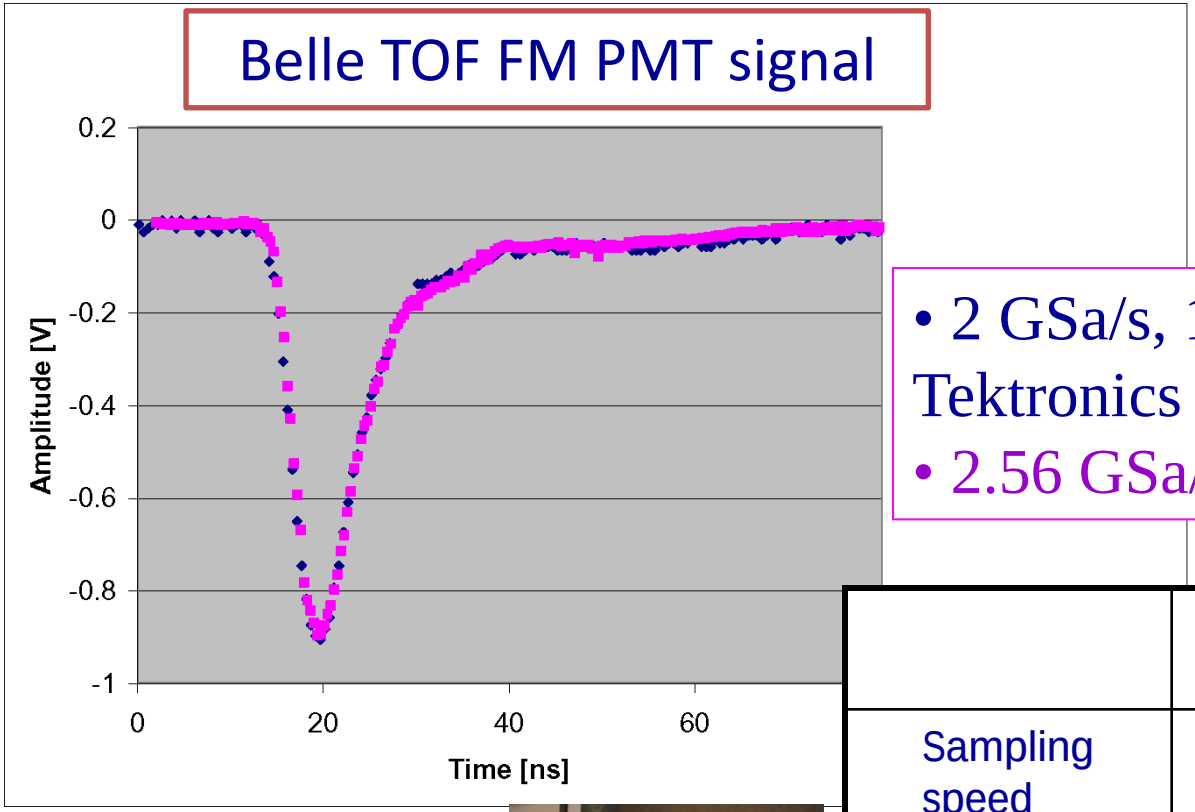
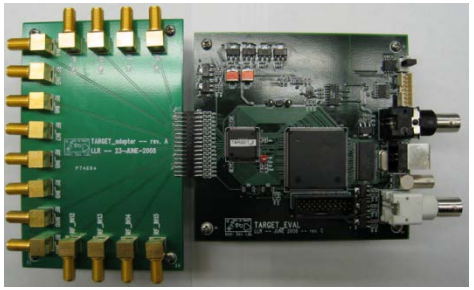
Future Directions in high-speed, transient waveform digitization

Gary Varner
University of Hawaii

Input to the Snowmass process

Switched Capacitor Array technology

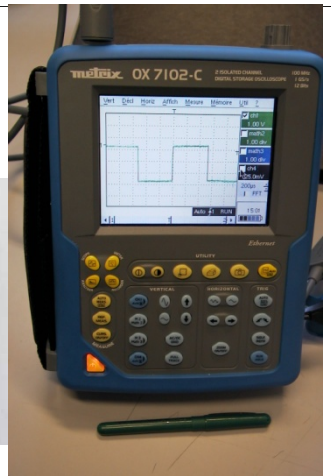




- 2 GSa/s, 1GHz ABW Tektronics Scope
- 2.56 GSa/s LAB

	WFS ASIC	Commercial
Sampling speed	0.1-6 GSa/s	2 GSa/s
Bits/ENOBs	16/9-13+	8/7.4
Power/Chan.	<= 0.05W	Few W
Cost/Ch.	< $10 (vol)	> 100$

"oscilloscope on a chip"



Belle II Detector

ent

BEAST (Background commissioning detector)

KLong and muon detector:
Resistive Plate Chambers (barrel outer layers)
Scintillator + WLSF + SiPM's (end-caps , inner 2 barrel layers)

EM Calorimeter:
CsI(Tl), waveform sampling (barrel+ endcap)

