

# Transient detector string development at WIPAC

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# The main motivation

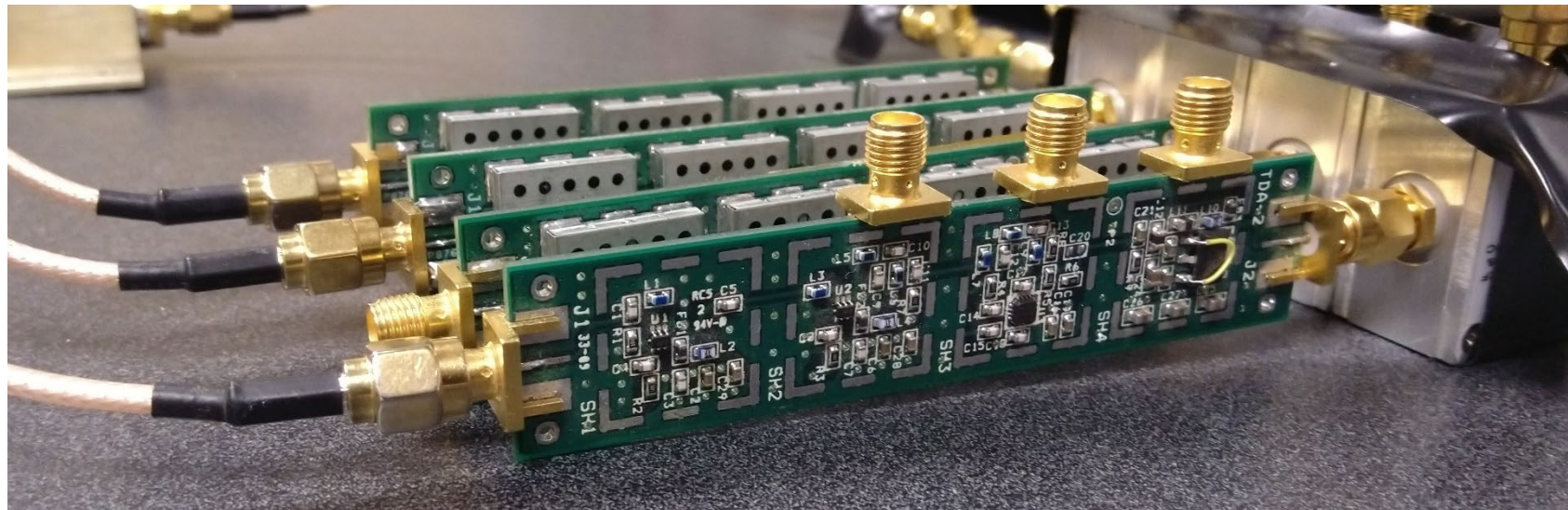
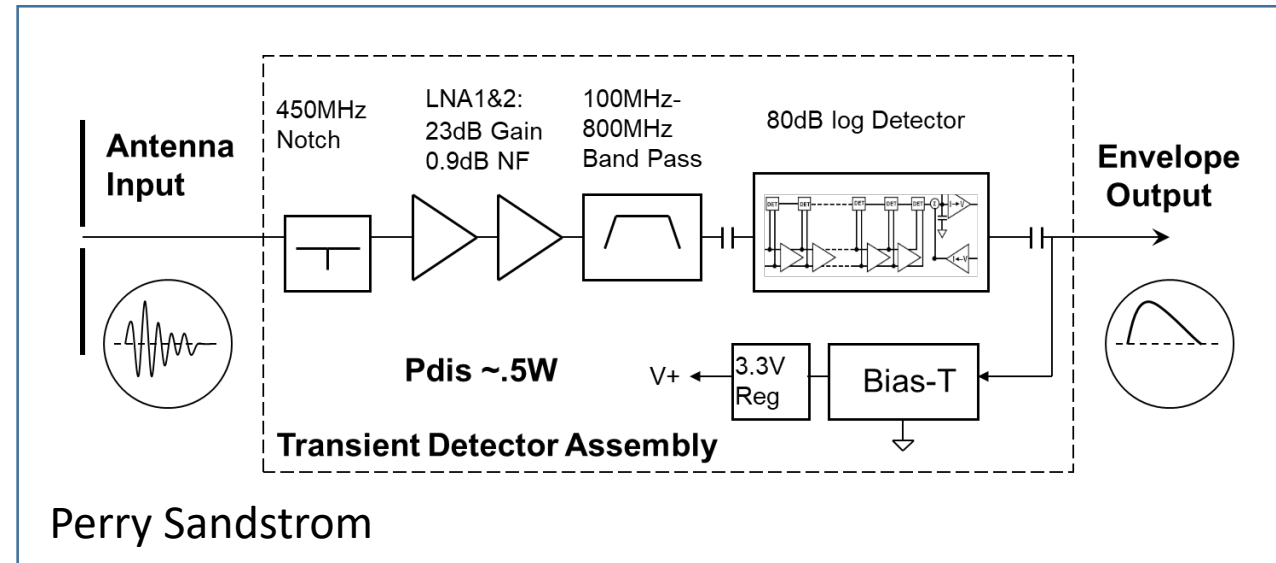
**For Gen2, need to design a system for:**

- mass production
- mass deployment
- mass operation
- Long term stability

**Need to build:**

- small electronics
- low power system
- simple electronics

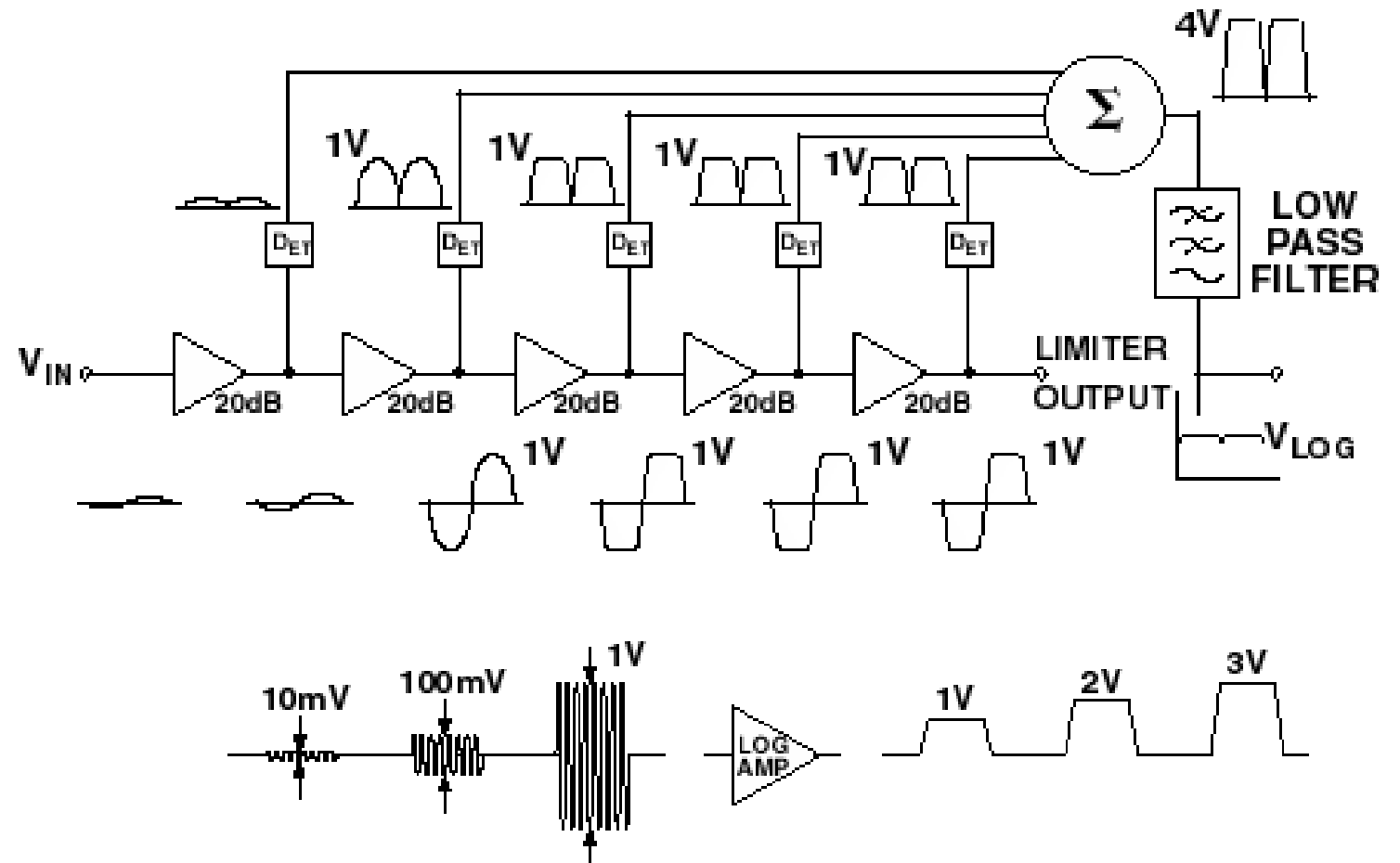
# The key ingredient: Transient detector assembly



