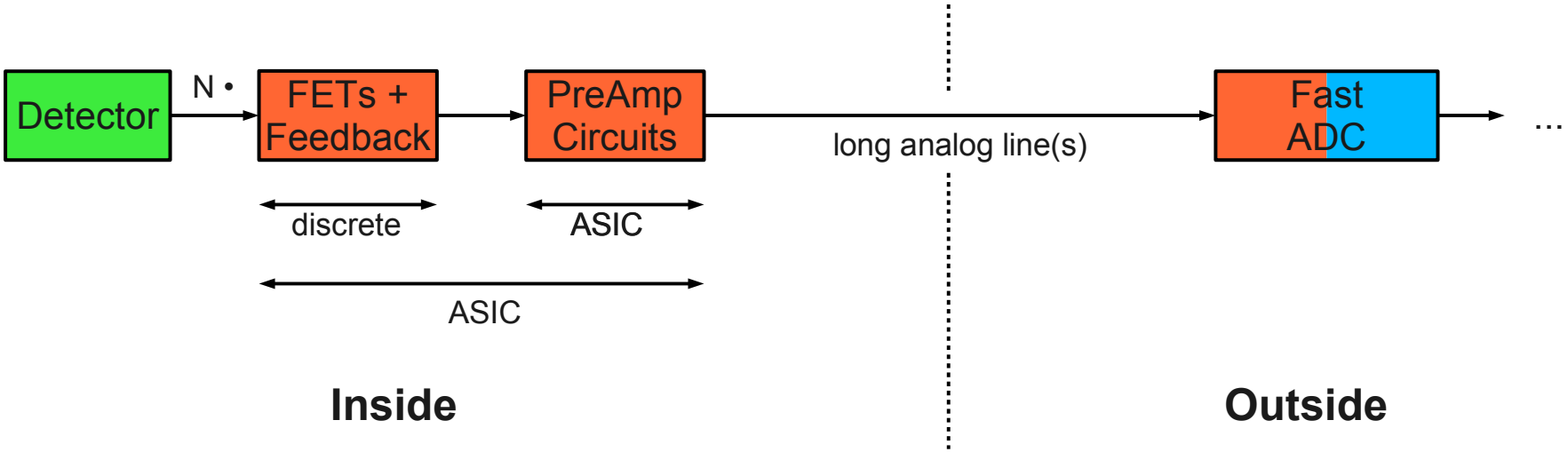

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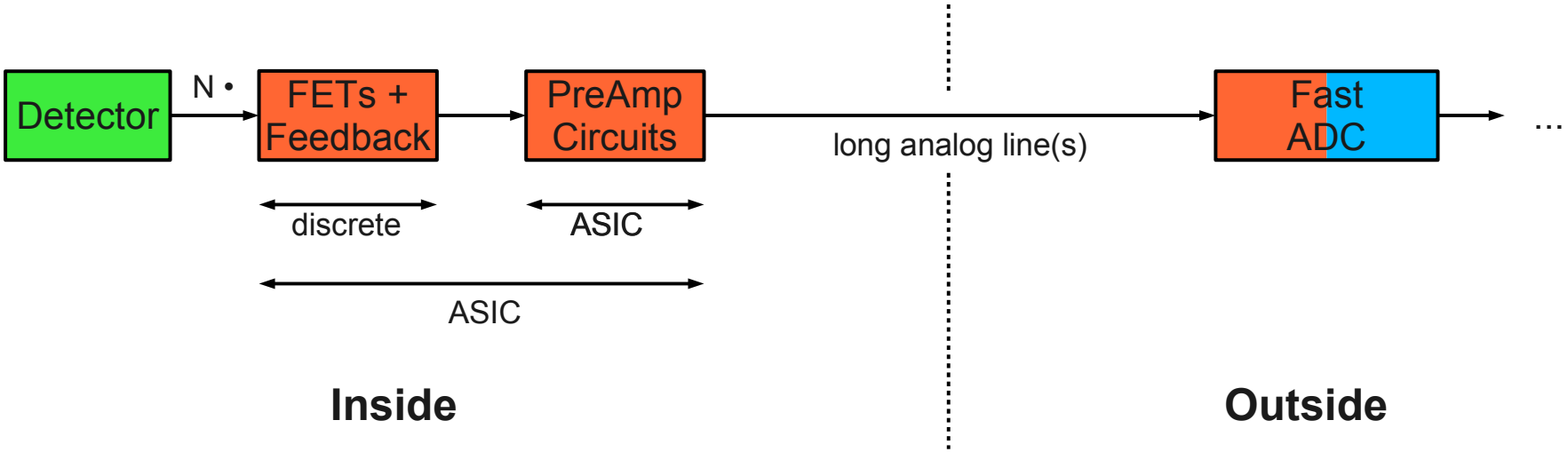

- Micro-scale circuits:
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- Output drivers near detector → robust signals
- Small and light → extremely low mass
- Radiopurity (preliminary, COBRA & others): ASICS can be clean

User's perspective: What's the output?

