The COREA experiment

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(Yonsei Univ.)

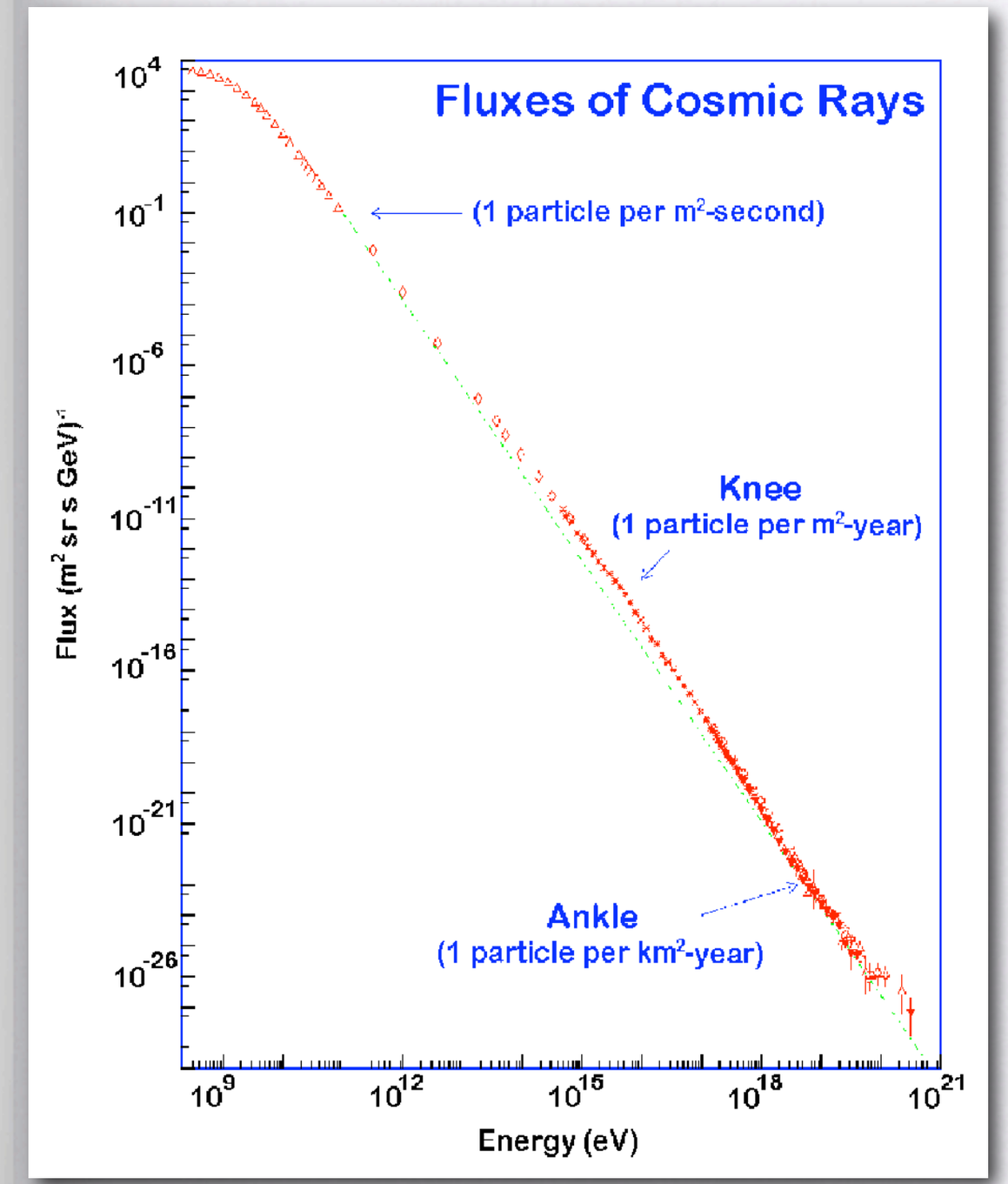
Contents

- What is COREA? -- an introduction
- Progress of COREA
  - hardware R&D
  - simulation study
- Other school-array projects

What is COREA?

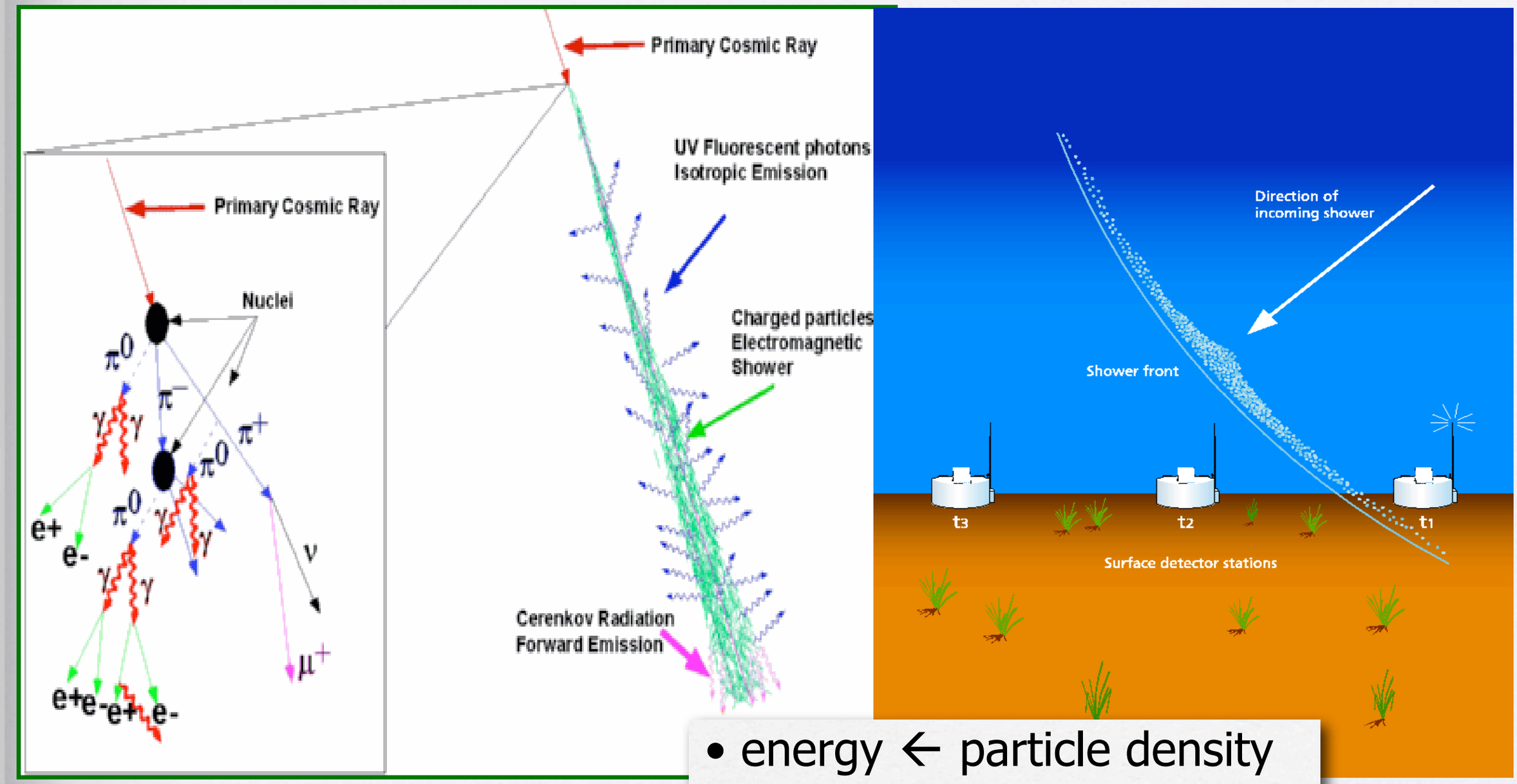
- **CO**smic ray **R**esearch & **E**ducation **A**rray in Korea
- School-array of CR detectors to study UHECR spectra

Cosmic-Ray energy spectrum



- Flux above 10^{19} eV :
  ~0.5 particle/km^2/year/sr
- Flux above 10^{20} eV :
  ~1 particle/km^2/century
- Composition (10^9 ~ 10^{15}):
  50% protons
  ~25% alpha particles
  ~13% C/N/O nuclei
  <1% electrons
  <0.1% gammas
- For > 10^{15} eV: Detecting "Extensive Air Shower" at ground by sampling shower secondary
  Energy, Direction, Particle ID

Extensive Air Shower



- energy ← particle density
- angle ← shower timing
- ID ← muon number

Detection Techniques

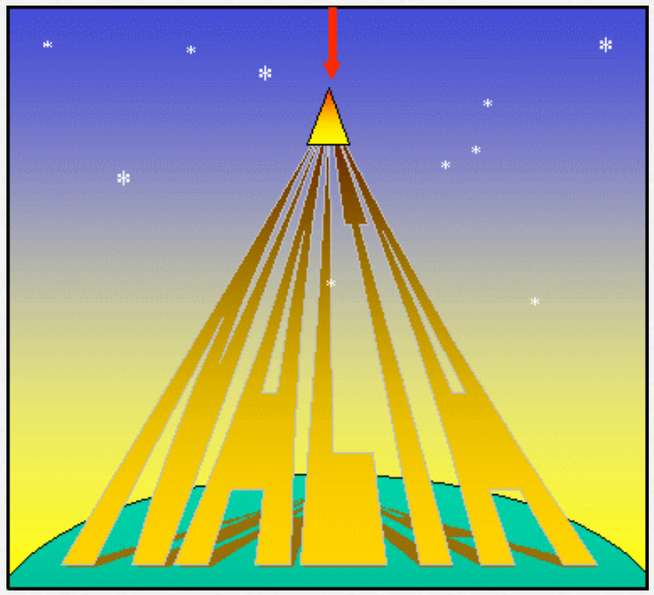
- Ground arrays – scintillators
  - oldest, simplest technique
  - Determine the approx. lateral dist. of EAS by sampling
- Ground arrays – Cherenkov counters
  - Electrons in EAS emit Cherenkov light; E_th ~ 21 MeV
  - Easy to increase areal acceptance
- Air fluorescence
  - Shower particles exciting N2 molecules
  - 300 ~ 400 nm, mostly → atten. Length ~ 15 km
  - “stereoscopic” binocular method

School Array approach

- High cost for UHECR experiment
  - land use; data network; personnel
- Physicists provide equipment and experiences
- schools provide sites; internet infrastructure and personnel for operation & monitoring
- Most of all, training for scientists of next-generation
- Pioneered by U. Alberta (ALTA) and U. Nebraska (CROP)

School arrays for UHECR

NALTA

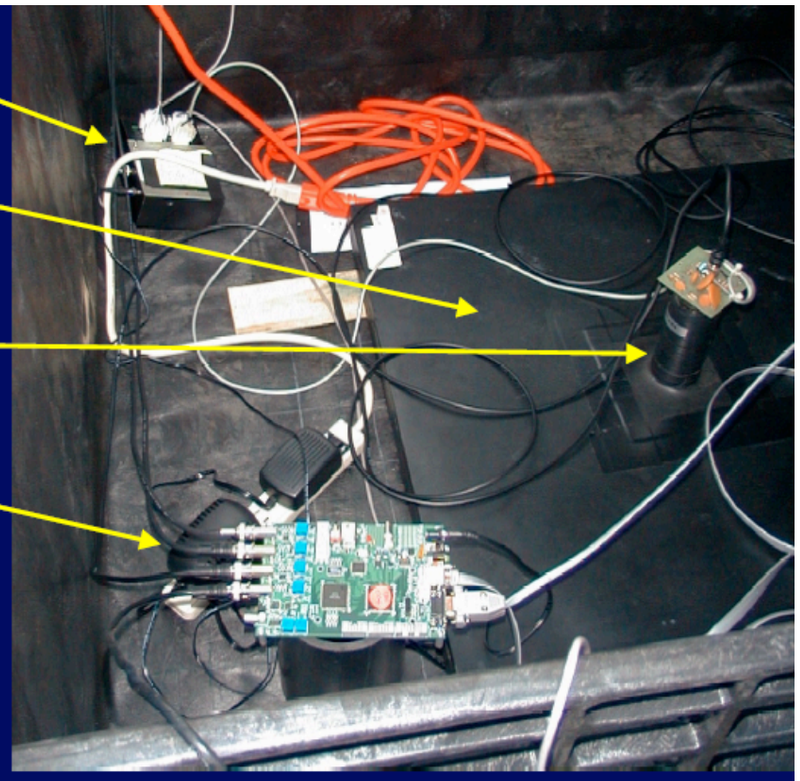


North American
Large area
Time coincidence
Arrays

WALTA/SALTA Detector : Simplest Option

3 detectors, each 1 m^2 * 1 inch
poor light collection efficiency (number of reflection, signal attenuation in the light path) (BC-408 att. length ~ 200cm)
variation of signal height depending on the hit position

