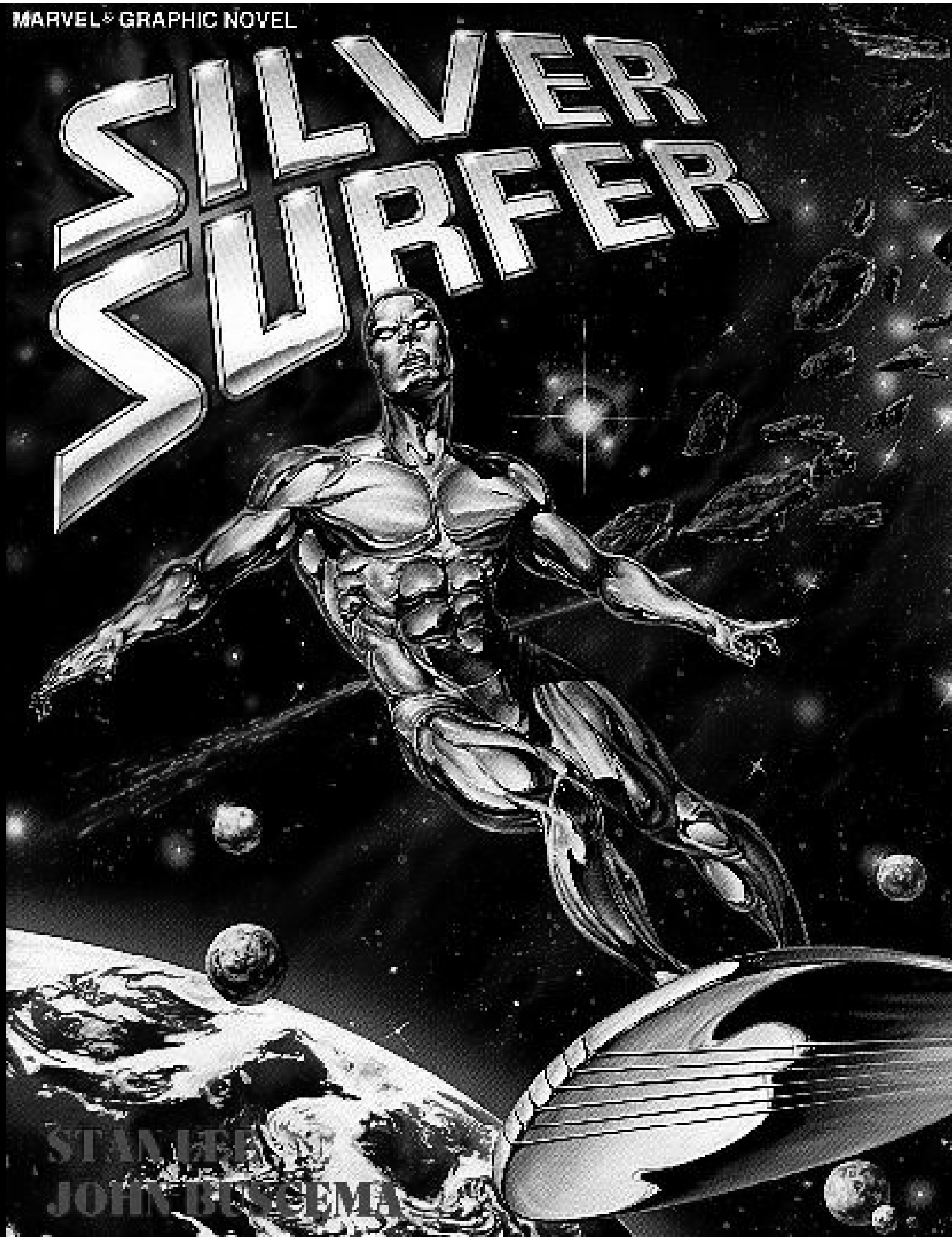
The Cosmic Ray Observatory Project: An outreach and education experiment in Nebraska

Gregory R. Snow
University of Nebraska

Southern Methodist University, April 14, 2003
University of Texas at Arlington, April 15, 2003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THAT SHOULD HAVE BEEN US UP THERE, SUE.
WE WERE THE ONES WHO WORKED SO HARD TO MAKE THIS DREAM A REALITY.
BUT NOW, SHE'S... GONE.
IT ONLY PROVES THAT YOUR WORK WAS A SUCCESS, REED.
BUT NOW, THE IMPORTANT THING IS TO STOP CONTACT ONE BEFORE WINGFOOT CAN CARRY OUT HIS PLAN.
ENOUGH OF THE WISHFUL THINKIN', PEOPLE. THE PROTOTYPE'S OUR *ONLY* TICKET OUTTA HERE.
SO LET'S GET MOVIN'!


"UP THERE, BAD LUCK WILL GET YOU *KILLED*.
"BUCKLE UP, FOLKS, I'M INITIATING THE COUNTDOWN!"
TEN... NINE... EIGHT... SEVEN... SIX... FIVE... FOUR... THREE... TWO... ONE...
IGNITION!
"OUTSTANDING!
"REED, WE HAVE *LIFT OFF!*"
SIR! I'M PICKING UP AN UNAUTHORIZED LAUNCH ON THE NUMBER TWO PAD! THE PROTOTYPE IS TAKING OFF!

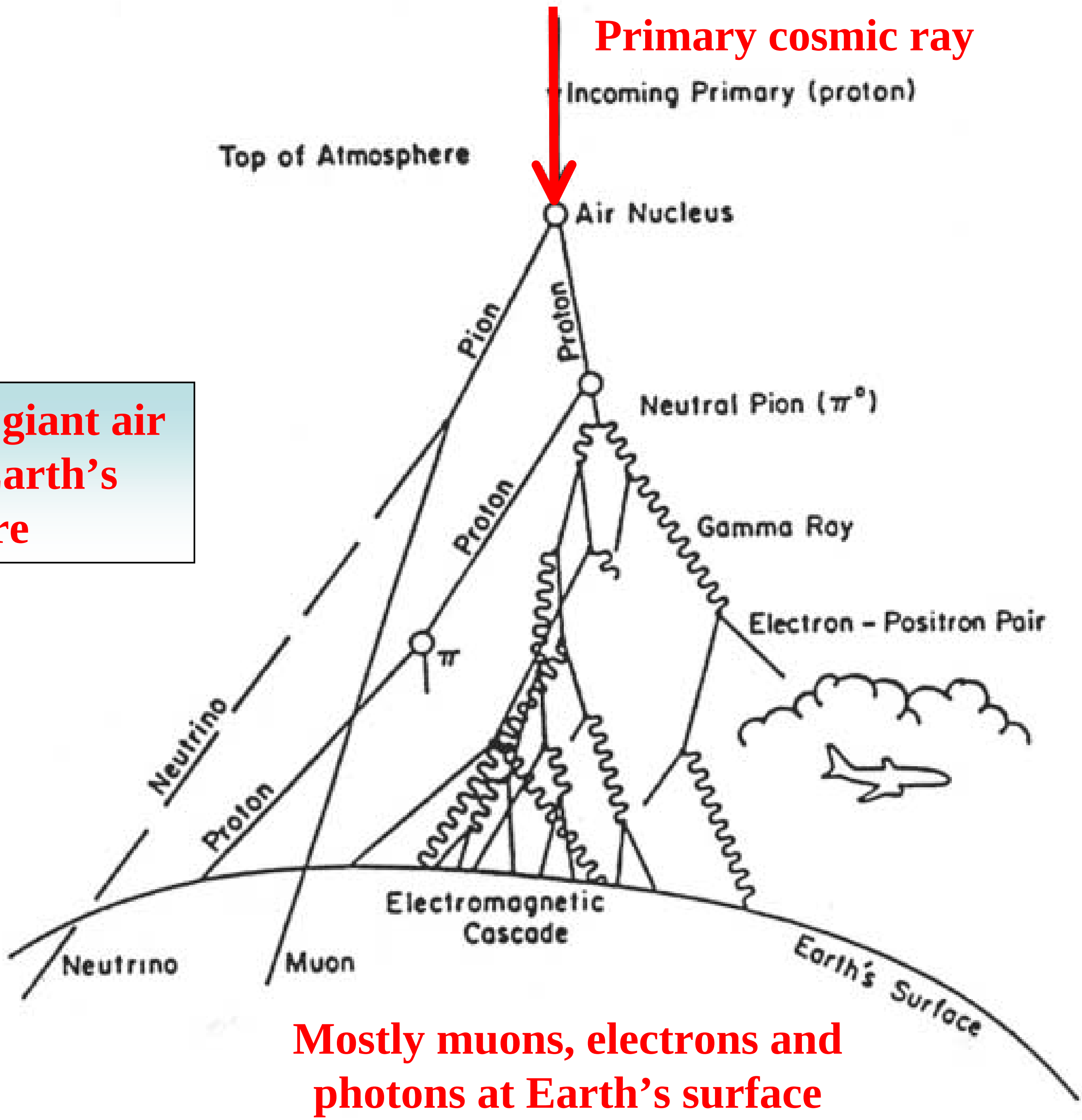

THE DREAM'S ALWAYS THE SAME.
IT BEGINS WITH A PERFECT LAUNCH.
YOU'RE LOOKING GOOD, EXCELSIOR!
BUT THIS TIME IT TAKES A FANTASTIC TWIST.
SUZIE AND JOHNNY?! WHAT'RE THEY DOING HERE?
YOU DID IT, BEN!
IT'S TOO DANGEROUS --
VREEP VREEP VREEP
THAT'S WHEN THE WARNING INDICATORS START LIGHTING UP LIKE A CHRISTMAS TREE!
RADIATION'S FLOODING INTO THE MAIN COMPARTMENT.
OUTTA NOWHERE, REED POPS INTO THE SCENE AND TRIES TO SALVAGE THE SITUATION. BUT EVEN HE RUNS OUT OF ANSWERS.
BEN! YOU'VE GOT TO GET US BACK TO EARTH!
BUT BEFORE I GET A CHANCE TO DO ANYTHING, JOHNNY BURSTS INTO FLAMES BEFORE MY VERY EYES!
MY FRIENDS! MY SHIP!
THEY'RE ALL DYING --
BRREEP BRREEP BRREEP
-- WHEN THERE'S SUDDENLY --
-- A PHONE CALL FOR ME?
MAJOR GRIMM? DO YOU COPY?
HELLO, BEN?


"BEN'S GONNA FREAK WHEN HE GETS A LOAD OF THIS!"
JUST MY LUCK...
SEVENTY FIVE PERCENT OF THE PLANET'S COVERED WITH WATER BUT I STILL MANAGE TO SLAM INTO THE SIDE OF A MOUNTAIN!
LOOKS WORSE THAN MY CRASH IN IRAQ, BUT AT LEAST I'M--
AARGH! HEAD POUNDING! PAIN -- TOO -- INTENSE!
HUH?!
KRRKK
NO! THIS -- THIS CAN'T BE HAPPENING!
MY HANDS -- TURNING INTO -- ROCK!
CAN'T -- FEEL -- ANYTHING!
KRRRKLE
UUNGH! HAR -- HARD -- TO BREATHE!
CAN'T -- STAND -- THE PAIN!
BODY -- FEELS -- LIKE IT'S -- BEING TORN -- APART!
AARRGH!

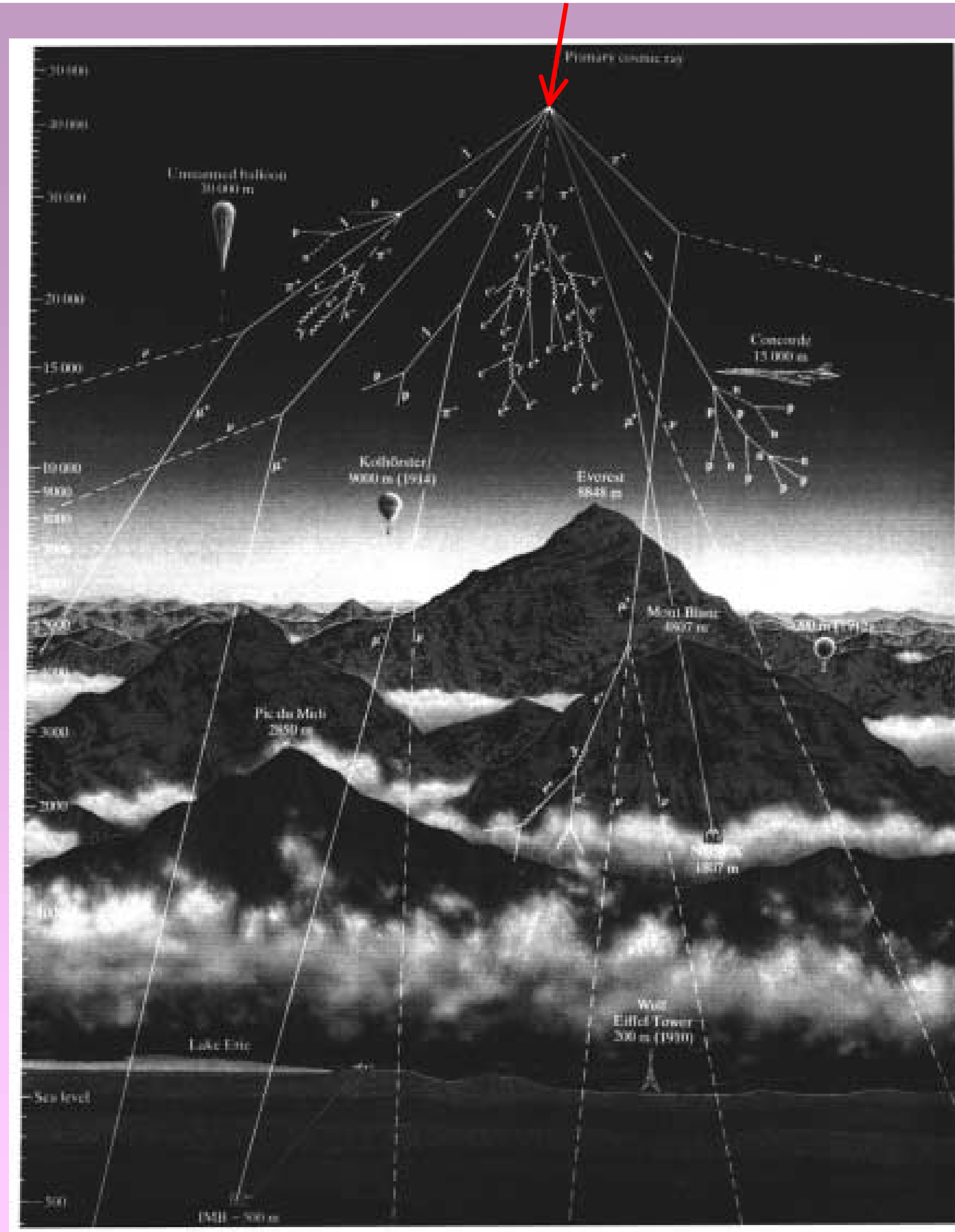
Outline

- Introduction to cosmic-ray extensive air showers
- CROP project overview and goals
- Tour of experiments which study extensive air showers
- The cosmic ray energy spectrum & GZK cutoff
- The science of CROP
- CROP's program of summer workshops
- "Mini-experiments"
  - Singles rates vs counter separation
  - Telescope rates vs time of day
  - Telescope rates vs barometric pressure
- Academic Year Workshop/Conferences
- Data acquisition card with GPS time stamp
- Other cosmic ray outreach programs
  - NALTA: WALTA, CHICOS, ALTA
  - European efforts
  - SALTA/Snowmass

Development of a giant air shower in the Earth's atmosphere

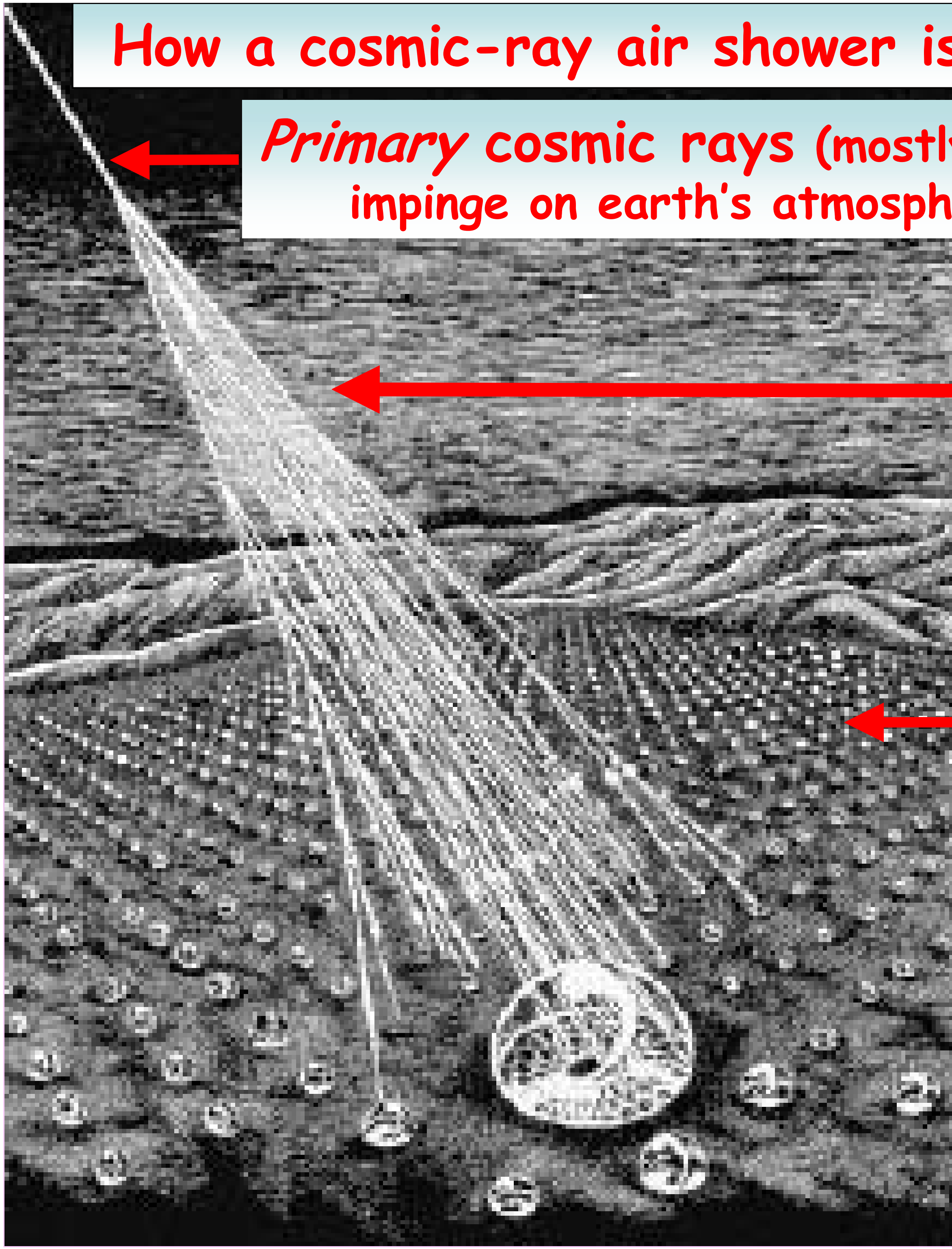


Development of a giant air shower in the Earth's atmosphere



How a cosmic-ray air shower is formed and detected

Primary cosmic rays (mostly protons or light nuclei) impinge on earth's atmosphere from outer space



