WIRELESS

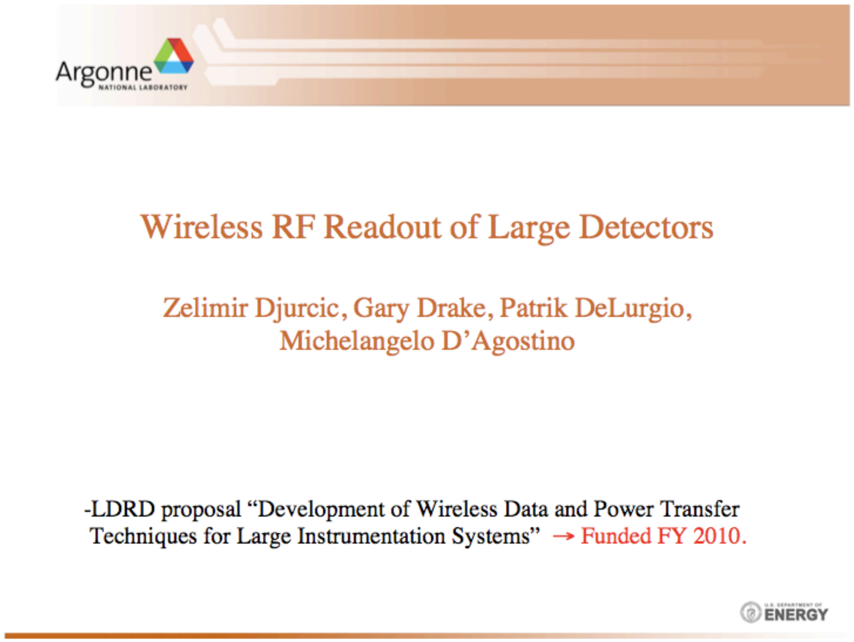
POWER & DATA ACQUISITION SYSTEM

FOR LARGE DETECTORS

A crazy! (brilliant???) idea

What says www about that?

https://twindico.hep.anl.gov/indico/getFile.py/access?contribId=78&sessionId=3&resId=0&materialId=slides&confId=304



Authors contacted
-> link to their latest publication

http://arxiv.org/abs/1310.1098

098v1 [physics.ins-det] 3 Oct 2013

A Prototype of Wireless Power and Data Acquisition System for Large Detectors

P. De Lurgio[a], Z. Djurcic[a], G. Drake[a], R. Hashemian[b], A. Kreps[a], M. Oberling[a], T. Pearson[b], H. Sahoo[a]

[a] *Argonne National Laboratory, Argonne, IL 60439, USA*
[b] *Northern Illinois University, Dekalb, IL 60115, USA*

Abstract

A new prototype wireless data acquisition system has been developed with the intended application to read-out instrumentation systems having a large number of channels. In addition such system could be deployed in smaller detectors requiring increased mobility. The data acquisition and control system is based on 802.11n compliant hardware and protocols. In this paper we describe our case study with a single readout channel performed for a potential large detector containing photomultiplier tubes. The front-end circuitry, including a high-voltage power supply is powered wirelessly thus creating an all-wireless detector readout. The benchmarked performance of the prototype system and how a large scale implementation of the system might be realized are discussed.

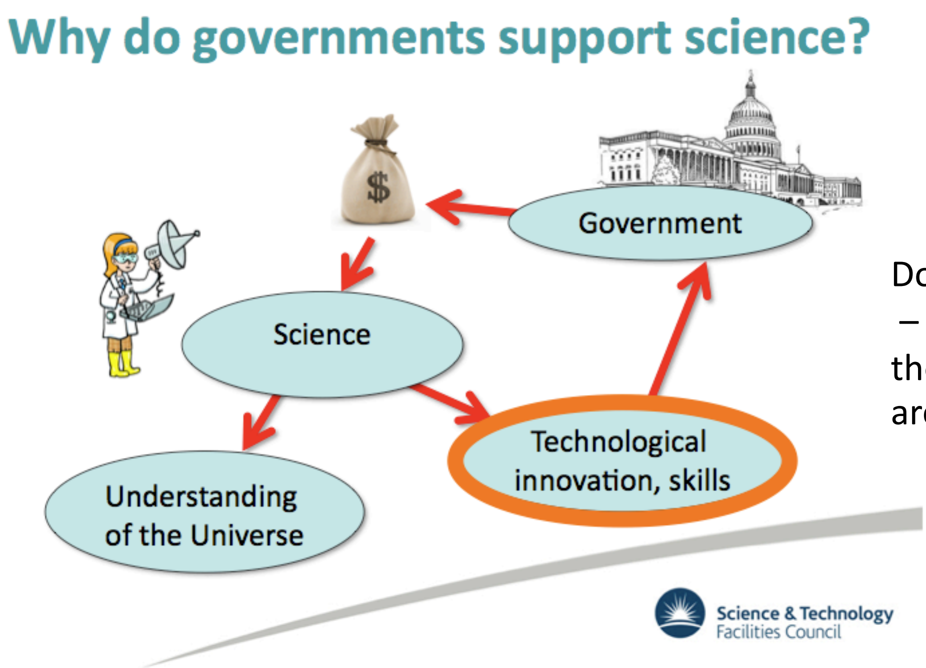
Keywords: Wireless communications, RF, Optical

