# Disruptive Inventions

WWW + PC (phone) + WiFi + mass production Si chips

→ revolutionary change in people's habits
and the world economy

CMOS integrated circuits (+electricity) now essential

try to exploit this in our experiments

Considerations for ECFA Detector R&D Roadmap

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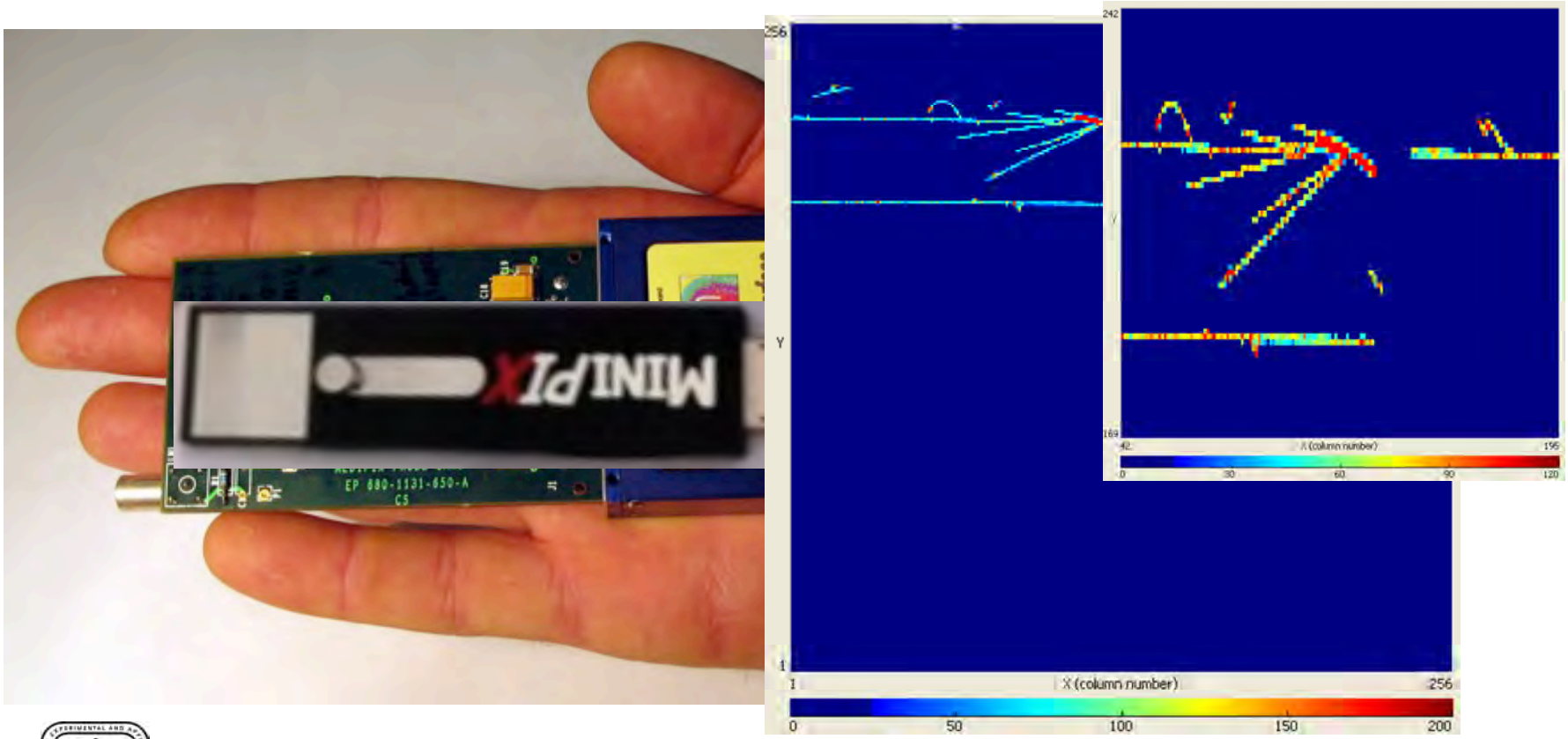
# nano-BUBBLE CHAMBER in your hand : TIMEPIX USB