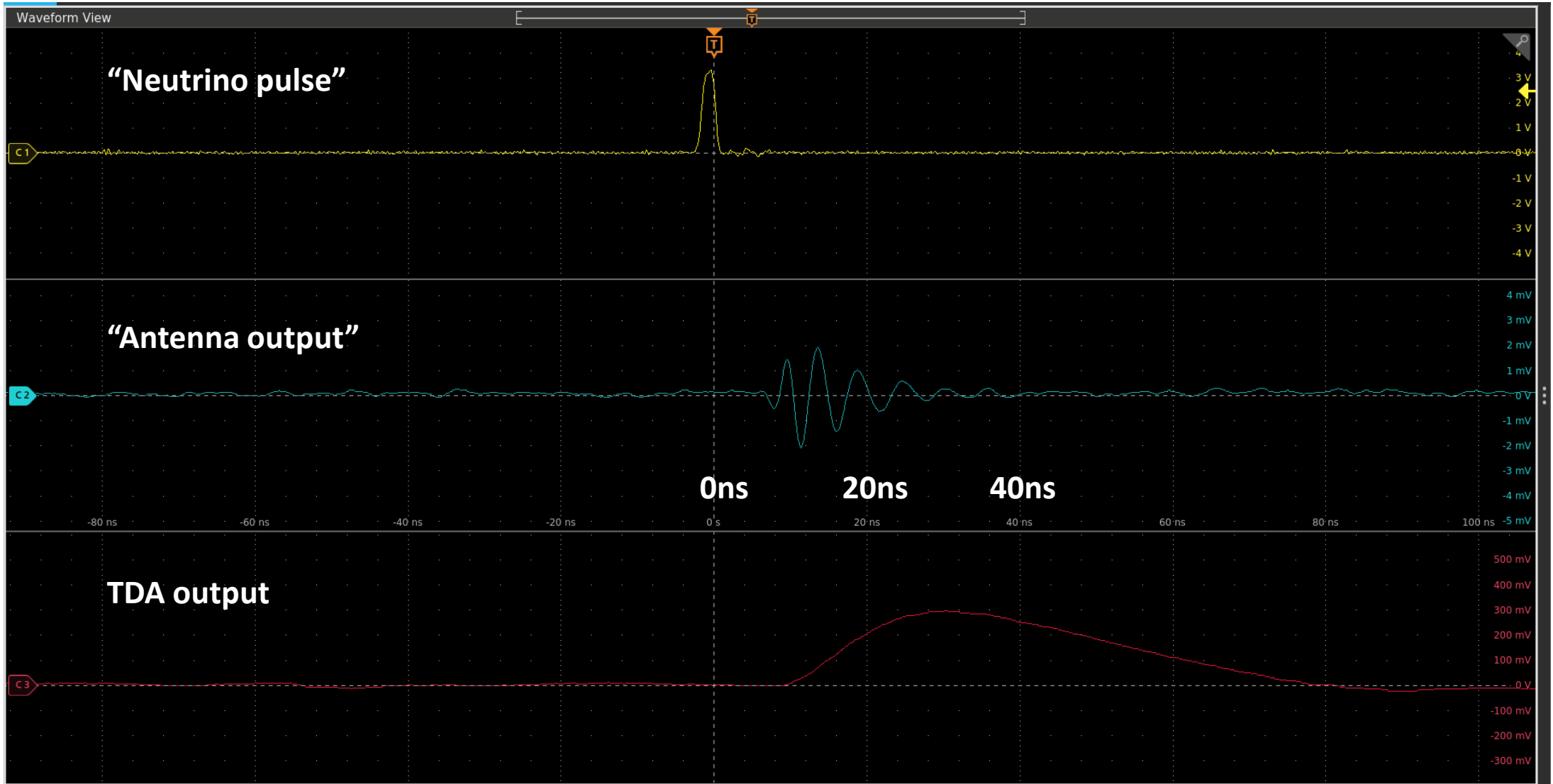
# Logarithmic amplifier – Working principle

## Working principle:

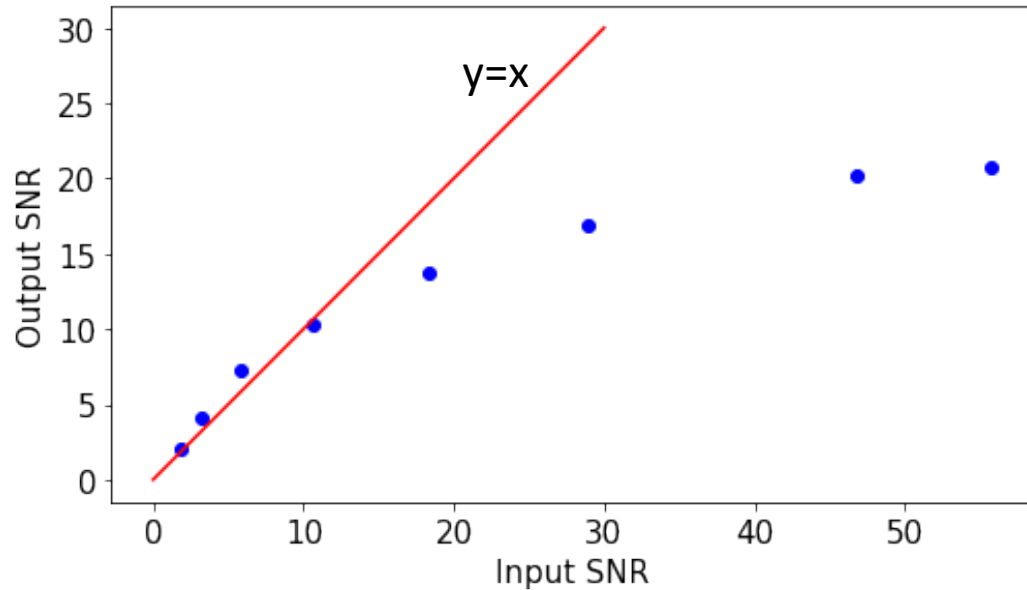
- Chain of amplifiers, limited to rail
- Adding rectified signals from points in amplification chain
- Low pass filter on output



# The Transient Detector Assembly



# The key ingredient: Transient detector assembly

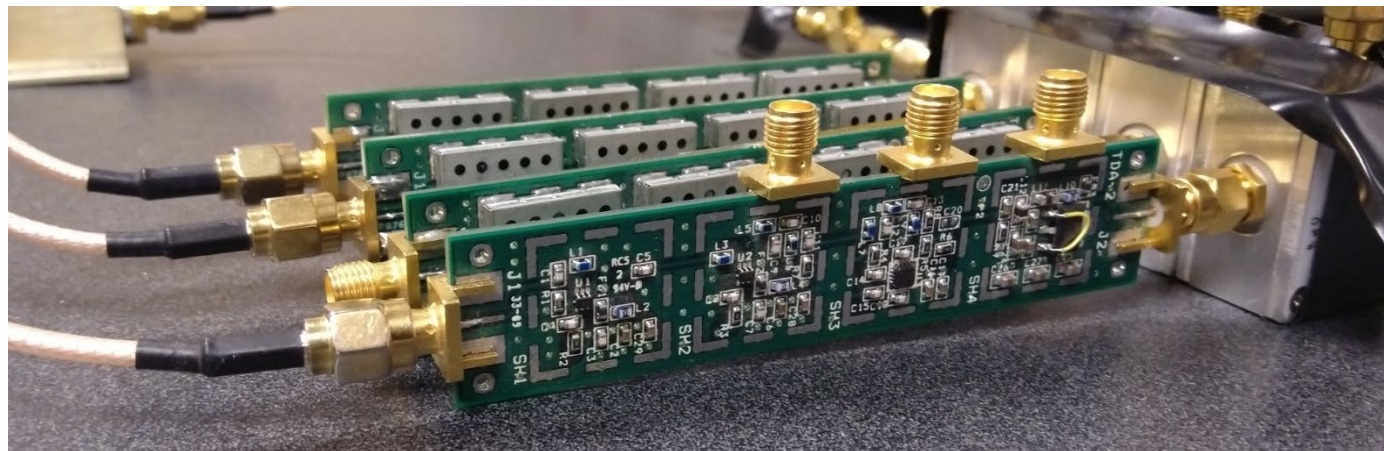


## Hard to provide:

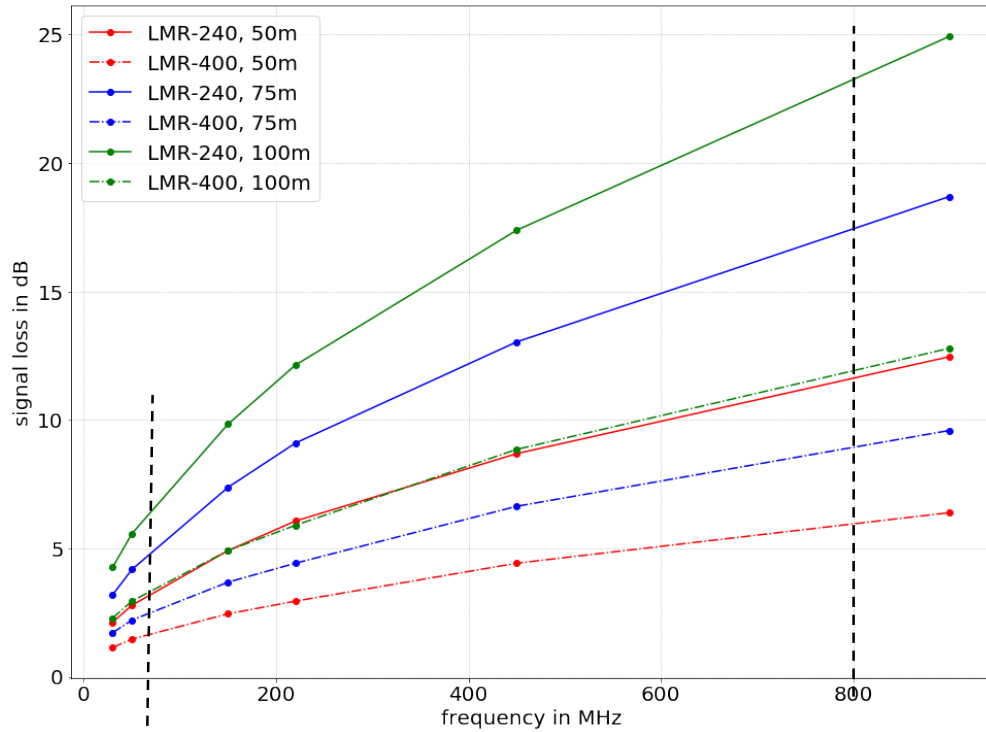
- Sub ns timing precision
- Full information on frequency content of primary signal

## Allows for:

- Timing precision  $\sim 1\text{ns}$
- Low sampling rate at receiving end  $\rightarrow O(100\text{MS/s})$ 
  - $\rightarrow$  low power consumption
  - $\rightarrow$  no need for custom digitizers
- Lossy cables for transmission to surface
- Log detector  $\rightarrow 57\text{dB}$  dynamic range