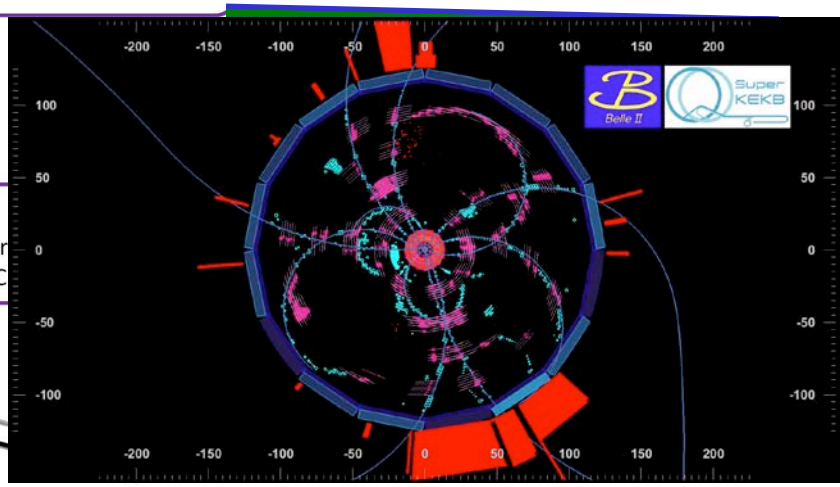
Particle Identification
TOP detector system (barr
Prox. focusing Aerogel RIC

electrons (7 GeV)

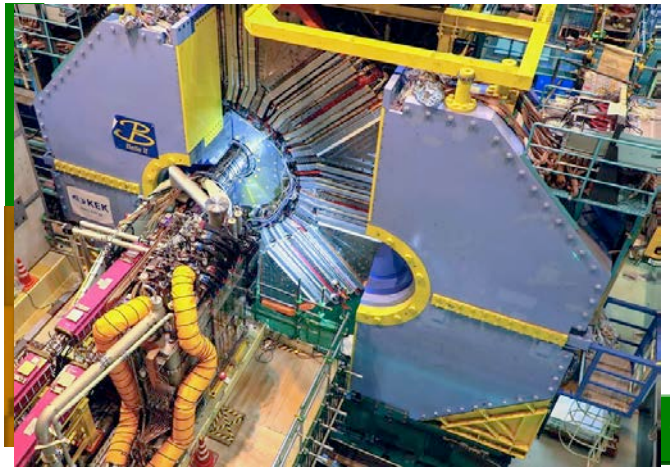
Beryllium beam pipe
2cm diameter

Vertex Detector
2 layers DEPFET + 4 layers DSSD

Central Drift Chamber
He(50%):C_2H_6(50%), small cells, long lever arm, fast electronics (Core element)



positrons (4 GeV)



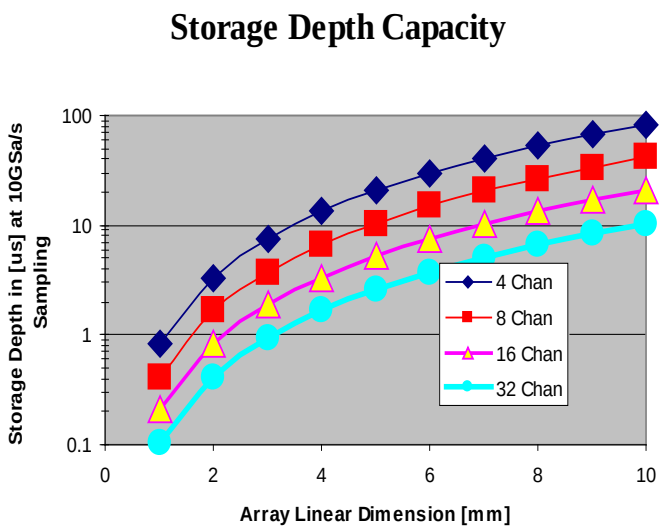
Belle II now has grown to ~947 researchers from 26 countries

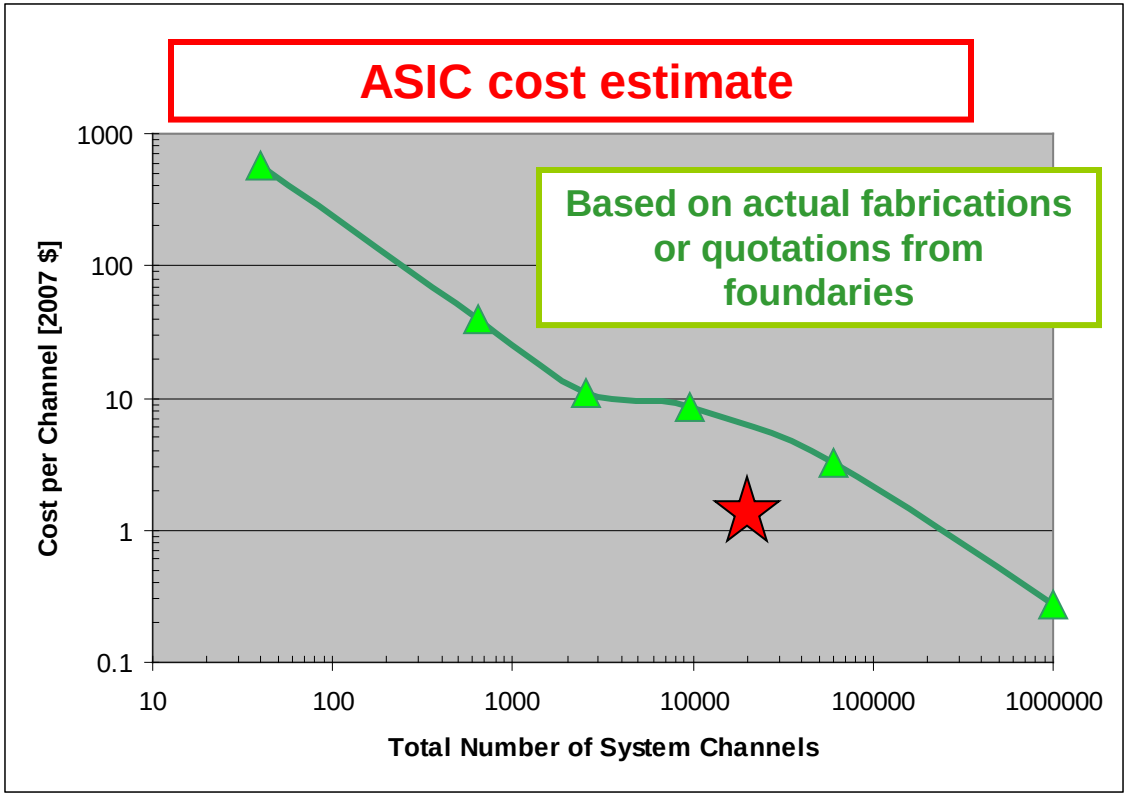
for the future: Snowmass prelude – July 2020