## laptop, tablet or raspberry-pi

## MiniPixAdvacam + CERN + IEAP-CTU



# Instruments for Particle Physics

Historically, progress made via 'disruptive' inventions:

| | |
|---|---|
| nuclear emulsions | precision imaging of decays |
| plastic scintillator | fast signals, MHz rate, electrical |
| bubble chamber | 1Hz rate, larger volume |
| multi-wire proportional chamber | >kHz rate, electrical |
| calorimeter | directly energy, larger volume |
| silicon microstrip | $\mu$m precision, >MHz rate |
| silicon hybrid pixel | multiplicity >>10/cm$^2$ |

radhard CMOS integrated circuits became essential overall

My first point: how to accomodate
disruptive ideas in a roadmap?
Plan for sufficient flexibility.....even if impossible

# Can ‘revolutionary’ innovation be facilitated ?

Open windows towards different
technical/scientific disciplins

Hiring of specialists besides ‘own’ scientists

Encourage (young) people (also the ‘technical’) to
build their personal worldwide network
‘sabbatical’, conferences, visits, ...

Boundary conditions: sufficient staff for baseload
travel is not a luxury, but a duty

2nd point: exchange is critical component (EU Erasmus)



# Nano- and pico integrated electronics 3rd point

Suppose: for new physics we need dreaming:

higher statistics (cut 1.2ns crossing in <100ps time-slots)
better precision in energies (see 24/3 LHCb result )
larger dynamic range (also downward: dark matter MeV ?)
on-detector intelligence (reduce transmission & off-line)

More effort for exploiting advanced silicon technologies

adequate budget for dealing with foundries (>>Mchf)
collaboration CERN & member-state institutes
more experienced staff, also from outside

(working conditions competitive with chip industry)