# Cable loss

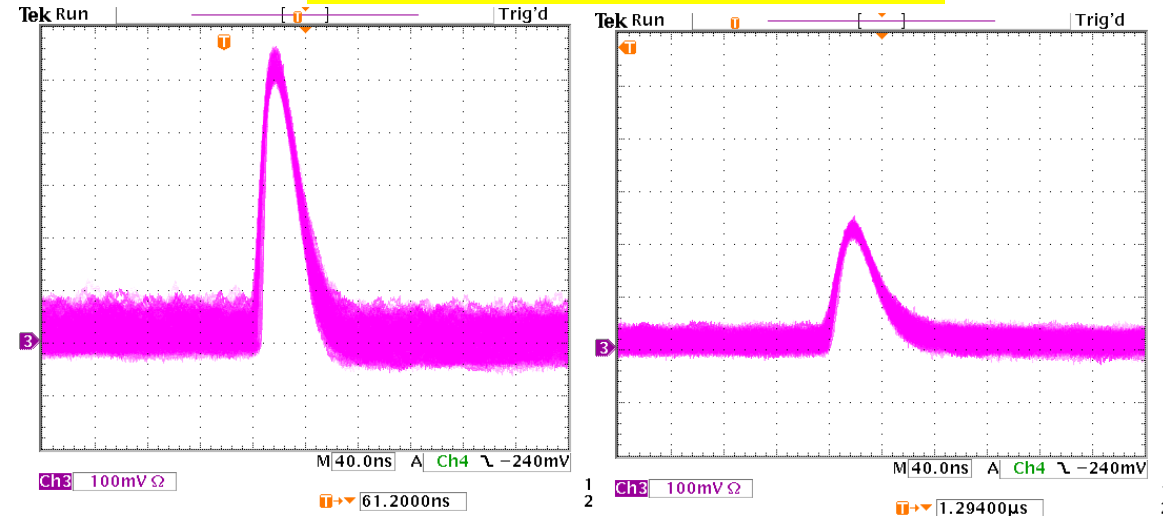


Max freq. of envelope

Max freq. of ARA full-band

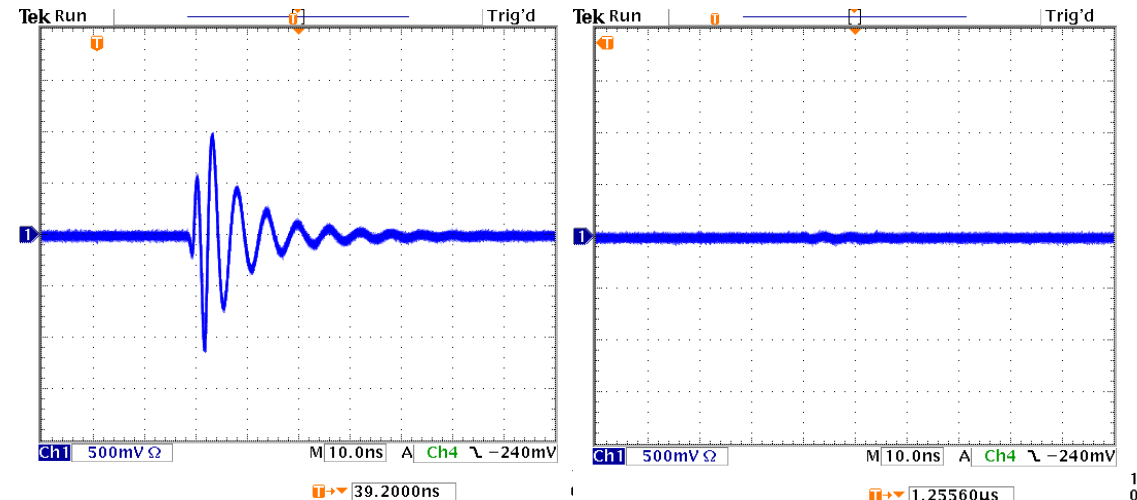
Solved for full-band by using RF-over fiber links  
 → Add power consumption  
 → Add complication

## Envelope attenuation through 300m of RG6 Coax



16 Jun 2009 21:02:03

## Full-band attenuation through 300m of RG6 Coax

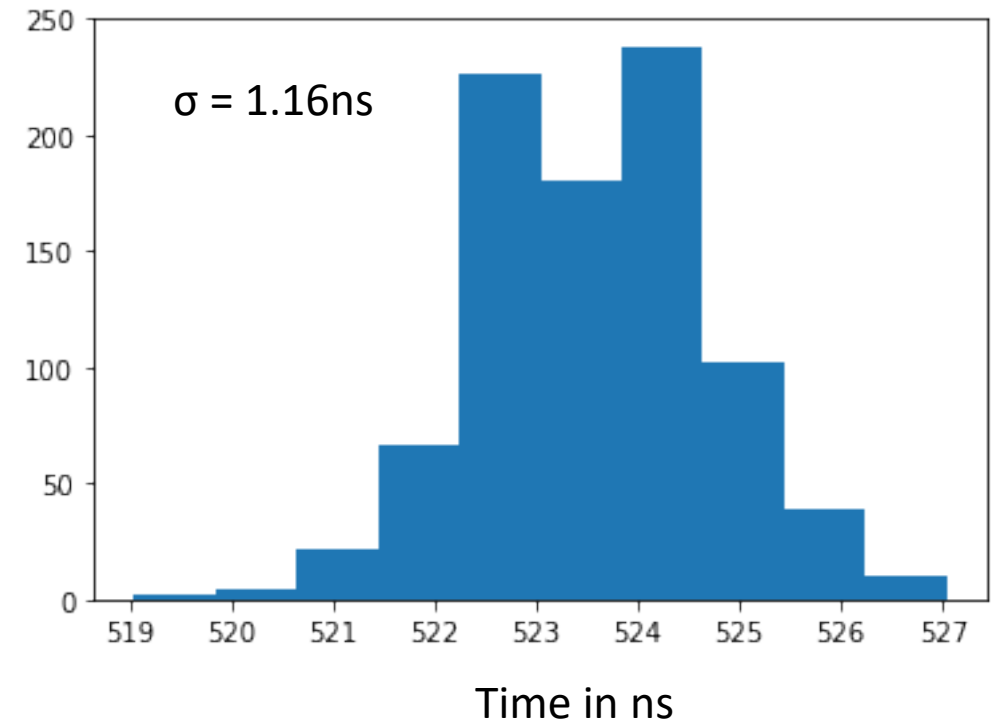
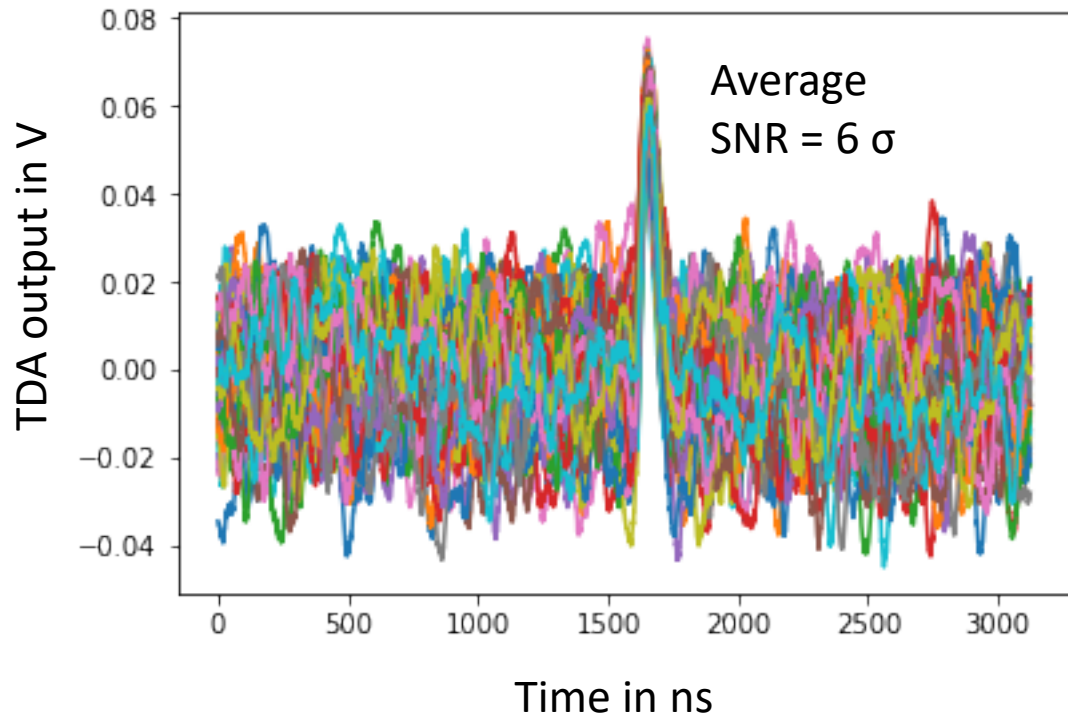


17 Jun 2009 06:58:40



# Timing precision

- Measure timing precision against scope trigger
- Use constant fraction discriminator at threshold 0.05 → Nothing too fancy
- Measured at 90% trigger efficiency