What can learn from these developments

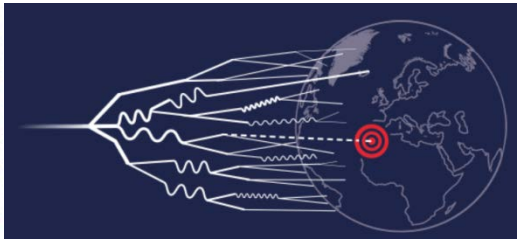
- ASIC costing well understood, very competitive!

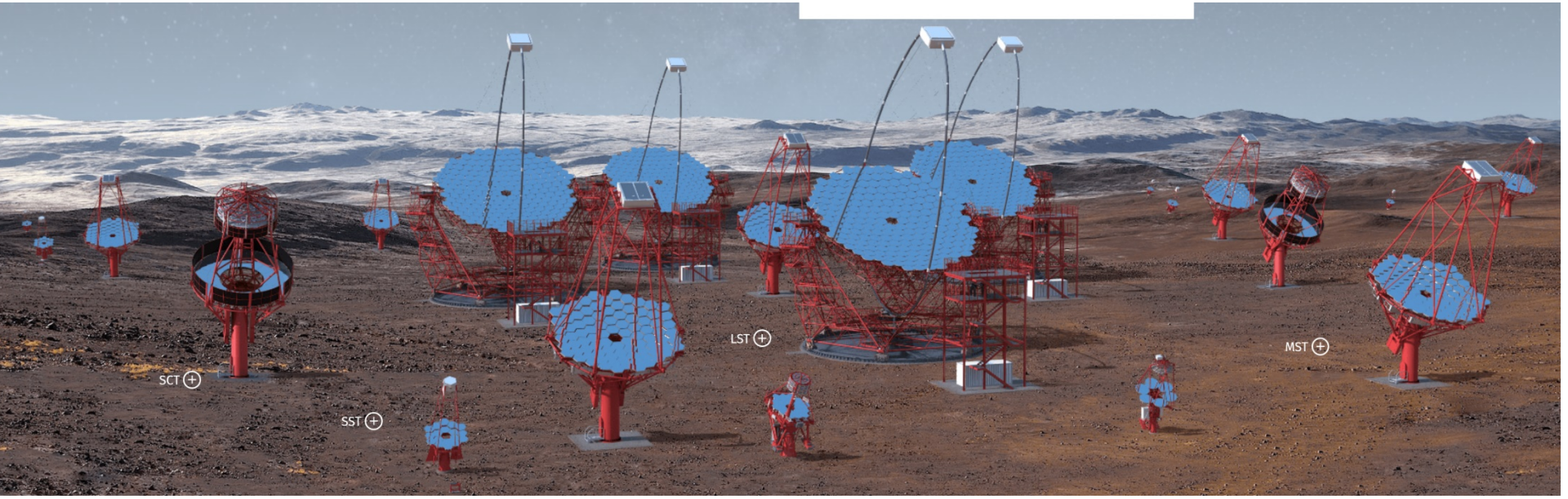
NIM A591 (2008) 534-345.