"Air shower" of secondary particles formed by collisions with air molecules

Grid of particle detectors intercept and sample portion of secondaries

1. Number of secondaries related to energy of primary

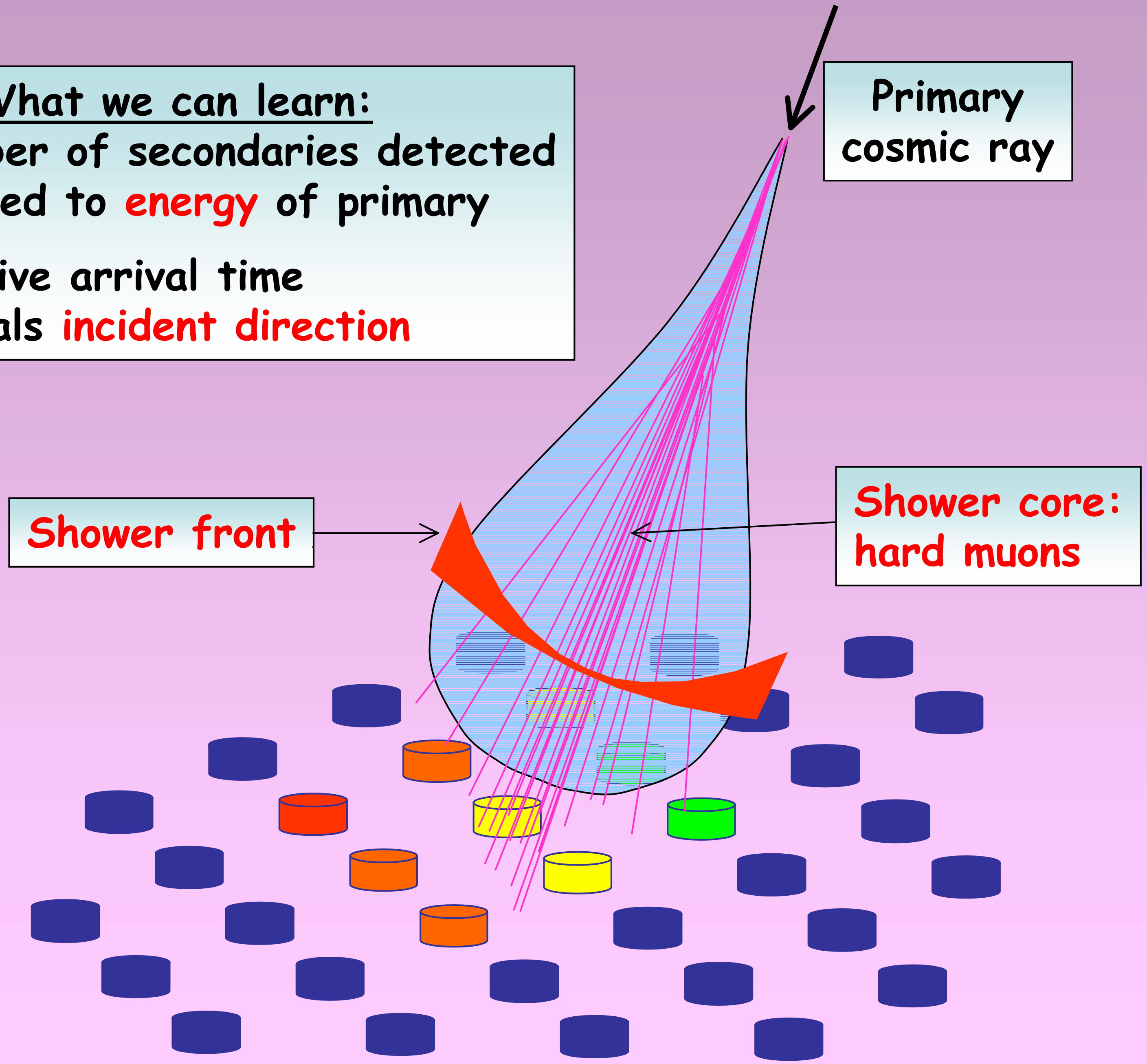
2. Relative arrival time reveals incident direction

CROP studies ultra-high energy extensive cosmic-ray air showers using a grid of high-school based research stations

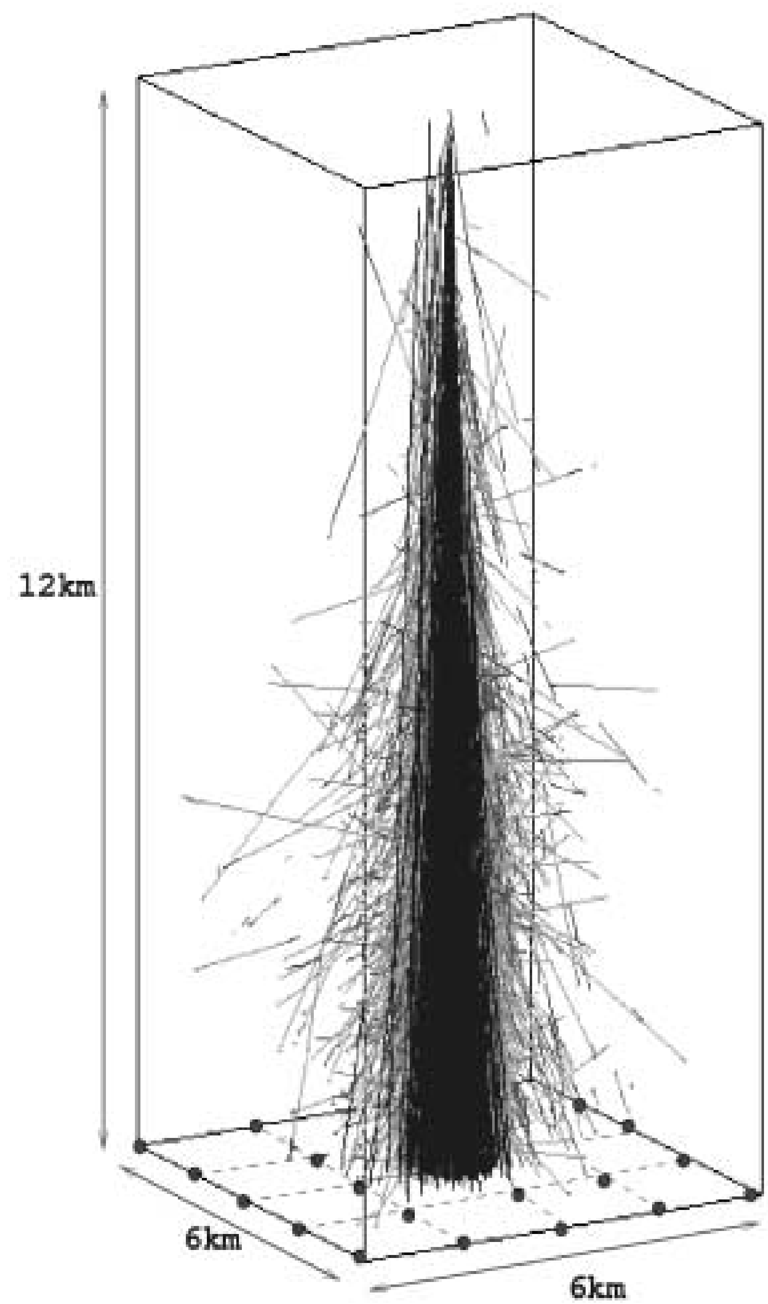
What we can learn:

- Number of secondaries detected related to energy of primary

2. Relative arrival time reveals incident direction



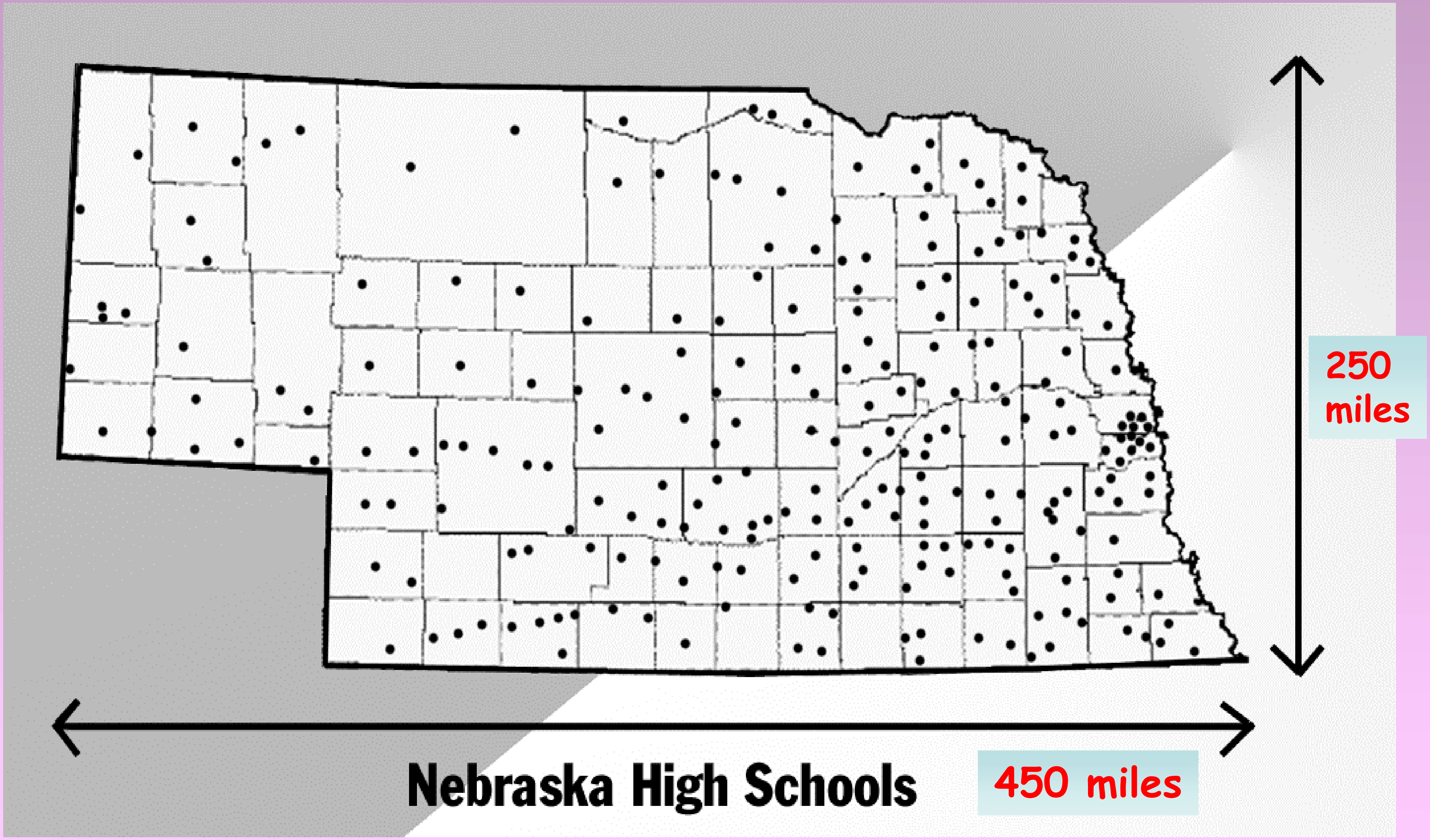
A 10^{19} eV Extensive Air Shower



100 billion particles at sea level

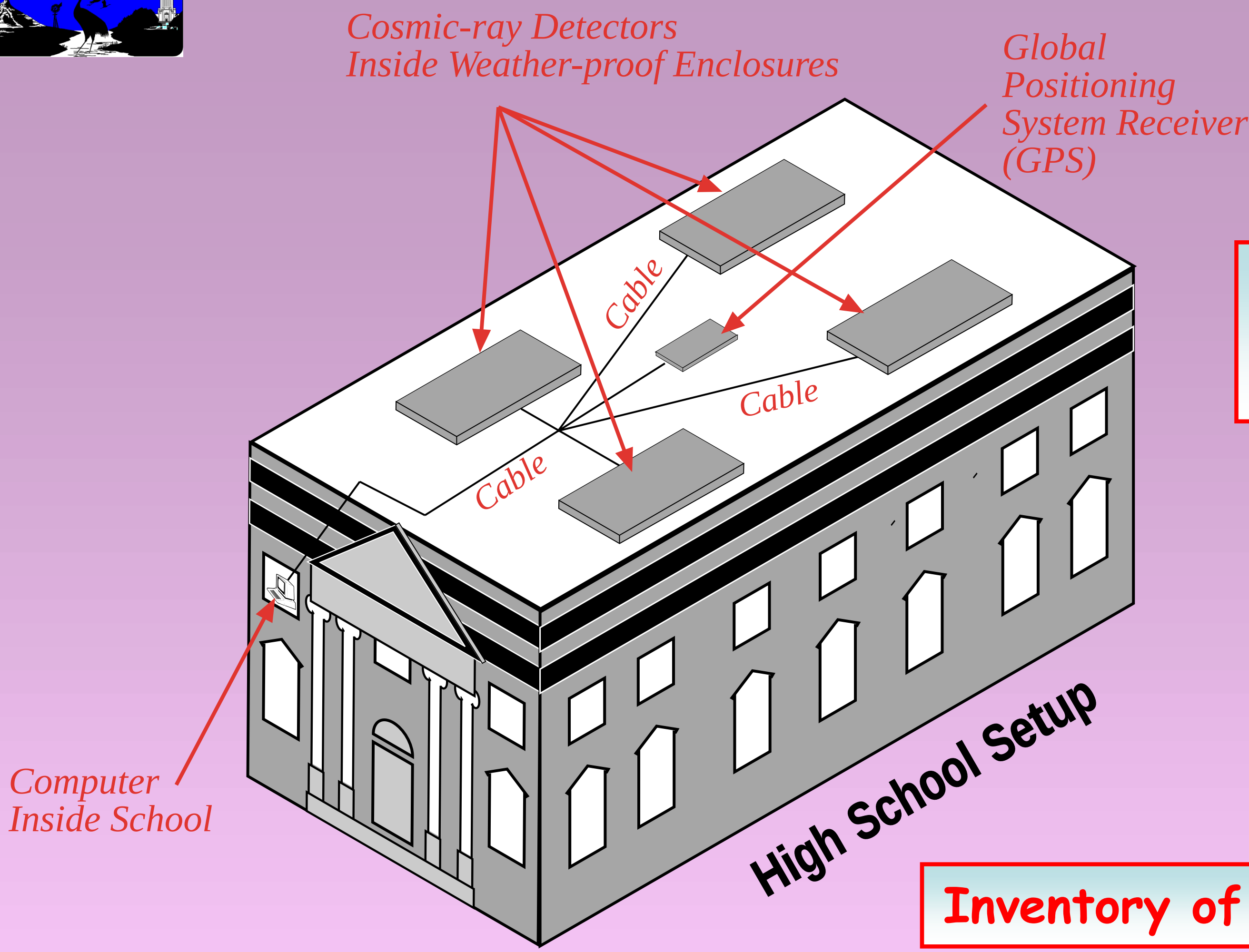
Note the large ground area hit by shower particles

The Cosmic Ray Observatory Project
A grid of cosmic ray research stations expanding across the state



Nebraska's 314 high schools

CROP detectors on school roof



Inventory of equipment at school

- 4 weather-proof enclosures for detectors
- 4 cosmic-ray detectors (polystyrene scintillator tiles and photomultiplier tubes)
- GPS receiver
- Power supply for detectors (not shown)
- Personal computer for data acquisition, monitoring, and data analysis with connection to Internet
- Triggering and data-acquisition electronics card connected to PC
- Software for PC
- Cables from rooftop detectors and GPS to PC

CROP Project Goals

Educational

Prepare teams of high school teachers and students to get involved in studies of extended cosmic ray showers using modern research techniques.

- 4-week summer intensive training program at UNL
- Biweekly phone conferences or chat rooms
- Two 1-day meetings every year
- Web-based help pages

Scientific

Build a statewide network of cosmic ray detectors.

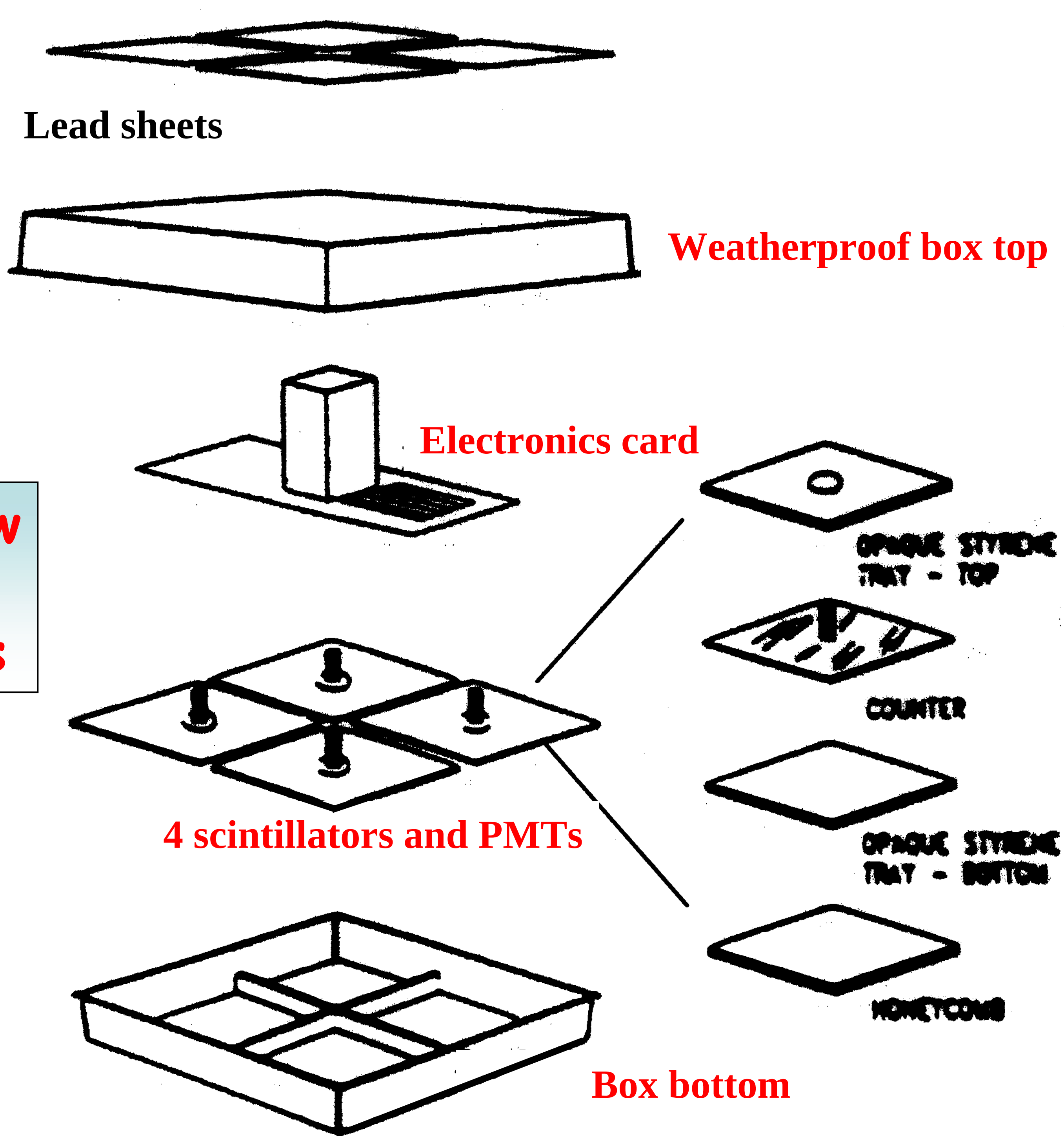
- Retired CASA detectors in weather-proof enclosures on roof
- GPS receiver gives local time stamp for shower arrival
- PC inside school takes data through a DAQ card at each site
- Student teams share data over Internet searching for time coincidences

Search for the sources of ultra-high energy cosmic rays.

The Chicago Air Shower Array

- CROP uses retired detectors from the Chicago Air Shower Array
- 1089 boxes each with:
  - 4 scintillators and photomultiplier tubes (PMT)
  - 1 high voltage and 1 low voltage power supply
- Two removal trips (September 1999, May 2001) yielded over 2000 scintillator panels, 2000 PMTs, 500 low and power supplies
- Sufficient hardware for all Nebraska high schools

Exploded view of CASA box contents



The CROP team at Chicago Air Shower Array (CASA) site

U.S. Army Photo

September 30, 1999

CASA detectors' new home
at the University of Nebraska

Equipment recovery trip to Dugway, Utah, May 2001

Equipment recovery trip to Dugway, Utah May 2001

C.R.O.P.