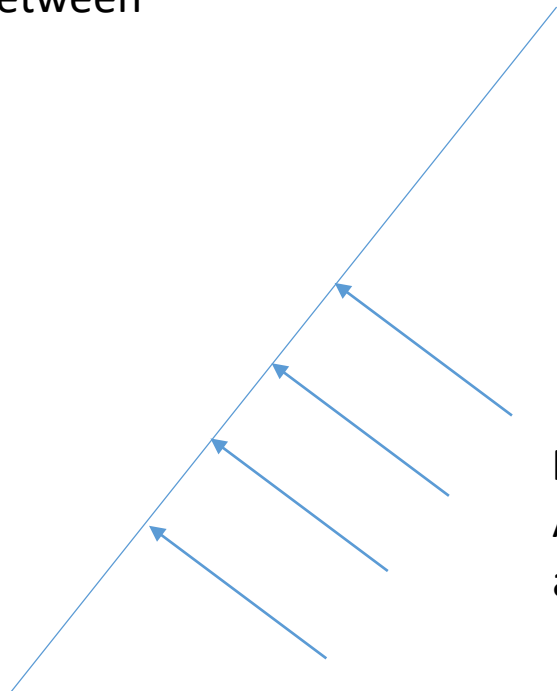


# More features

Investigate single beam phased array

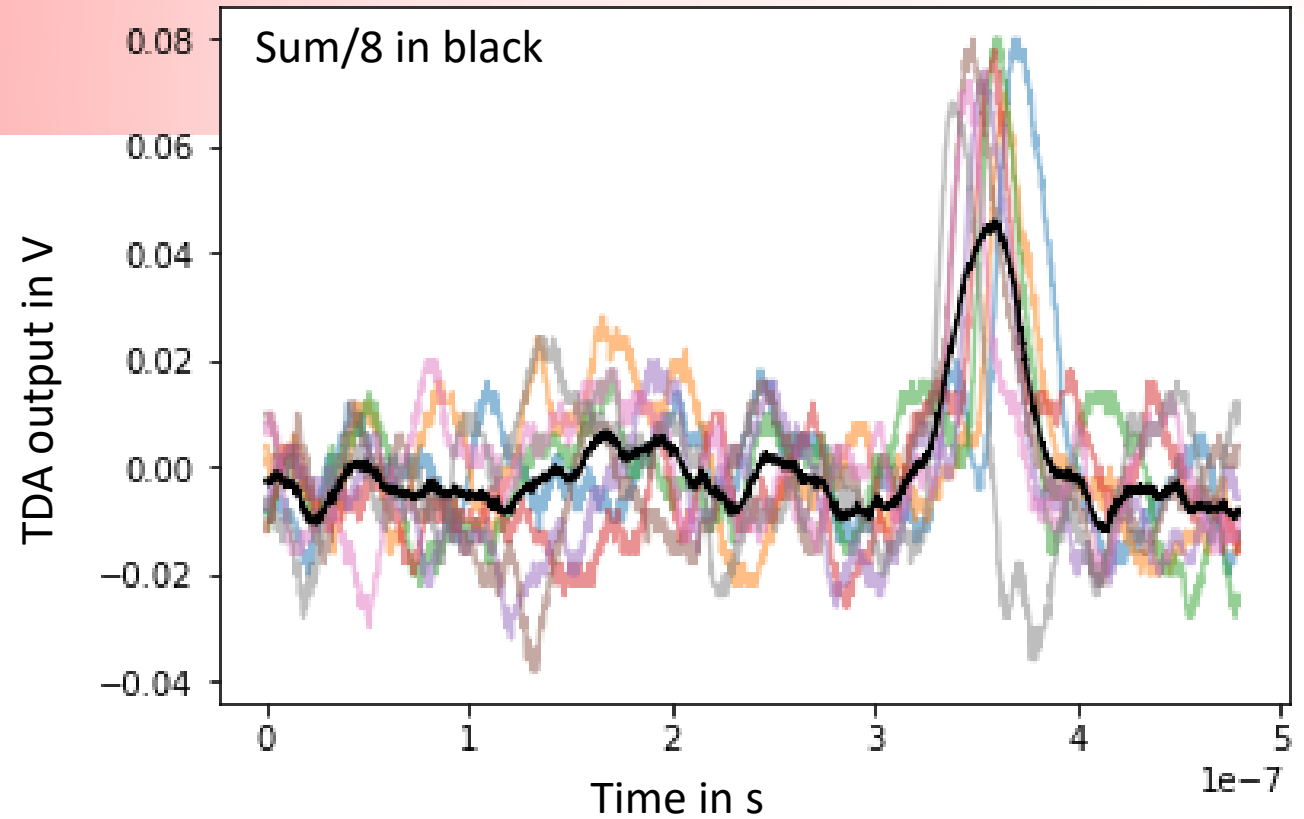


8 antennas, 1m spacing,  
add 4ns of cable between  
sensors



**Radio signal from neutrino**

Arrival time difference between neighboring  
antennas: -5ns  $\rightarrow$  +5ns



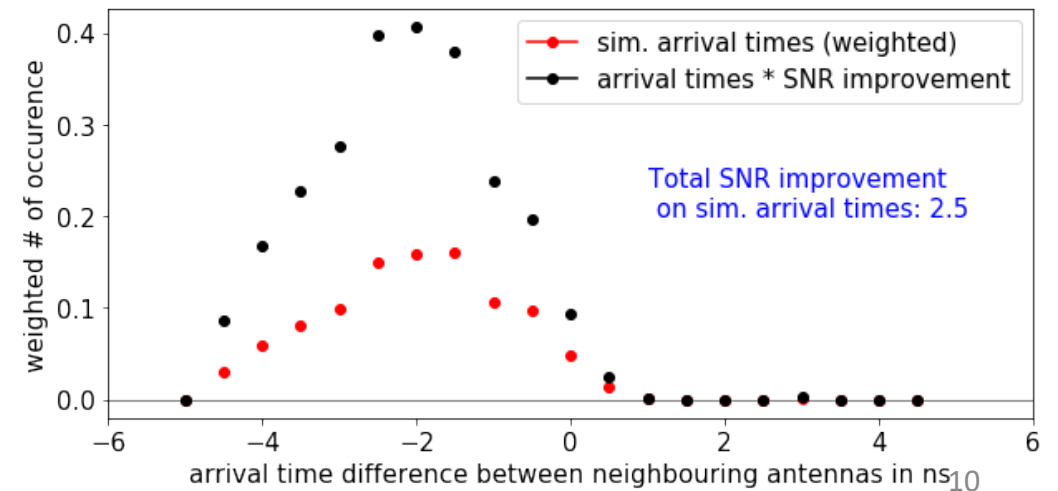
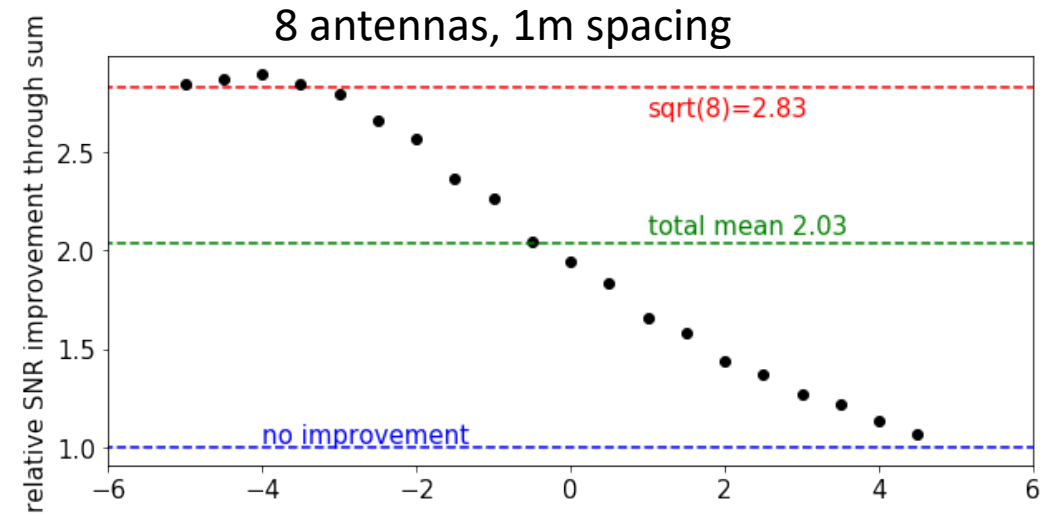
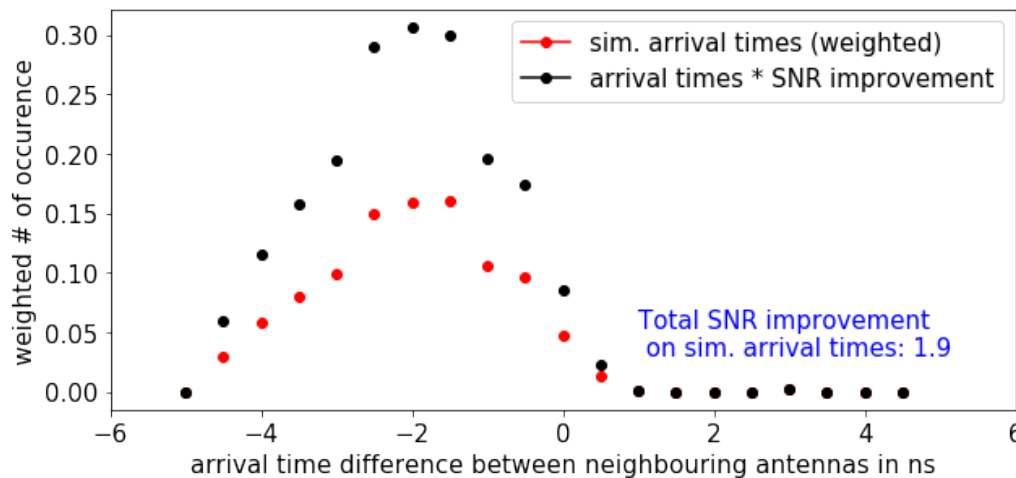
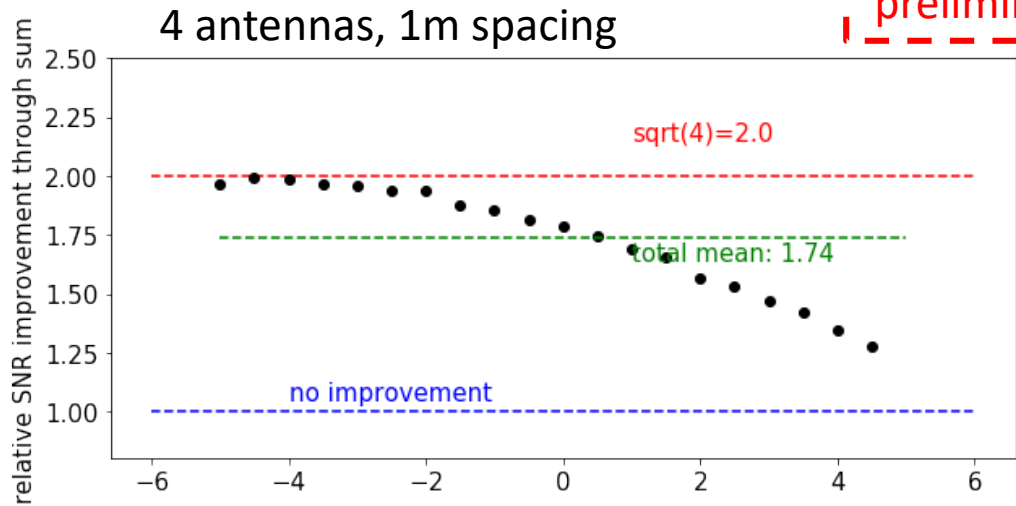
20-40ns pulse width

$\rightarrow$  Beams overlap for most angles

# Single beam phased array

- Only 1 ray solution
- Pulses from lab measurement
- Amplitude variation not taken into account
- Arrival times and weights from Ben's simulation