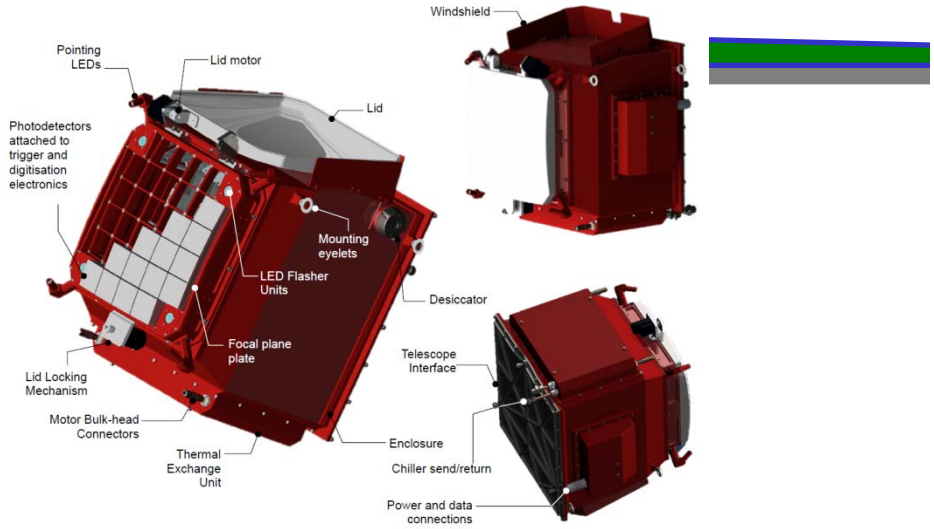


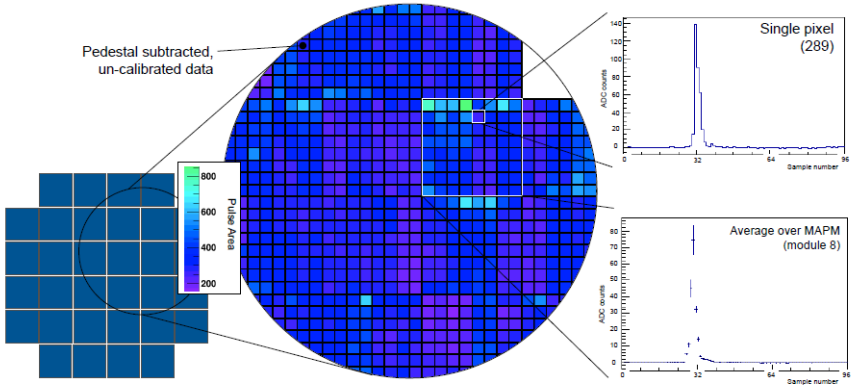
Cherenkov Telescope Array

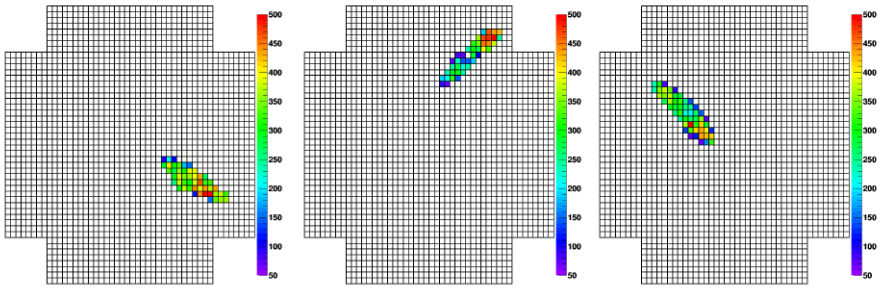


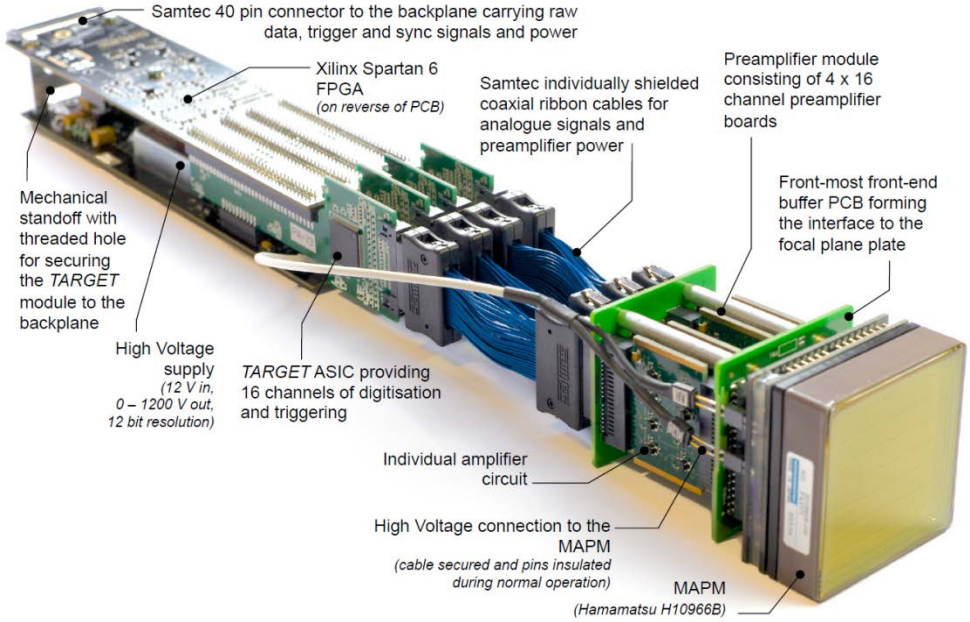


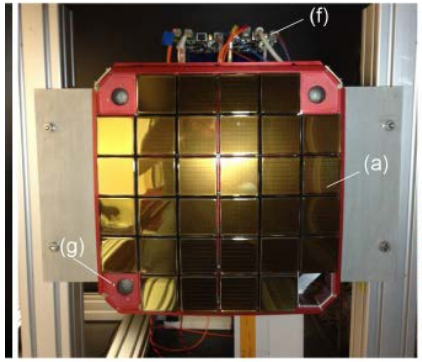
GCT Camera (CTA) – Gearing for prod.