- High voltage power supply
- Scintillator
- Photomultiplier tube
- Custom electronics card (from Fermilab)



COREA Status

The Collaboration

- First organizational meeting @ Ewha W.U. in 2004/12
- Currently, ~20 professors (in physics, astronomy, science education) & ~80 high-school teachers
- h
- n
  f

COREA member list (*t*)

Universities

지역	소속	이름	전화(휴대폰/직장/자택/팩스)
서울	경희대학교	김성수	
서울	서울대학교	박용선	/ 02-880-8979/ /
서울	서울대학교	방형찬	/ 02-880-6608/ /
서울	서울대학교	소광섭	/ 02-880-7750/ /02-870-7991
서울	서울대학교	이형목	010-9966-6489/02-880-6625/ /
서울	서울대학교	임명신	010-6612-0908/02-880-9010/ /
서울	서울대학교	최선호	/ 02-880-9193/ /02-84-3002
서울	서울시립대학교	박동수	
서울	서울시립대학교	박인규	010-30[illegible]2245-653 1
서울	성균관대학교	김윤배	017-283-7051/031-290-7051/02-537-7260
서울	성균관대학교	유인태	031-290-7052
서울	연세대학교	강주환	010-2227-2621/02-2123-2621 / /
서울	연세대학교	권영준	019-9143-1579/02-2123-2625/ /
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서울	한양대학교	김항배	010-9569-1981/02-2220-1981 / /
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경상도	경북대학교	김홍주	010-4506-4221/053-950-5323/ /
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부산	부산대학교	강혜성	019-418-2702/051-510-2702/051-936-2702/051-513-7495
부산	부산대학교	안홍배	/051- 510-2705/051- 625-0732/051- 513-7495
부산	부산대학교	유인권	011-9283-7549/051-510-2594/051-513-7549/051-583-8428
부산	부산대학교	이창환	011-9047-8124/051-510-2165/051-256-9549/051-513-7664
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부산	경남고등학교	서옥조	010-3483-0059
부산	광명고등학교	하동기	011-5789-9728/051-405-6290/051-626-9728
부산	금성고등학교	[illegible]	
부산	남산고등학교		
부산	내성고등학교		
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부산	부산여자상업고등학교		
부산	부산중앙고등학교		
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Jr. High S.

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대전	만년중학교	양명수	042-486-8244
부산	개림중학교	최인희	010-3341-1921
부산	개성중학교	정은화	010-3021-1631
부산	구남중학교	윤성희	010-655[illegible]-3134
부산	금곡중학교	이지영	016-601[illegible]
부산	금명중학교	박혜경	019-396[illegible]
부산	금양중학교	성종규	017-561-0696
부산	다송중학교	박송원	016-862-8679
부산	모라중학교	이정아	019-532-0239
부산	반송여자중학교	장운태	016-795-3954
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서울	상봉중학교	김경미	017-289-9897
서울	신사중학교	황윤진	019-228-8919
서울	인수중학교	신승희	011-9568-4849
전남	여도중학교	김태익	061-682-0155/

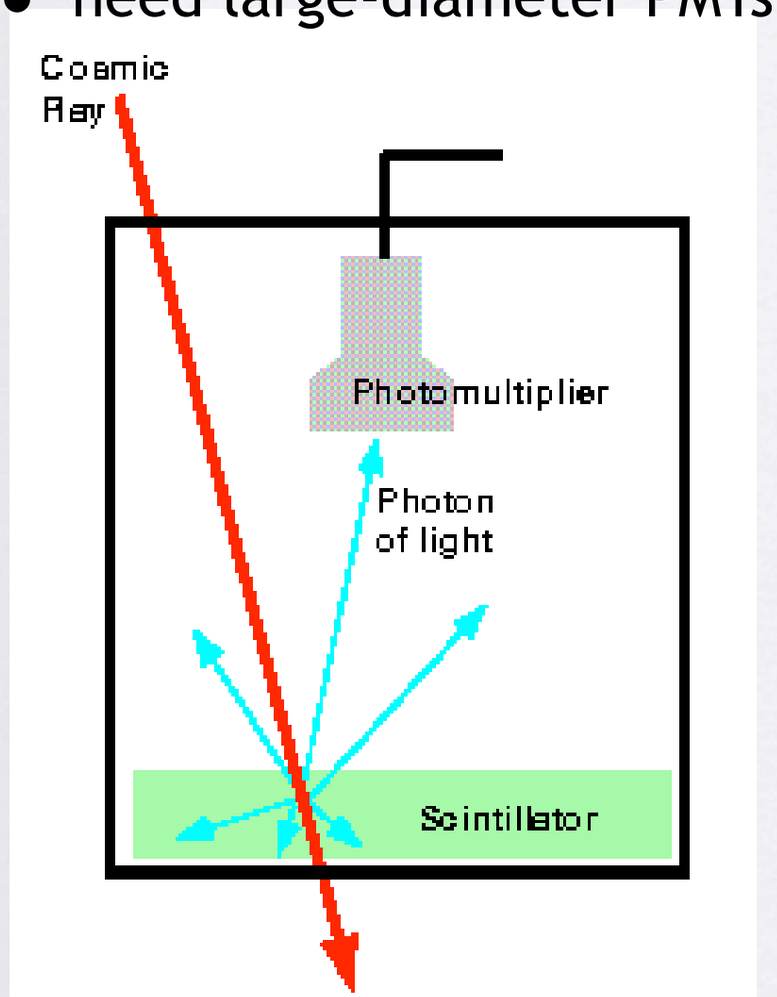
Detector R&D

- Detector type & Efficiency test
- DAQ / GPS
- coincidence measurements...

Detector types considered

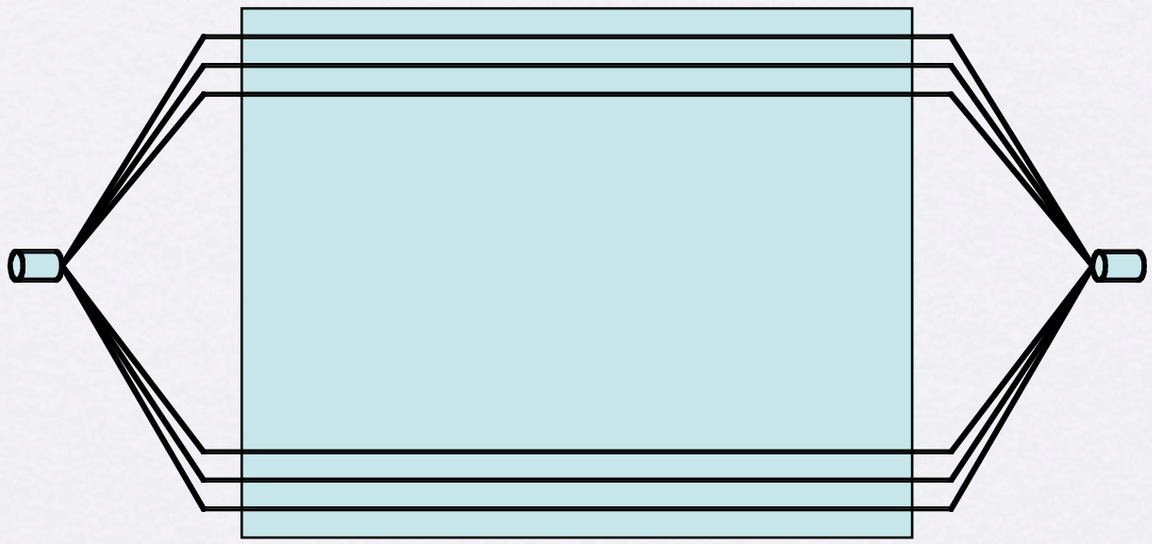
Thick scintillator in a big tube w/ PMT at the top:

- Simple assembly
- Scintillator price vs. photon collection efficiency
- need large-diameter PMTs



Thin scintillator with WLS fibers:

- Need machine work for grooves
- Careful assembly process
- Small diameter PMTs ok



Tube type

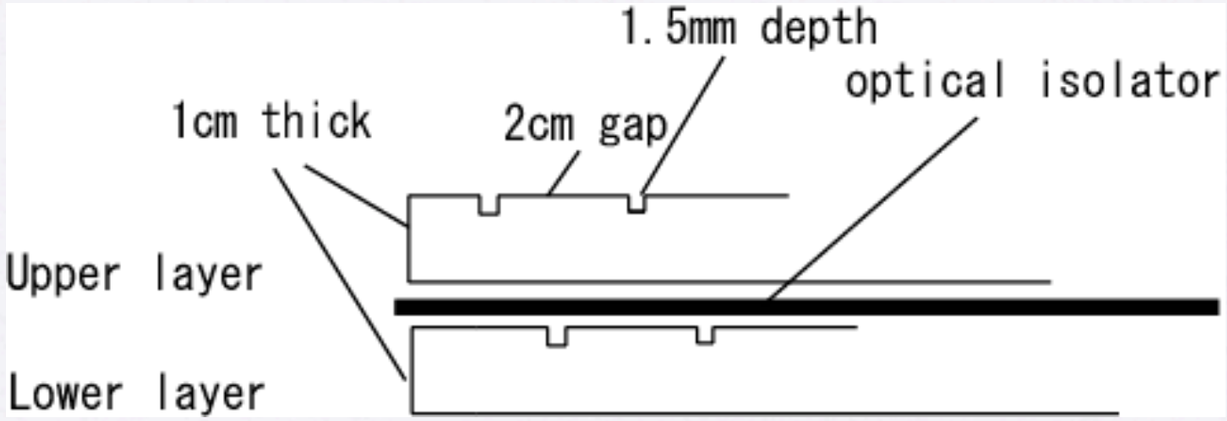
- Used for KASCADE, AGASA ...
- Homogeneous detector response over whole area
- Poor light collection effi. → need good reflectivity of container & thick scintillator
- High cost for thick plastic
- Difficult for muon detection

KASCADE : stainless steel container, 4cm thick scintillator

AGASA : 5 cm thick scintillator, single PMT

Fiber type

- Light collection effi. increases with
  - thick WLS fiber
  - more fibers
- Muon detection with electron shielding b/w layers
  - early AUGER option

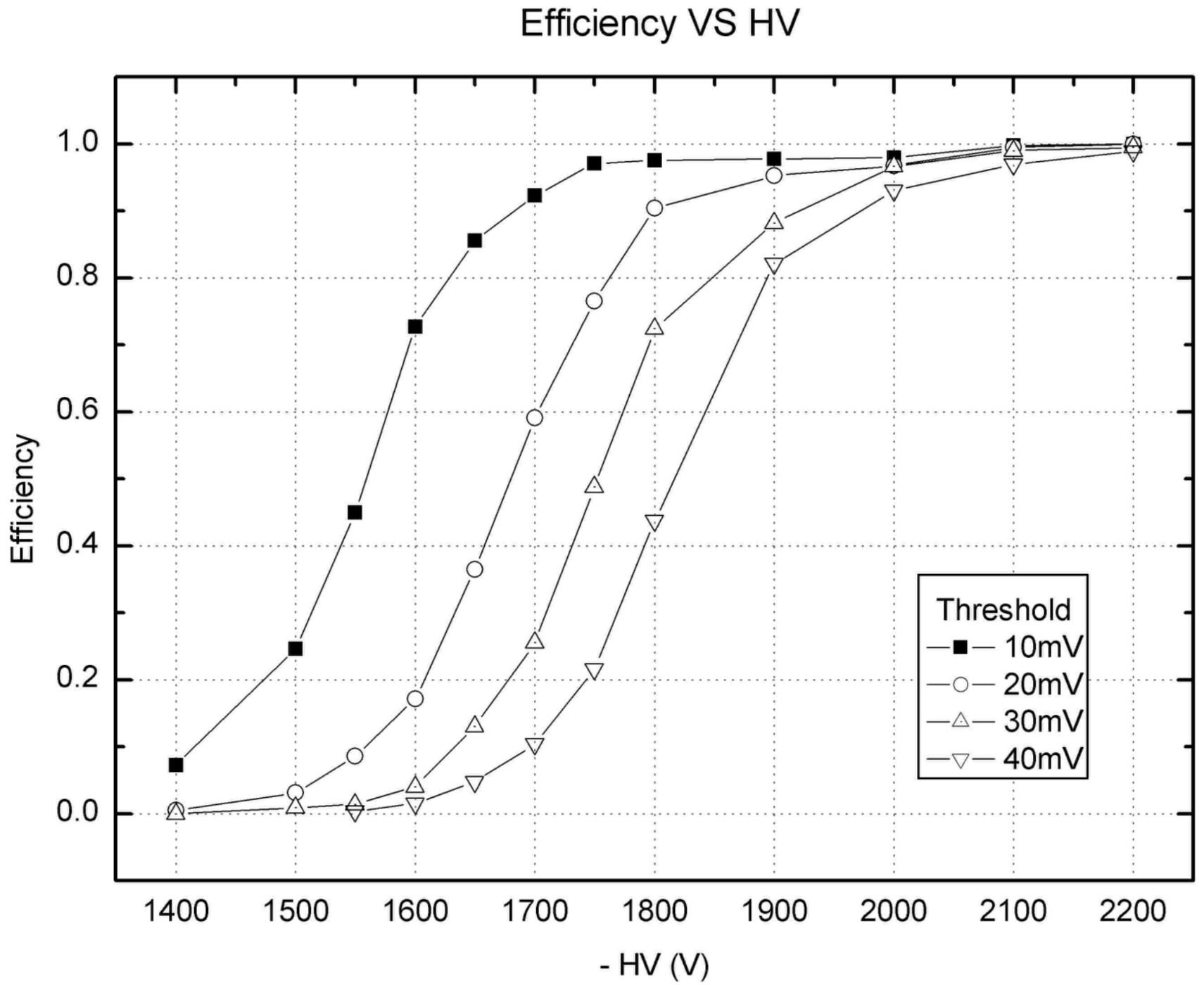


WLS : Wave Length Shifter Fiber Scintillator 50cm x 50cm x 1.2cm with 16 σ shape grooves