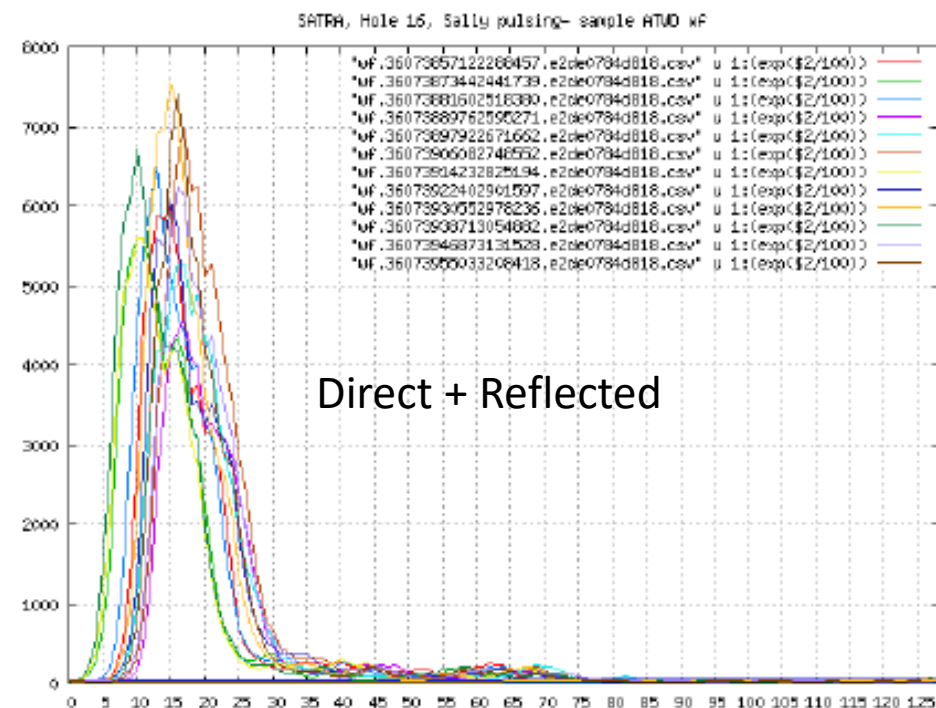
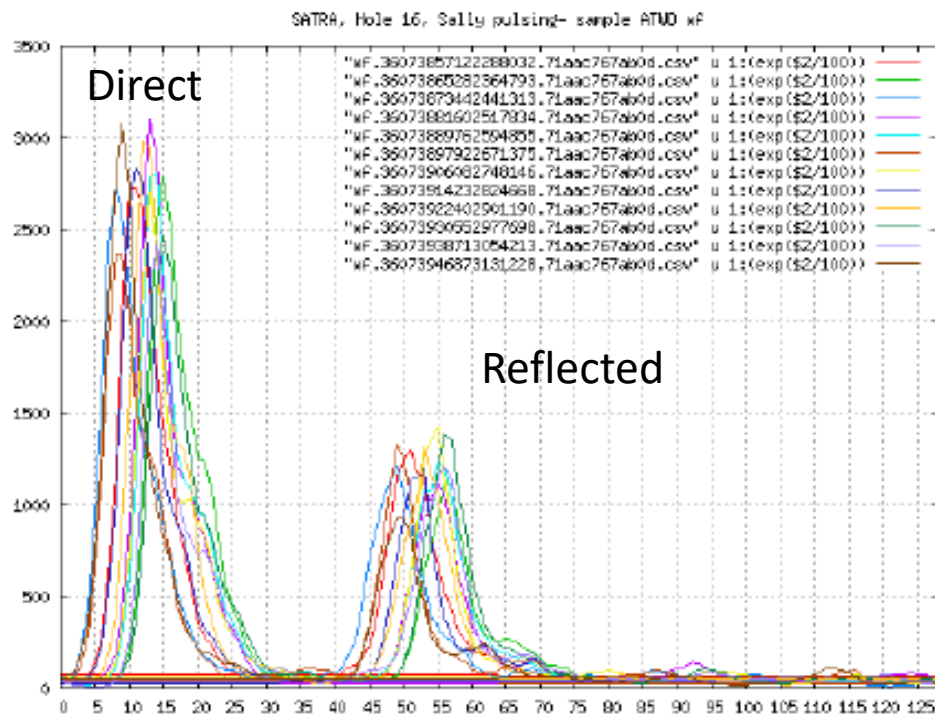
preliminary



# Proof of Concept (SATRA) at IceCube Holes 6,9,16



# Envelope waveforms recorded by SATRA

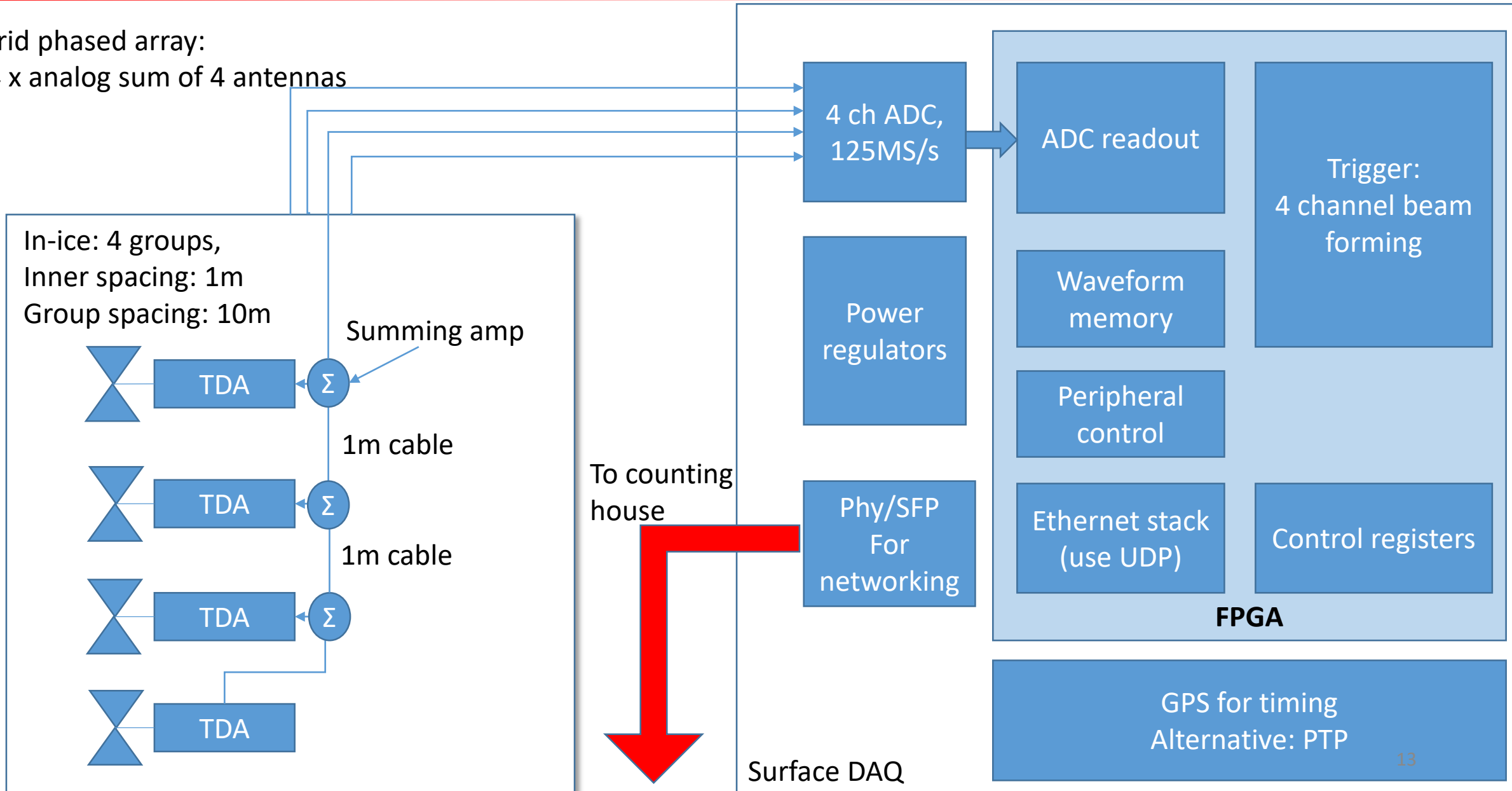


from 250m deep pulser ~350m distance

# Concept of string system

Hybrid phased array:

- 4 x analog sum of 4 antennas





# Some expected features

## Sensitivity:

- Simulation suggests improvement by factor 3.34 through all angles
- Still need to work out what that means for triggering
  - Depends on allowable noise rate
  - Trial factor for 12 beams (depends on allowable noise rate)

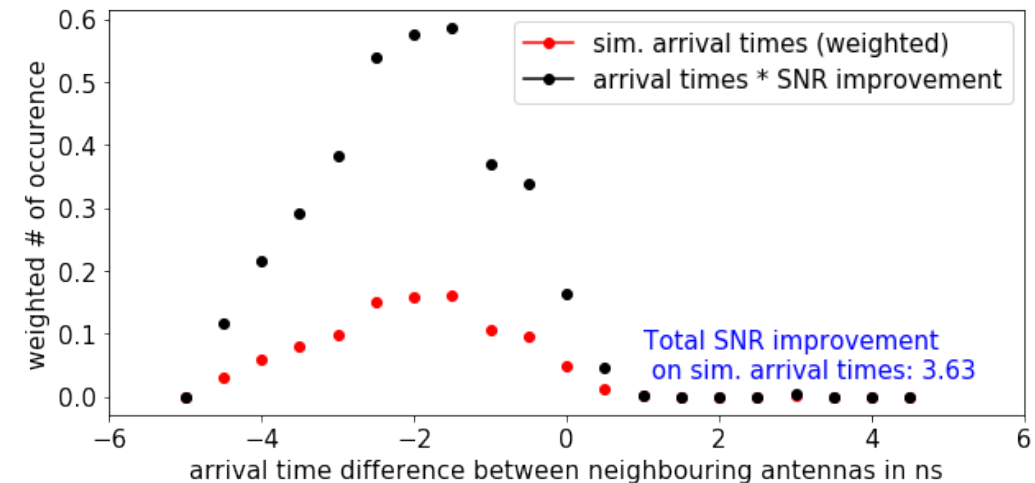
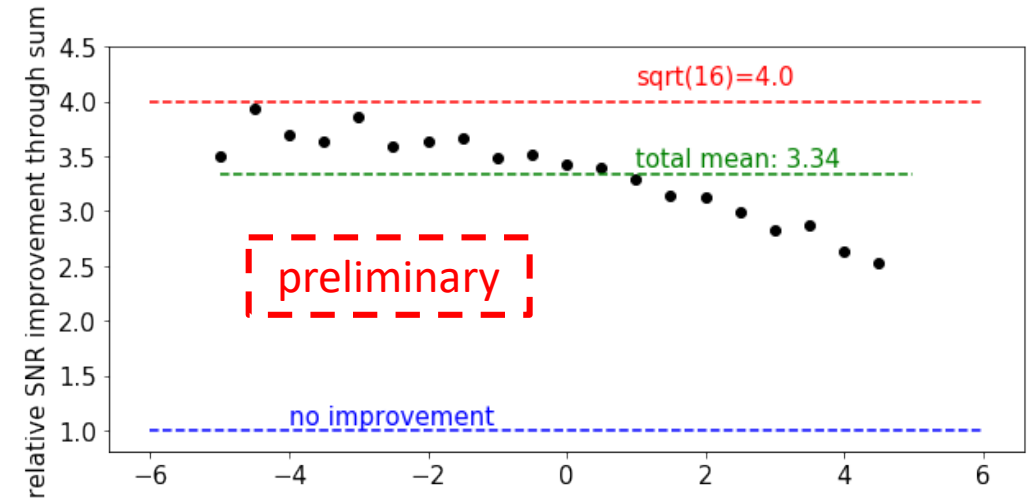
## Power consumption estimate:

- TDA:  $<0.3\text{W}$   $\rightarrow$  5W per string +  $\sim 2\text{W}$  cable loss
- Digitizer:  $<600\text{mW}$
- FPGA:  $<1\text{W}$
- Auxiliary: regulators, summing amp, Ethernet Phy or SFP  $\rightarrow$  another  $\sim 2\text{W}$

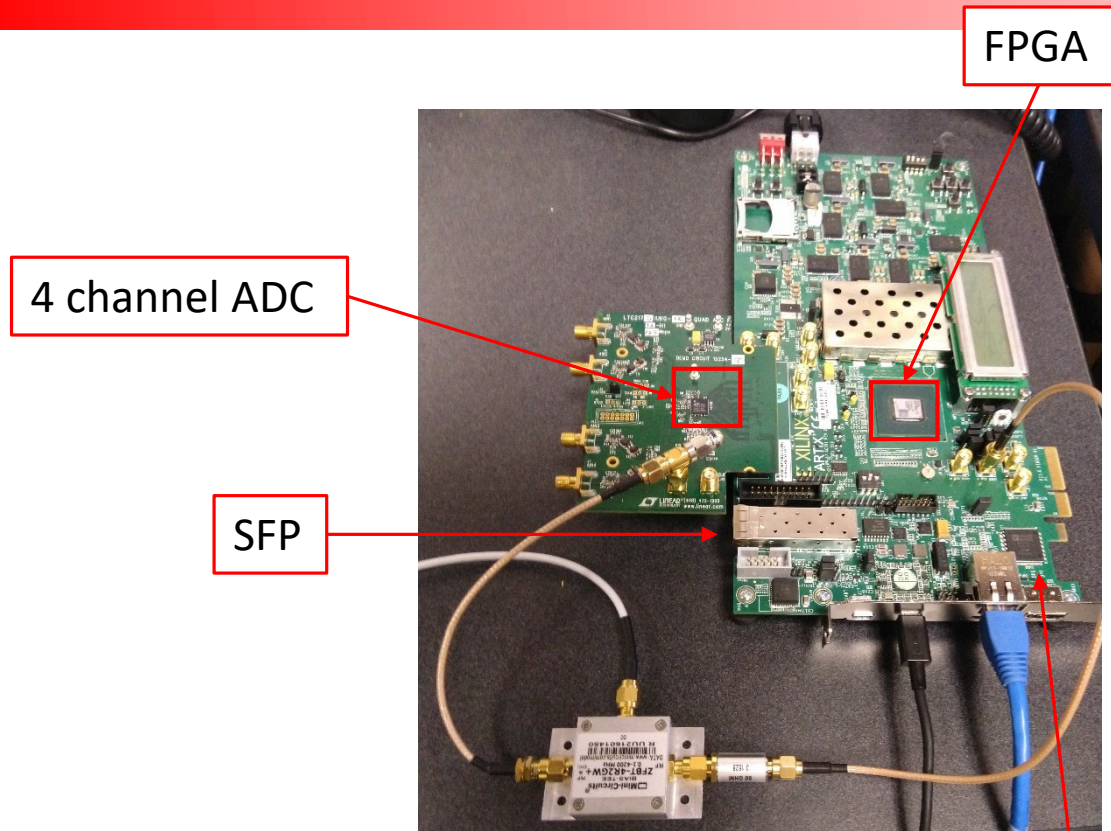
**Total  $<11\text{W}$  power consumption per string expected**

## Multiple applications:

- Can be used anywhere if 1ns timing precision is sufficient
- Low power consumption makes it interesting for large detectors with high number of strings

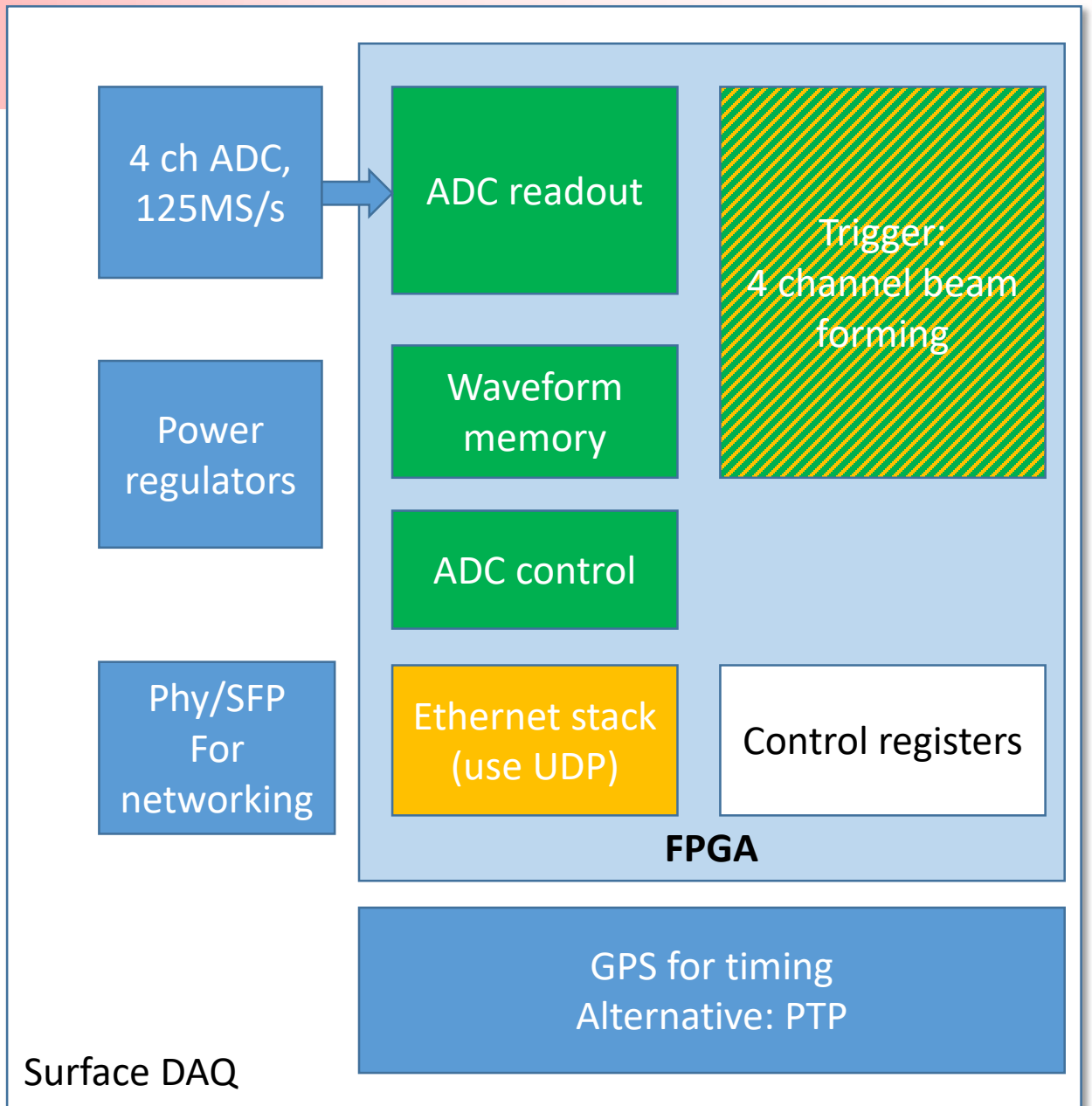


# Current status



## More Todo:

- Summing amp design by Kyra
- Need redesign, mass production of TDAs
- Full system tests
- More simulations for detector optimization, once concept has been proven to work





# Route to South Pole

## Goal:

- Proof manufacturability of low cost, low-power string system with high sensitivity
- Verify simulations/measurements (suggest promising sensitivity)
- Study if this system would be interesting for Gen2-radio
- Aim for test deployment in 2020/21 season

## Status:

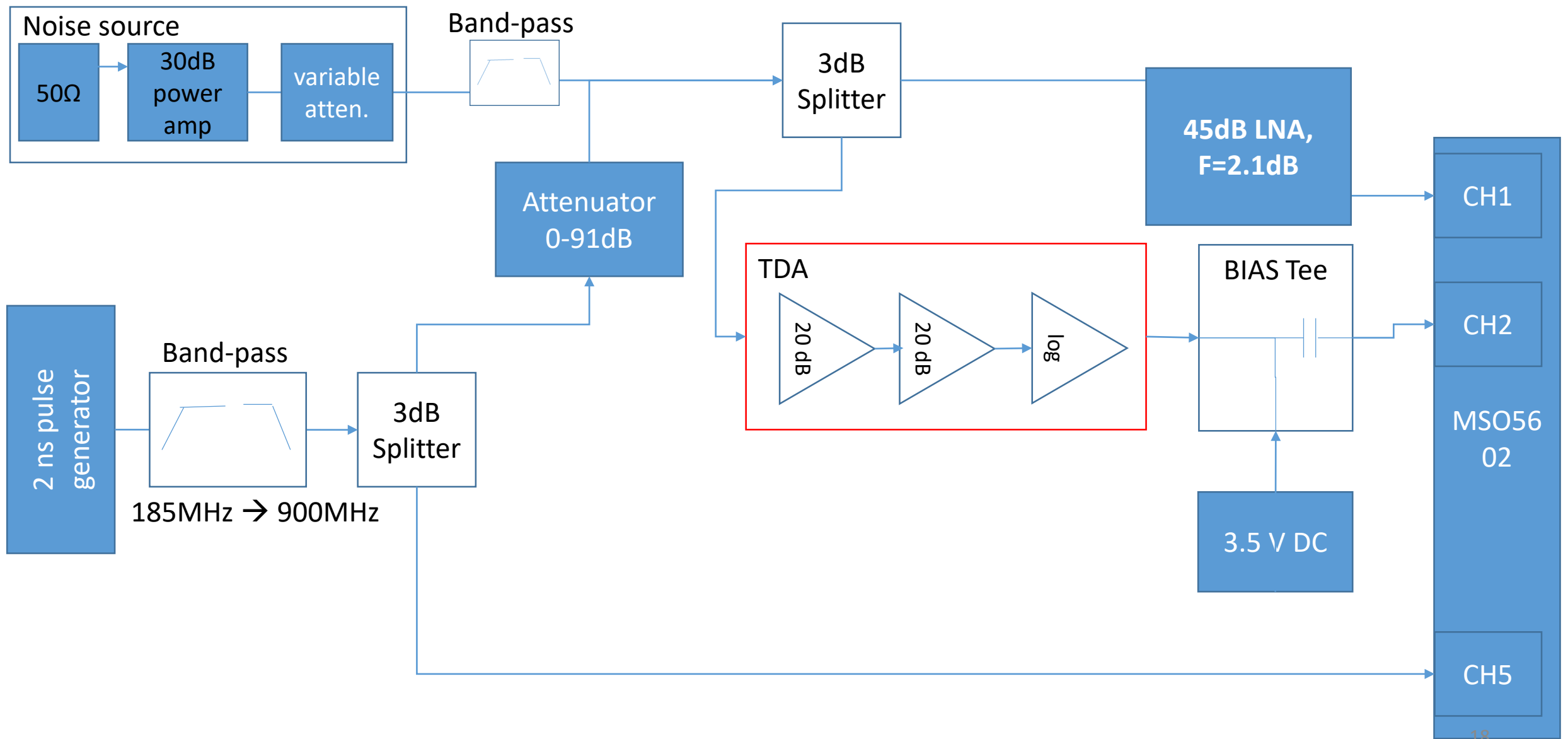
- We have key component: Transient Detector Assembly