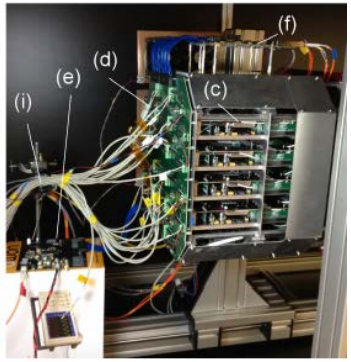






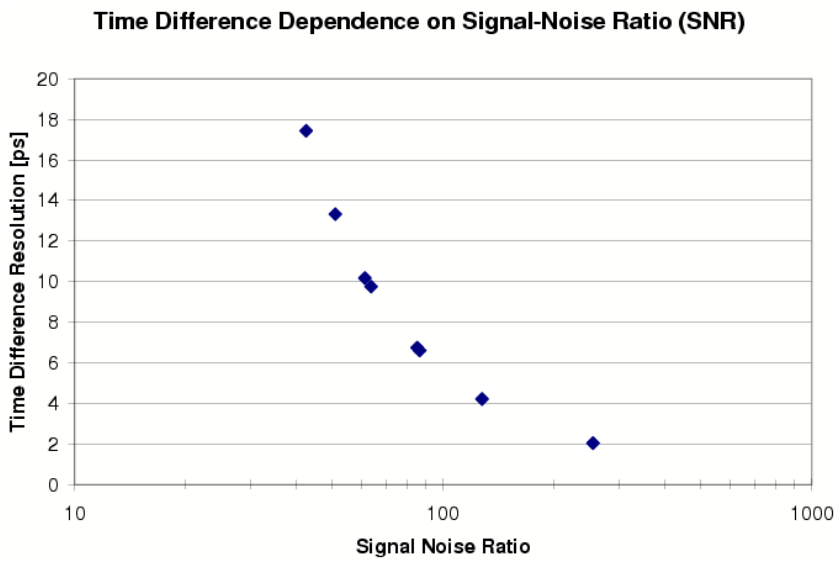






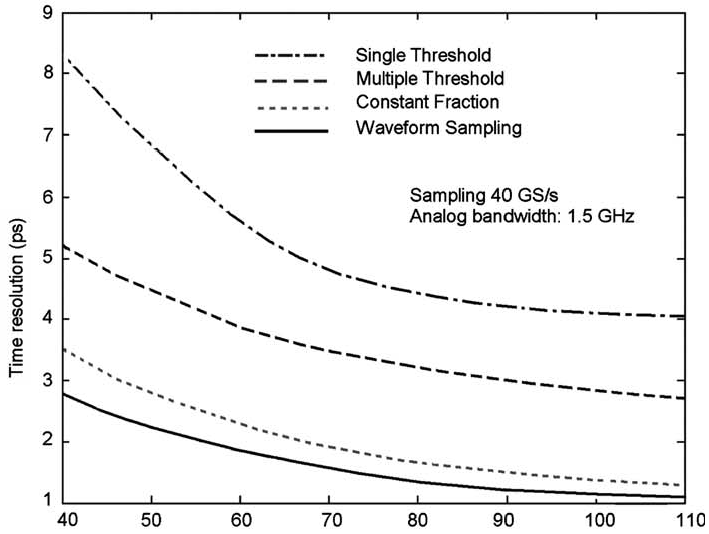
Technology has room to improve

1GHz analog bandwidth, 5GSa/s



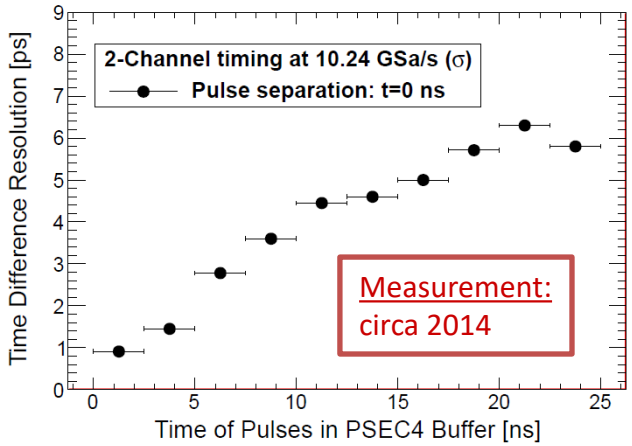
G. Varner and L. Ruckman
NIM A**602 (2009) 438-445**.

Simulation includes detector response



J-F Genat, G. Varner, F. Tang, H. Frisch
NIM A**607 (2009) 387-393**.

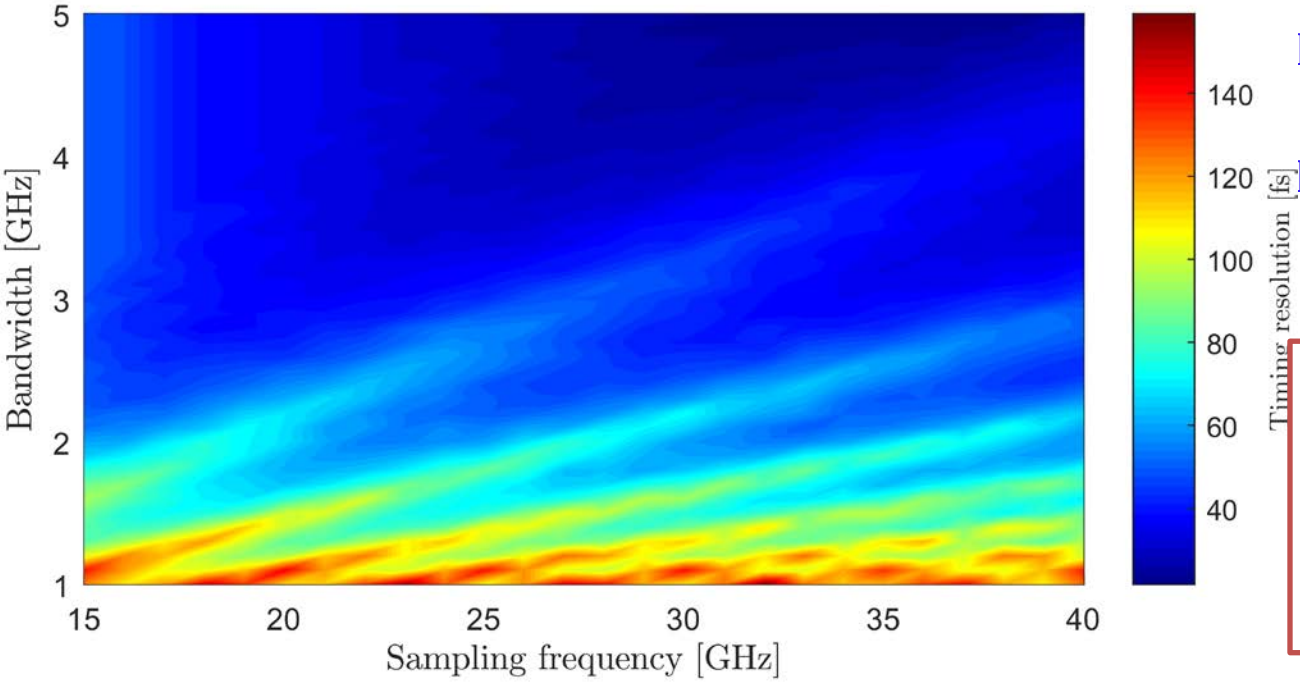
E. Oberla, J-F Genat,
H. Grabas, H. Frisch,
K. Nishimura, G. Varner
NIM A**735 (2014) 452-461**.