Unloading trucks with CASA detectors at UNL June 2001





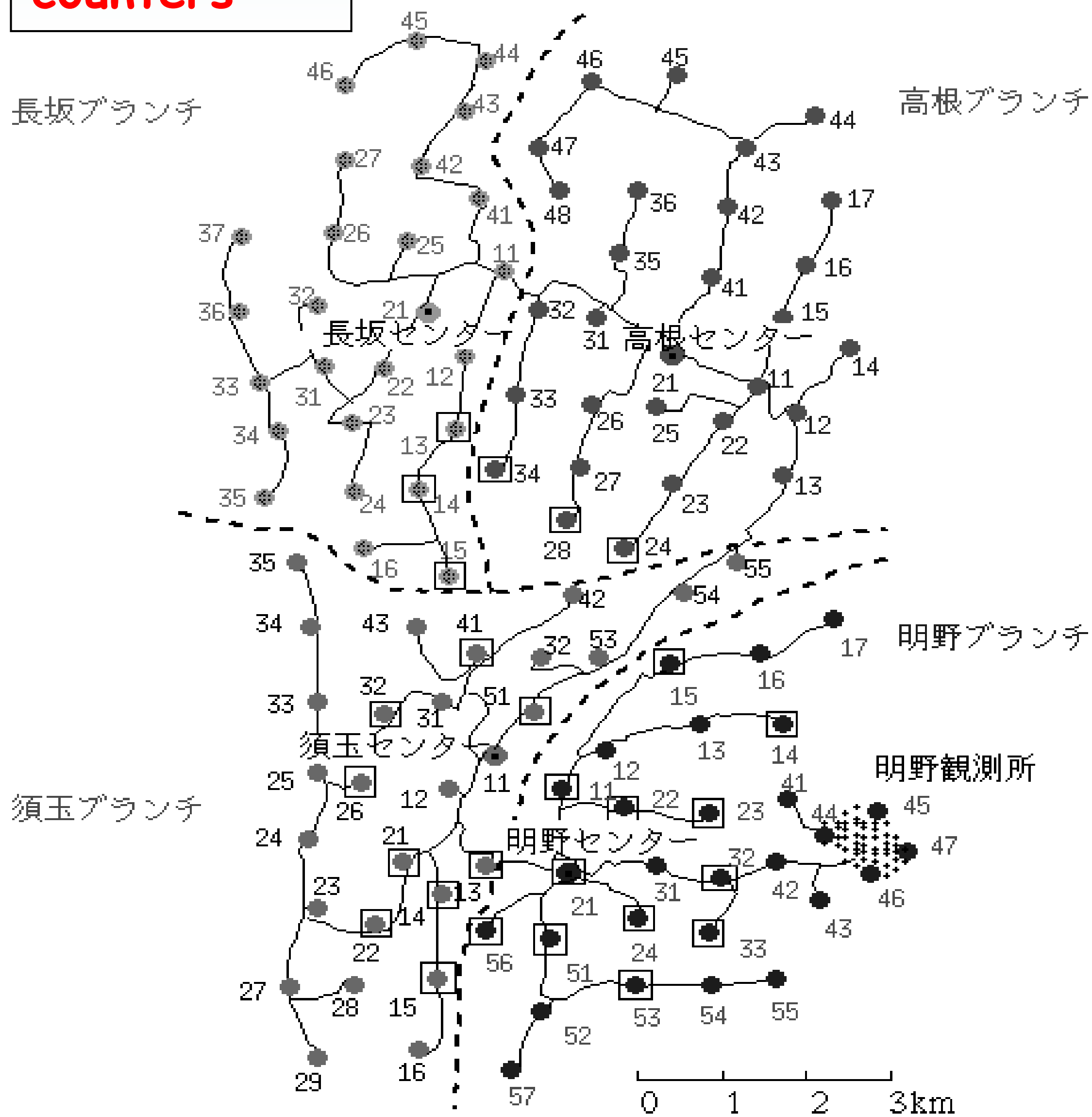

The KASCADE experiment in Karlsruhe, Germany

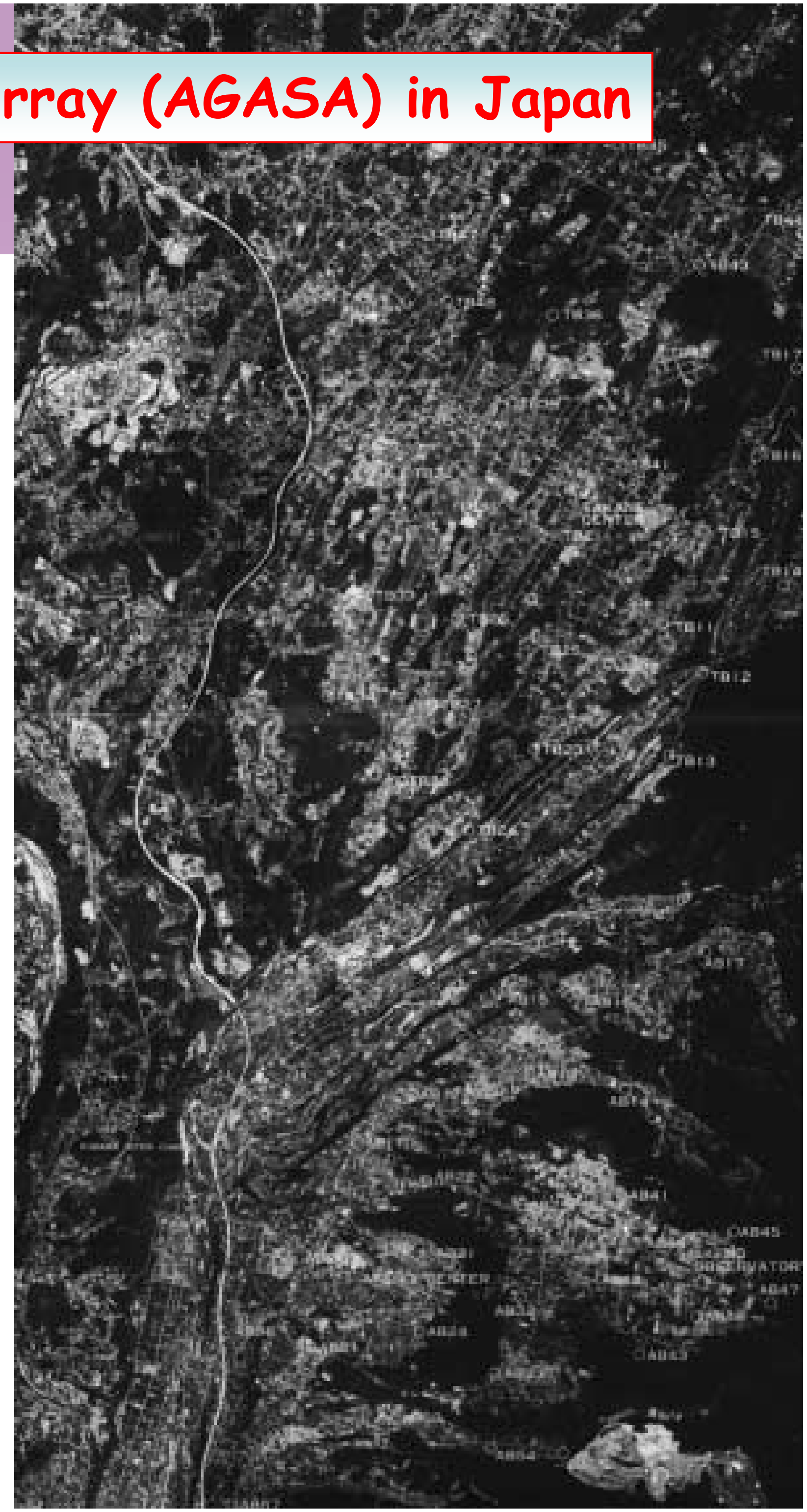
The Akeno Giant Air Shower Array (AGASA) in Japan

111 sites of scintillation counters

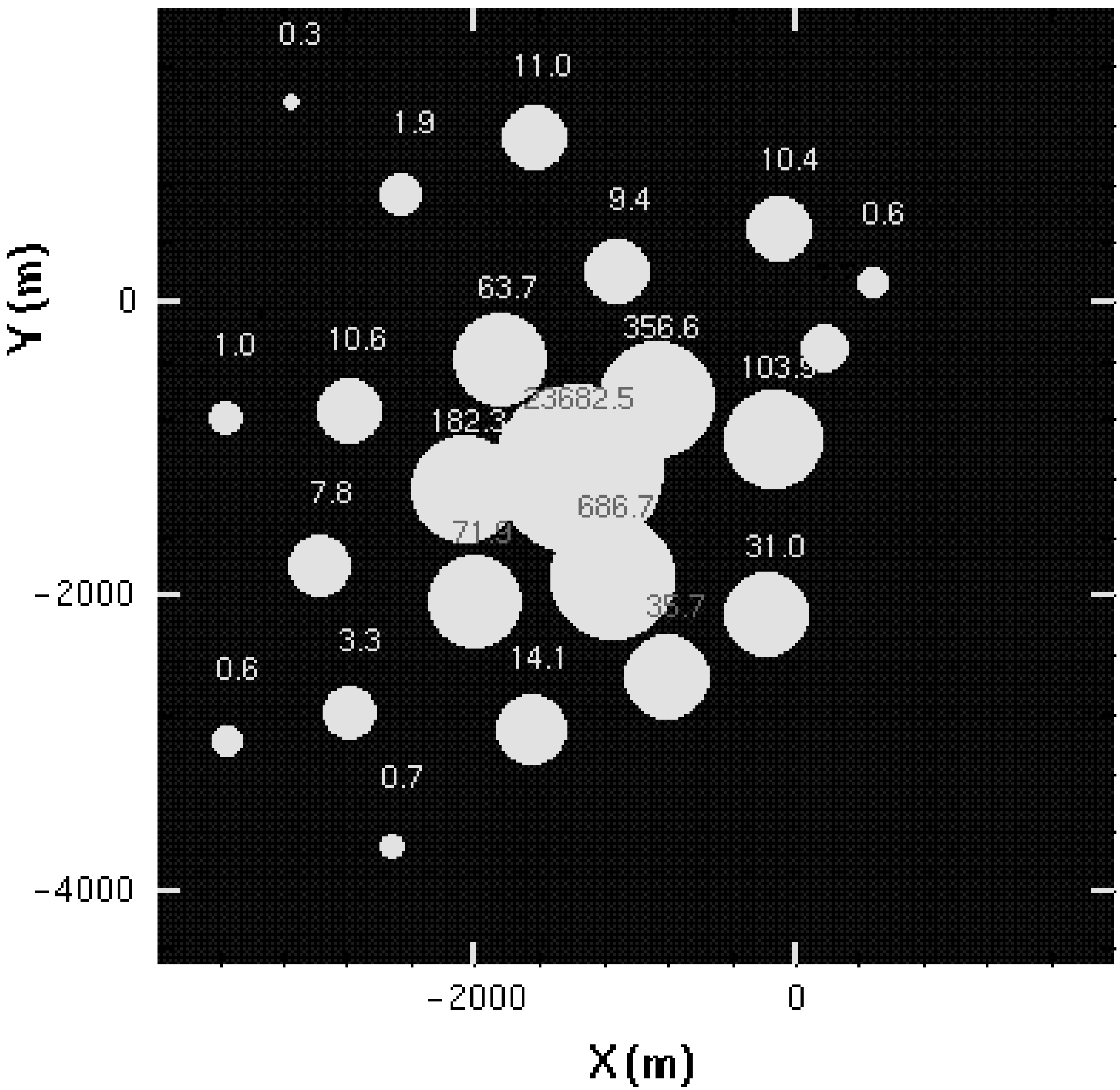
~1 km spacing between sites

Coverage ~100 km^2





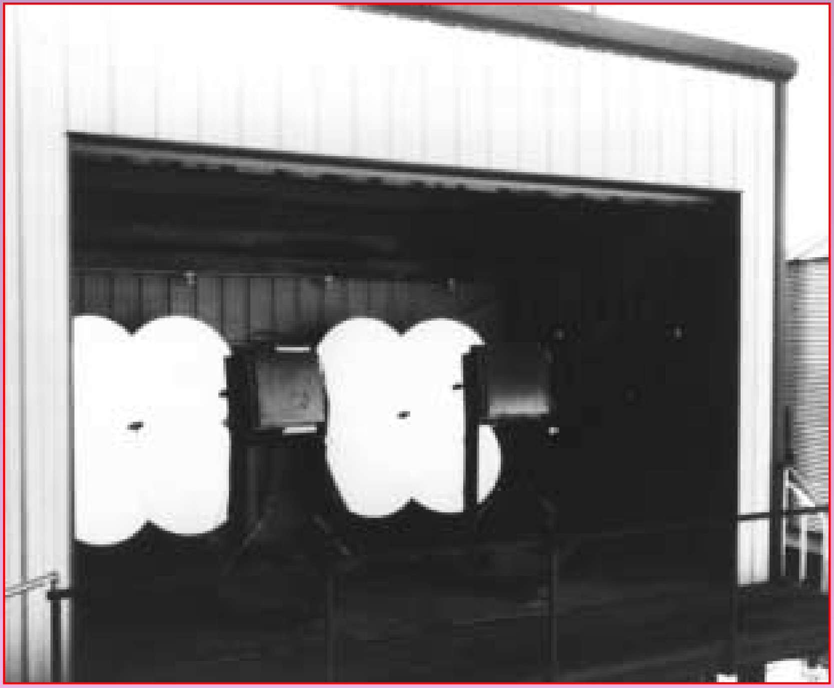
Akeno Giant Air Shower Array (AGASA) in Japan



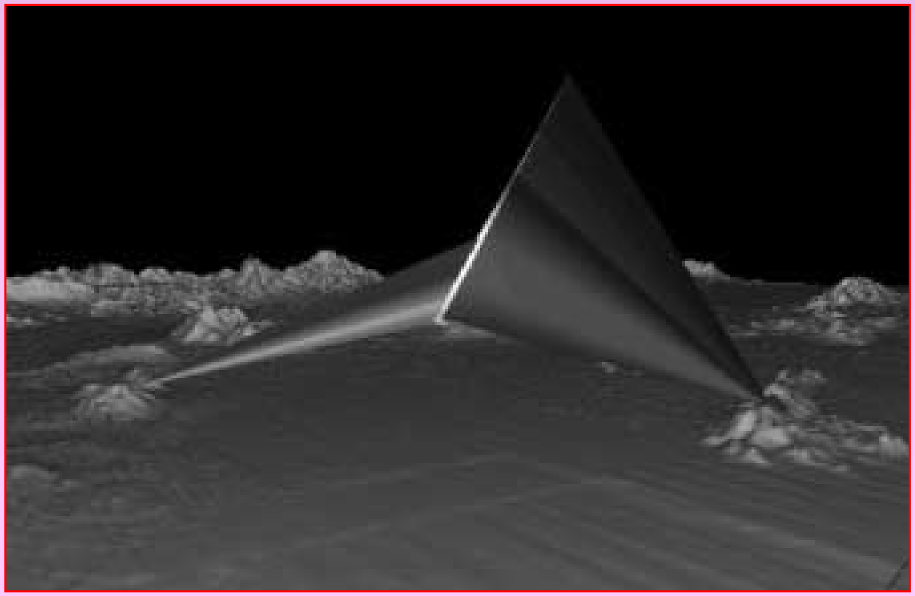
Primary energy
2×10^{20} eV

- World's 2nd-highest energy cosmic ray event
- Recorded Dec 3, 1993
- Covered 4km×4km area
- 23 detector sites recorded coincident hits
- Yellow circles represent particle densities (radius = log $N_{particles}$)

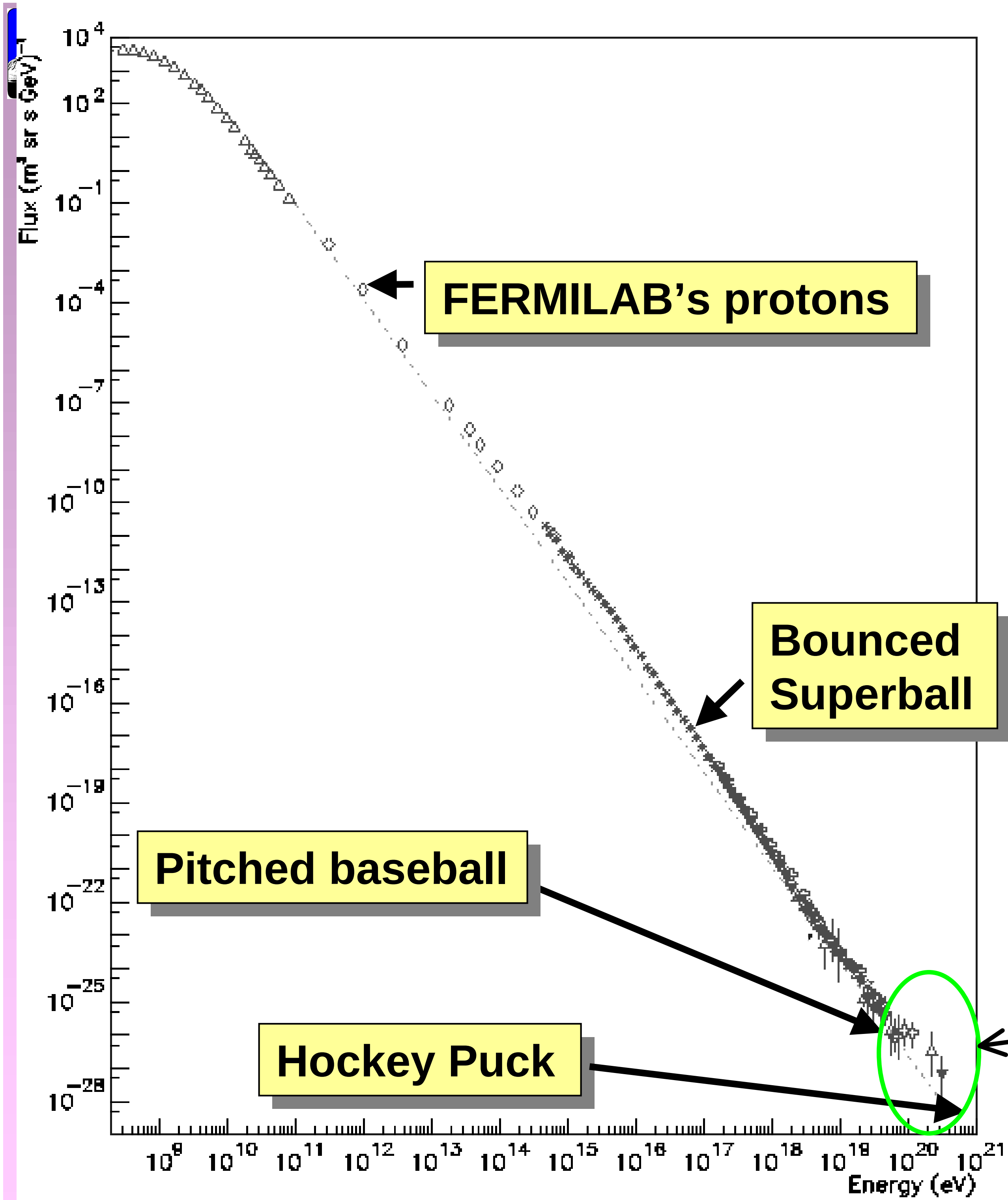
HiRes Experiment in Dugway, Utah



Two sets of fluorescence detectors give binocular view of fluorescent trail (N_2) of cosmic ray showers

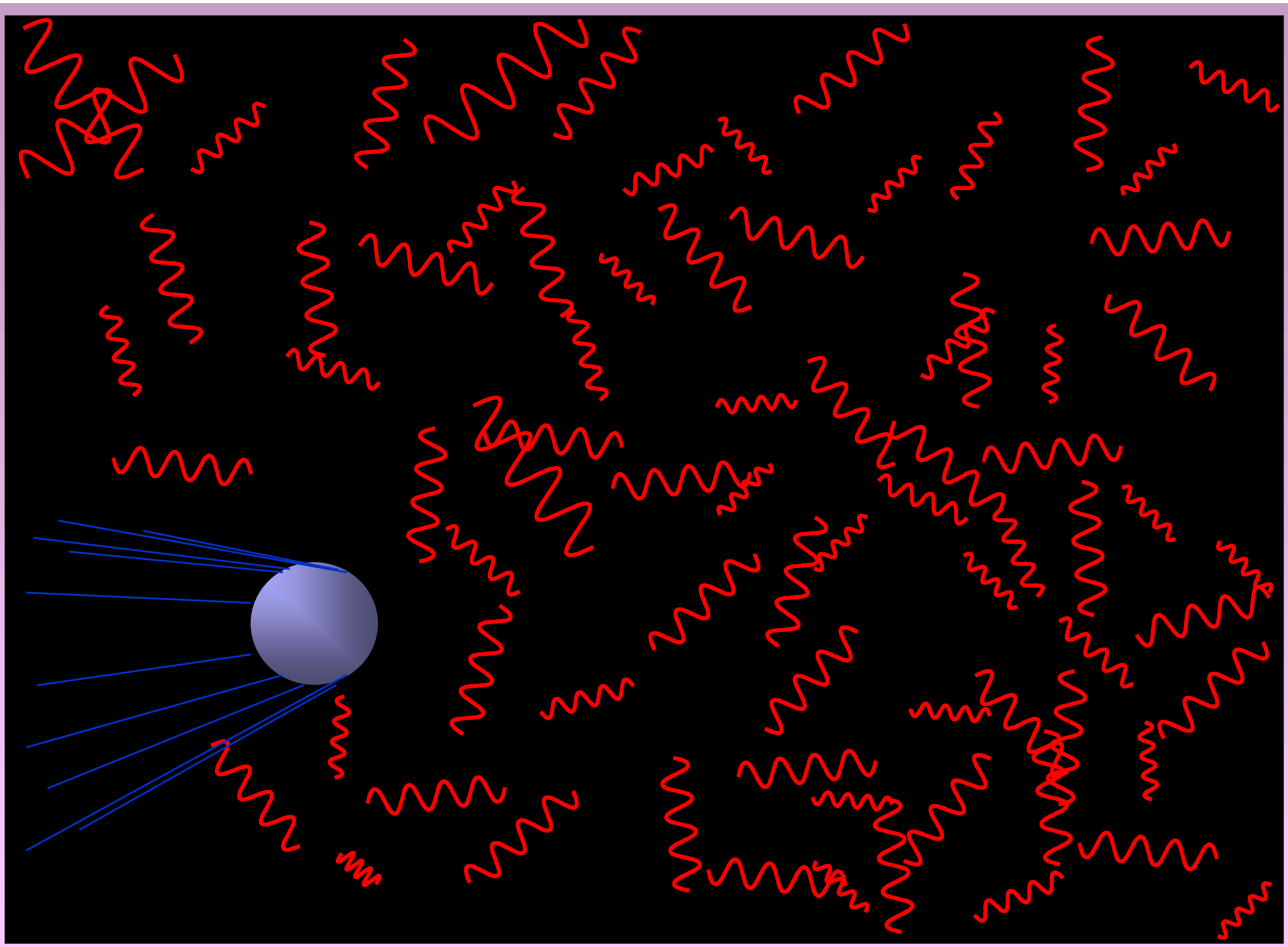


The Cosmic Ray Energy Spectrum



These should not exist unless their origin is "close"

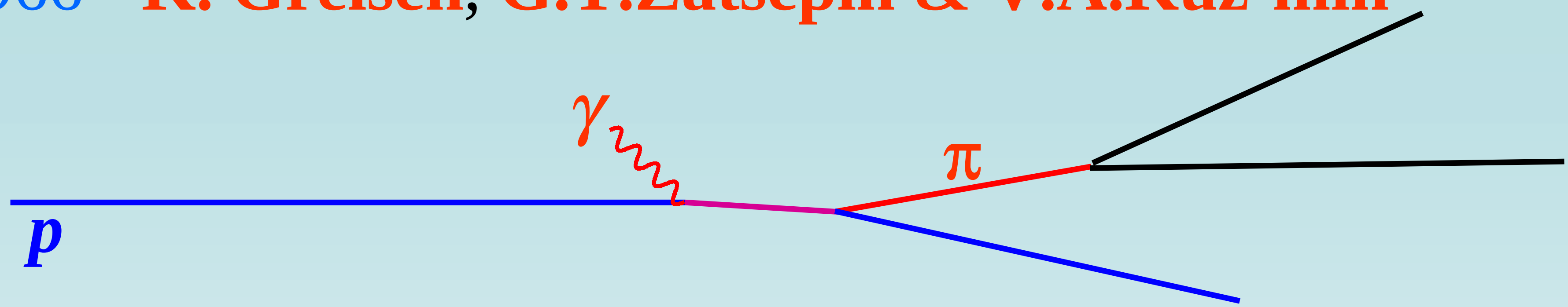
K. Greisen, G.T.Zatsepin & V.A.Kuz'min (1966)



showed the recently discovered *cosmic microwave background radiation* (CMBR) effectively makes the universe **opaque** to sufficiently high energy cosmic ray particles.