Motivation

Elimination of massive cable plants

- Cost reductions
- Simplified installation & repair
- Reductions in dead material
- Reductions of radioactive waste (my comment)

Motivation



my added comment

Don’t compromise science excellence
– but especially in tough economic times, the non-science impacts of major projects are an important part of the case

“What will it do for jobs and economic growth?”

J.W. Wormersley
FCC kickoff meeting

Goal

https://twindico.hep.anl.gov/indico/getFile.py/access?contribId=78&sessionId=3&resId=0&materialId=slides&confId=304

Build a detector module

- operating from wireless power
- sending data wirelessly

R & D

Design

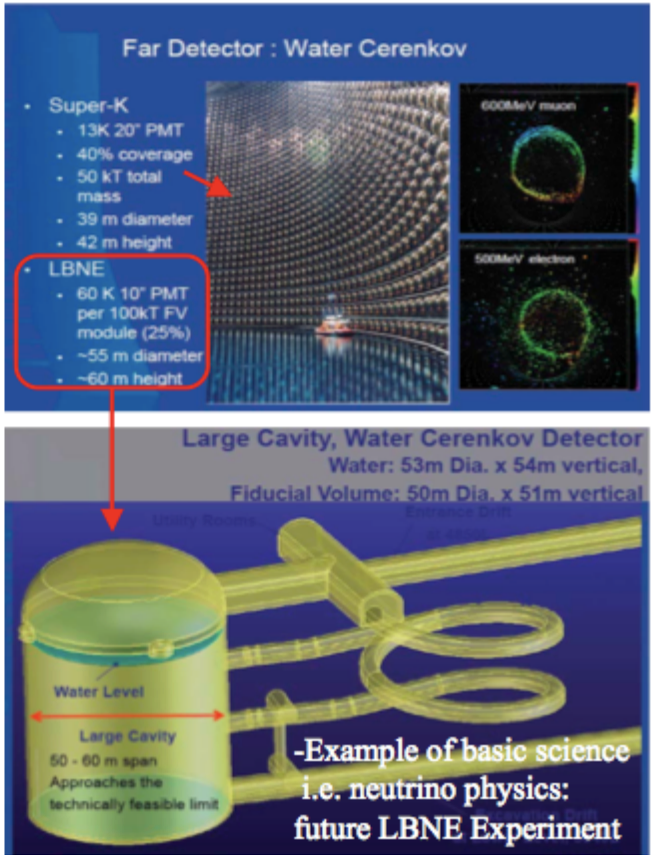
- Wireless data transmission
- Wireless power transmission

Prototype

Performance

Design

Context



From Volume 4: Water Cherenkov Detectors https://wiki.bnl.gov/dusel/index.php/CDR

Parameter	Value	Notes
Total PMT count	50,000	
PMTs per rack	512	
PMT Dark Noise Rate	10 kHz	Very conservative
Bytes per hit	8 bytes	32 bits time, 16 bits channel no., 16 bits charge

Design

Assume:

Data of 6 bytes : 2 bytes for pulse-height
4 bytes for time-stamp

at 10 kHz

➢ 480 kb/s

Challenge: 24 Gb/s total data rate from the whole detector (50000 PMTs)

TLEP
HZ0W-W+tt̄

Irfu
Institut de recherche sur les lois fondamentales de l'Univers

Design

Wireless data transmission

- optical link
- radio frequency (RF)