Extending to 1ps and lower, with advanced calibration techniques

Now pushing to the femtosecond regime

Pushing sampling speed and analog bandwidth



P. Orel, G. Varner and P. Niknejadi

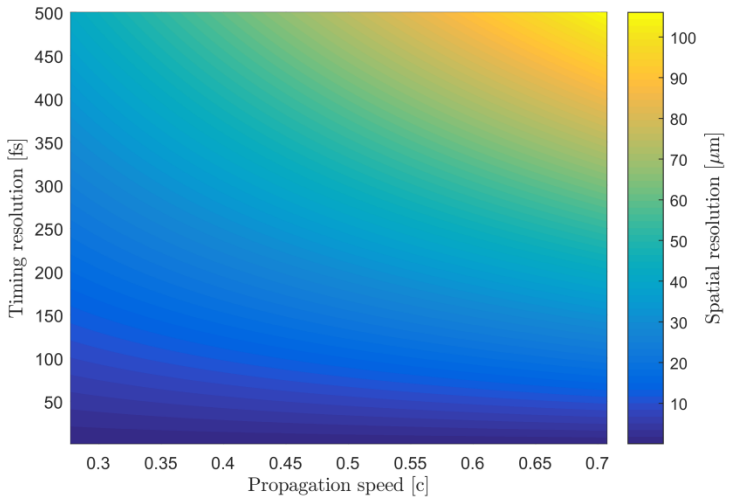
NIM A**857 (2017) 31-41**.

Femtosecond timing: exchange timing for micron spatial dimension (channel count reduction)

And pushing the **space-time limit**
(new type of PID or DIRC devices?)

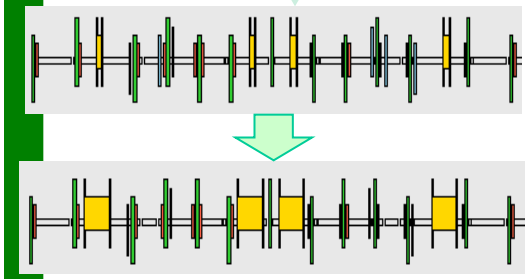
P. Orel and G. Varner

IEEE Trans. Nucl. Sci. **64 (2017) 1950-1962**.



KEKB to SuperKEKB

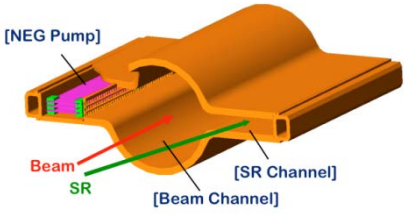
Replace short dipoles with longer ones (LER)