GZK Cutoff

1966 - **K. Greisen**, **G.T.Zatsepin & V.A.Kuz'min**



For example: $\mathbf{p\gamma^* \rightarrow \Delta^+ \rightarrow \pi^0 p}$

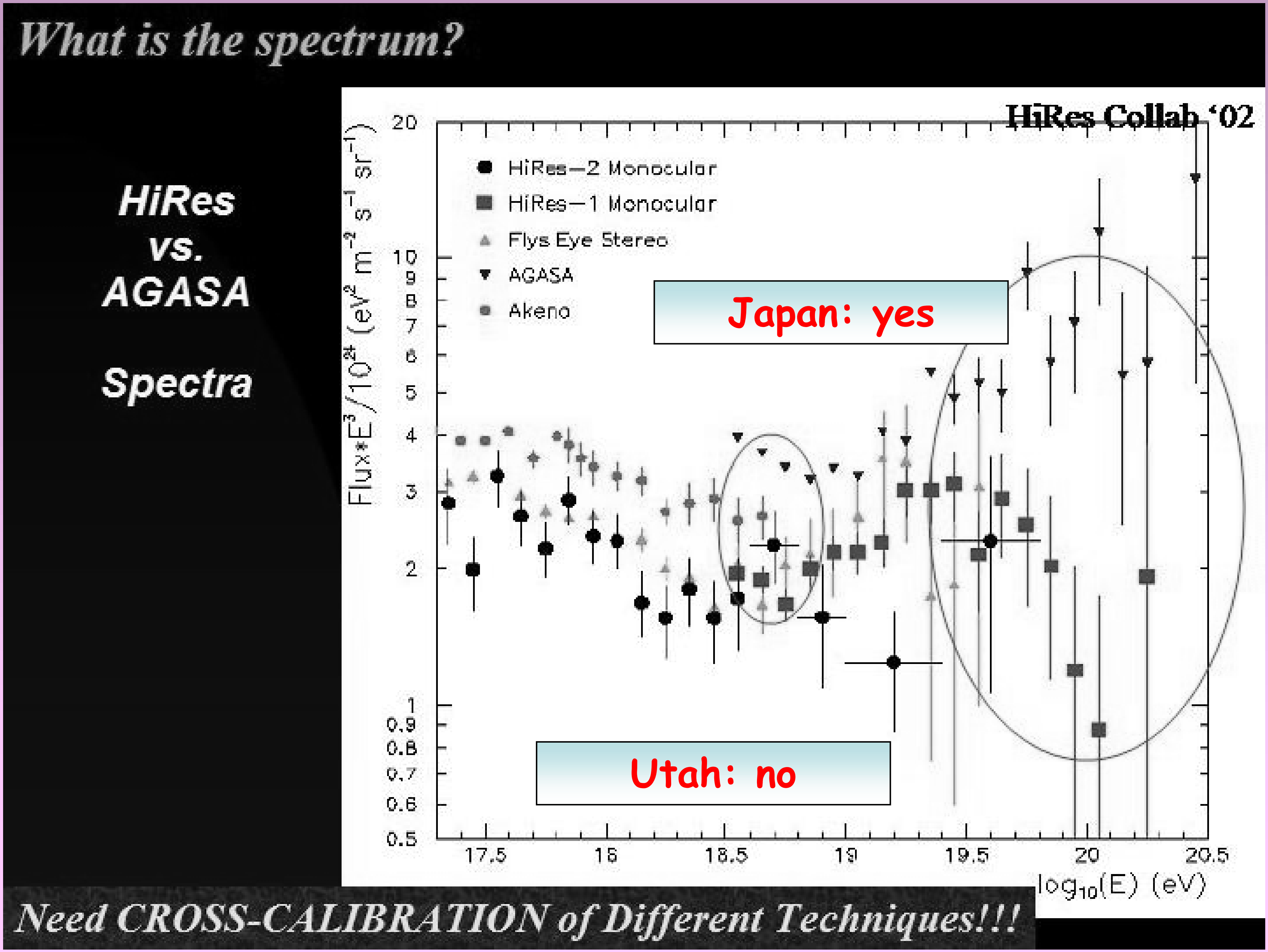
$\mathbf{\rightarrow \Delta^+ \rightarrow \pi^+ n}$

and similar resonances yield attenuation lengths mere 10s of ***Mega parsecs*** *for cosmic ray protons with* $E>10^{19}$ *eV.*

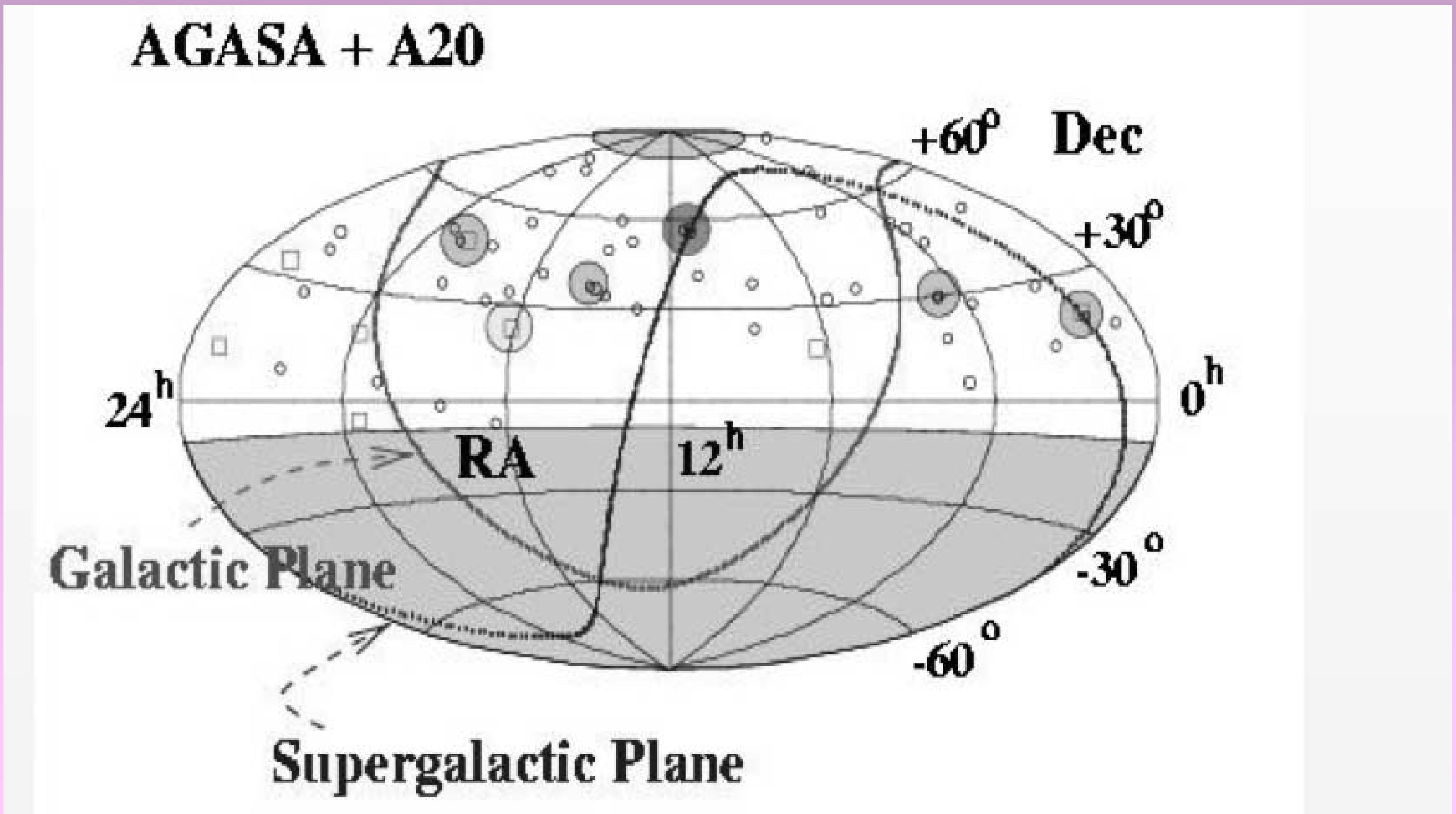
Center of (our)Virgo supercluster is ~20 Mpc away
Diameter of Milky Way disk = 0.024 Mpc
Distance to Andromeda galaxy = 0.6 Mpc

All ***$E>10^{19}$ eV*** **primaries must originate within 100 Mpc of the earth**

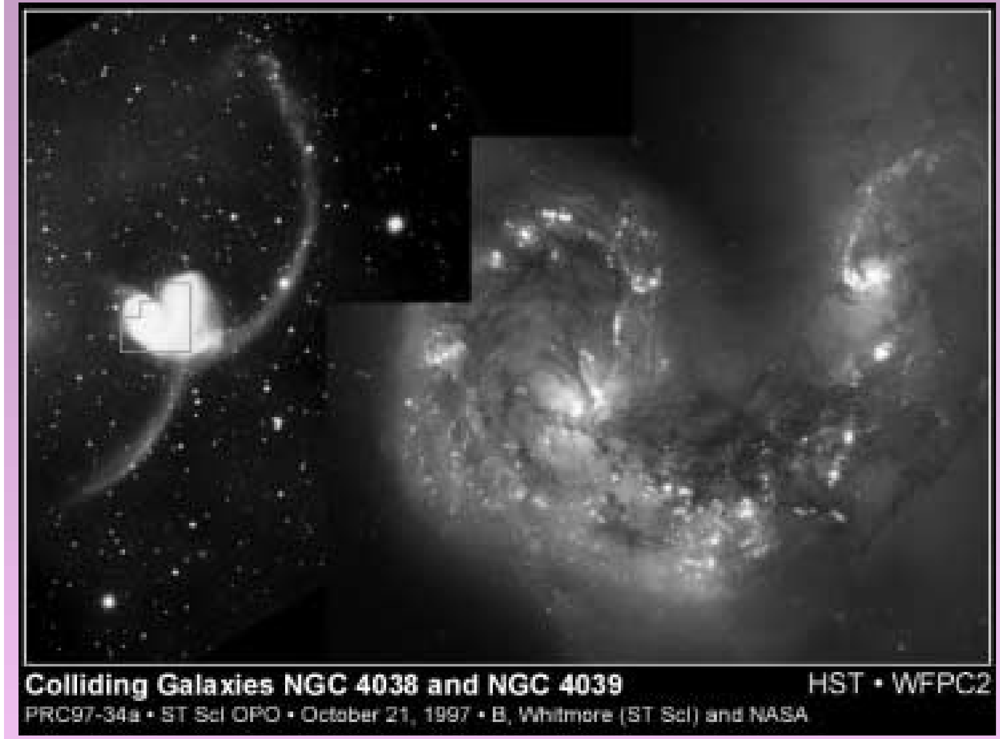
Is the GZK cutoff observed?...Jury still out



Arrival directions for cosmic rays above 4×10^{19} eV – five doublets, one triplet

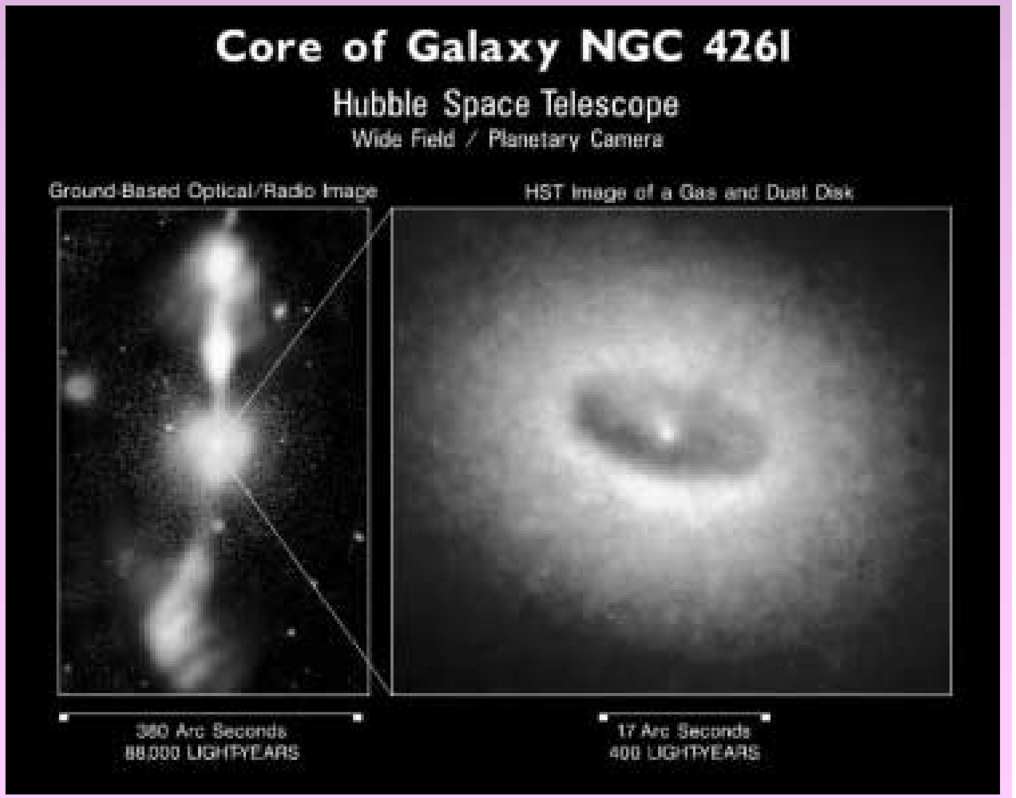


Two possible sources of the highest energy cosmic rays



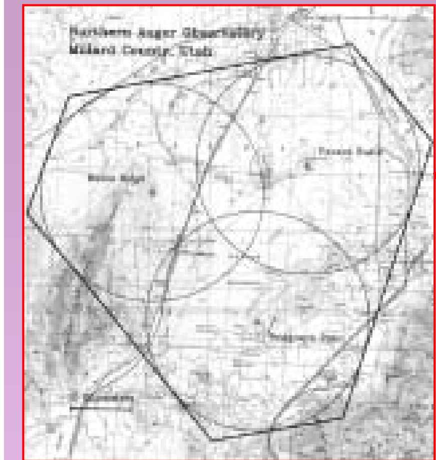
Colliding galaxies

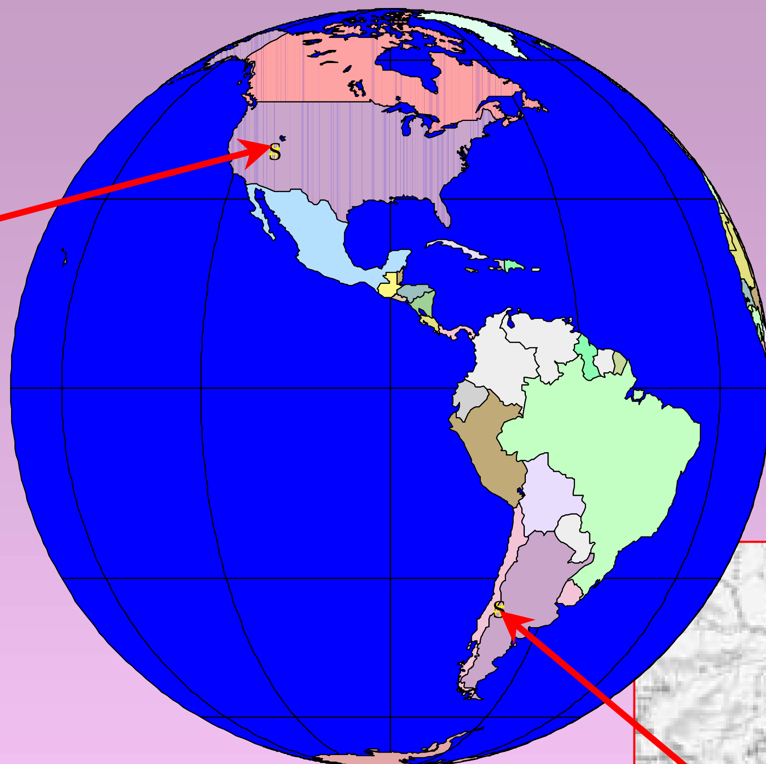
Active galactic nucleus



But the true origin and acceleration mechanism for the highest energy cosmic rays is UNKNOWN -- that's why we want to study them

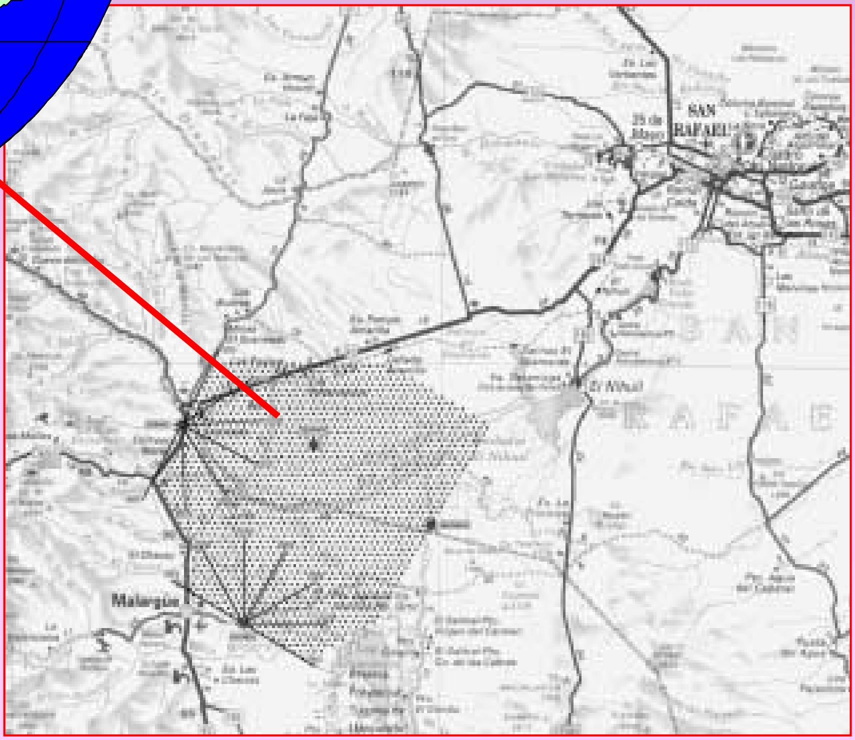
The Pierre Auger Observatory – the World's Largest Array





Northern Hemisphere: Millard County, USA (to be built)