1x1 m^2 x 10 mm, 2 layers of polystyrene scintillator plates
5x5x2=50 plate of 194x194 mm^2 size, 5 mm thickness and 4 grooves
Maximum light emission at 420 nm, decay time 2 nc.
22 WLS-fibers of Y-11 type of 1 mm in diameter.
4x5=20 fibers glued in plate grooves + 2 additional fibers glued on side of the layer
Far end of each fiber has Al-mirror.
Fiber light attenuation length about 330 cm.
Light output homogeniety along the counter sensitive area about 6%.
For homogenization of the light output (along the WLS-fibers)
Small PMT (FEU-115M), Test measurements : 20 photoelectrons for a MIP

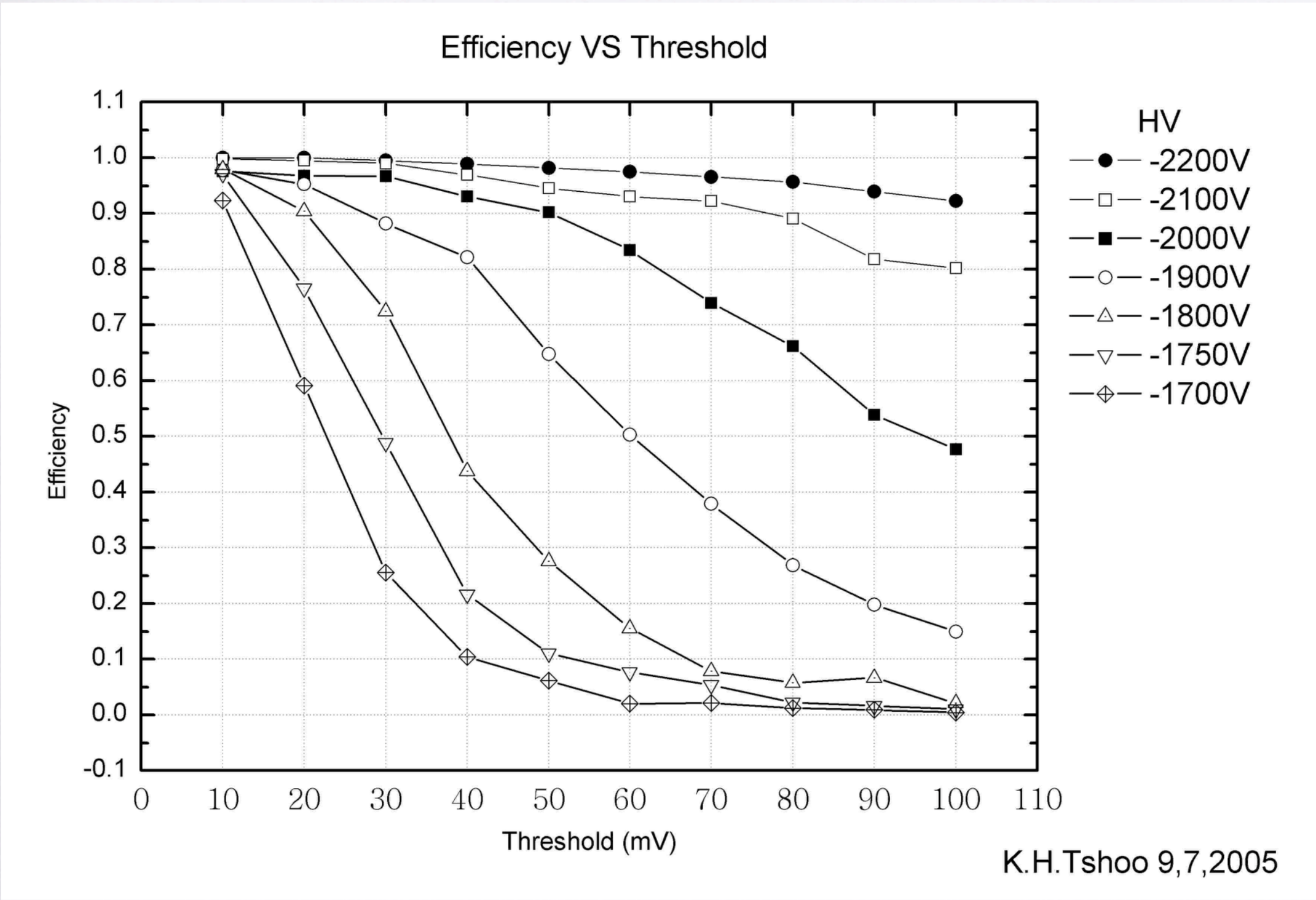
Russia IHEP

Scintillator Effic'y Test

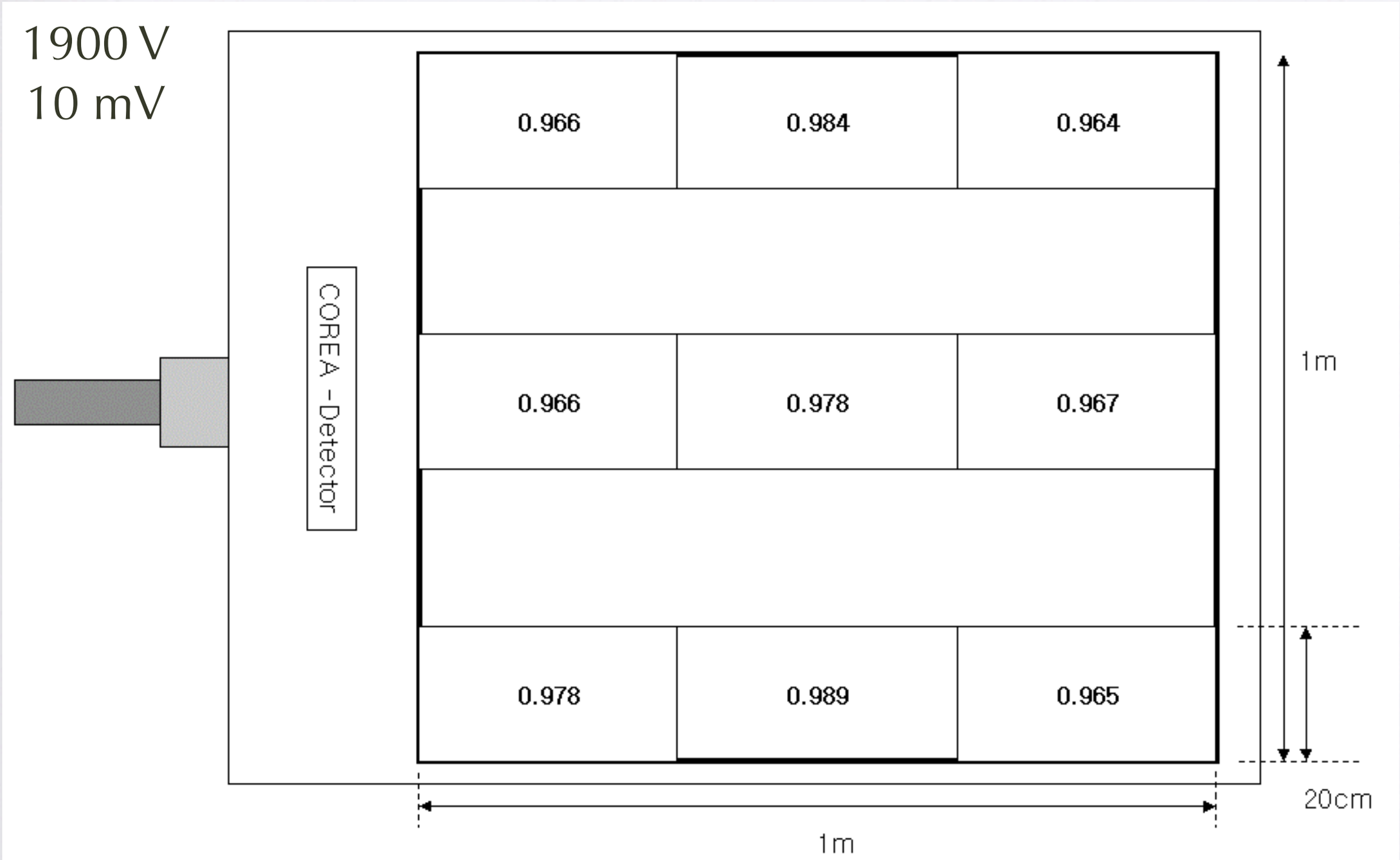


K.H.Tshoo 9,7,2005

Scintillator Effic'y Test

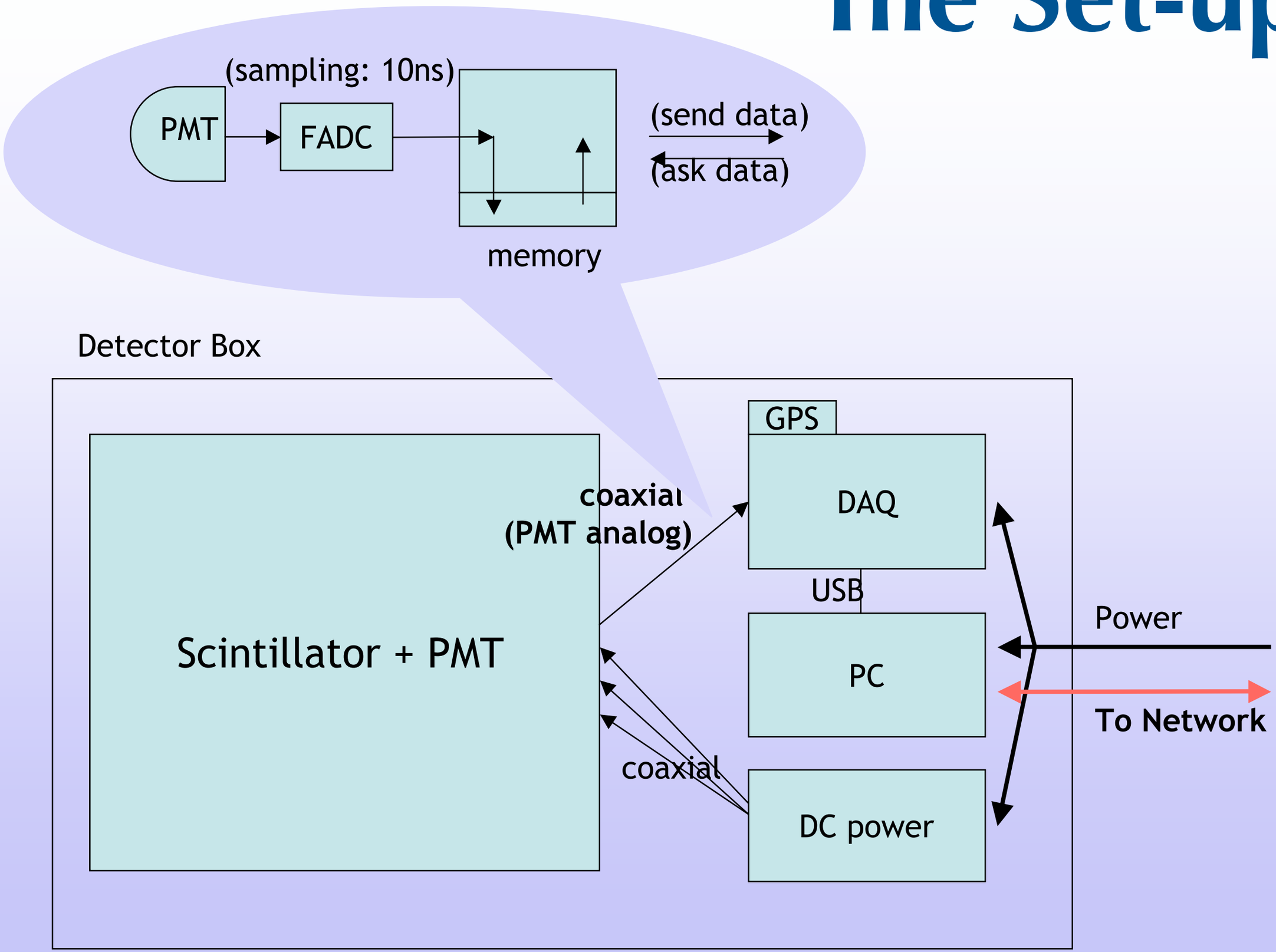


Scintillator Effic'y Test



DAQ / GPS

The Set-up


(sampling: 10ns)
PMT
FADC
memory
(send data)
(ask data)
Detector Box
GPS
DAQ
coaxial
(PMT analog)
USB
Power
Scintillator + PMT
PC
To Network
coaxial
DC power