### Allows for:

- Low sampling rate at receiving end → O(100MS/s) instead of O(3GS/s)
  - Lossy cables for transmission to surface
  - Log detector → 57dB dynamic range
  - Wide range single beam forming
- 
- String system partly integrated
  - Test holes available for deployment
  - **Still lots to do ...**

# Backup

# Measurement system

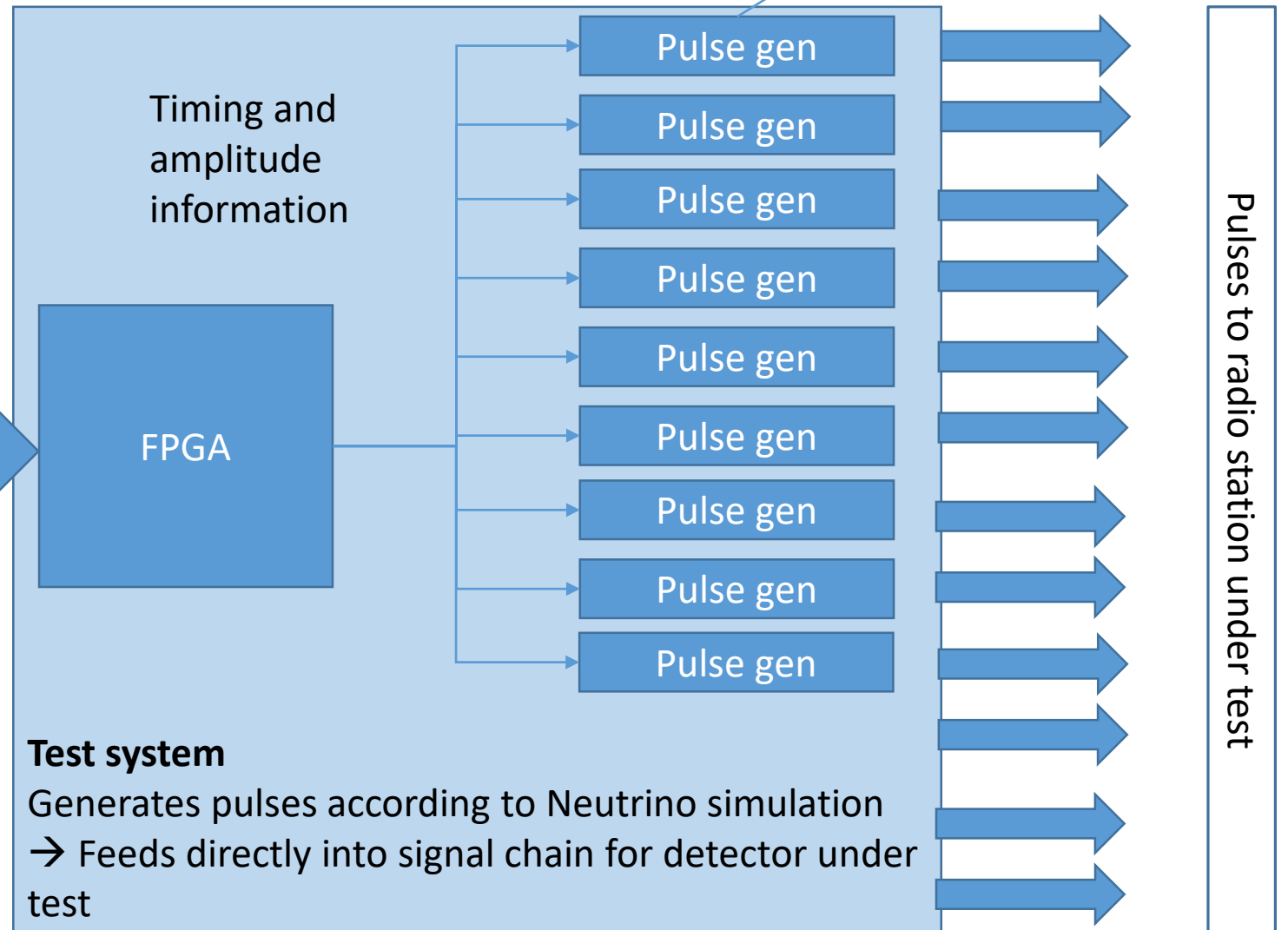


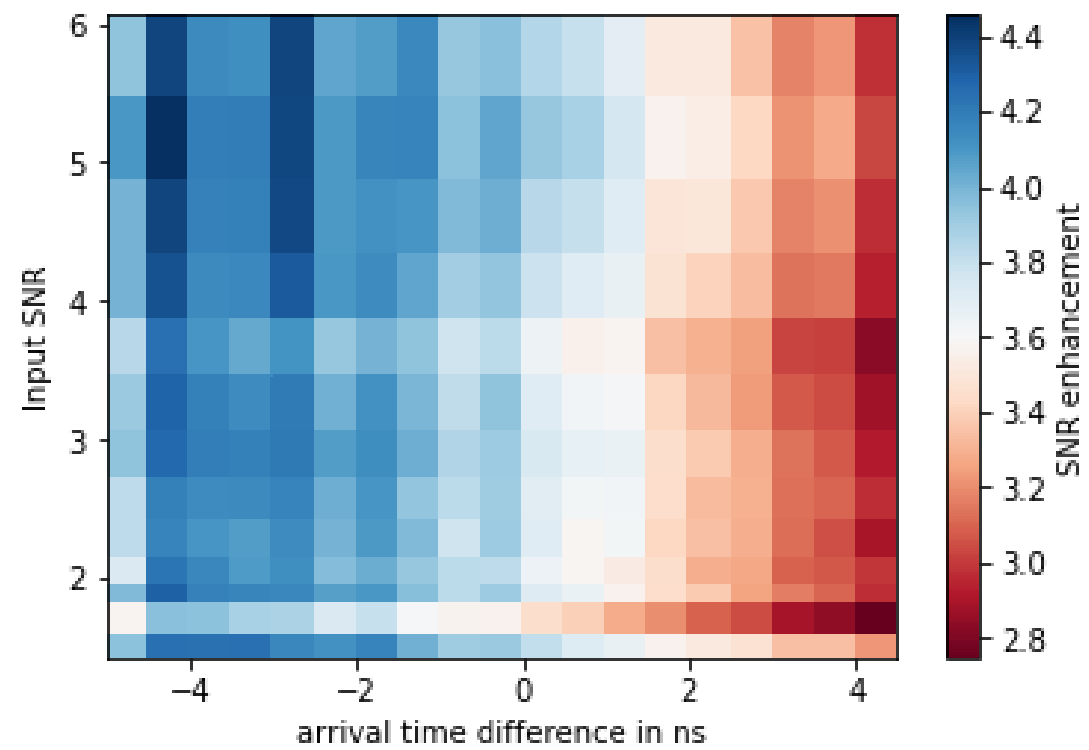
# Need detector test system

- Detector simulations are hard
  - Lots of parts with influence on the signal processing
- **Measure it directly**

Neutrino simulation  
Contains: arrival time, pulse shape, amplitude at given antenna locations

- Generate “neutrino pulse” with right amplitude and timing at antenna
- Connect various frontends to mimic different antennas
- Feed directly into signal chain electronics





# Simulation of station and grid approach

## Notes:

- trigger condition: **at least 4 antennas on at least 3 strings**
- Number of strings and number of antennas are constant for all types

## Some observations:

- Widely same sensitivity, when covering same area
- Grid less sensitive at low energy, due to minimum string spacing

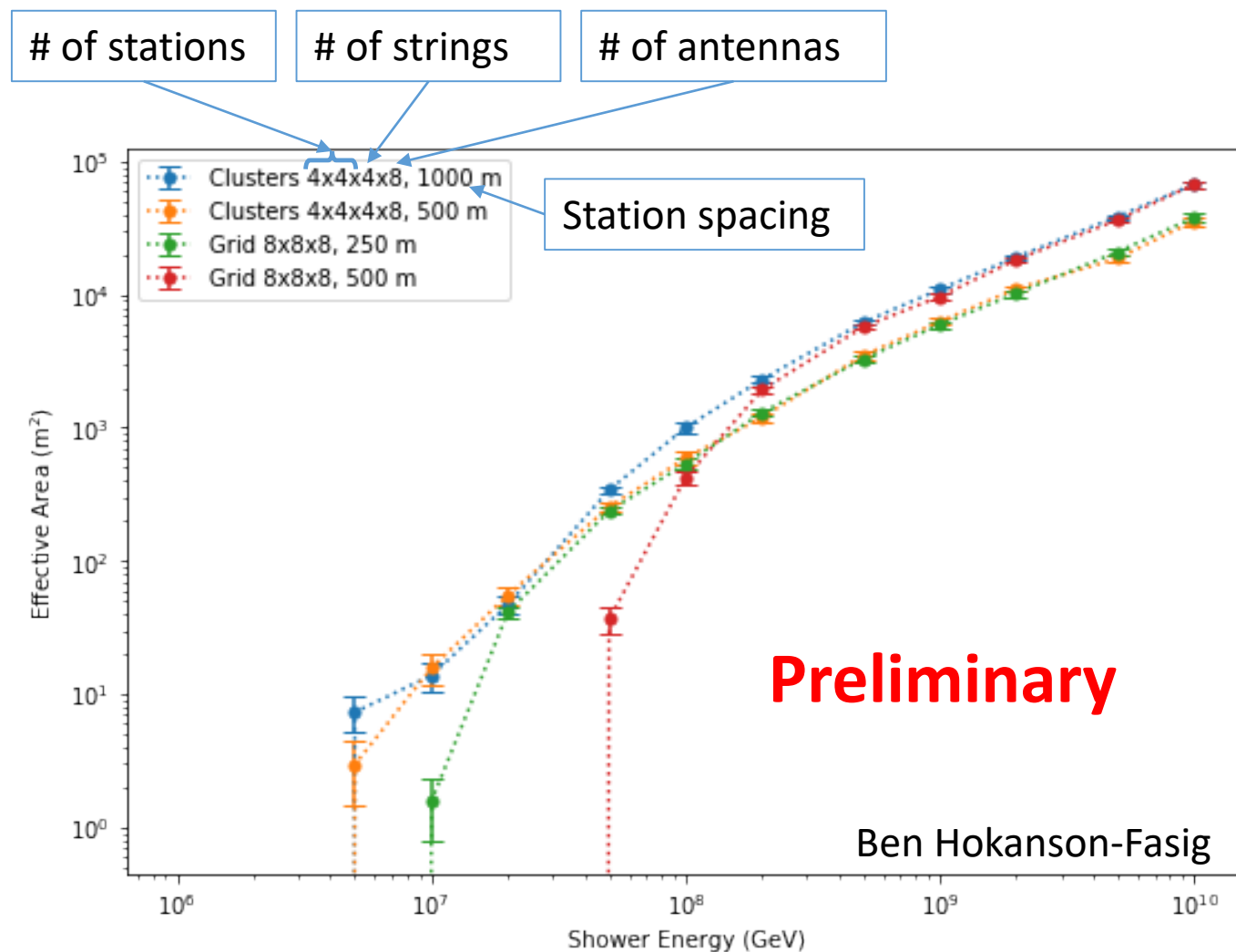
## Ultimate detector quality:

1. \$/neutrino
2. Feasibility, Event quality

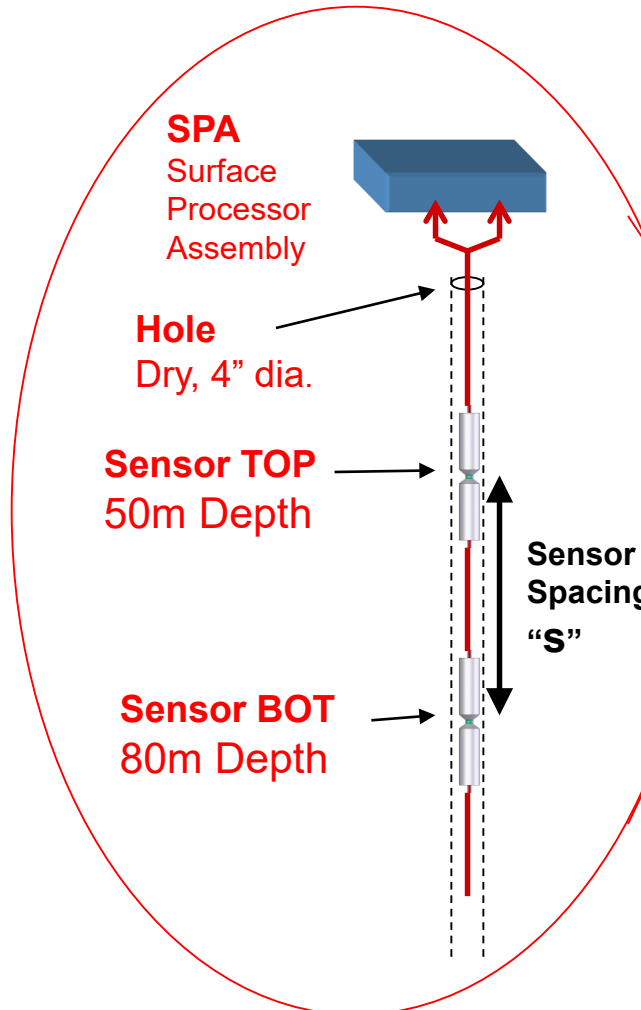
## This includes:

- Robustness: lifetime, man-power
- Complexity: man-power
- Power consumption: costs
- Installation/construction effort: costs, man-power

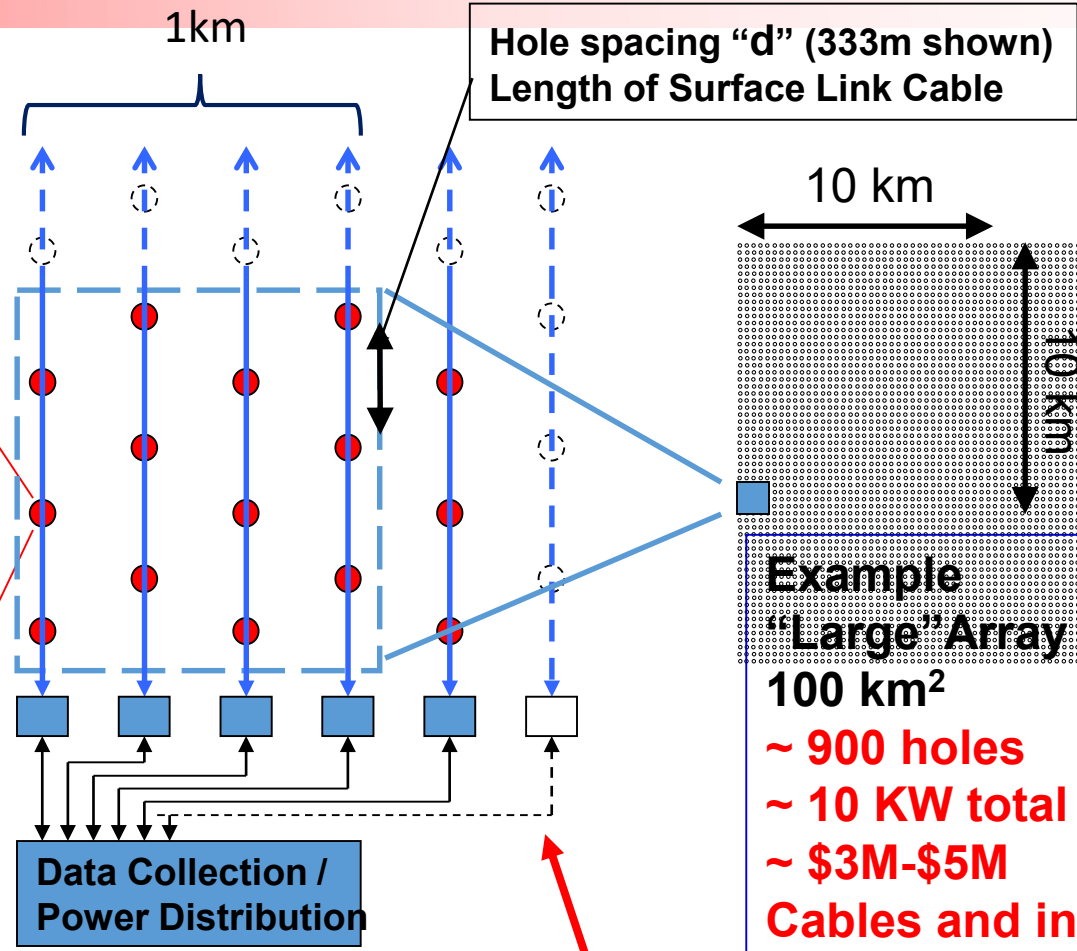
→ **Need low cost, low power strings with high sensitivity**



# Is this feasible?



Hole with two vertically-spaced transient sensors or clusters  
**<10Watts per hole**



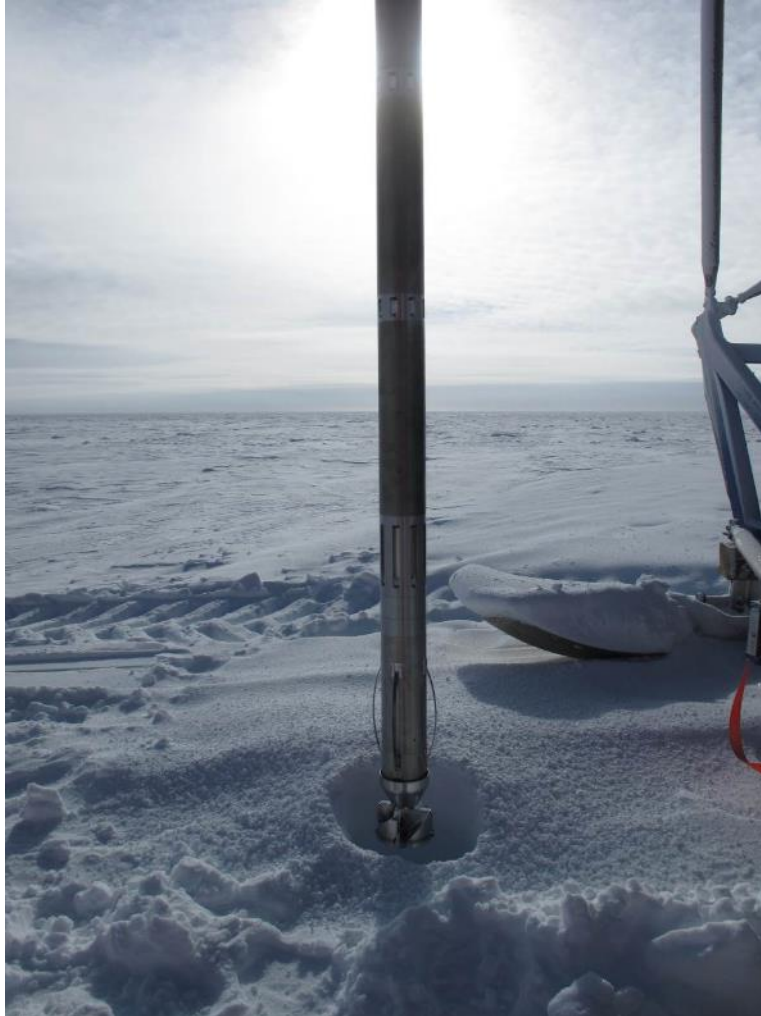
10km x 10km Array of holes  
**<300 Watts/Row**

**Daisy Chain Wired Power For Entire Row**

**Example "Large" Array (333m grid)**  
**100 km<sup>2</sup>**  
**~ 900 holes**  
**~ 10 KW total**  
**~ \$3M-\$5M**  
**Cables and instrumentation**



# Rapid Air Movement (RAM) Drill



- 45m-50m holes in approximately 20 minutes each
- Drilled about 20 holes 4" diameter at NPX
- Drilled 200 x 4" diameter, 50m deep in one season at WAIS divide
- Air loss in porous firn limits hole depth to about 50m
- **There are ideas to extend this to larger depth**