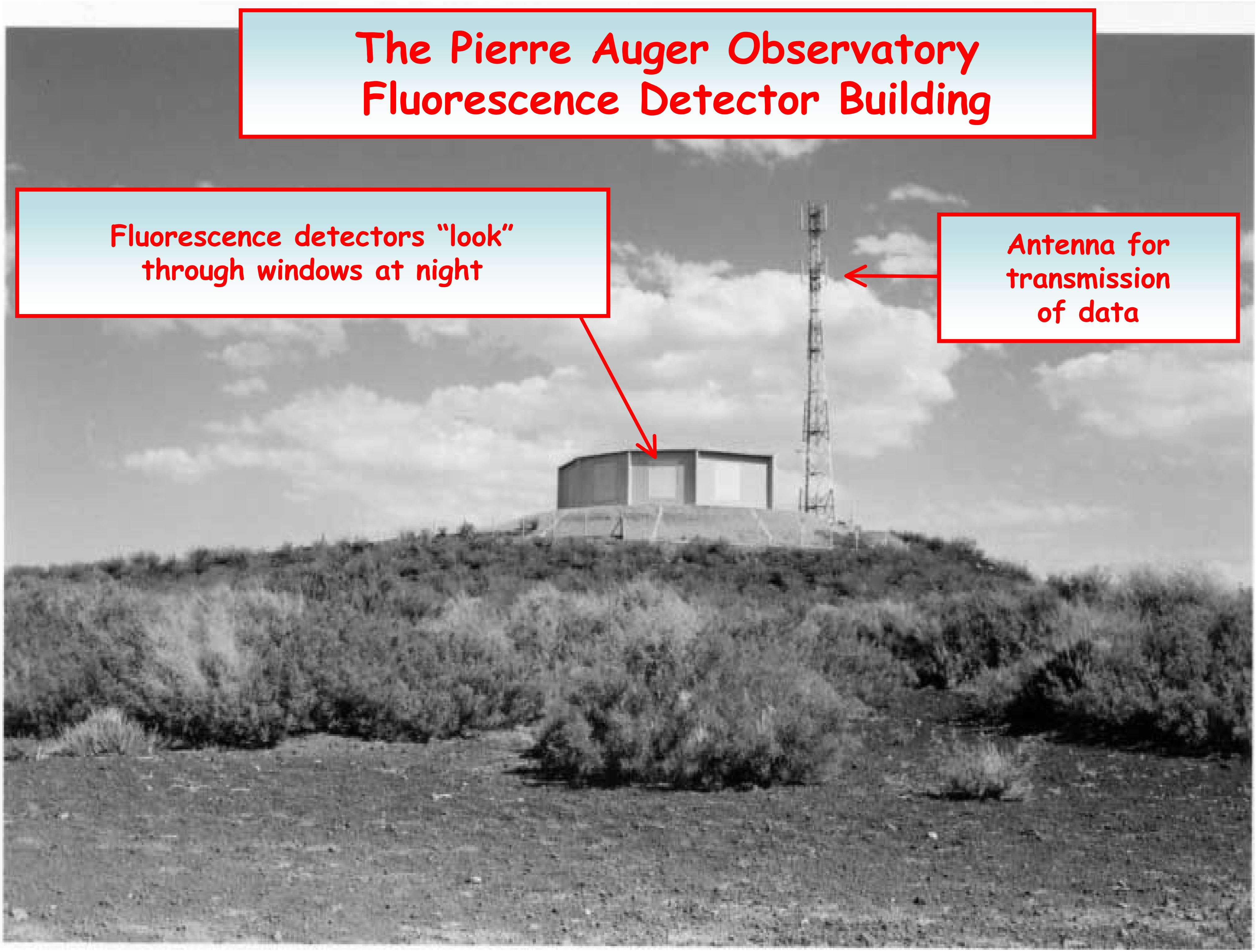
Southern Hemisphere: Malargüe Province of Mendoza Argentina (being constructed now)



1600 detectors, 3000 km^2 each site

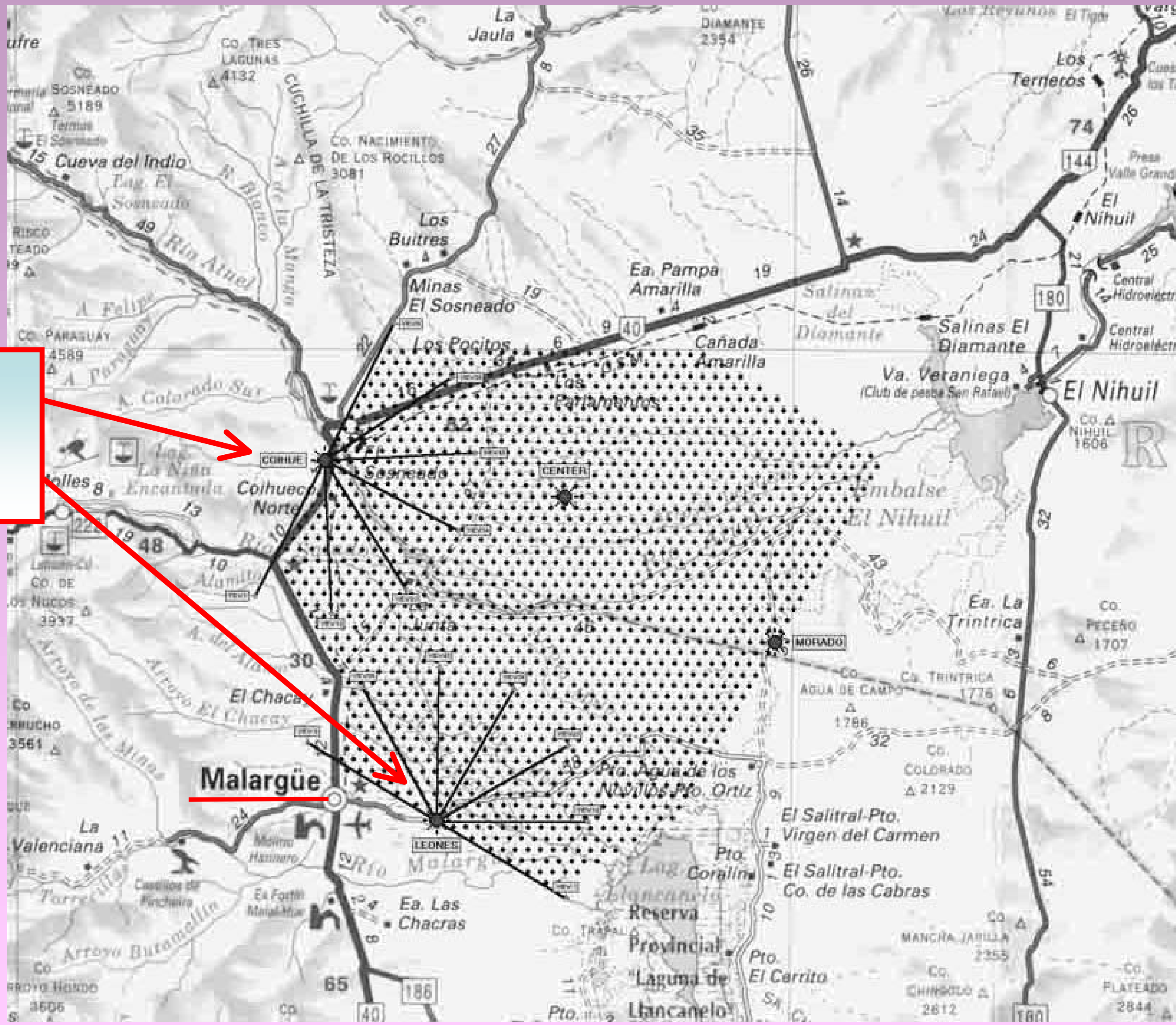
The Pierre Auger Observatory
Grid of Surface Detectors

The Pierre Auger Observatory Fluorescence Detector Building

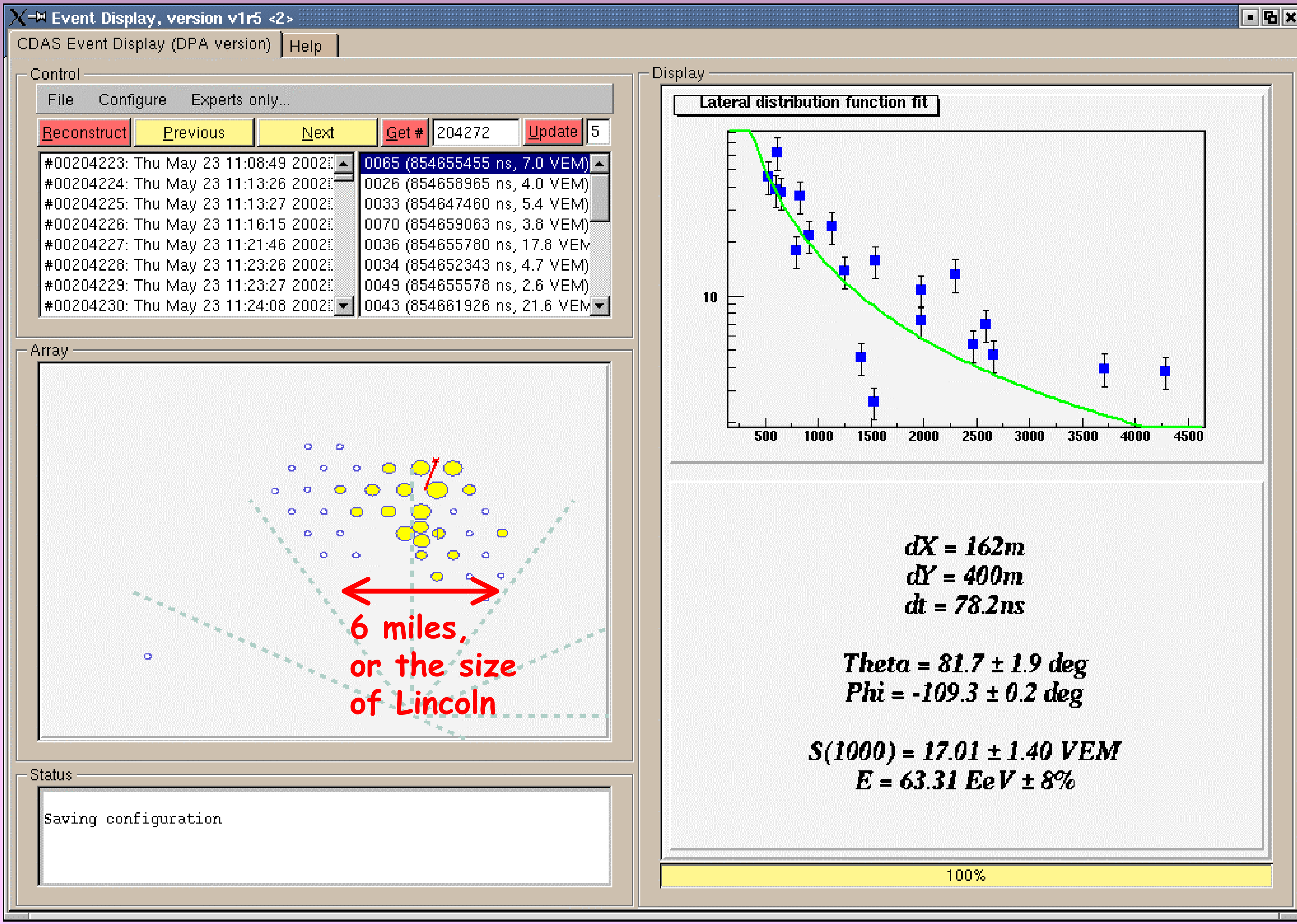


Auger's planned 1600 detector array

Optical coverage expanding with 2 Fluorescence Detectors

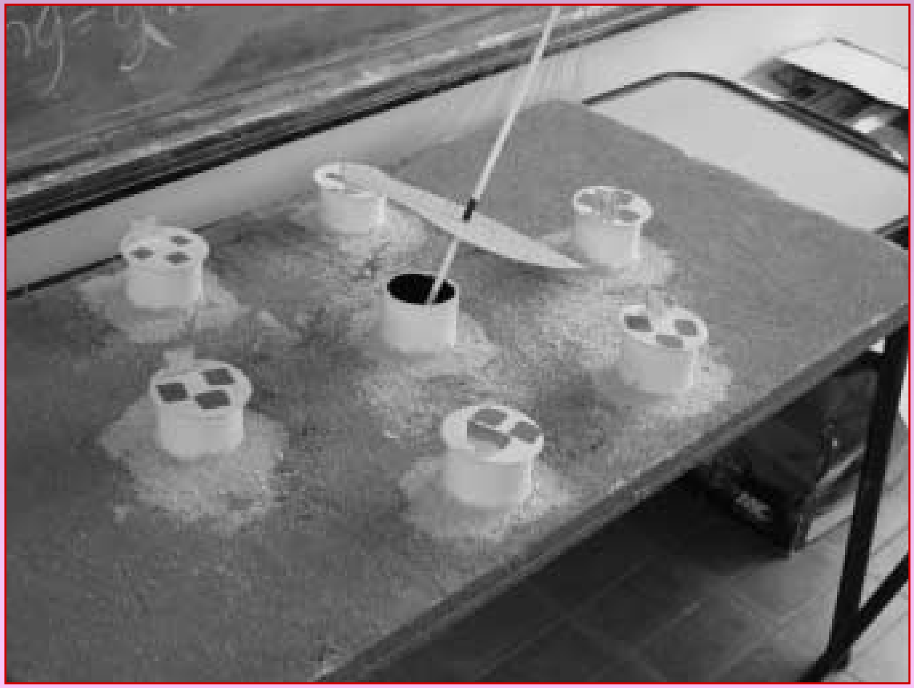


This shower hit 20 surface tanks !



Education and Outreach Activities in Argentina

- **April 2002 ceremony to name Escuela No. 4 - 190 after Jim Cronin – now known as the "James Cronin School"**
- **Visit by G. Snow and J. Valdez**



- **Three students place 11th (out of 300) in Mendoza Science Fair with their Auger exhibit and accompanying posters (Auger advisor: Ingo Allekotte)**

CROP's Brief History and Milestones

July 2000	Major funding secured from the U.S. National Science Foundation ($1.34 Million over 5 years)
Summer 2000	5 schools join CROP via 4-week summer
Summer 2001	6 schools training workshops
Summer 2002	5 schools (17 total)
2000 – 2003	Schools embark on program of mini-experiments with detectors they have refurbished and installed in building or on rooftop
2000-2002	Development of DAQ card, GPS interface
Spring 2003	Production run of DAQ card, distribution to schools
Summer 2003	Simultaneous data-taking begins

The Cosmic Ray Observatory Project (CROP)

A Proposal to the National Science Foundation program for

Teacher Enhancement through Research Experiences for Students and Teachers

Gregory R. Snow and Daniel R. Claes
Department of Physics & Astronomy
116 Brace Laboratory
University of Nebraska
Lincoln, Nebraska 68588-0111

August 1999

($1,000,000 requested over 5 years)
awarded: $1,340,002

C.R.O.P.

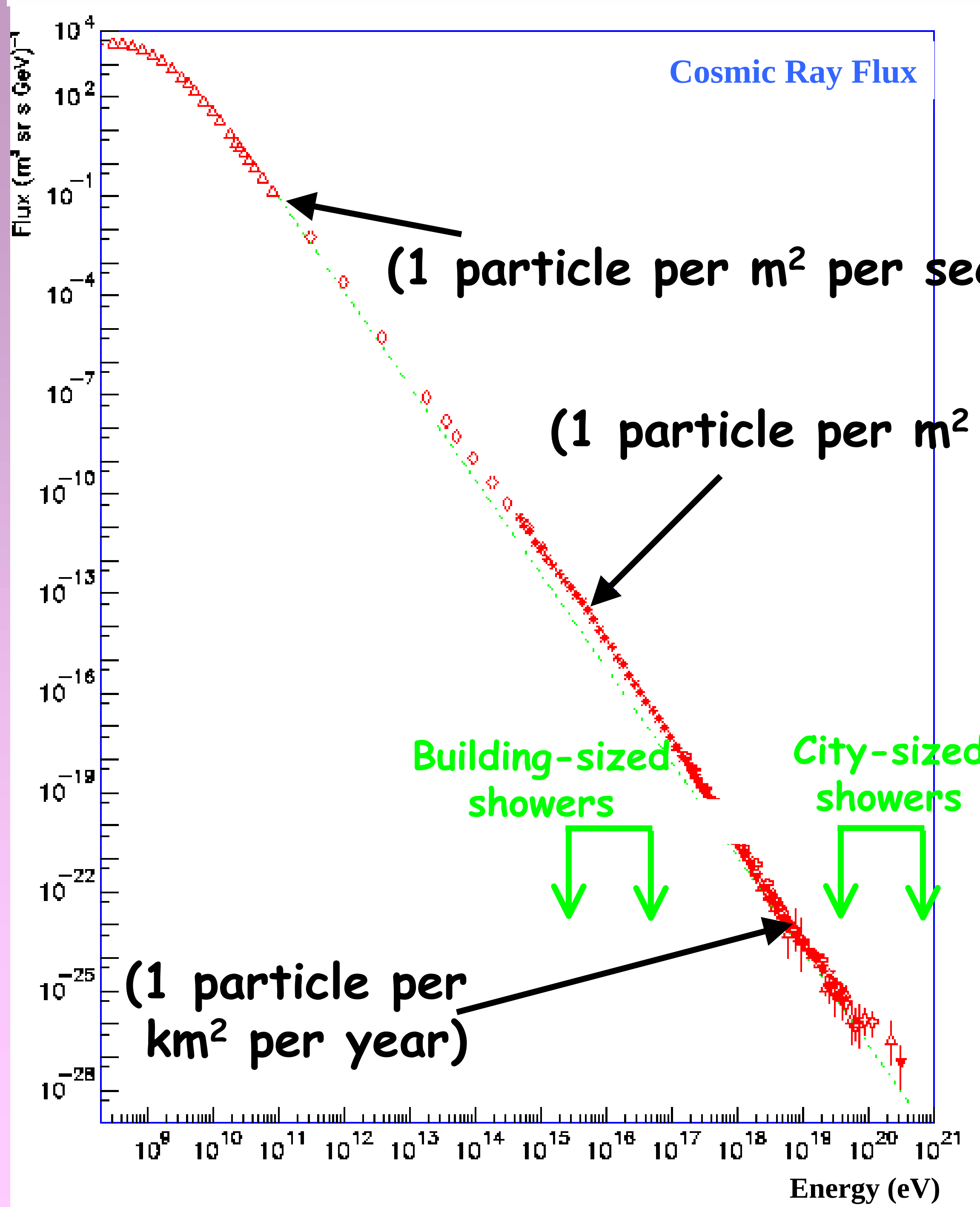
The Science of CROP

- Each school records building-sized showers -- plenty of rate.
  - 2500 ft^2 shower (10^{14} eV)
- Neighboring schools in same city (Lincoln, Omaha) see coincidences from highest-energy showers -- low rate.
  - 10 sq.mi shower ~10^{19} eV
  - 50 sq.mi shower ~10^{20} eV
- Nebraska is 450 x 250 square miles -- schools separated by very large distances explore whether showers come in large, correlated bursts

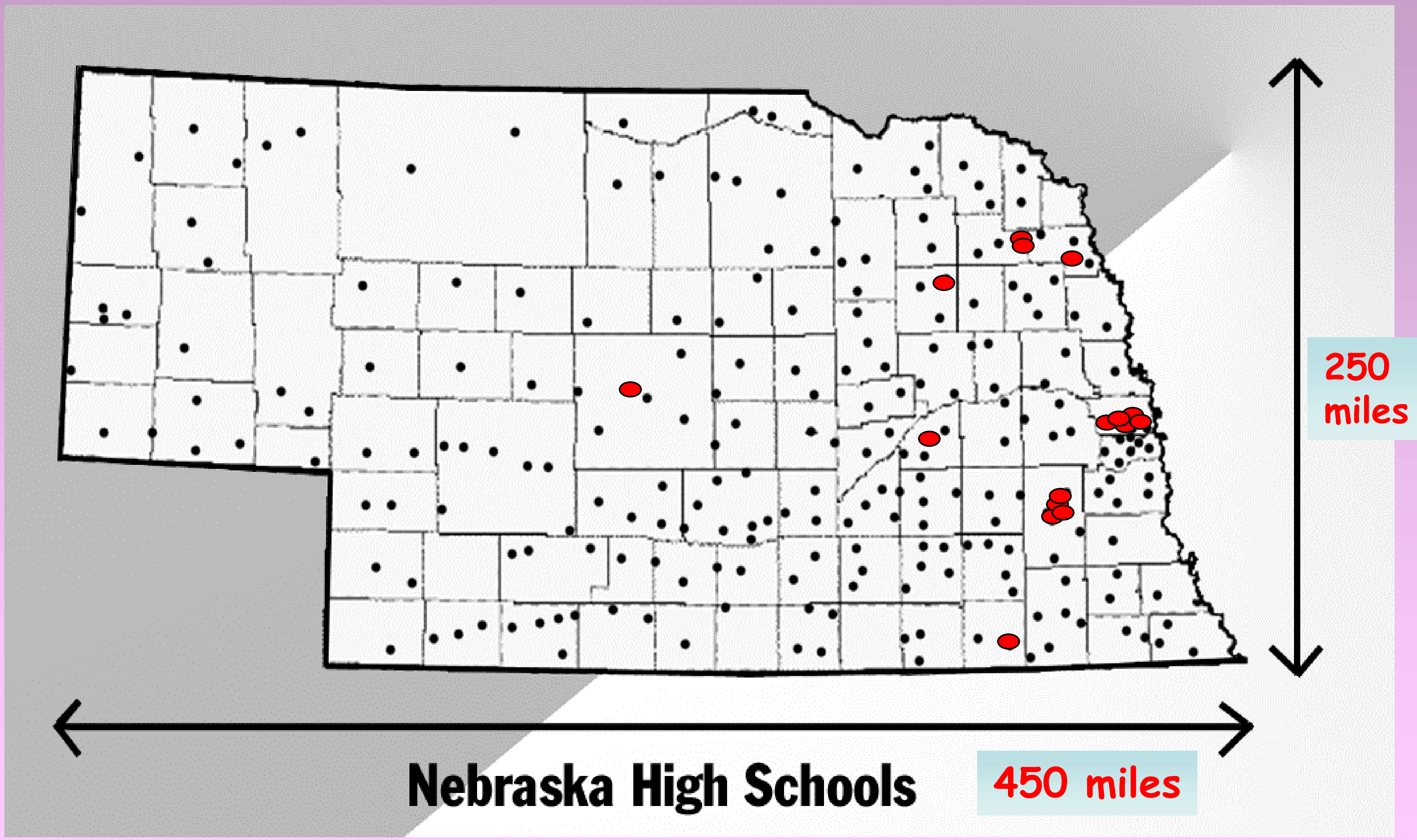
That is, does the whole state of Nebraska ever light up?