The COREA DAQ box

100 MHz, 10bit ADC

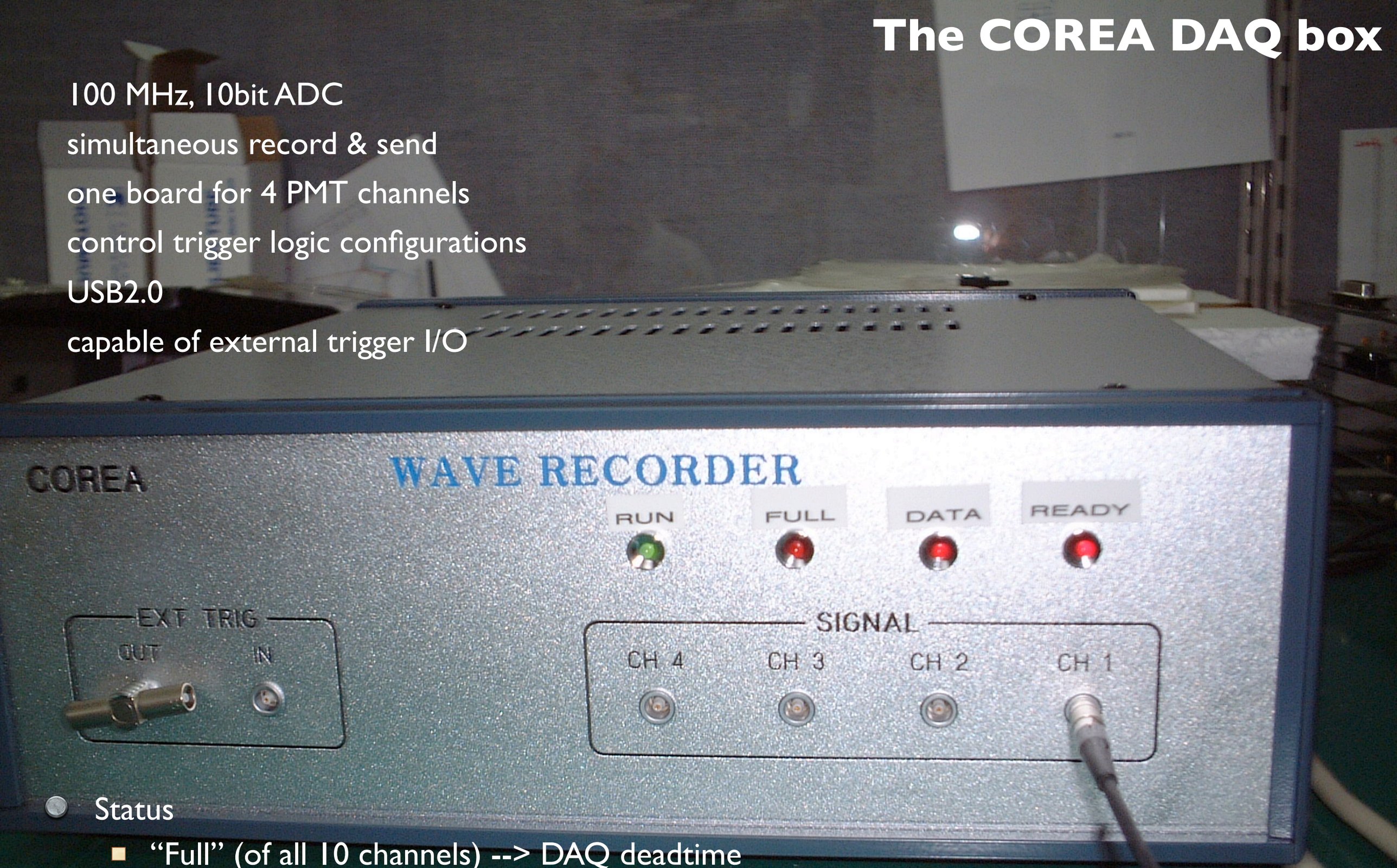
simultaneous record & send

one board for 4 PMT channels

control trigger logic configurations

USB2.0

capable of external trigger I/O



- Status
  - "Full" (of all 10 channels) --> DAQ deadtime
  - "Ready" : event(s) in ≥ 1 channel
- 1 event ↔ 20 sampling ↔ 200 ns
- simultaneous handling of 4 channels

inside the DAQ box

Parallel port connector

Power Supply (+/- 12V)

Parallel port I/O buffer

Xilinx FPGA chip
With internal mem.

Oscillator 100MHz

4 ADC 100 MHz 10 bit

Signal Buffer

Ext. Trigger In/Out

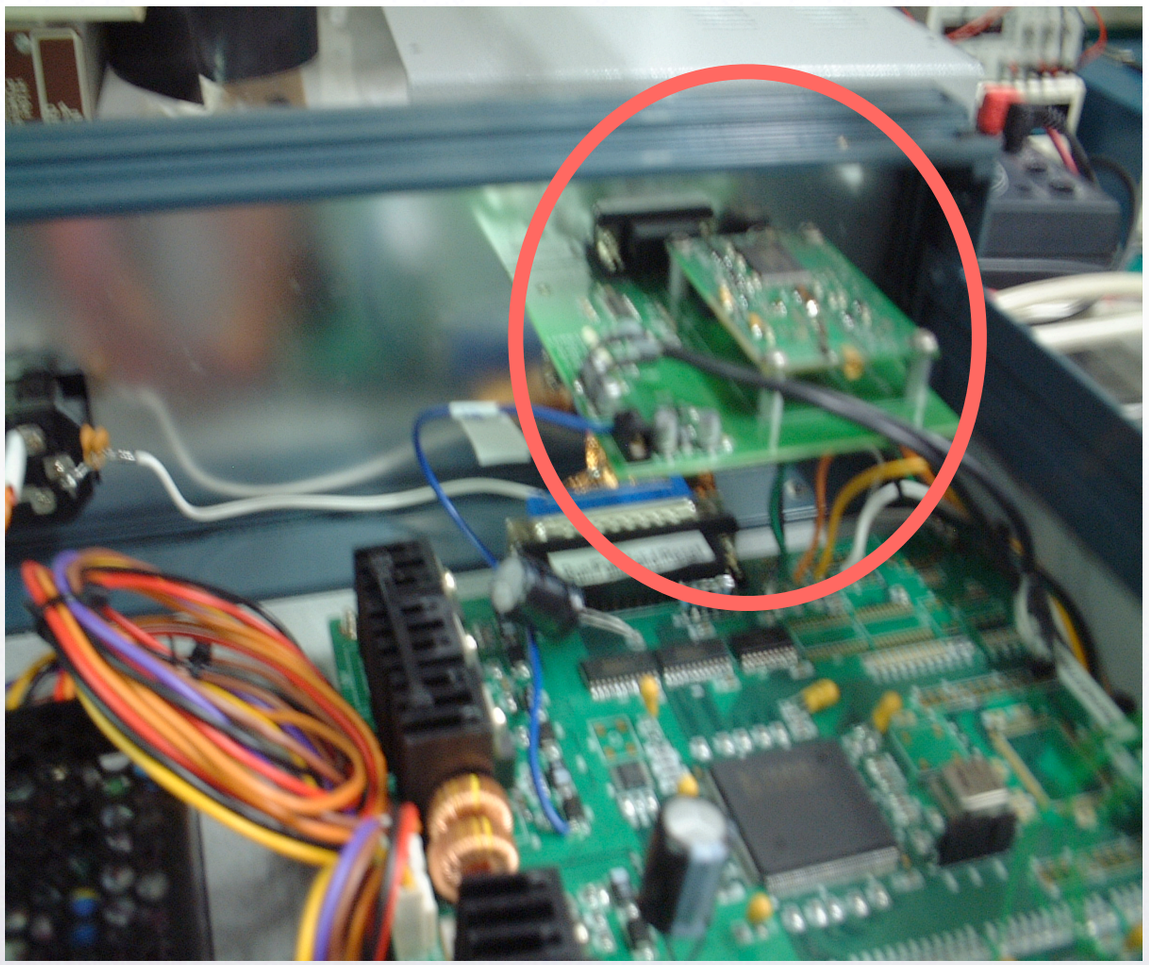
OP amps

4 PMT signals

Trigger modes

0 --> 1*2*3*4
1 --> 1*2*3 or 1*2*4 or 1*3*4 or 2*3*4
2 --> 1*2*3 or 1*2*4
3 --> 1*2*3
4 --> 1*2 or 1*3 or 1*4 or 2*3 or 2*4 or 3*4
5 --> 1*2 or 1*3 or 1*4
6 --> 1*2 or 1*3
7 --> 1*2
8 --> 1 or 2 or 3 or 4
9 --> 1 or 2 or 3
10 --> 1 or 2
11 --> 1 // the default
12 --> 2
13 --> 3
14 --> 4

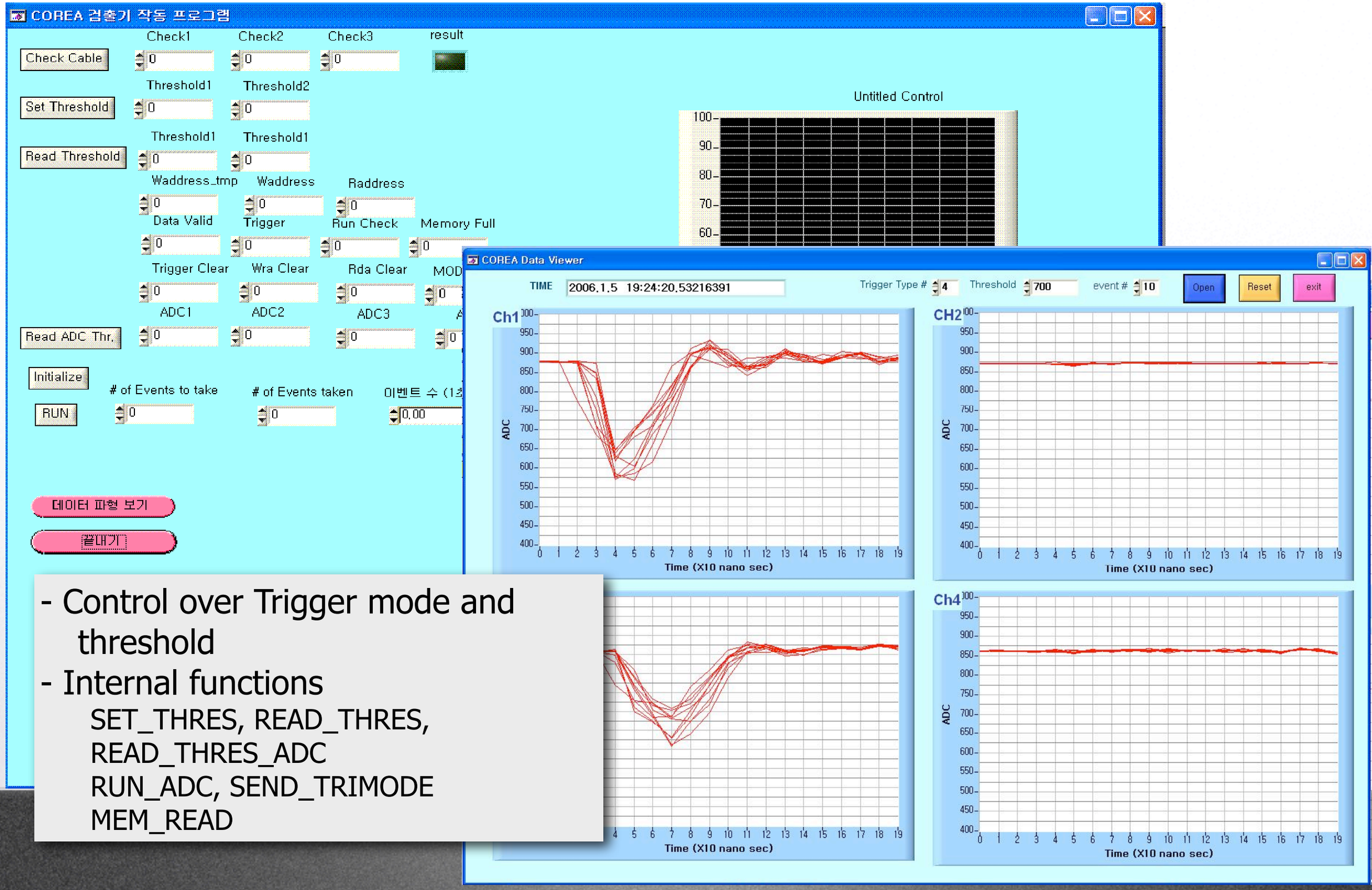
GPS Receiver



- M12+ Oncore™ Timing Rcvr.