- Event data:
  - 50 MHz to 100 MHz sampling
  - 14 to 16 bit per sample
  - minimum 20 us to 40 us trace per event
  - $\sim$ 4 kB / event

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- Event data:
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  - minimum 20 us to 40 us trace per event
  - $\sim$ 4 kB / event
- Maximum data volume: Full calibration
  - 1E6 events per detector, max. 24 h
  - $\sim$ 16 TB for full array
  - data rate $\sim$ 2 Mbit / s

Minimal cabling?

- Boundary data and low-voltage wiring
  - Probably all-copper inside:
    No radio-pure fiber optics / electronics available
    $\rightarrow \sim$ 100 Mbit/s per channel
  - $\sim$ 3 diff. pairs per data channel (in, out, clock), $\sim$ 2x supply
  - 20 data channels $\rightarrow \sim$ 200 long-distance data wires

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- High voltage: Select detectors for similar properties and group them, e.g. 6 detectors per HV line
- Comparison:
  - Current (GERDA): > 2.5 or 3 long cables / detector
  - Possible: < 0.4 long cables / detector
- But how to multiplex? Need buffering!

Switched-Capacitor Array Sampling

- Digitization: Quantization in time and amplitude - doesn't have to happen in one step
- Early quantization, at least in time

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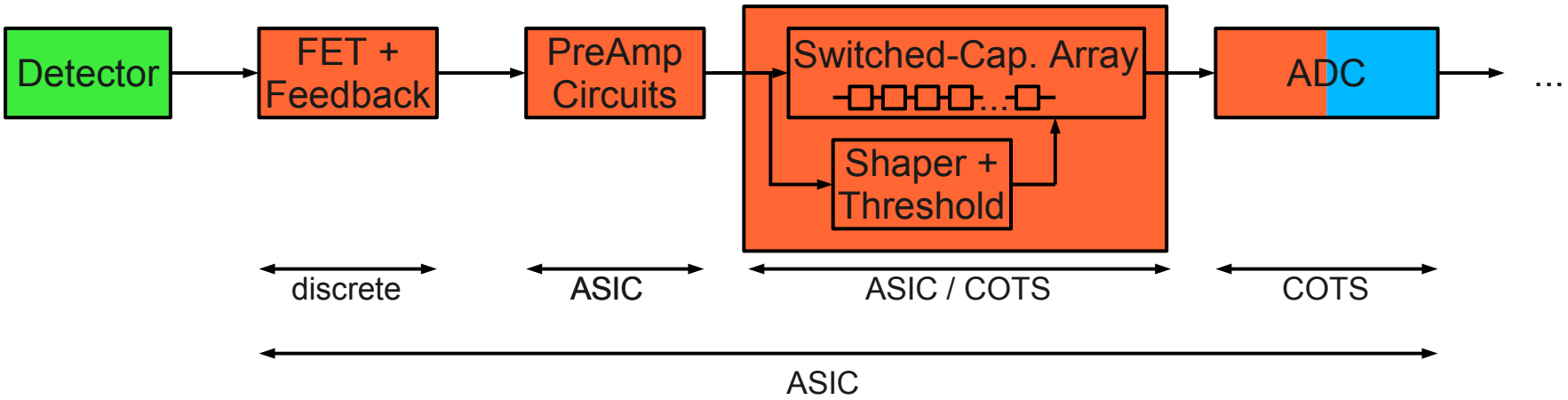

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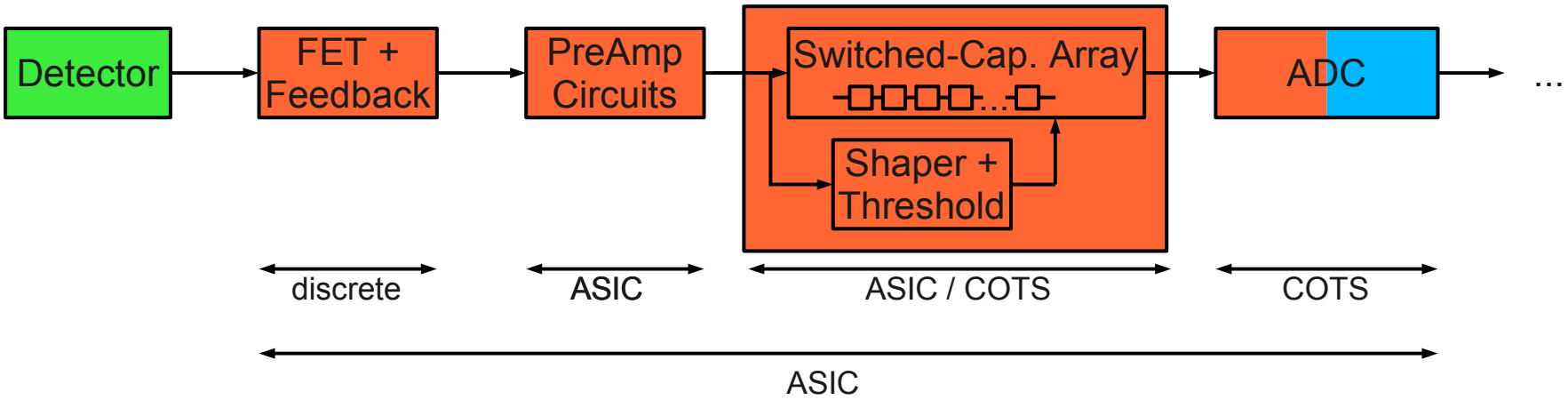