The Cosmic Ray Energy Spectrum

The Science Reach of CROP

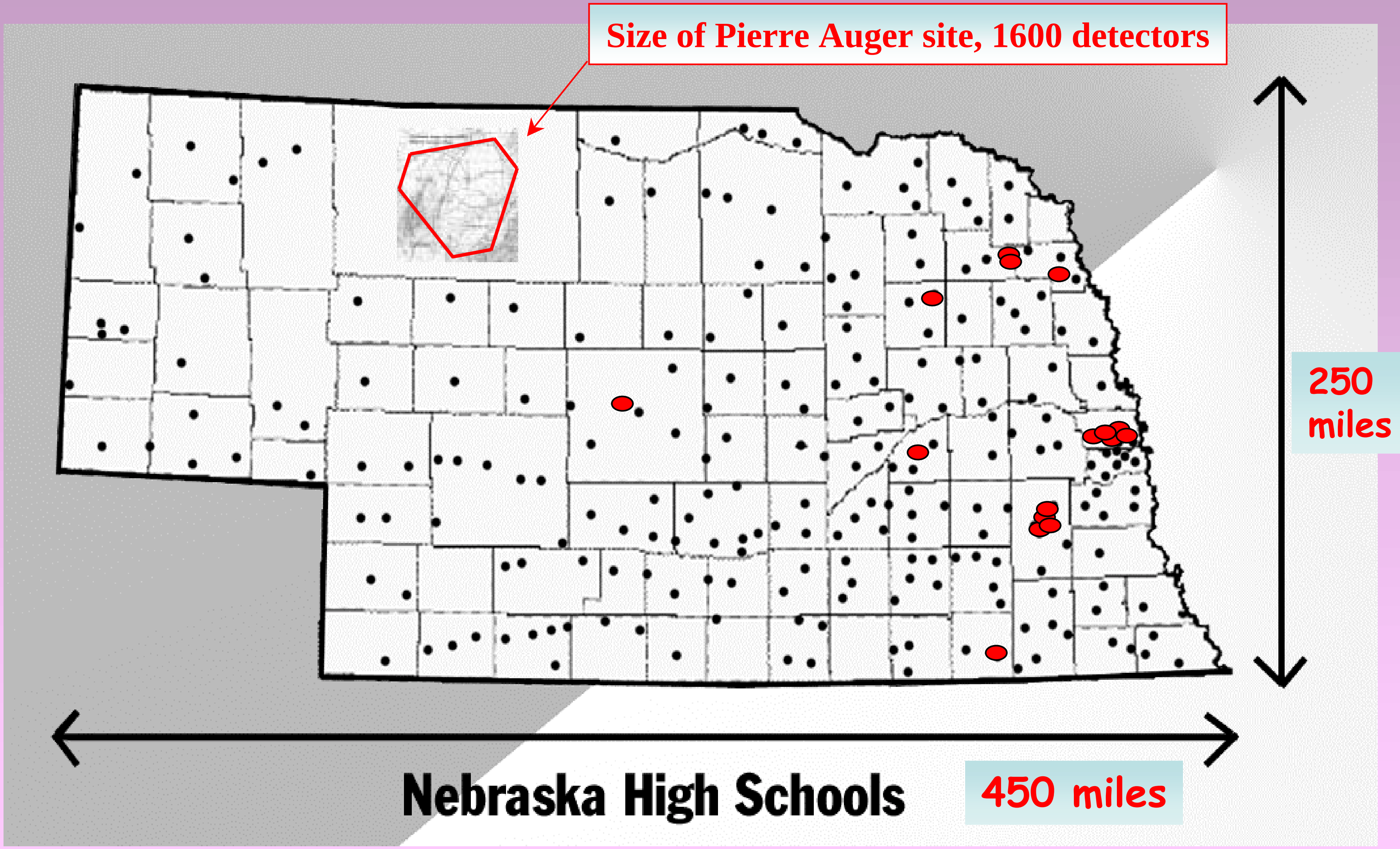


CROP can also search for coincidences over large distances



Does the whole state ever light up at once?

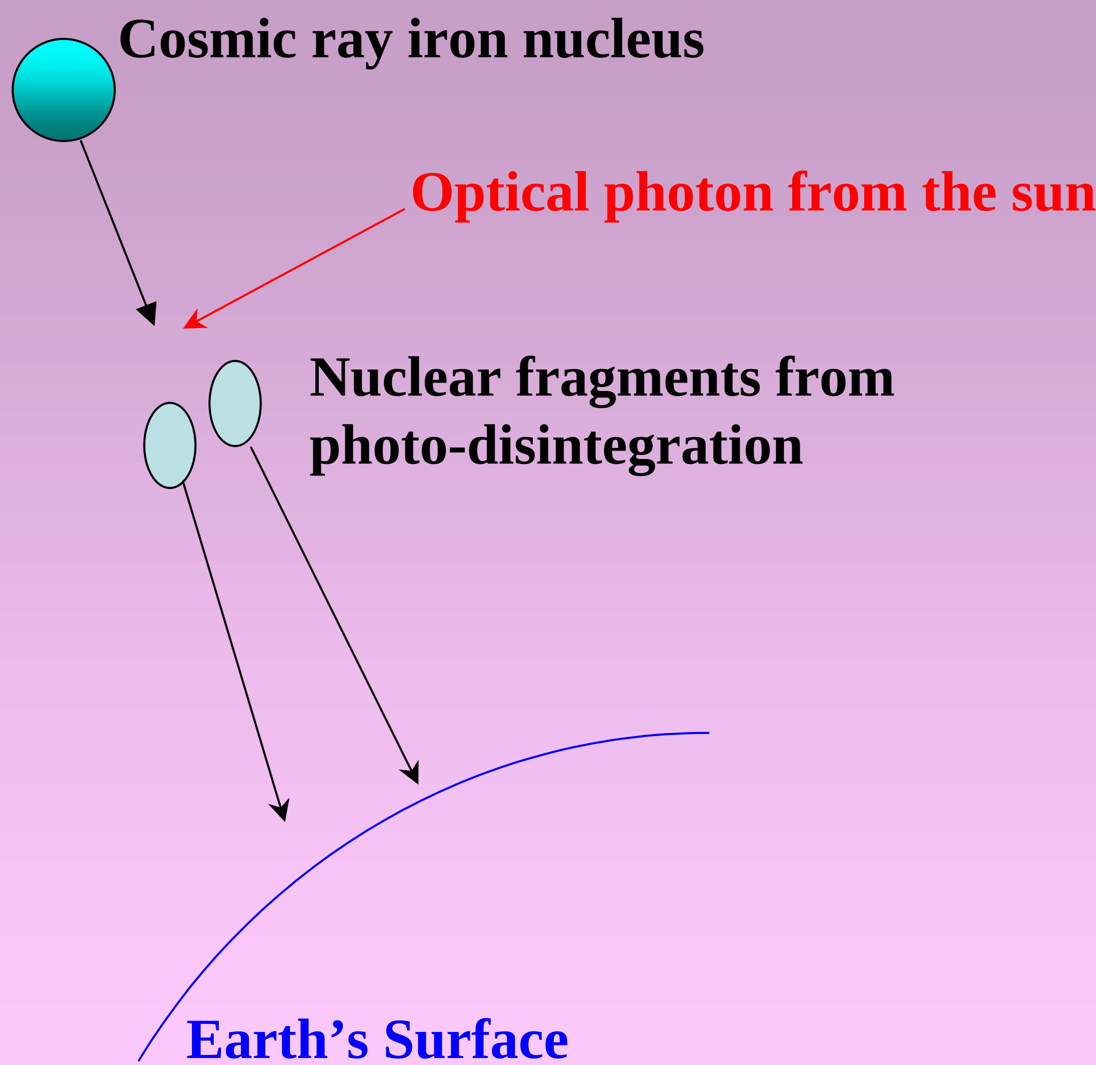
CROP can also search for coincidences over large distances



Does the whole state ever light up at once?

Possible Source of Coincident, Widely-Separated Showers

The GZ Effect (Gerasimova-Zatsepin)



- **Watson and Medina-Tanco revisit this 1960-predicted phenomenon in astro-ph/9808033**
- **Calculation for 6 × 10^{17} eV Fe → Mn + proton**
- **Shower separations of 100's to 1000's of kilometers possible, dominated by deflections by interplanetary magnetic fields**
- **Rates not encouraging**

CROP Personnel at UNL

<u>CROP staff at UNL</u>

- Faculty: Dan Claes and Greg Snow
- Educational evaluator: Dr. Duane Shell
- Physics graduate student: Victoria Mariupolskaya
  - December 2002, Vicky moved to University of Texas, Austin

Summer 2002

- September 2002, Computer Science graduate students:
  Steve Becker: Programming of DAQ card
  Jared Kite: LabView control screen for DAQ card
  Cory Strope: Computer simulations of cosmic ray air showers
- January 2003
  Secondary science ed graduate student: Tracie Evans
- Undergraduate research assistants: M. Dennsberger, M. Everett, A. Fuchser, P. Jacobson, A. Kubik, S. Mahoney
- Administrative Secretary: Marilyn McDowell

High school teams attend a 4-week summer workshop at UNL with class and lab activities

Year 2000 participants from 5 Nebraska high schools

Year 2001 participants from 6 Nebraska high schools

Joined CROP summer 2000

Lincoln Science Focus Program
Lincoln Northeast High School
Mount Michael High School
Marian High School
Norfolk High School

Joined CROP summer 2001

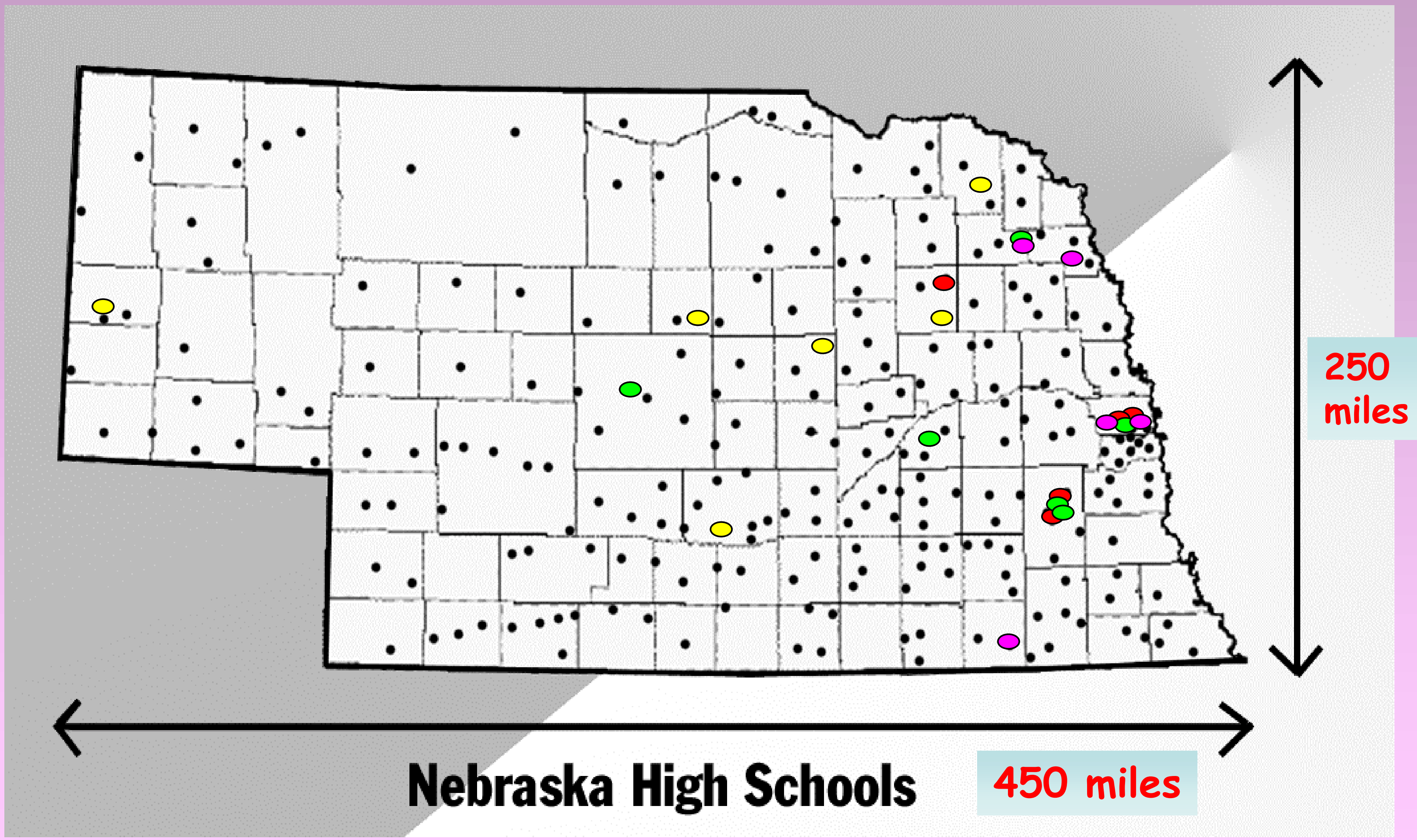
Lincoln Lutheran High School
Lincoln High School
Wayne State College
Omaha Westside High School
Anselmo-Merna High School
Osceola Public High School

Joined CROP summer 2002

Fairbury High School
Wayne High School
Roncalli Catholic High School
Bancroft-Rosalie High School
Waterloo High School

Summer 2002 Participants

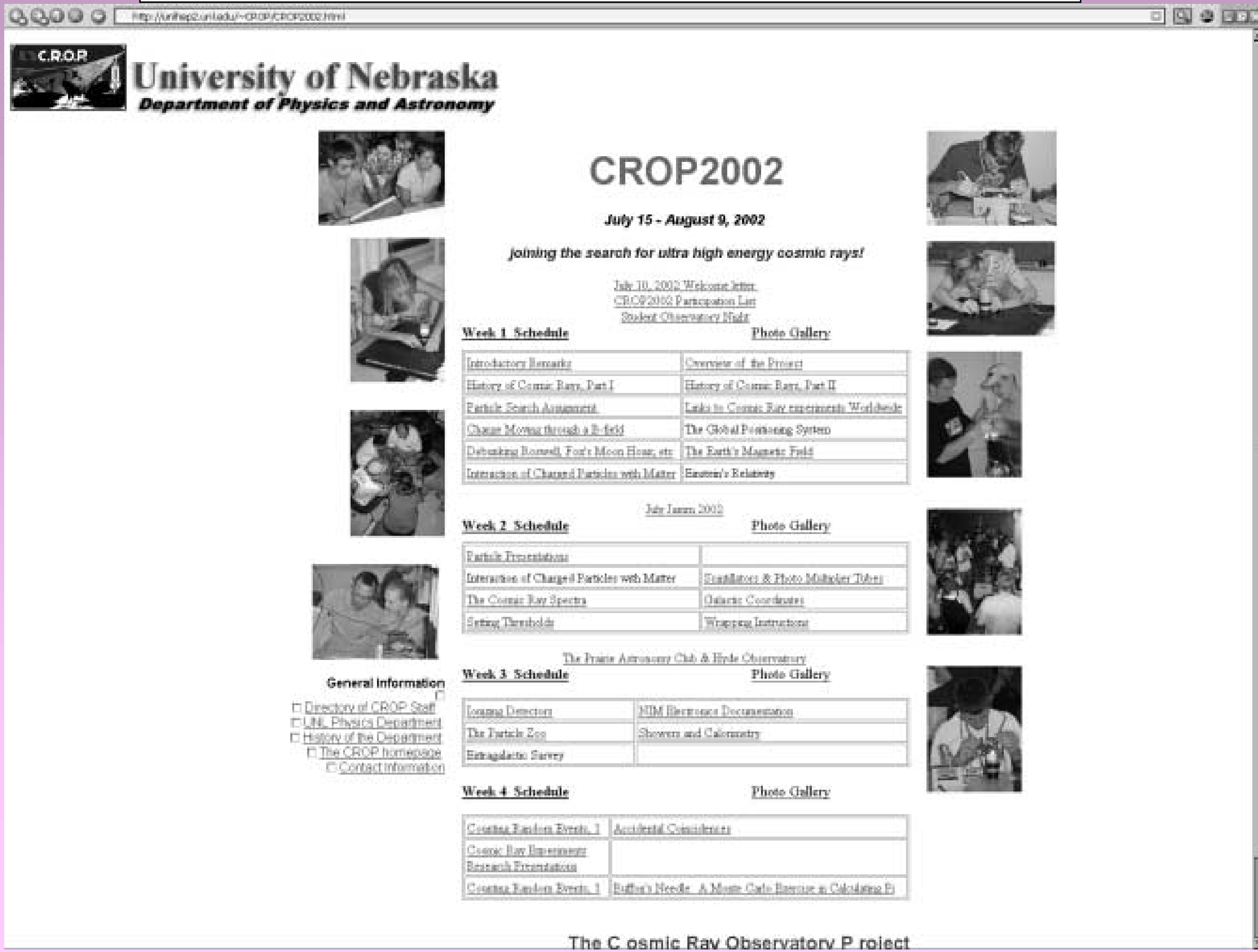
The Cosmic Ray Observatory Project
A grid of cosmic ray research stations expanding across the state



CROP schools enlisted in 2000 (red) 2001 (green) 2002 (magenta) 2003 (yellow)

Summer 2002 Web Site

http://unlhep2.unl.edu/~CROP/CROP2002.html



http://unlhep2.unl.edu/~CROP/CROP2002.html

University of Nebraska

Department of Physics and Astronomy

CROP2002

July 15 - August 9, 2002

joining the search for ultra high energy cosmic rays!

July 10, 2002 Welcome letter
CROP2002 Participation List
Student Observatory Night

Week 1 Schedule Photo Gallery

Introductory Remarks	Overview of the Project
History of Cosmic Rays, Part I	History of Cosmic Rays, Part II
Particle Search Assignment	Links to Cosmic Ray experiments Worldwide
Charge Moving through a B-field	The Global Positioning System
Debunking Roswell, Fox's Moon Hoax, etc	The Earth's Magnetic Field
Interaction of Charged Particles with Matter	Einstein's Relativity

July James 2002

Week 2 Schedule Photo Gallery

Particle Presentations	
Interaction of Charged Particles with Matter	Scintillators & Photo Multiplier Tubes
The Cosmic Ray Spectra	Galactic Coordinates
Setting Thresholds	Wrapping Instructions

The Prairie Astronomy Club & Hyde Observatory

Week 3 Schedule Photo Gallery

Ionizing Detectors	NIM Electronics Documentation
The Particle Zoo	Showers and Calorimetry
Extragalactic Survey	

Week 4 Schedule Photo Gallery

Counting Random Events, 1	Accidental Coincidences
Cosmic Ray Experiments Research Presentations	
Counting Random Events, 1	Buffon's Needle: A Monte Carlo Exercise in Calculating Pi

General Information

- Directory of CROP Staff
- UNL Physics Department
- History of the Department
- The CROP homepage
- Contact information

The C osmic Ray Observatory P roject

C.R.O.P.