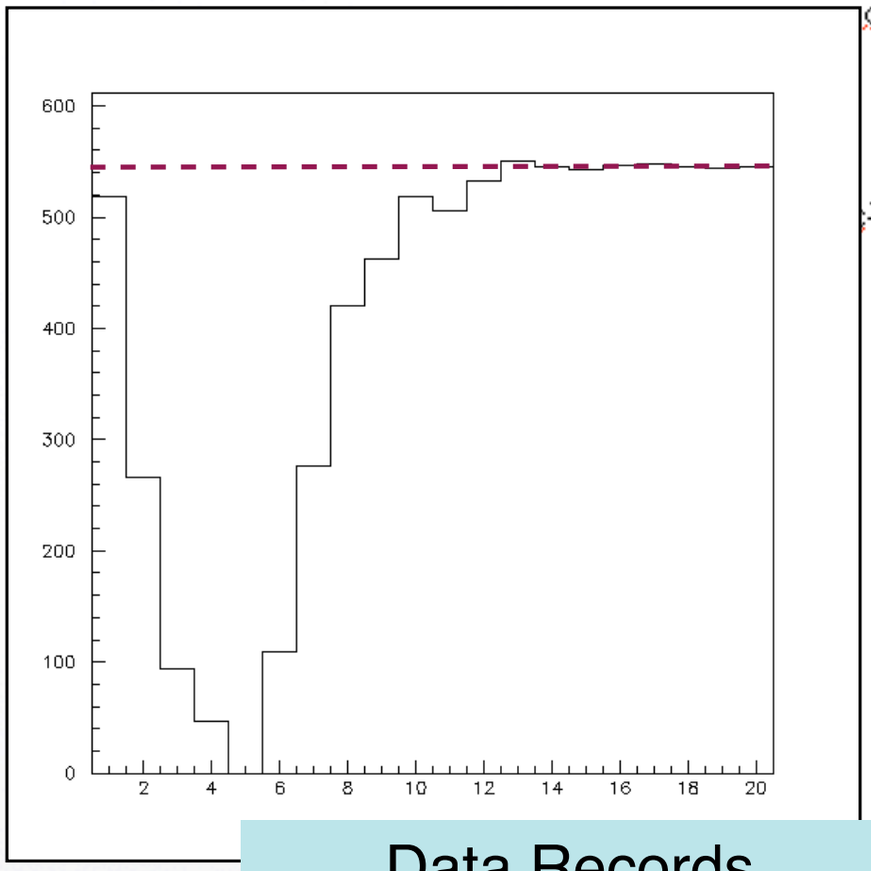
  - from Synergy Systems, USA
  - 3 Volt, low power consumption
  - timing performance < 2ns

GUI for control



- Control over Trigger mode and threshold
- Internal functions
  - SET_THRES, READ_THRES, READ_THRES_ADC
  - RUN_ADC, SEND_TRIMODE
  - MEM_READ

Triggered, GPS-tagged data



ch1 data　ch3 data　time data　check
ch2 data　ch4 data　ram addr　1:ok,0:fail
간격

```
0 878 871 859 863 7 200 56 1
1 877 871 860 862 214 201 56 1
2 873 872 859 863 1 202 56 1
3 710 869 857 859 5 203 56 1
4 648 870 829 862 19 204 56 1
5 699 869 728 864 24 205 56 1
6 761 871 723 861 19 206 56 1
7 867 871 686 863 4 207 56 1
8 900 873 765 863 239 208 56 1
9 913 871 810 864 213 209 56 1
10 868 872 861 862 62 210 56 1
11 865 871 873 865 0 211 56 1
12 892 872 865 865 0 212 56 1
13 898 870 852 859 8 213 56 1
14 878 871 864 861 0 214 56 1
15 880 871 868 863 0 215 56 1
16 895 873 869 861 0 216 56 1
17 890 870 865 865 0 217 56 1
18 878 871 873 865 0 218 56 1
19 889 872 869 858 0 219 56 1
```

time data에서
<이벤트시간>

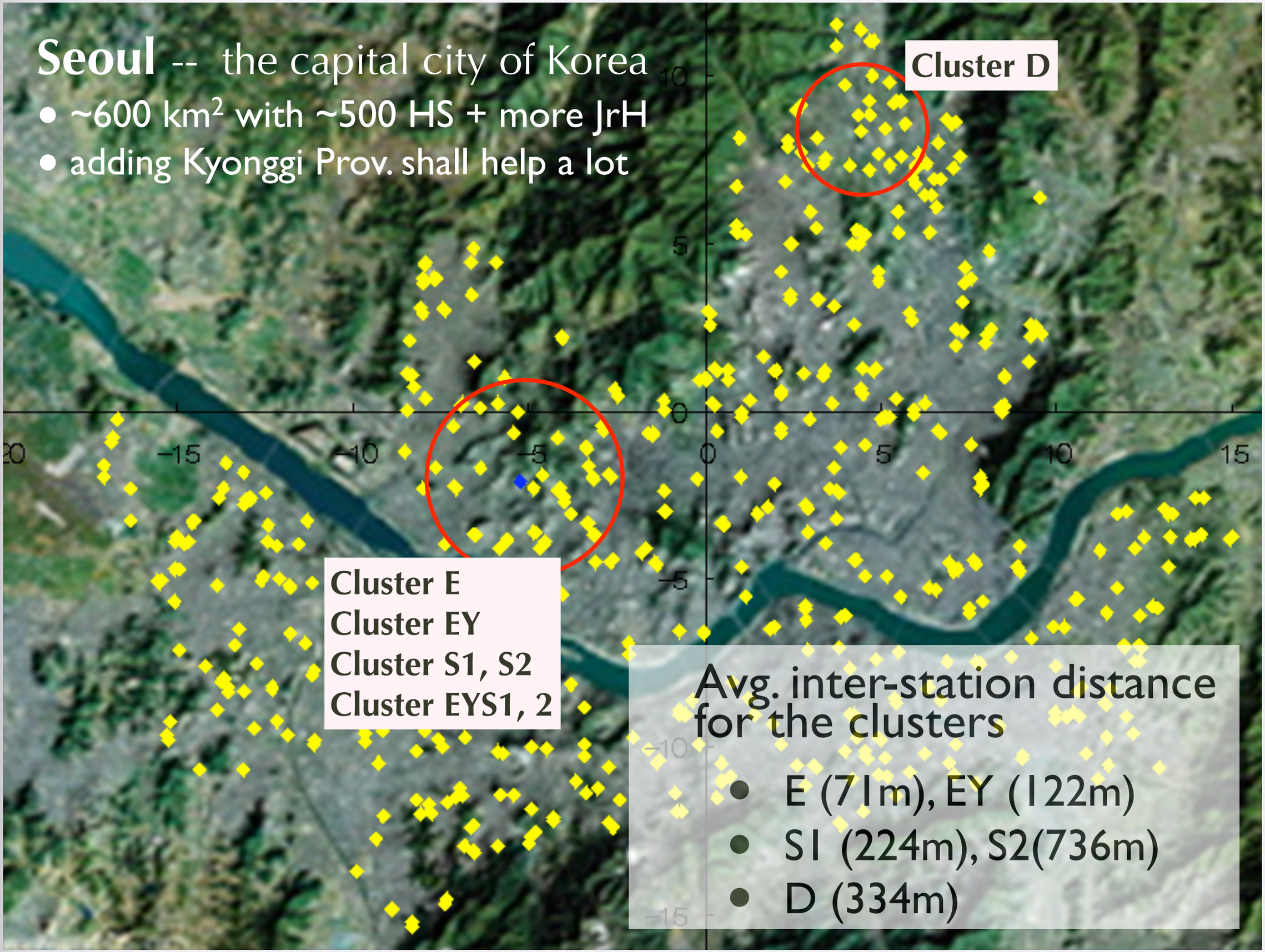
0,1행은 GPS 7*256+ 214=2006년
2행은 GPS 1월
3행 GPS 5일
4행 GPS 17시
5행 GPS 24분
6행 GPS 19초
7,8,9,10은 단위 초아래카운트값
4*16777216+ 239*65536+ 213*256+ 62
=82826558nsec

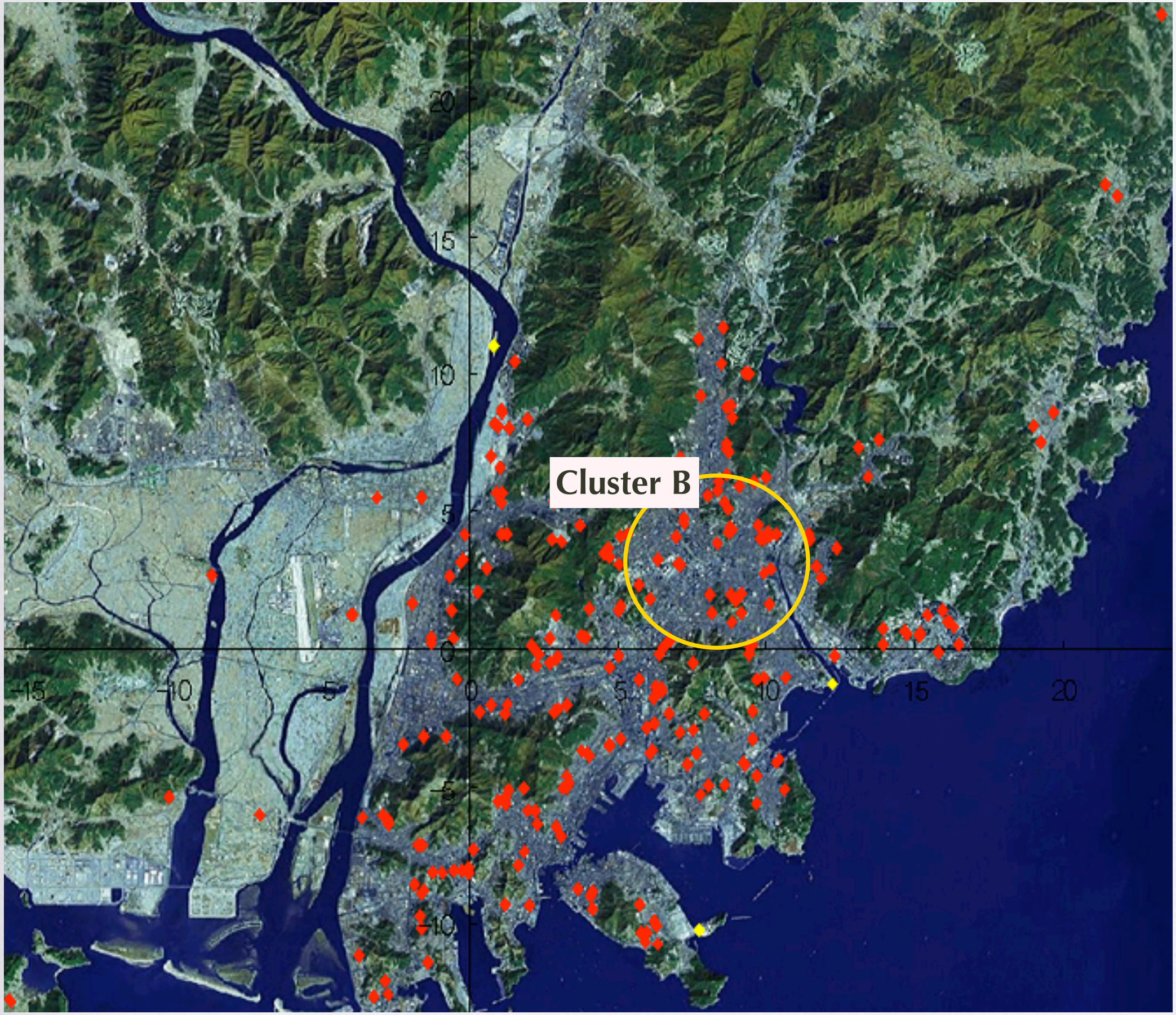
Data Records

1. Sampling point
2. Signal – channel 1
3. Signal – channel 2
4. Signal – channel 3
5. Signal – channel 4
6. Time
7. Read address
8. Size of data
9. Flag for memory full