Efforts ought to be at same level as those for accelerator

compare with R&D for superconductivity LHC/FCC magnets

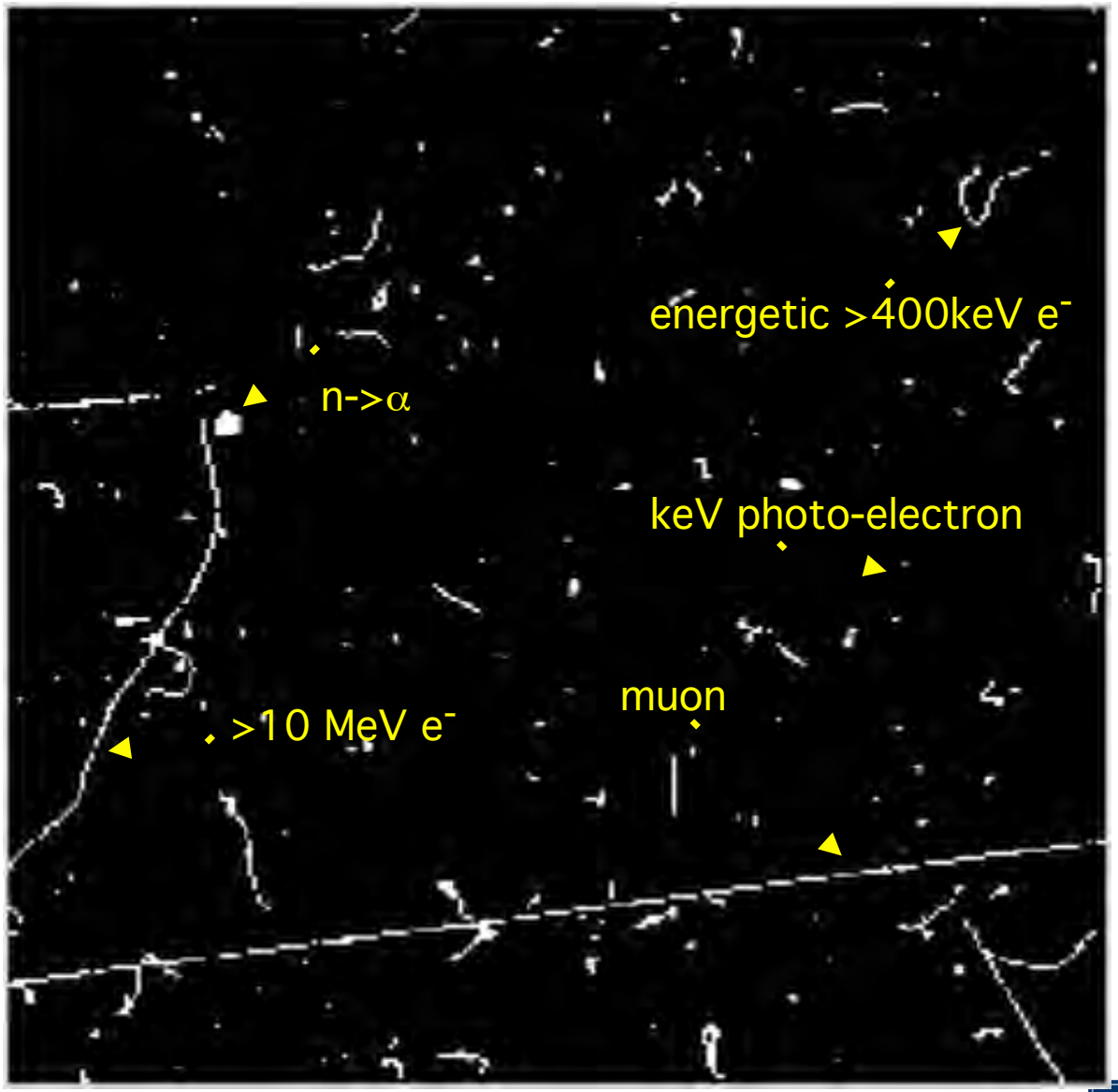
# MEDIPIX identifies elementary Quanta

256 x 256 PIXELS
300 $\mu$m THICK Si

traversing particle
gives ~15keV/pixel
pixel threshold <5keV

SPECIFIC QUANTA
- electrons
- photo-electrons
- MIPs
  - muons
  - (hadrons)
- neutrons via Alpha's

typical frame
~400s exposure
IEAP CTU Prague



# Blue sky examples

Very thin pixelated trackers: 3$\mu$m x 3 $\mu$m x 3$\mu$m
compare with industrial imagers for visible

Thicker 0.5mm silicon trackers with on-detector
4D pattern recognition & cluster classification

nm transistor gates themselves (aF capacity) as sensing elements
(as in DNA nanopore arrays)

Combine ionization and optical effects (TRD, Cerenkov, ..??)