Optical links support higher data rates than RF (1Gb/s, meters) but require line-of-sight

With RF, the total data rate is rather modest (65Mb/s; 35Mb/s payload data rate)
but an individual receiver can communicate with many front-ends ⟹ Their choice

Design

Wireless data transmission: RF choice

2 primary categories

- ➢ mobile/cellular* modest data rate / widespread coverage
- ➢ wireless local area network (WLAN) larger data rate / limited coverage

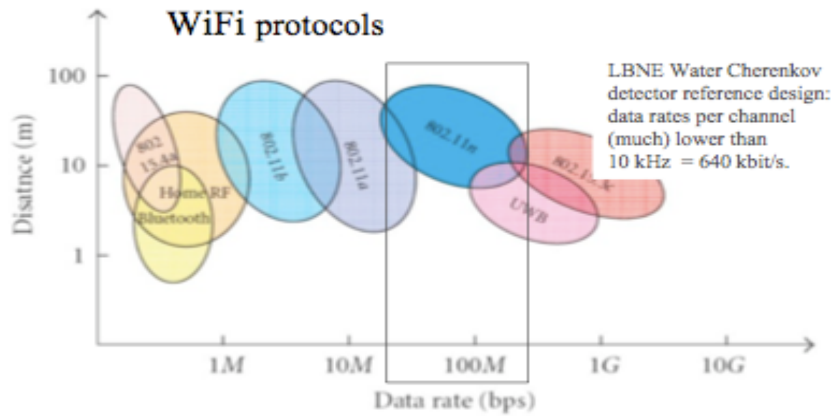
⟹ their choice

*my comment: not necessarily true with coming 5G : tens of Gbs/s expected ?

Design

Wireless data transmission: RF choice

- wireless local area network (WLAN)



Focus on 802.11n standard: sufficient data rate & range
65 Mb/s total rate, 35 Mb/s payload rate

Design

Wireless data transmission: RF choice

- wireless local area network (WLAN)

One frequency range in 802.11n is centered at ≈ 5.5 GHz with an overall bandwidth of ≈ 1.2 GHz (4.9-6.1 GHz)

Single stream access points can have individual operating bandwidth of 20 MHz

⟹ 48 access points possible
each communicating with 64 PMT wireless readouts

⟹ 3072 FE & overall data throughput 1.68 Gb/s

Design

Wireless power transmission

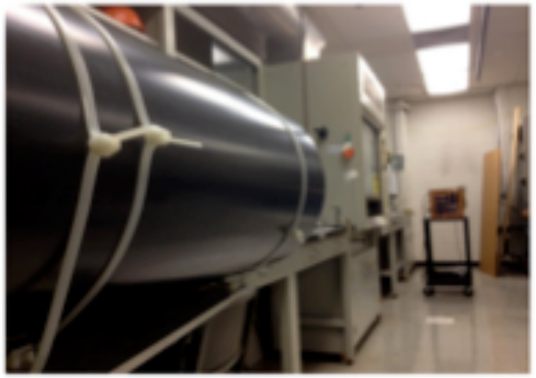
- optical
- radio frequency (RF)

Optical device: LED OSRAM SFH 4751, 3.5 W optical output, operated at max DC current of 1 A, λ = 940 nm matching the peak efficiency of the photovoltaic cell (156x156 mm^2 in 312x280 mm^2 PV array)
Requirement: 0.25 W at 5 m.

RF device: a function generator driving a 14 dBi Yagi antenna at 915 MHz, output power 10 dBm, received by a 11 dBi gain patch antenna.

Design

Wireless power transmission: Optical device



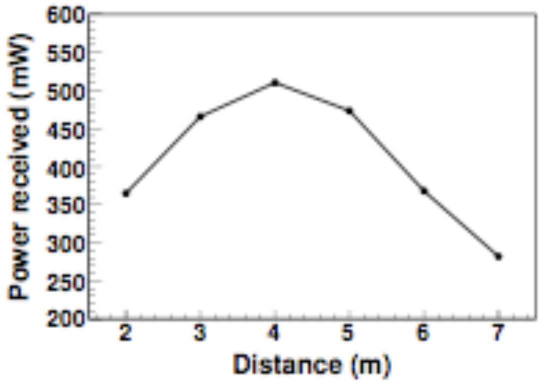


Figure 1: Apparatus for optical power transmission. Left figure shows the tube containing LED and lens, and the photovoltaic receiver at the far end. Right figure shows the power received (mW) by the photovoltaic panel as a function of distance (m) from the optical source.