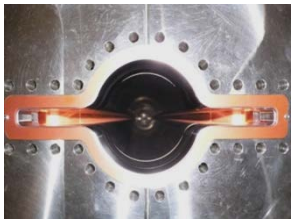


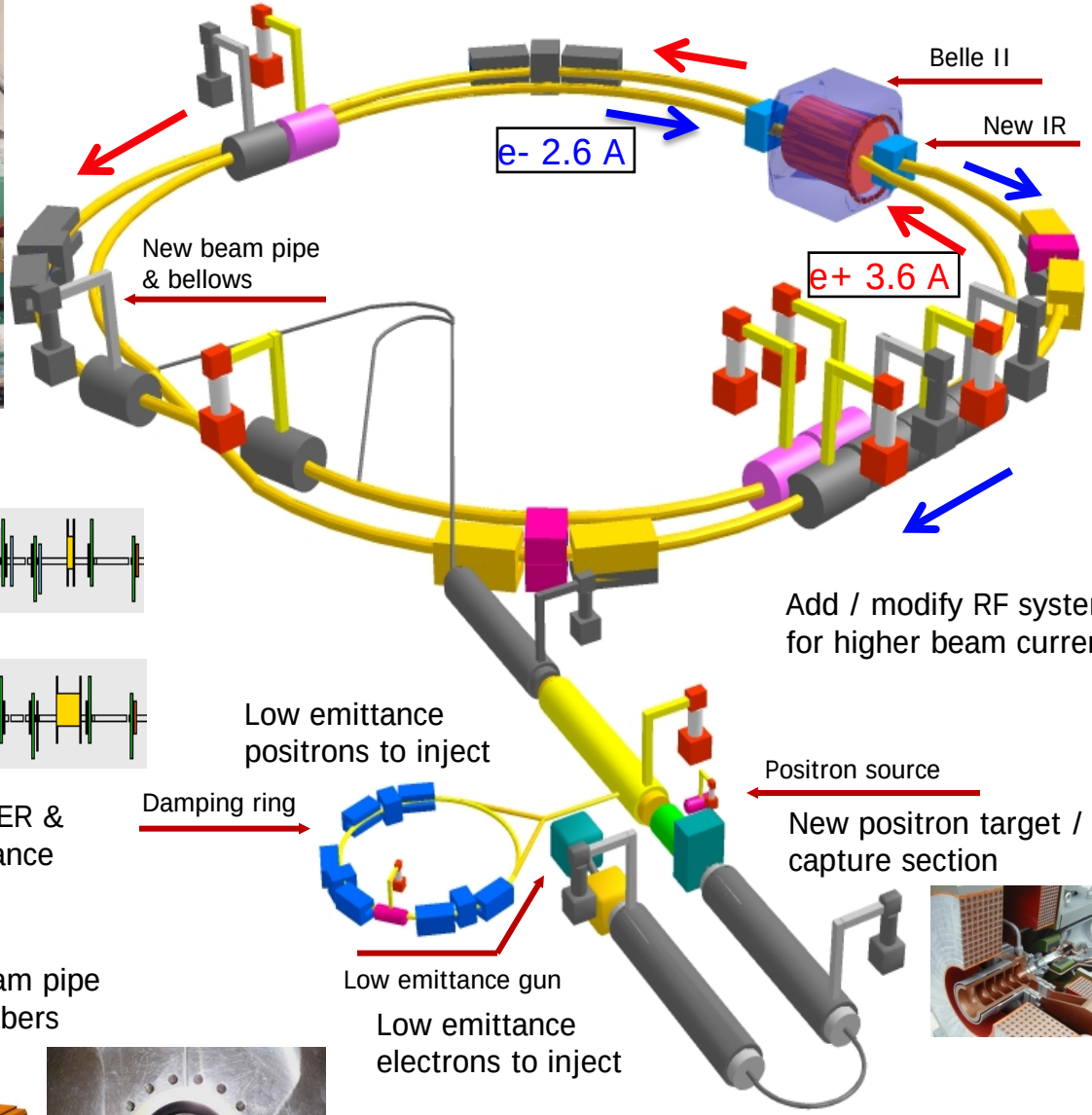
Redesign the lattices of HER & LER to squeeze the emittance

Nano-beams!

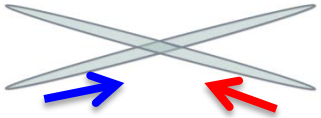
TiN-coated beam pipe with antechambers



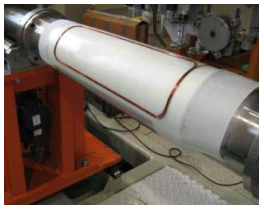




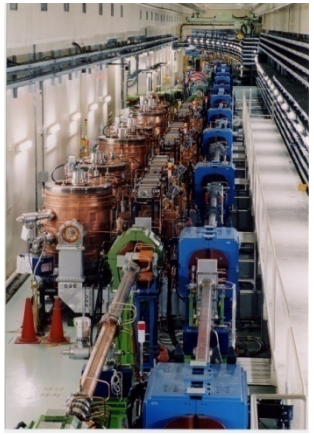
Colliding bunches



New superconducting /permanent final focusing quads near the IP



Add / modify RF systems for higher beam current

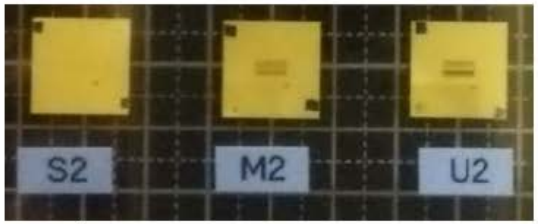


New positron target / capture section

To get x40 higher luminosity

Huge data challenge: online reduction (many TB/s)

X-ray beam line under construction at LER



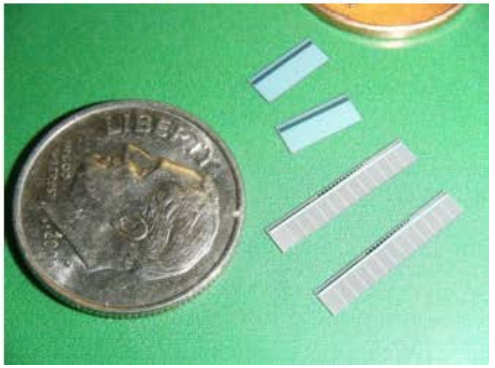
Masks: ~20 μm Au on 600 μm CVD diamond substrate