Preparing detectors to take to your schools, experimental techniques

Learning the physics of comsic rays and particle detectors

Lab Curriculum

- Polishing, cleaning scintillator
- Gluing PMT and wrapping scintillator
- Assembling high-voltage supply
- Oscilloscope lesson
- Turning on counters, source tests, finding/fixing light leaks
- Measure counter efficiency, high voltage plateau

Curriculum Topics Available

Class Curriculum

- History of cosmic rays
- Interaction of charged particles with matter
- Scintillators and photomultiplier tubes
- Cosmic ray energy spectrum
- Julian calendar, UTM, galactic coordinates
- Global positioning system
- Ionizing particle detectors
- Calorimeters and showering
- Particle zoo and the Standard Model
- Tour of high-energy particle accelerators
- Random events, probability
- Monte Carlo simulations
- Lightning protection

What we expect to accomplish in 4 weeks

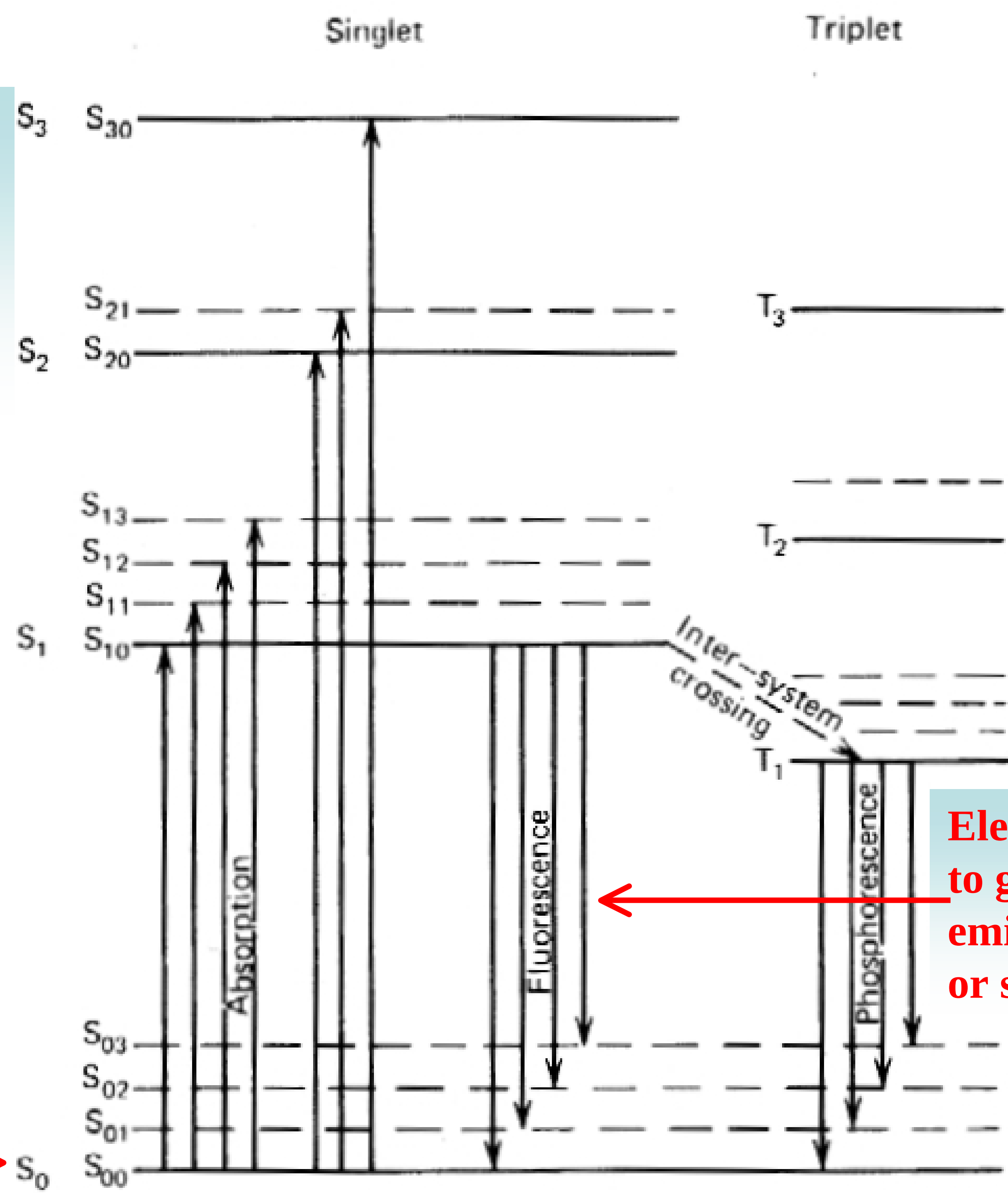
Each classroom session begins with a set of learning objectives

Scintillators and Photomultipler Tubes

- Understand the basic operation of CROP scintillation counters and photomultiplier tubes (PMTs) and their use in measuring cosmic ray air showers
- Understand how light is generated in a scintillator
- Understand how light is transmitted to a PMT
- Understand how a PMT generates an electric signal
- Be able to hook up a scintillation counter to its high voltage and an oscilloscope for viewing signals
- Be able to identify light leaks in a scintillation counter
- Be able to observe scintillation counter signals using an oscilloscope and identify cosmic ray muons
- Be able to discuss scintillation counter performance in terms of gain, efficiency and attenuation length

Energy absorption and emission diagram

Electrons excited to higher energy levels when a charged particle passes, absorbing part of its energy



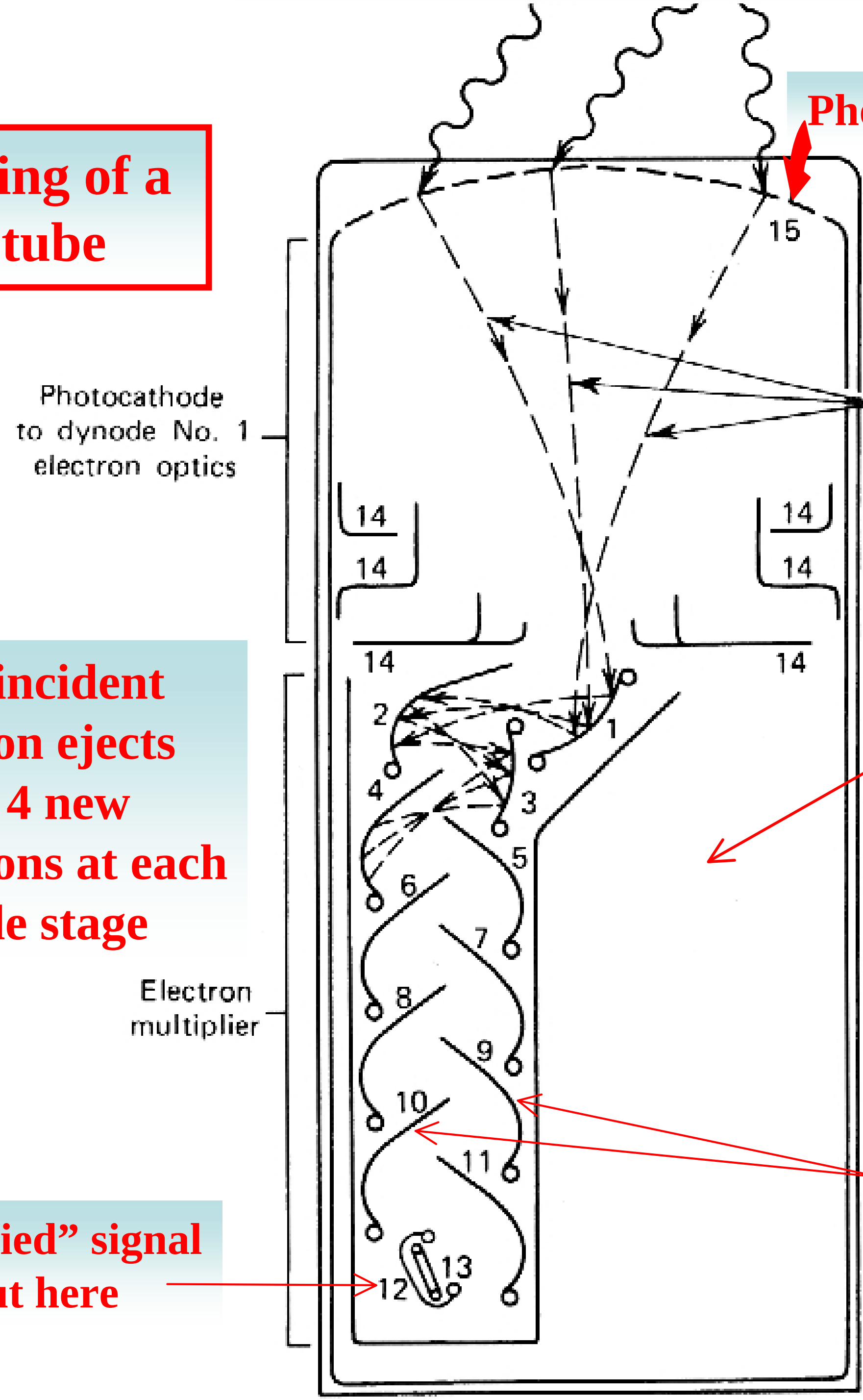
Electrons drop back to ground state, emitting fluorescence or scintillation light

Electron ground state

Schematic drawing of a photomultiplier tube

Incident light from scintillator

Photocathode



Photons eject electrons via photoelectric effect

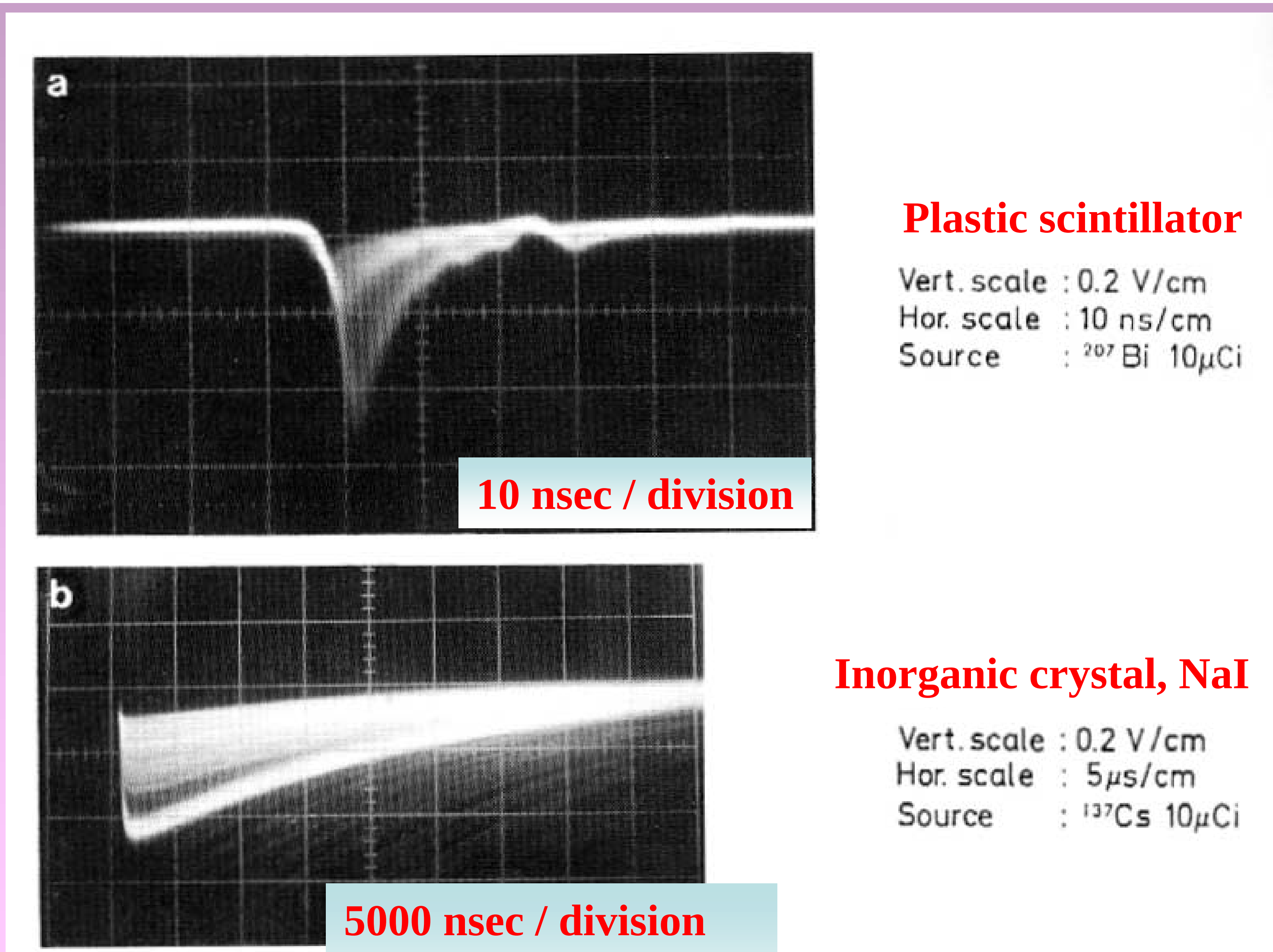
Each incident electron ejects about 4 new electrons at each dynode stage

Vacuum inside tube

“Multiplied” signal comes out here

An applied voltage difference between dynodes makes electrons accelerate from stage to stage

Oscilloscope traces from scintillation counters



Plastic scintillator

10 nsec / division

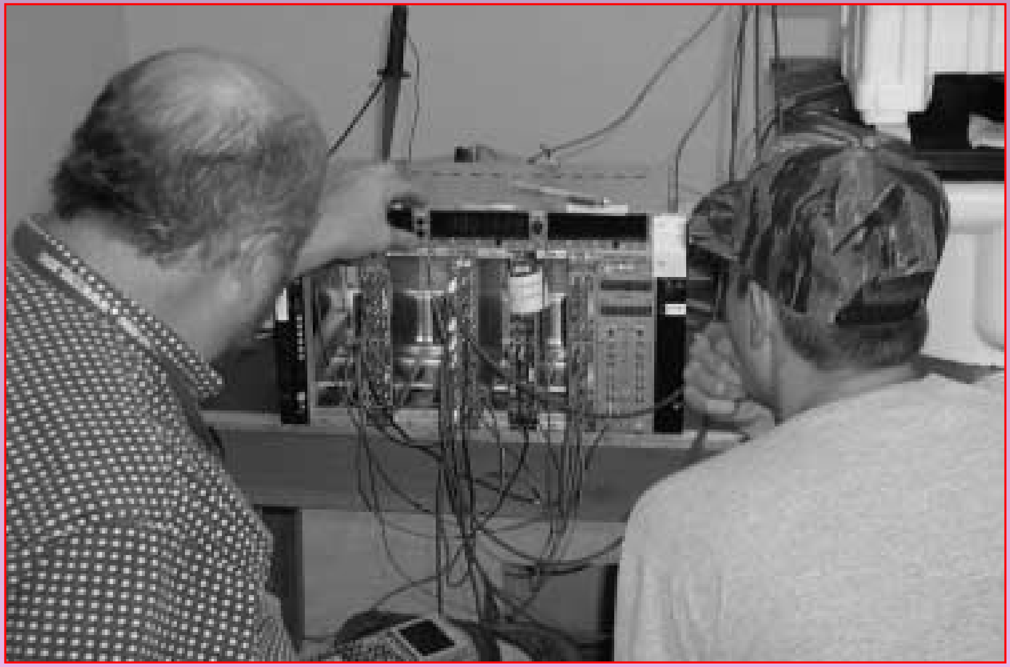
Inorganic crystal, NaI

5000 nsec / division
(Longer time scale for fluorescence to occur)

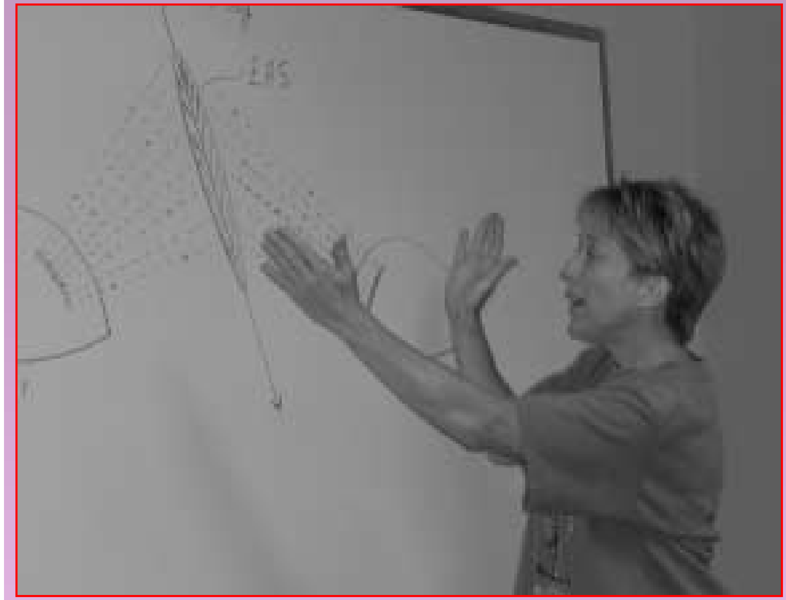
Endless scraping, polishing, and soldering

Endless wrapping, taping, and observing

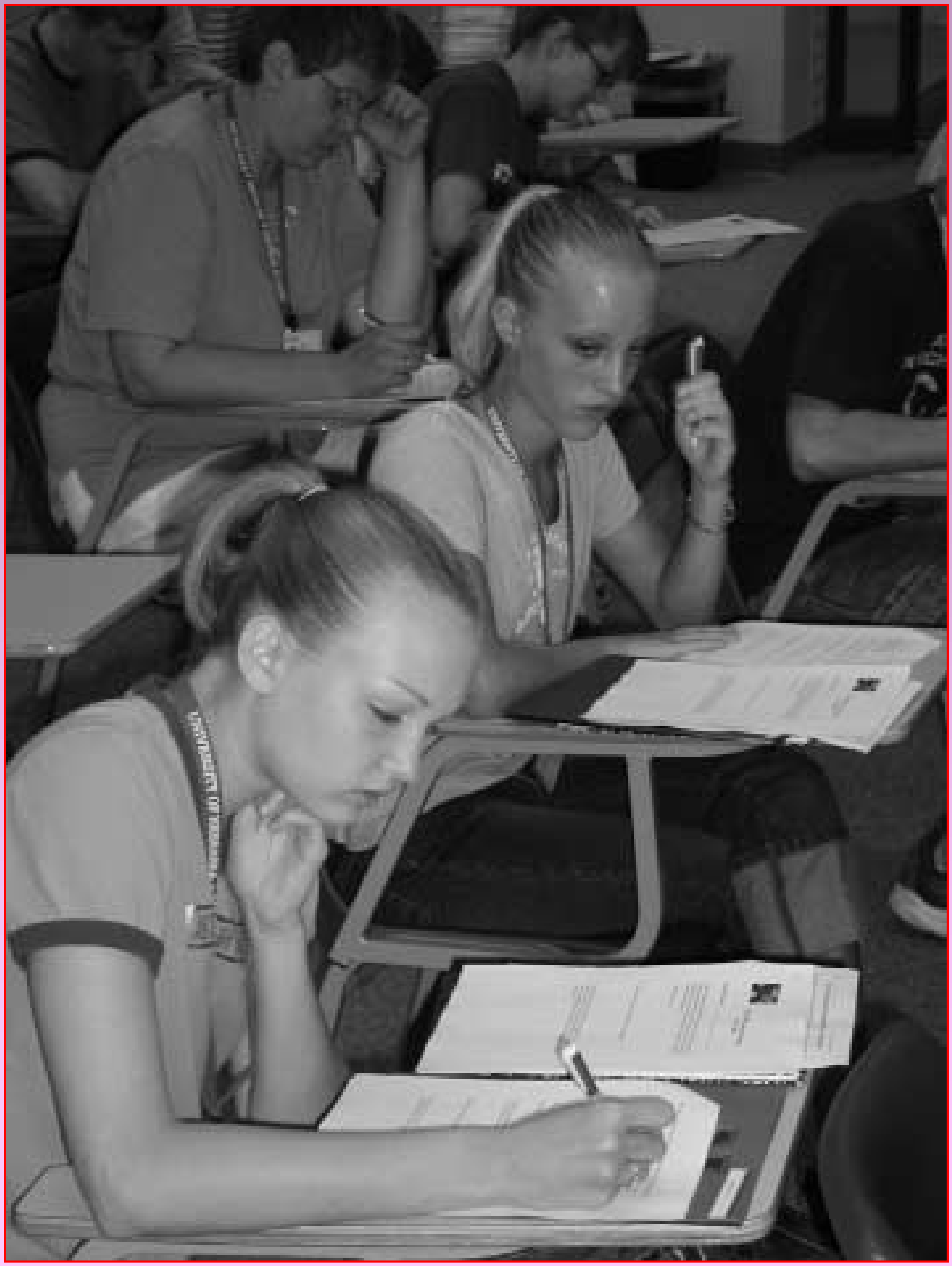
Endless cabling and adjusting



Presentations on web research on cosmic ray experiments



Pre-workshop and Post-workshop testing

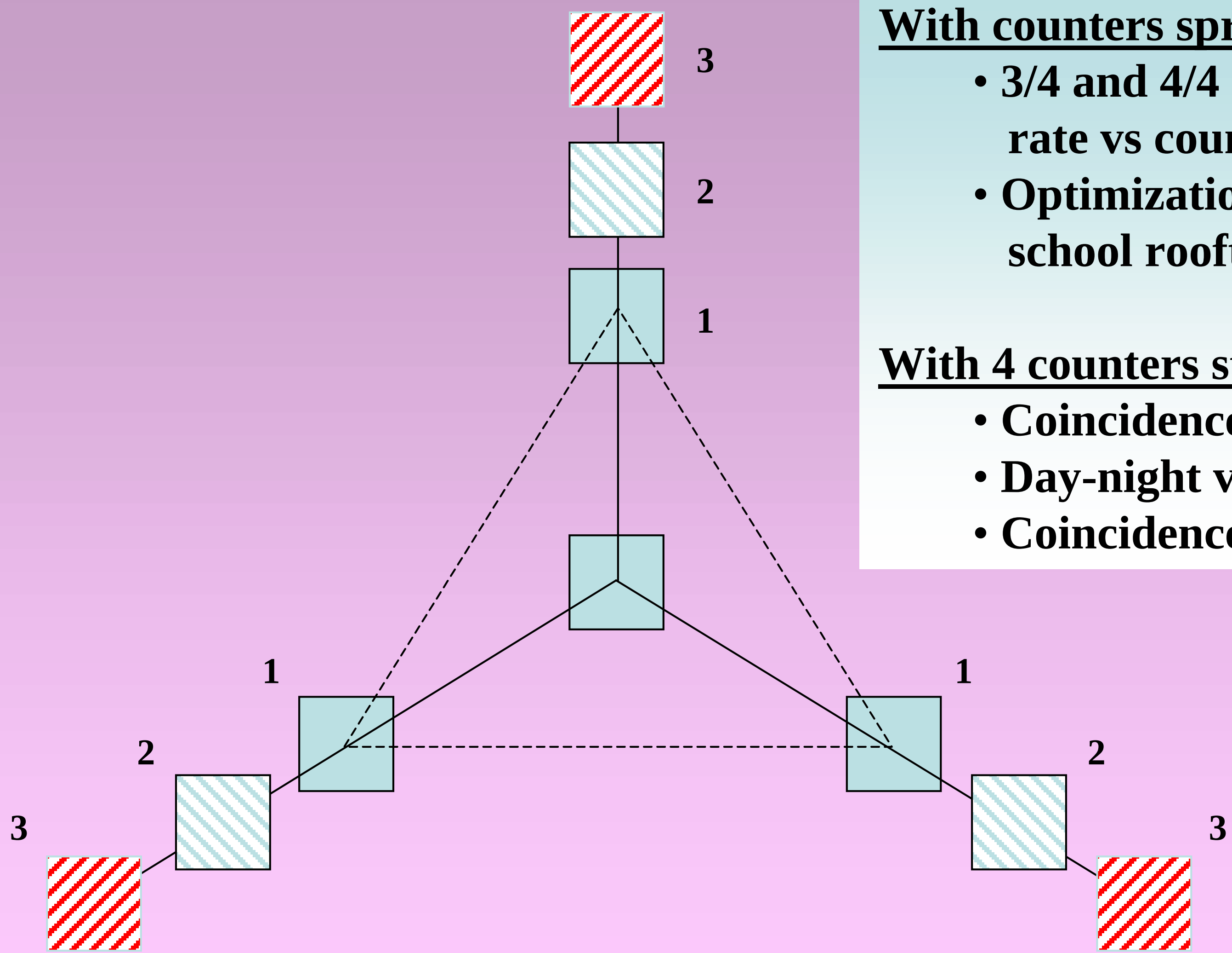


Positive outcomes-assessment results from professional evaluator

C.R.O.P.