Simulation Study

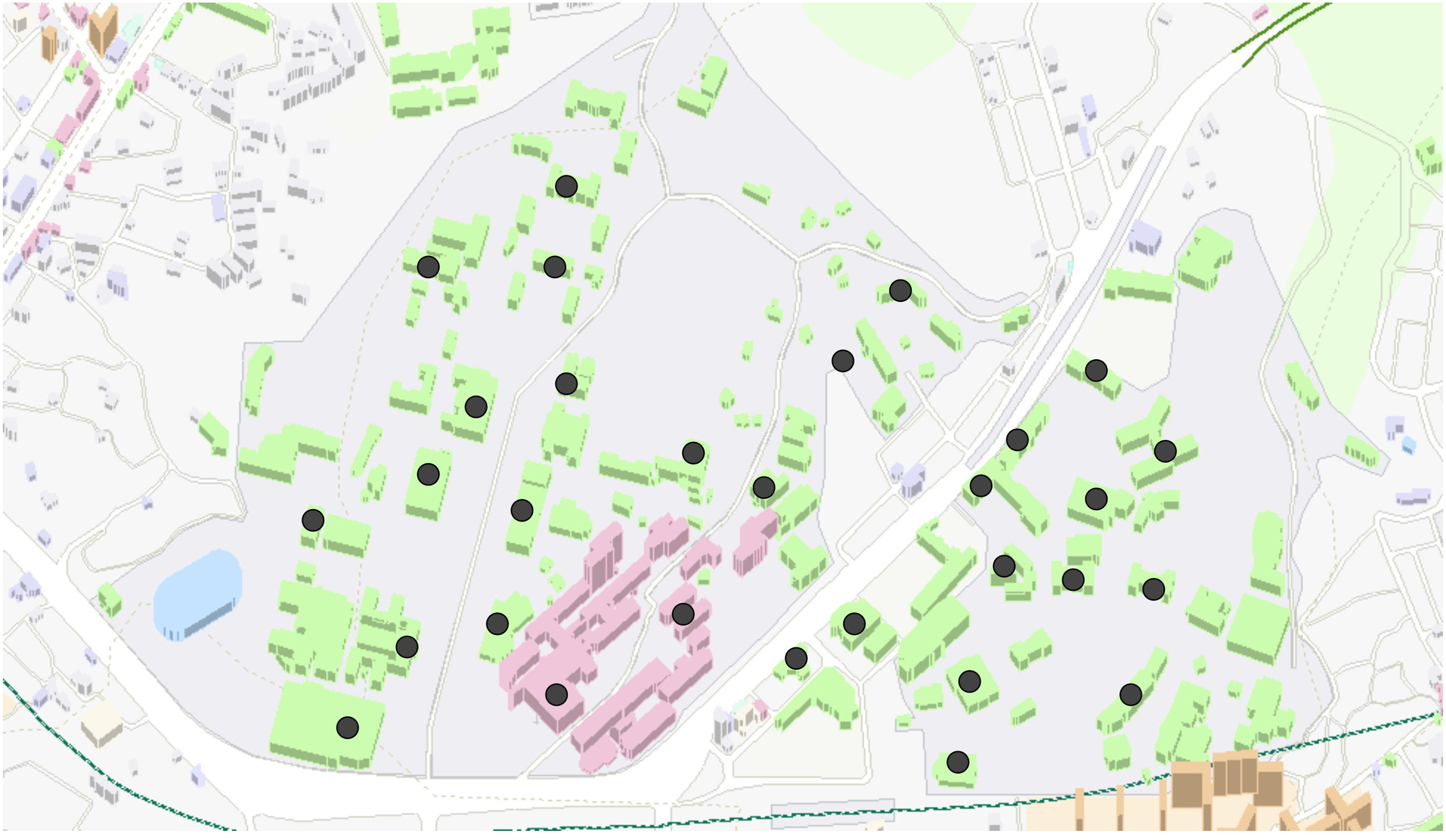
- for a small-scale detector array
- strategy: where & how many?
  - geography of school distributions


Seoul -- the capital city of Korea
• ~600 km² with ~500 HS + more JrH
• adding Kyonggi Prov. shall help a lot
Cluster D
Cluster E
Cluster EY
Cluster S1, S2
Cluster EYS1, 2
Avg. inter-station distance for the clusters
• E (71m), EY (122m)
• S1 (224m), S2(736m)
• D (334m)

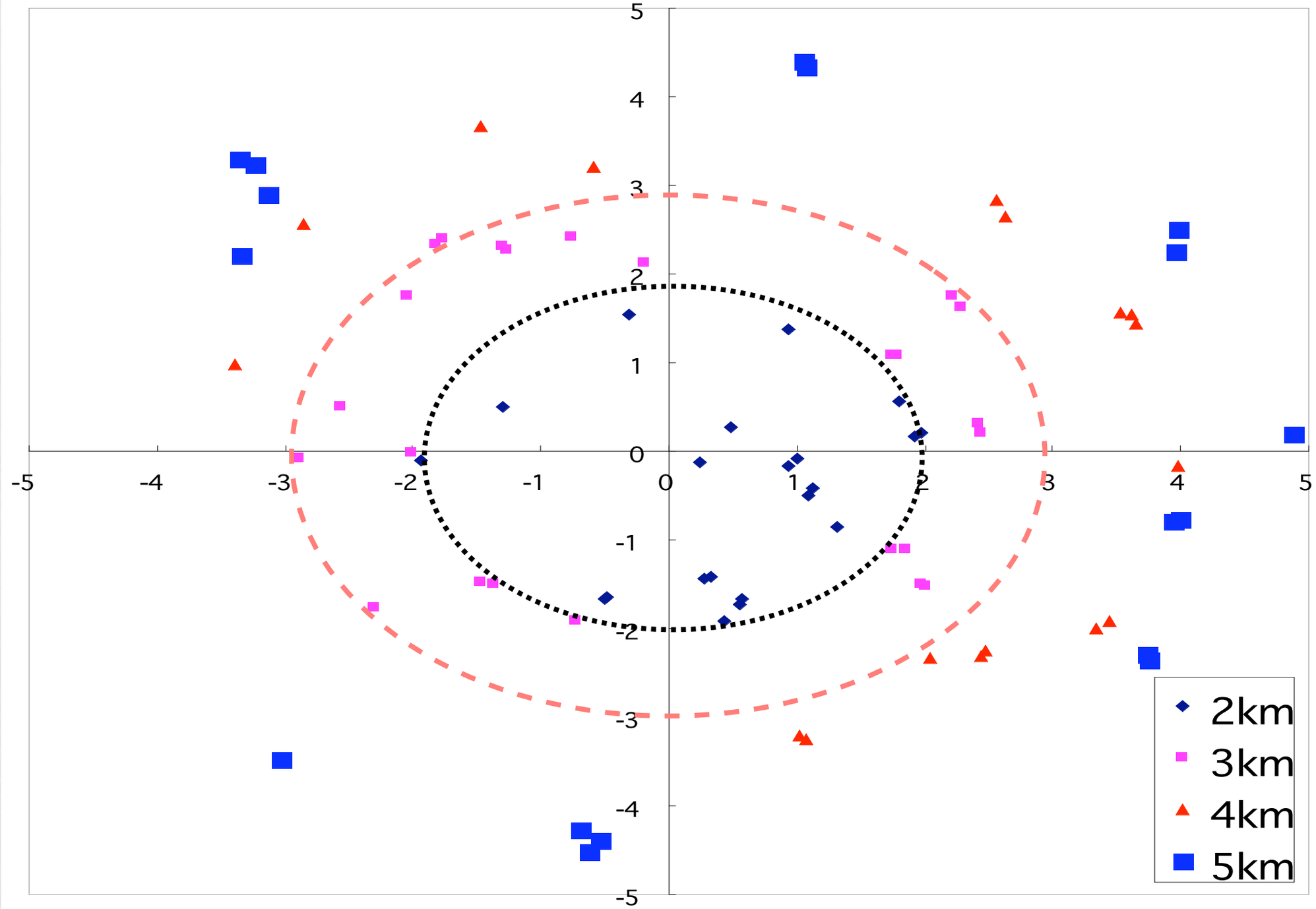

Cluster B
20
15
10
5
0
-5
-10
-15
-10
-5
0
5
10
15
20

Cluster E (30 stations)

Cluster EY (30 stations)