Meet requirements of receiving 250 mW at 5 m. Their choice

Design

Wireless power transmission: RF device

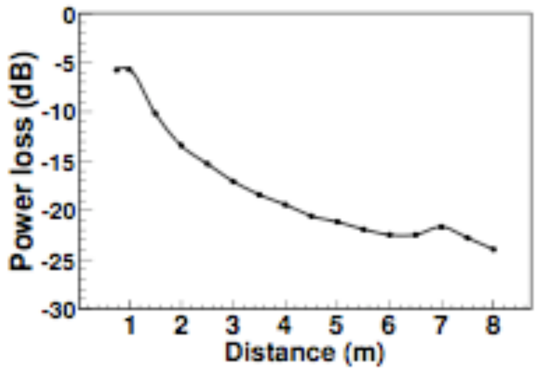


Figure 2: Apparatus for RF power transmission. Left figure shows the RF transmitter (14 dBi gain Yagi antenna) in the foreground, with the RF receiver (11 dBi gain patch antenna) at the far end. Right figure shows the power loss (dB) as a function of distance (m) from the source.

A 25 W source would be required to receive targeted 250 mW

Prototype

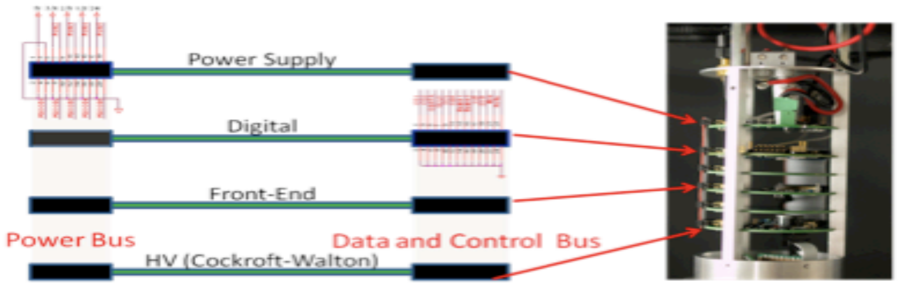


Figure 8: Partial assembly of the system with the PMT.

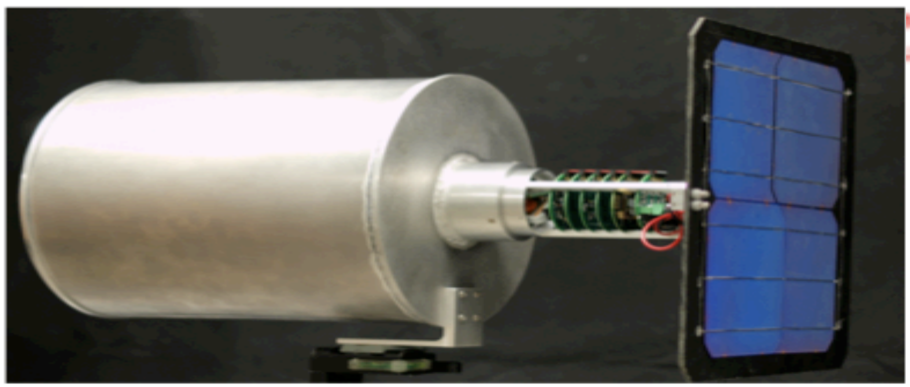


Figure 9: Picture of the completed system. Shown with light tight PMT enclosure and photovoltaic panel attached to a tripod (electronic enclosure open for reference).