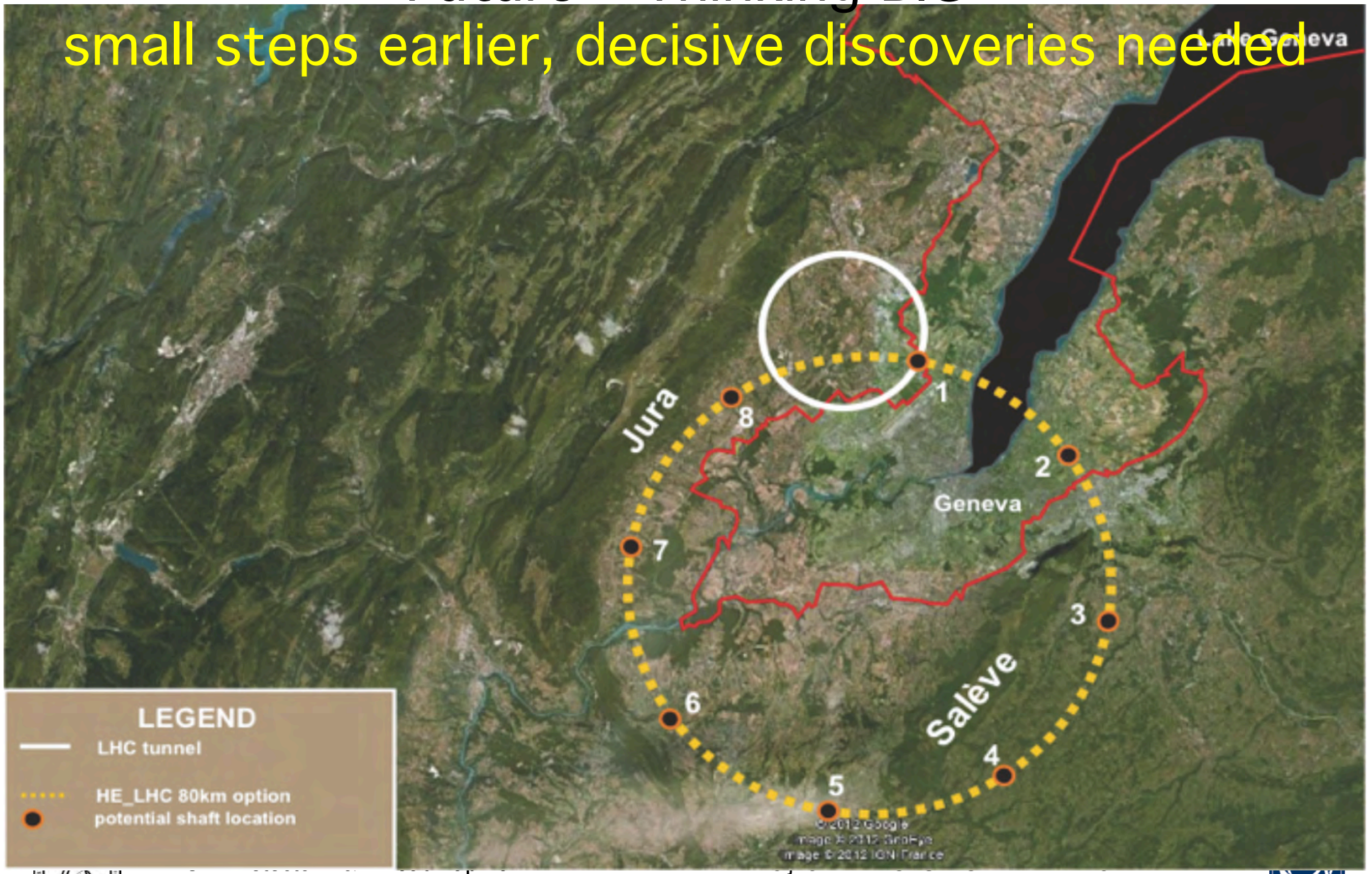
Application of lasers for interferometry? (such as for gravity waves)

Chemical processes (also as in DNA .....)

bubble chambers lasted 1955-1985, maybe there is an end for Si ?

# Future – Thinking BIG

small steps earlier, decisive discoveries needed



# Smaller steps final point

Even if significant efforts in nm/3D Si technology will be costly,
expenses (100-500Mchf) much lower than the future accelerator

Better precision, higher rates, etc. may already lead to discovery
remember: Sam Ting found J/psi at 'old' BNL AGS,
using 'new instrument' : muon pairs behind iron shielding
maybe, dark matter is 'under our nose....'

Advanced instrumentation is prelude to future experiments at FCC

Advancing instrumentation helps to keep enthusiasm

Spin-off in quantum radiation applications can support funding
Medipix/Timepix is good example, now spin-back into LHCb

Roadmap: Bon Voyage to atto/zepto world