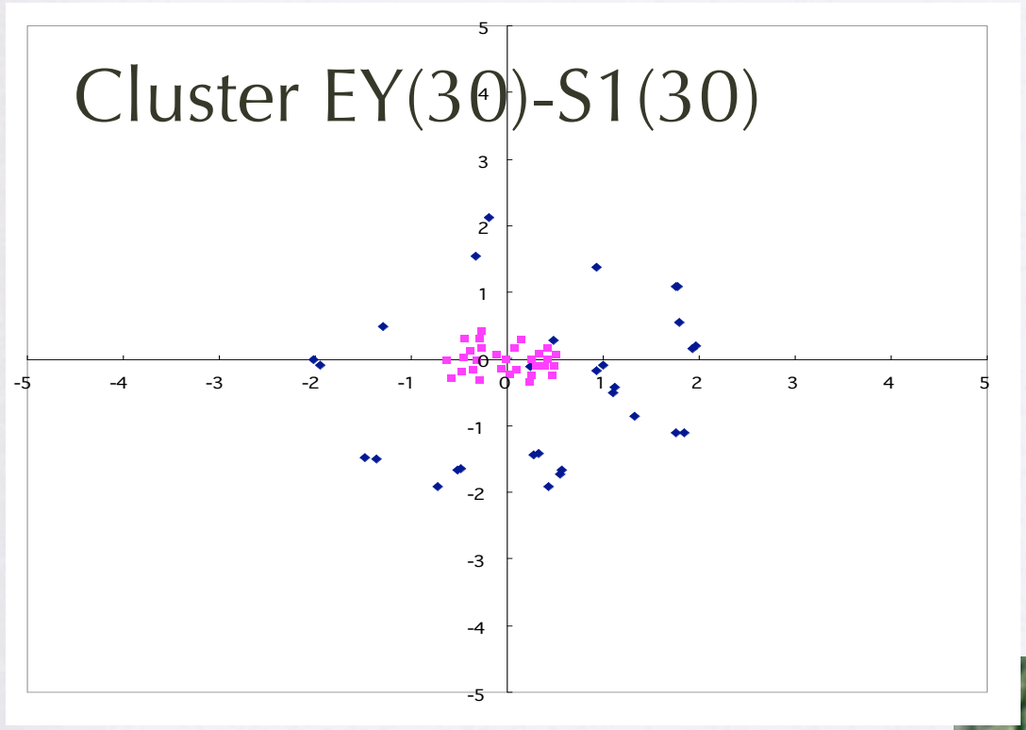


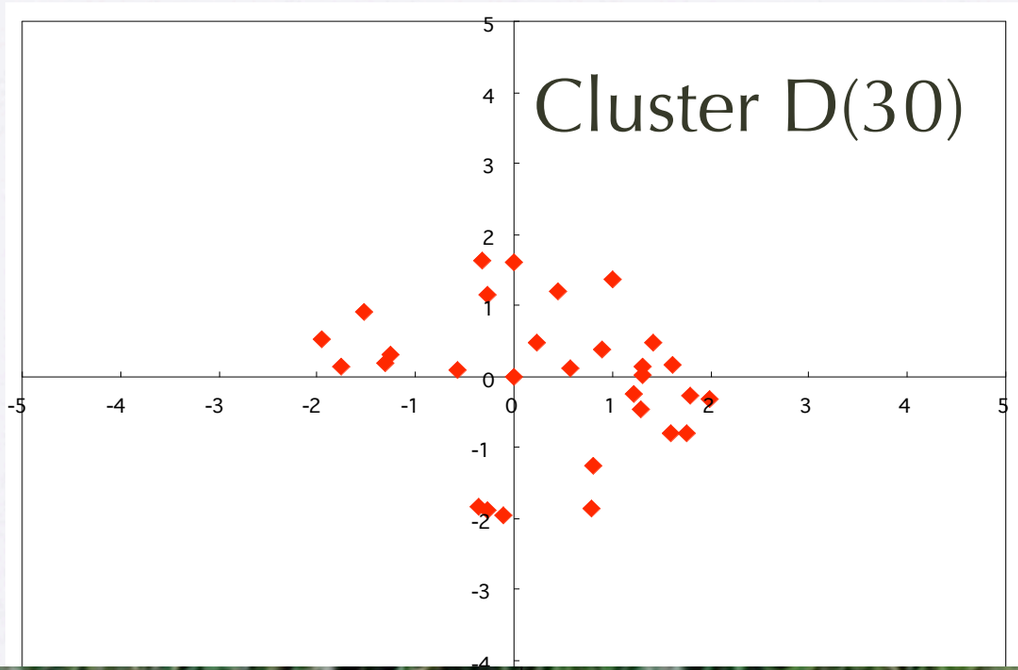
School locations for Clusters S1, S2

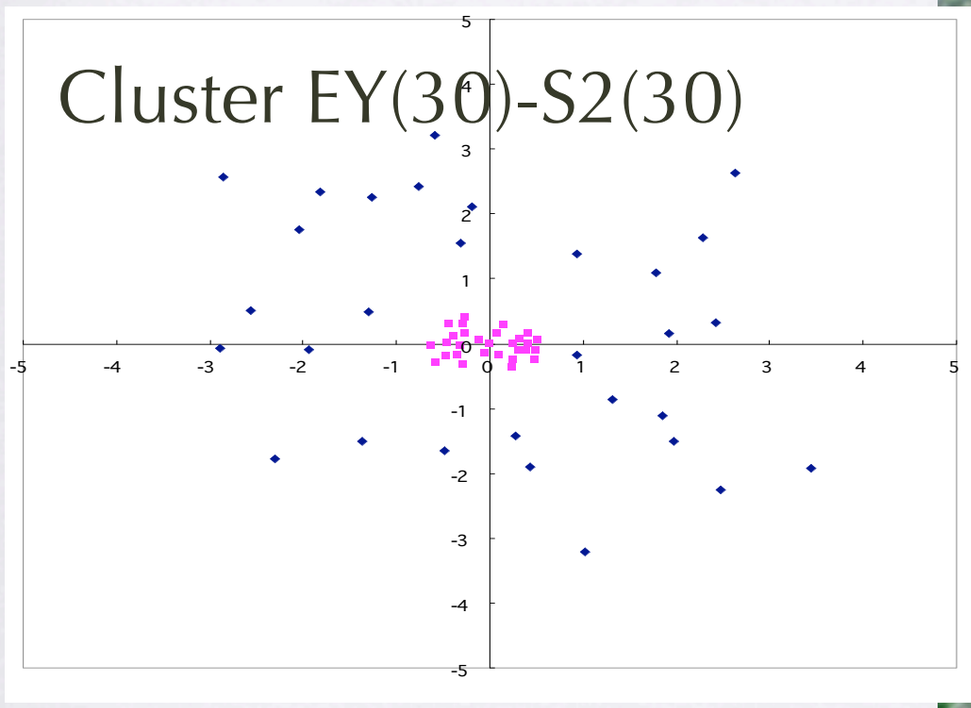


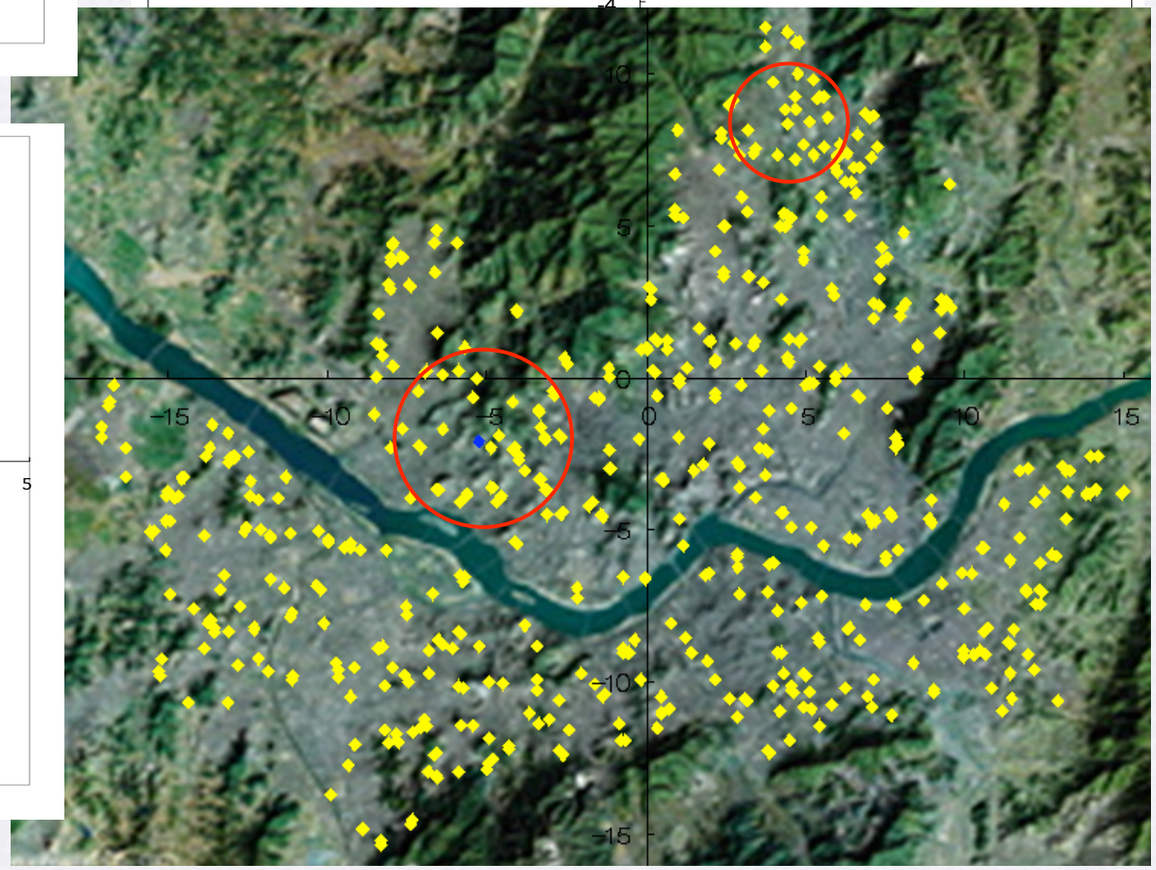
30 schools chosen, for both S1 and S2 in the simulation study

Candidate arrays



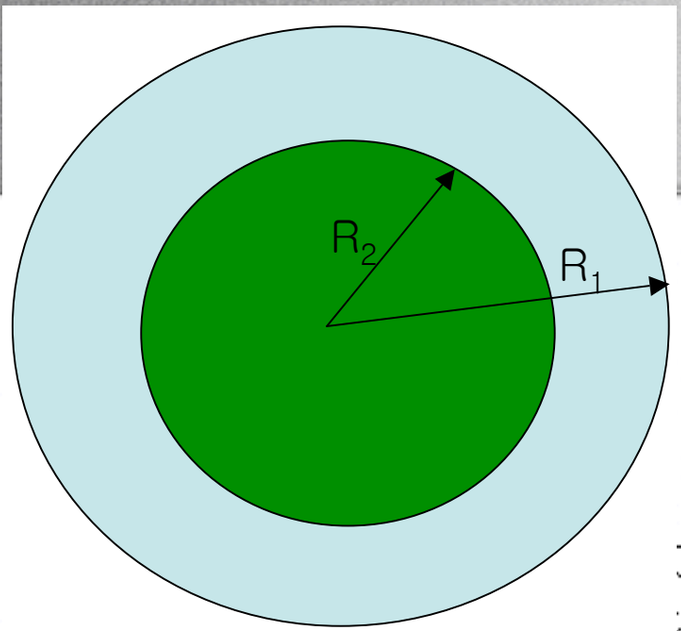






Simulation set-up

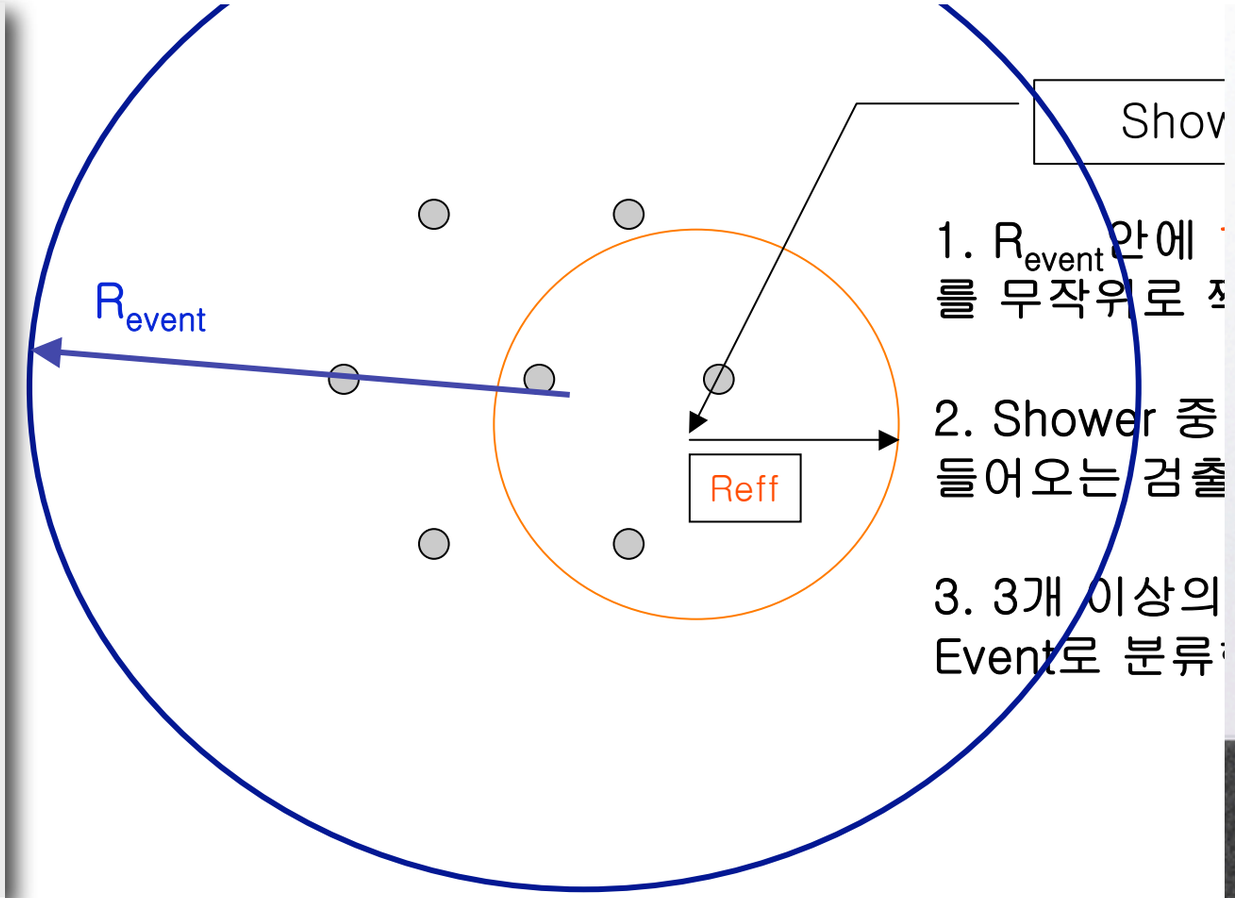
- CORSIKA package
- primary particle: proton
  - vertical entry (zenith angle = 0)
  - energy: 10^{16}, 10^{17}, 10^{18}, 10^{19}, 10^{20} (eV)
- shower particles: e, μ



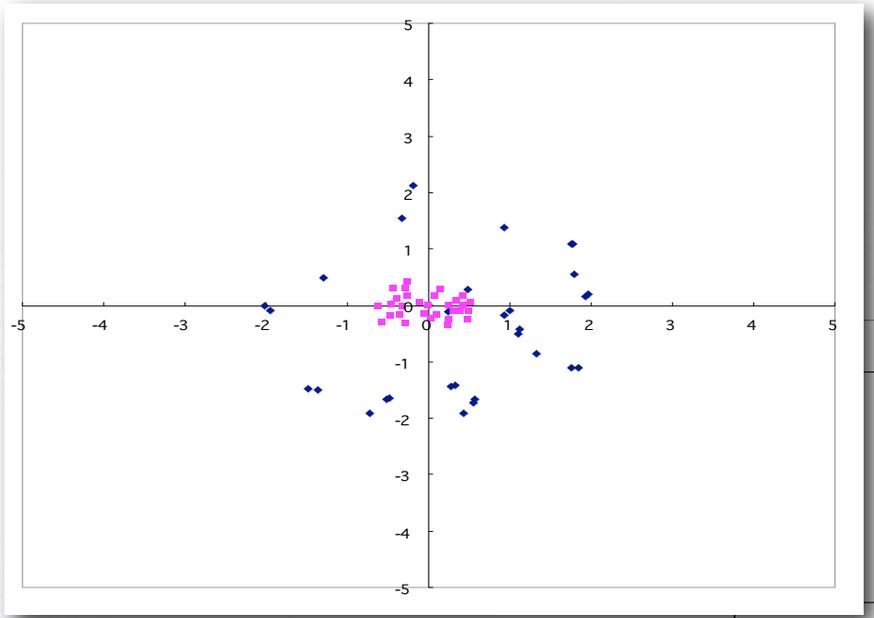
Effective Radius (R_{eff})