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- Read out by ADC to quantize amplitudes

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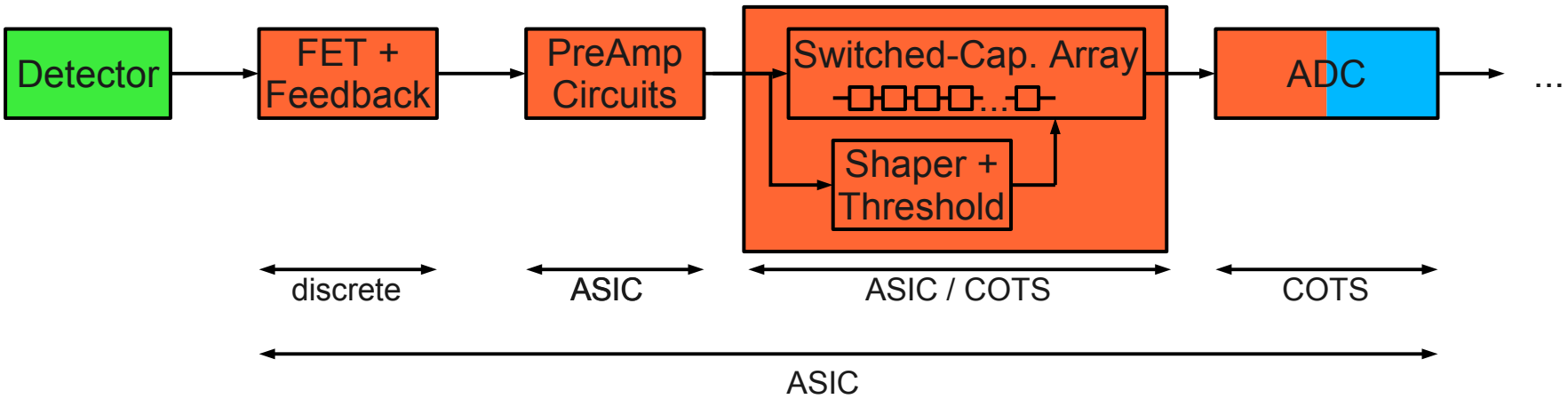

- Switched capacitor sampling used extensively in the astro-particle community now: ANTARES, AUGER, ICECUBE, HESS-2, MAGIC, VERITAS, ...
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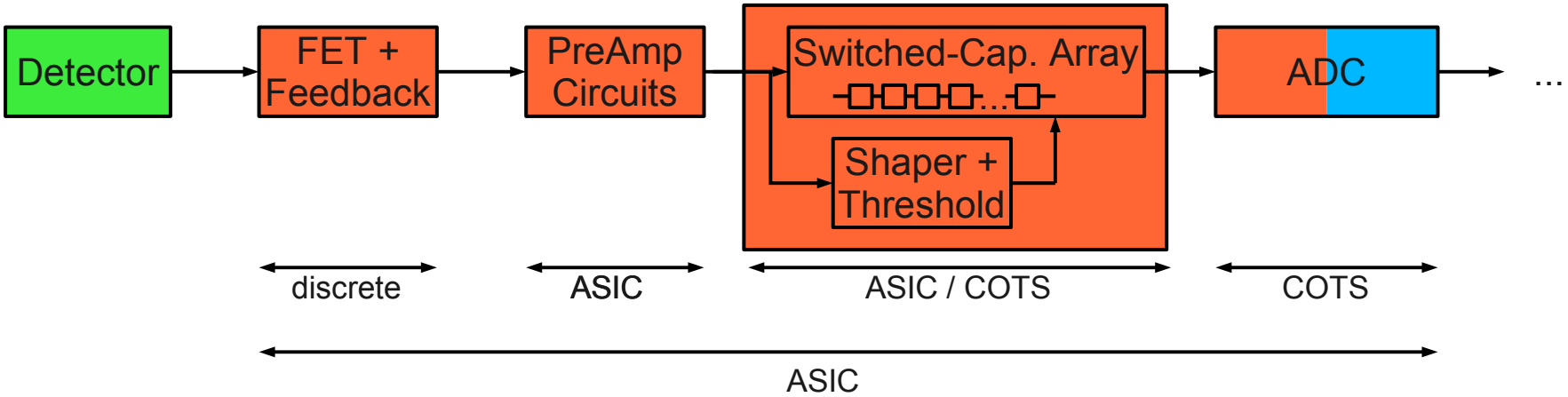

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- Also for multi-channel RTSDs: POLARIS (CdZnTe), ...
- Used in many different ASICS in production now, ADC on chip or separate
- $\sim$ 5-50 mW per channel

Summary

- Have excellent preamps, even low-background
- Currently, painful compromises when combining low background and long cables / many channels
- ASICs may help
- Should look into early digitization