Water-cooled mask holder

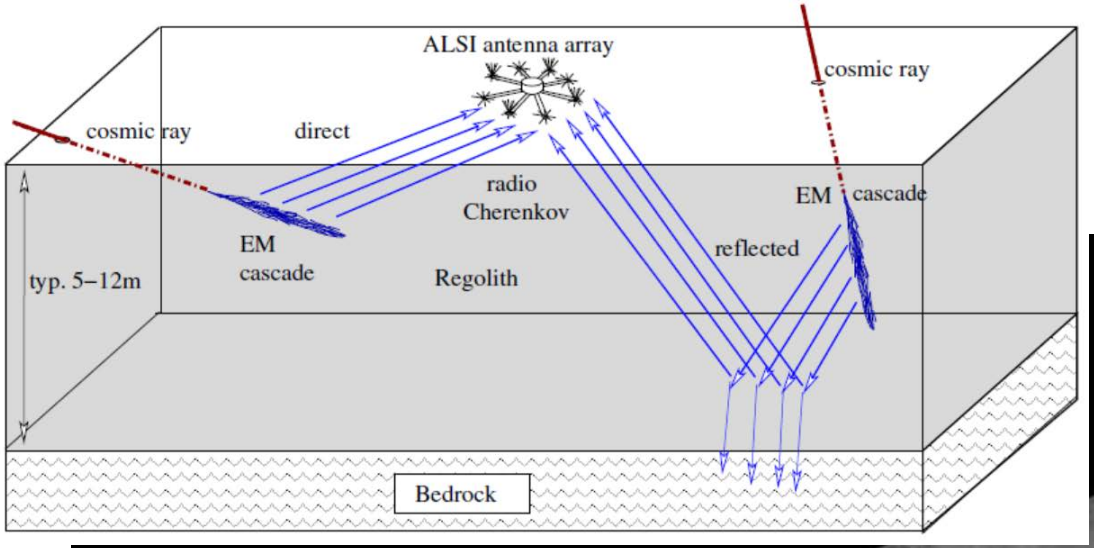
US-Japan Collaboration (U. Hawaii, SLAC, Cornell U.)

High-speed readout electronics for the X-ray monitor, being developed by U of Hawaii.

Deep Si pixel detector and spectrometer chips for the X-ray monitor, being developed at SLAC.

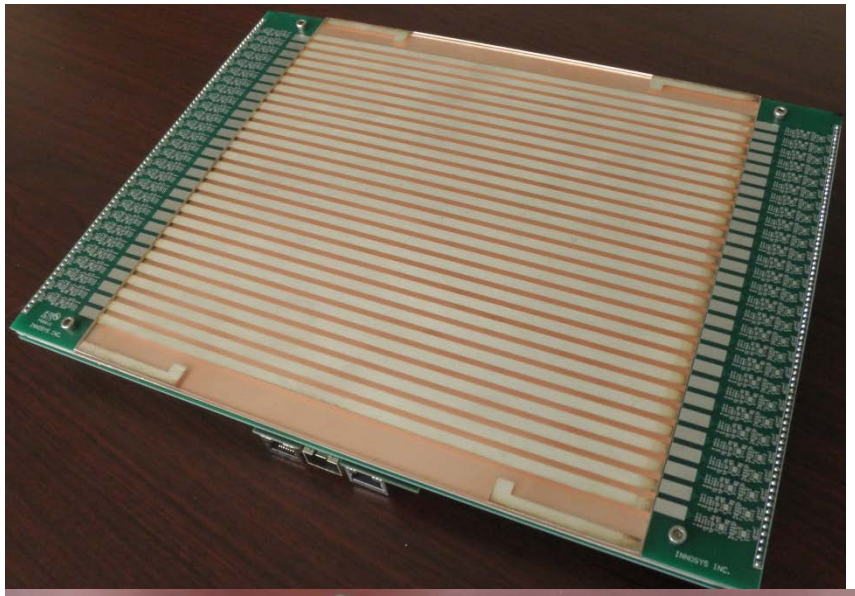


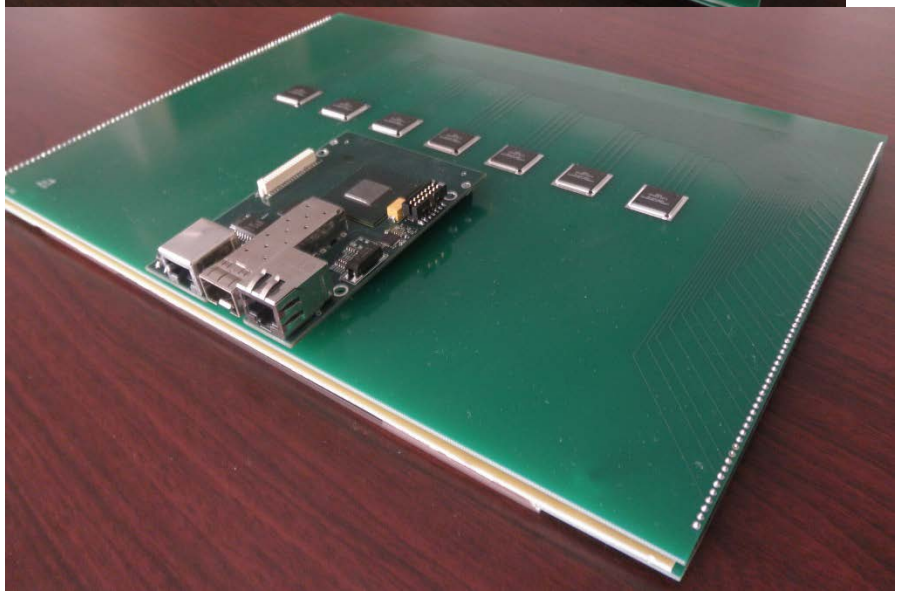
Low power: Lunar cosmic-ray radio geology



Strategy for Extreme Low Power operation

- Only power what actually need
- CMOS intrinsically zero power when idle
- Strategy works for either strip or pixel geometry
- Places to reduce power:
  - Remove FPGA
  - Low-power processing
  - Single ASIC





Future directions (summary)

1. Femtosecond timing to provide
   a. Reduction of spatial granularity (8M -> 4k ch.)
   b. “streak camera” diagnostics
2. Feature extraction (marry more digital processing with power of SCA) for ‘up front’ data reduction
3. As scale to large experimental systems, cost and POWER are huge (existential) issues