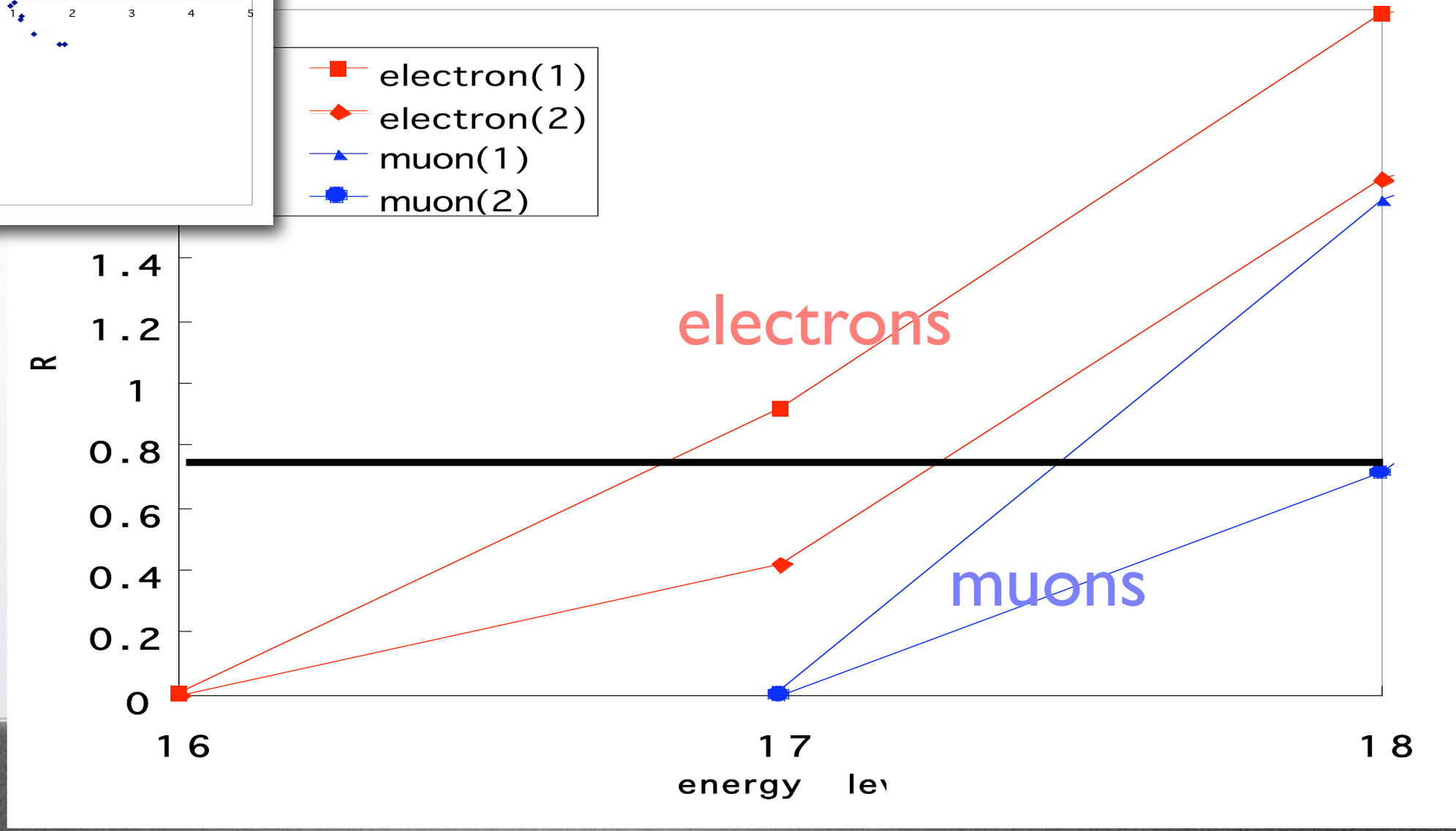
energy / icle		10^{16} eV	10^{17} eV	10^{18} eV	10^{19} eV	10^{20} eV
1	electron	168	421	745	1130	1920
	muon	37	188	545	1120	1995
2	electron	133	298	562	977	1760
	muon	16	126	375	942	1640

- MC-generated 10k events within R_{event} --> then, scaled to E spectrum
- Required ≥3 stations to register an event
- Counted N(stations) within R_{eff}

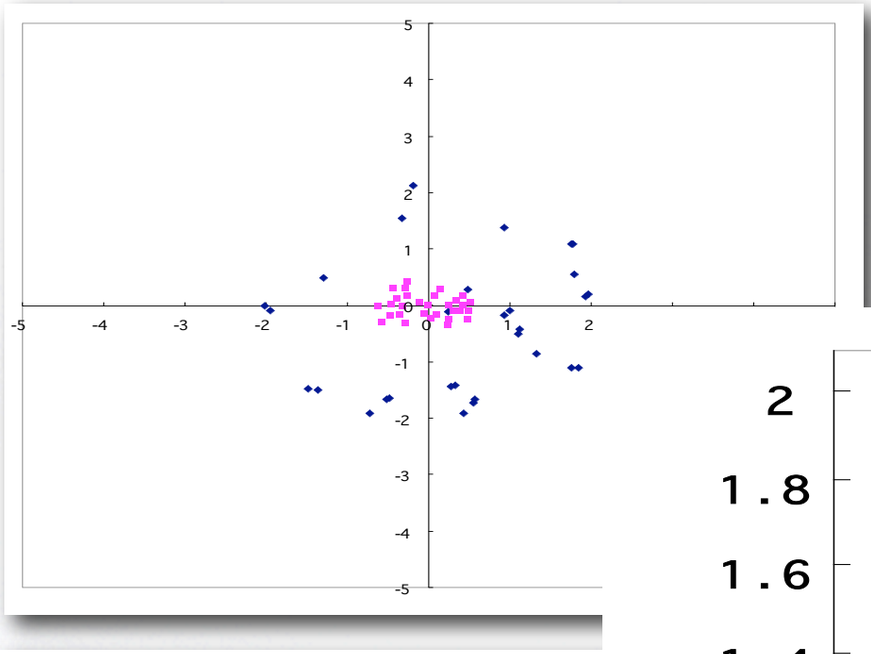


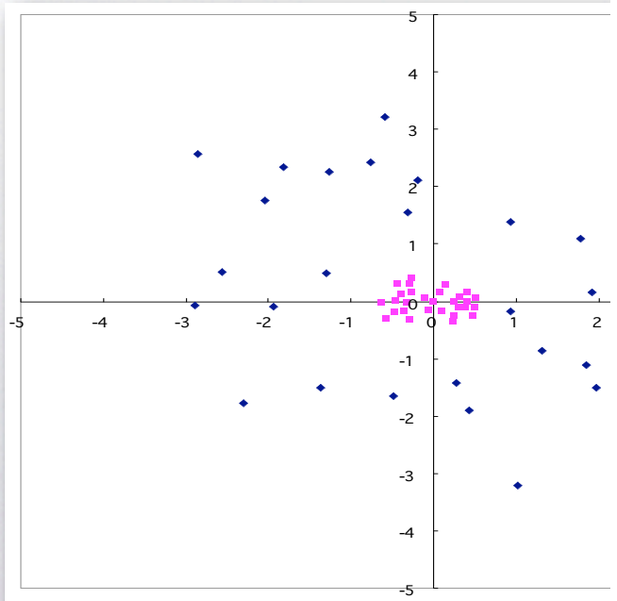
Results: S1 vs. EY

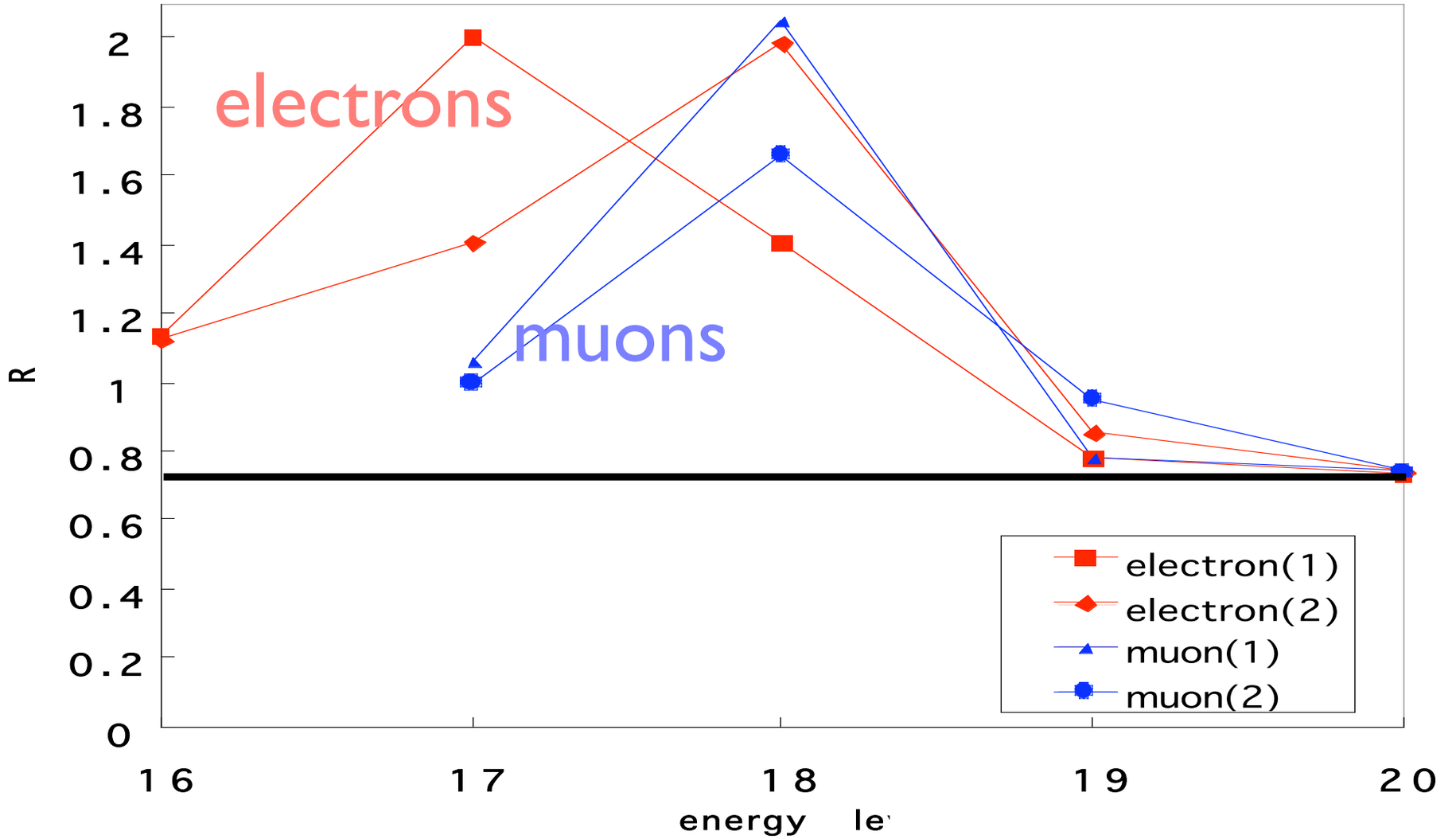




Results: EY-S1 vs. EY-S2







What we have learned

from this simulation study

- hybrid (30+30, e.g. EY-S1) array covers wide energy range (10^{16} ~ 10^{19} eV)
- with only 30 stations
  - EY for low-E (10^{16} ~ 10^{17} eV)
  - S1 for med-E (~10^{18} eV)

Summary

- **CO**smic ray **R**esearch & **E**ducation **A**rray
- A school array for UHECR program has been formed in Korea
- Key R&D activities going on
  - Single station tested with home-made DAQ including GPS
  - Simulation study for initial operation strategy
- But, still long way to go; need your encouragement

Thank you!