Prototype

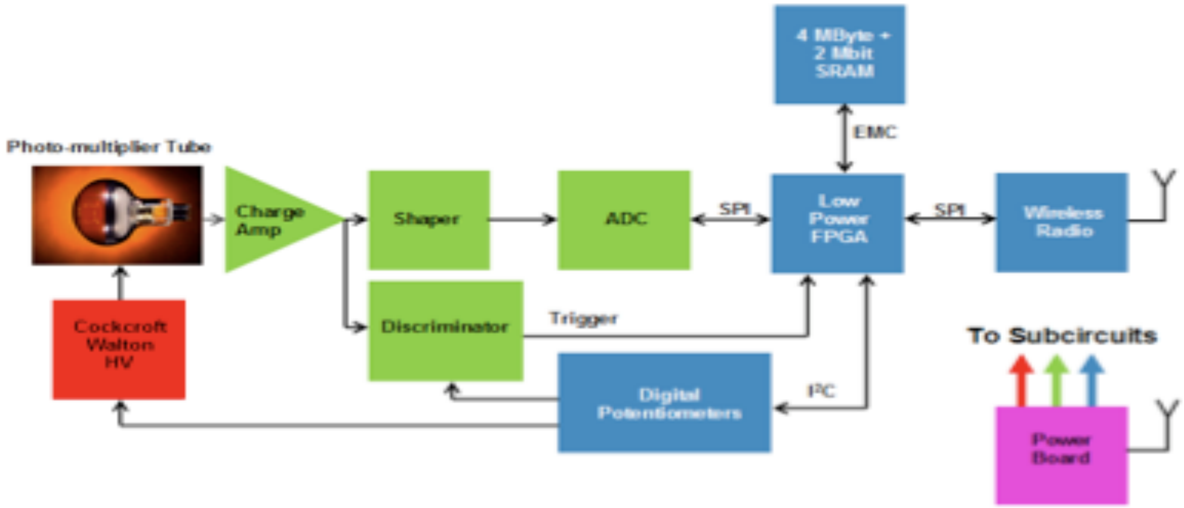


Figure 6: Block diagram of the wireless prototype system.

Power Board: receives wireless power & generates different voltages

Digital Board: processes the data & does wireless data transmission

Front-end Board: does shaping & digitization of PMT signal

HV Board: generates HV for the PMT

Performance

Table 1: Summary of the initial goals and achieved performance for the wireless data acquisition system.

Specification	Target	Performance
Total power consumption (@ 10 kHz)	250 mW	386 mW
Digital	120 mW	216 mW
Front-end	30 mW	39 mW
HV	80 mW	131 mW
Maximum event rate	10 kHz	80 kHz
Data transfer rate	35 Mb/s	11 Mb/s ★
Bit Error Rate	$< 1\times10^{-12}$	Dropped Packets ★★

★ Limited by SPI clock rate & latency caused by the driver code (solutions found)

★★ Due to UDP use
(significant reduction of packet loss expected)

Summary

A wireless demonstrator,
which was implemented in a PMT base
& received power and transmitted data wirelessly
has been successfully built & tested

Longer term:

Address the SPI clock rate issue and SPI bus latency

Use RF power transfer, allowing the use of one transmitter to power many receivers.

Conclusions

The approach of wireless techniques
for power & data transmission works !
For a "large number" of channels (a few 10000)

What about our super-large detectors
with > 1 Million of channels??

2 extensions of this concept to increase the data throughput:

- directional antennas
- MIMO wireless streams

Conclusions

- **directional antennas**

  the intrinsic shielding created by the detector volume should allow the same frequency range to be utilized in different locations of the detector

  ⟹ multiplies the usable spectrum (geometry dep.)

- **MIMO wireless streams**

  4x4 (now 8x8) MIMO supports 4 simultaneous transmit & receive streams to yield a data throughput of 600 Mb/s (320 Mb/s payload)

  ⟹ 4x4 MIMO requires 40 MHz wide channels

  ⟹ 1.2 GHz band supports ≈ 24 access points

  ⟹ total payload 7.68 Gb/s

Conclusions

Directional antennas & MIMO wireless streams
should bring significant improved data throughput
in the readout of large detectors

unsufficient TODAY (this is the important word!)

TOMORROW (next 20 years)

About than 10 years ago, cellular phones, wireless internet
were simply speculative … Gigantic progress since then!

TLEP

$HZ^0W^-W^+t\bar{t}$

Irfu Institut de recherche sur les lois fondamentales de l'Univers

My Conclusions

An additional benefit to society, synergy with industry in the line of:

- Need to present (additional) **benefits to society** from the very beginning of the study (examples: sc technologies)

R. Heuer (FCC kick-off meeting)

Be ambitious, there is still some time !

L. Linssen (FCC kick-off meeting)

- **Let's us work for our dream**

R. Heuer (FCC kick-off meeting)