And we manage to have some fun too

Mini-experiments for CROP Schools



<u>With counters spread out in horizontal plane</u>

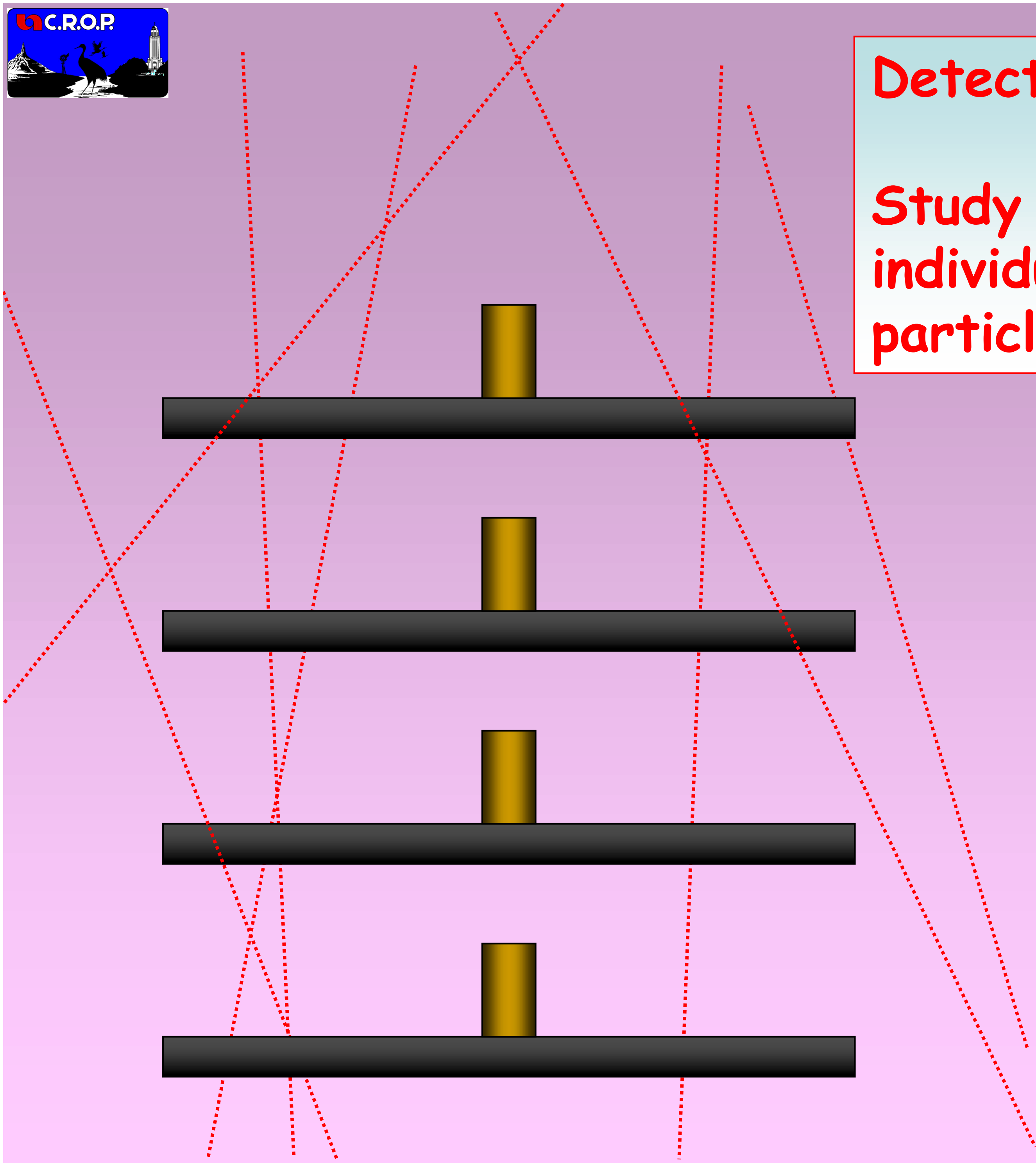
- 3/4 and 4/4 coincidence rate vs counter separation
- Optimization of counter geometry on school rooftops

<u>With 4 counters stacked in vertical telescope</u>

- Coincidence rate vs. barometric pressure
- Day-night variation of cosmic ray rate
- Coincidence rate vs. angle of incidence

- Muon lifetime measurement
- Singles rates vs. rainfall

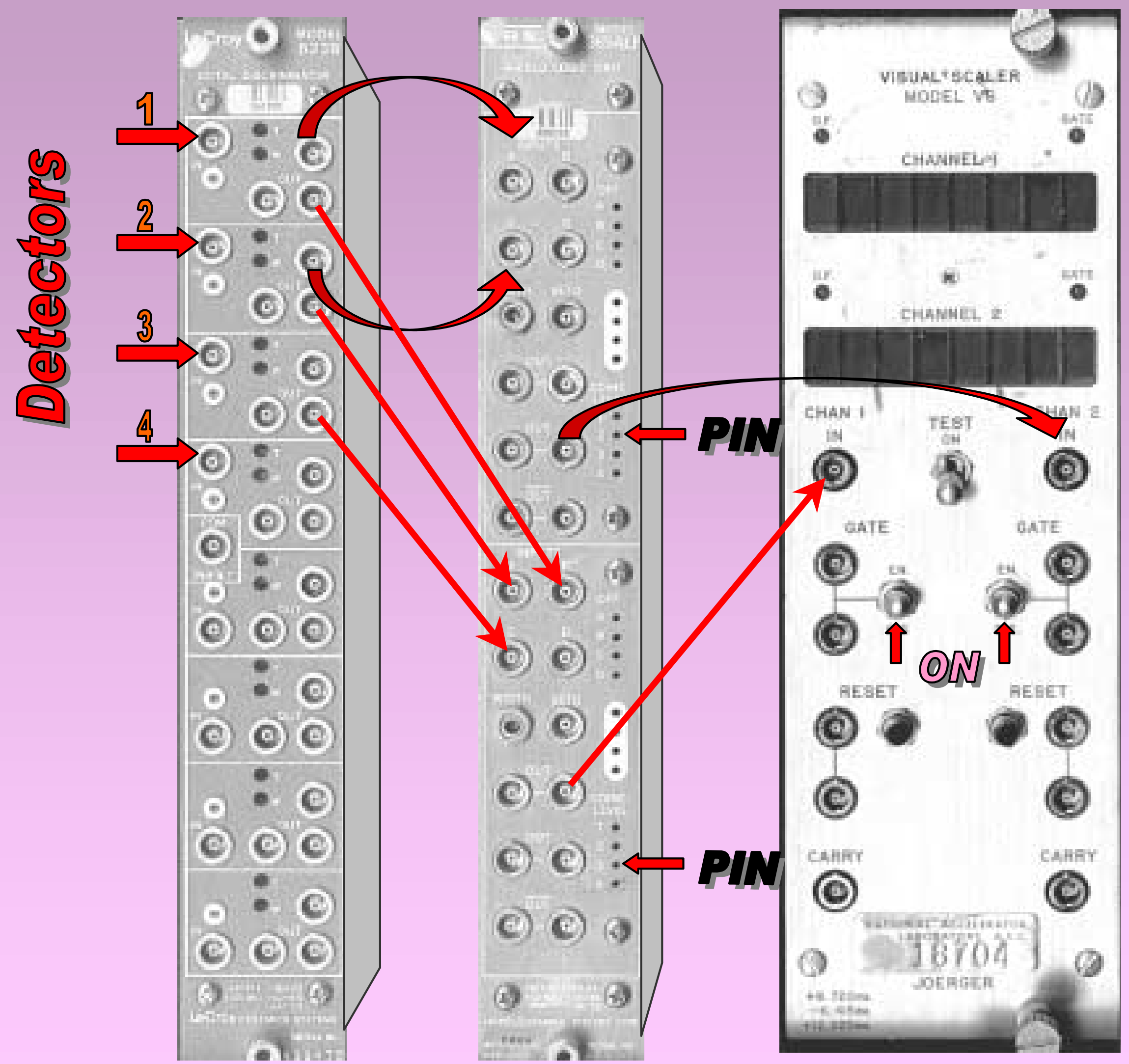
- Using NIM electronics on loan from Fermilab



Detectors in a "telescope"

Study coincidences from individual cosmic-ray particles

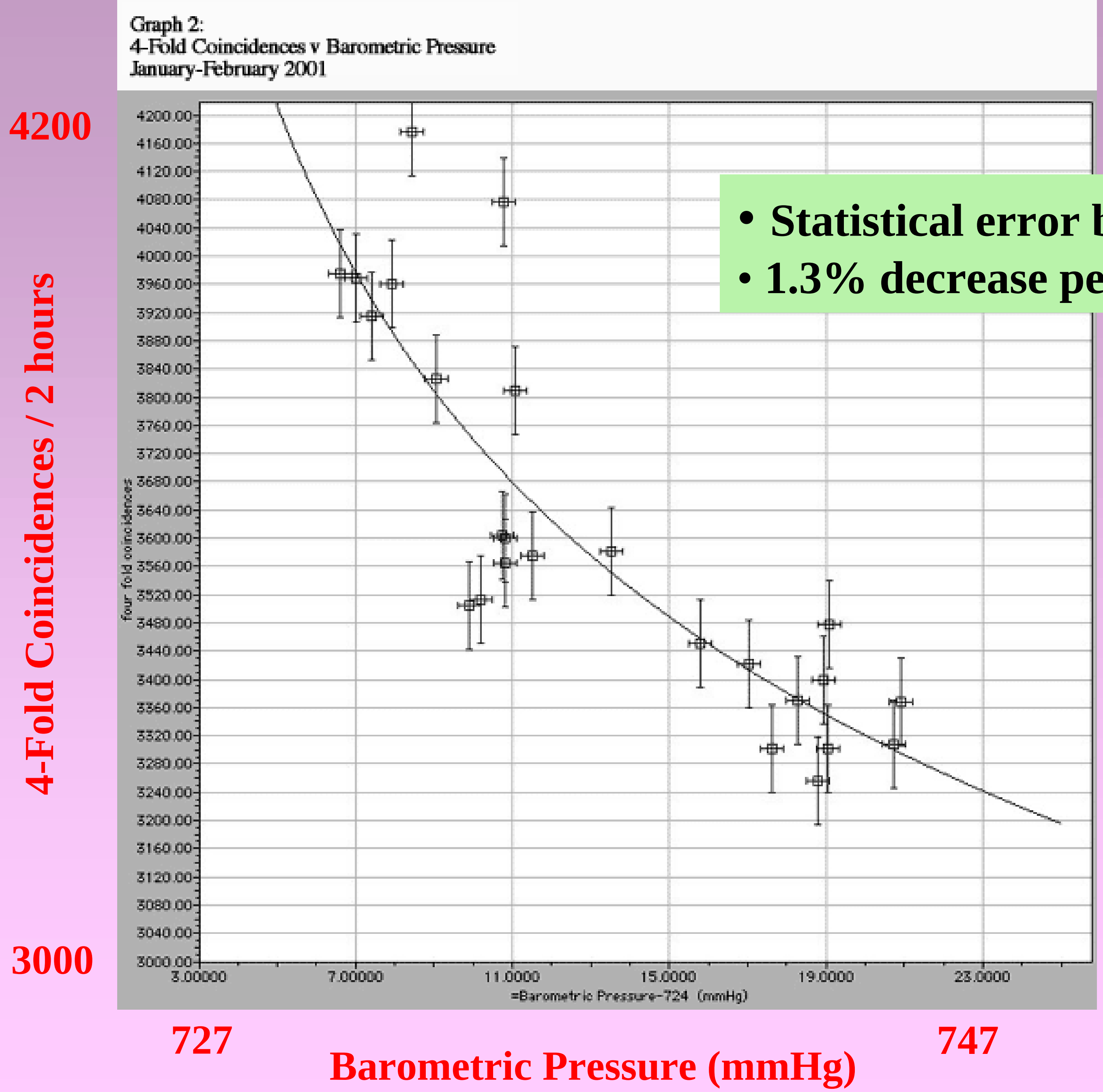
Electronics Configuration for Telescope



Detector set-ups at schools

"Telescope" set-ups for indoor experiments

Marian High School's Measurement of Cosmic Ray Rate vs. Barometric Pressure



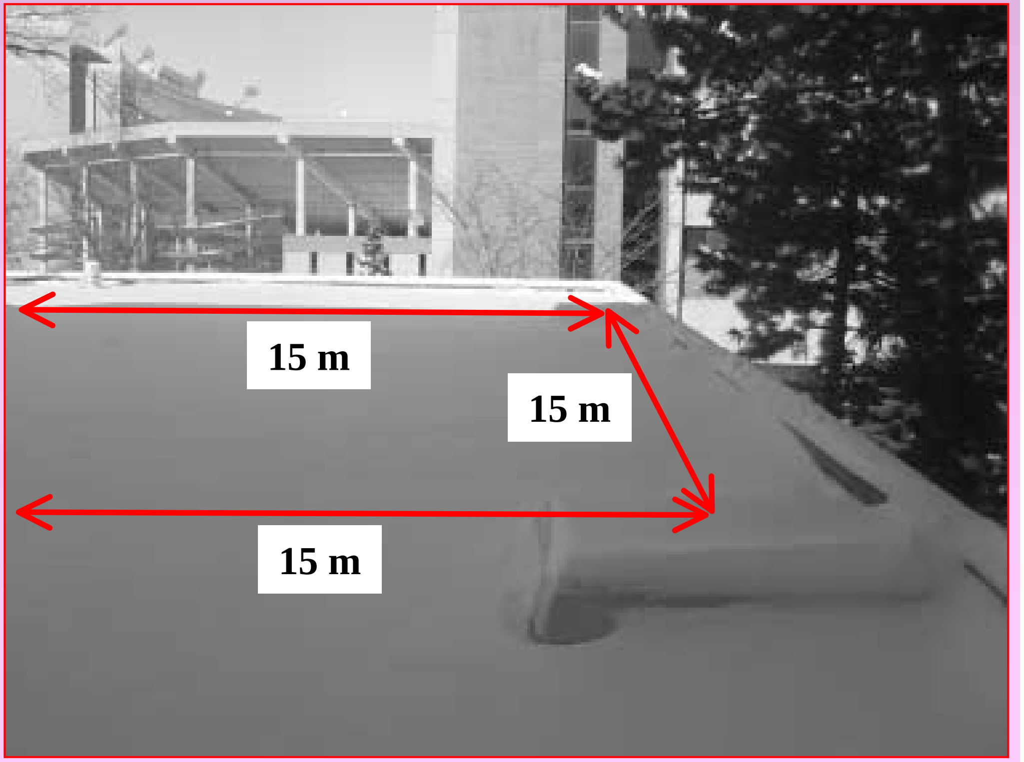
- Statistical error bars shown
- 1.3% decrease per mmHg

Coincidence Rates vs. Separation Experiment
October – December 2002

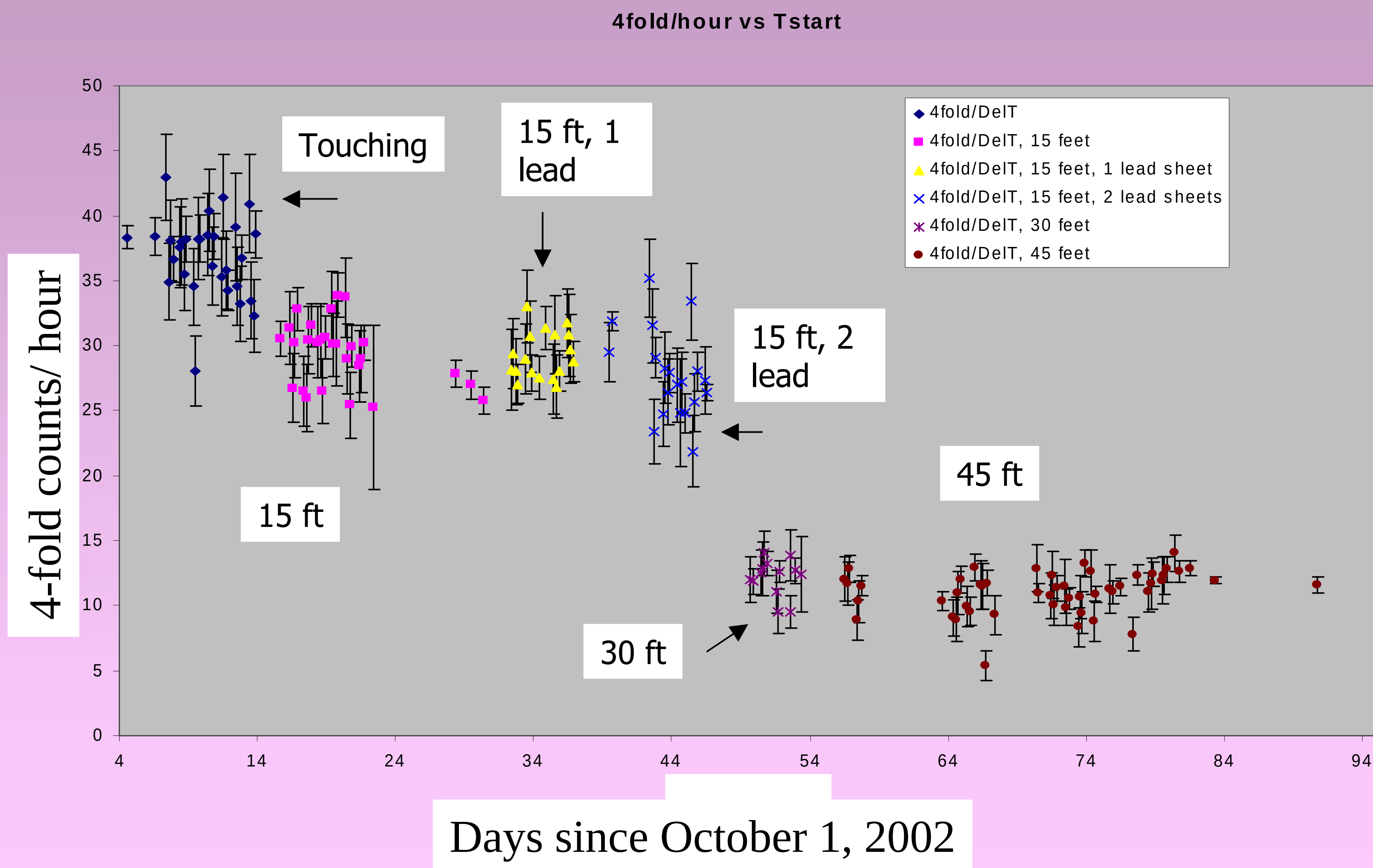
Installation on Physics Department roof, February 2002

4 detectors on corners of a square

15 meter
(45 feet)
separation shown



4-fold Coincidence Rates vs. Separation



Rates high enough to sustain student interest

CROP data acquisition electronics card

Developed by Univ. Nebraska, Fermilab (Quarknet), Univ. Washington

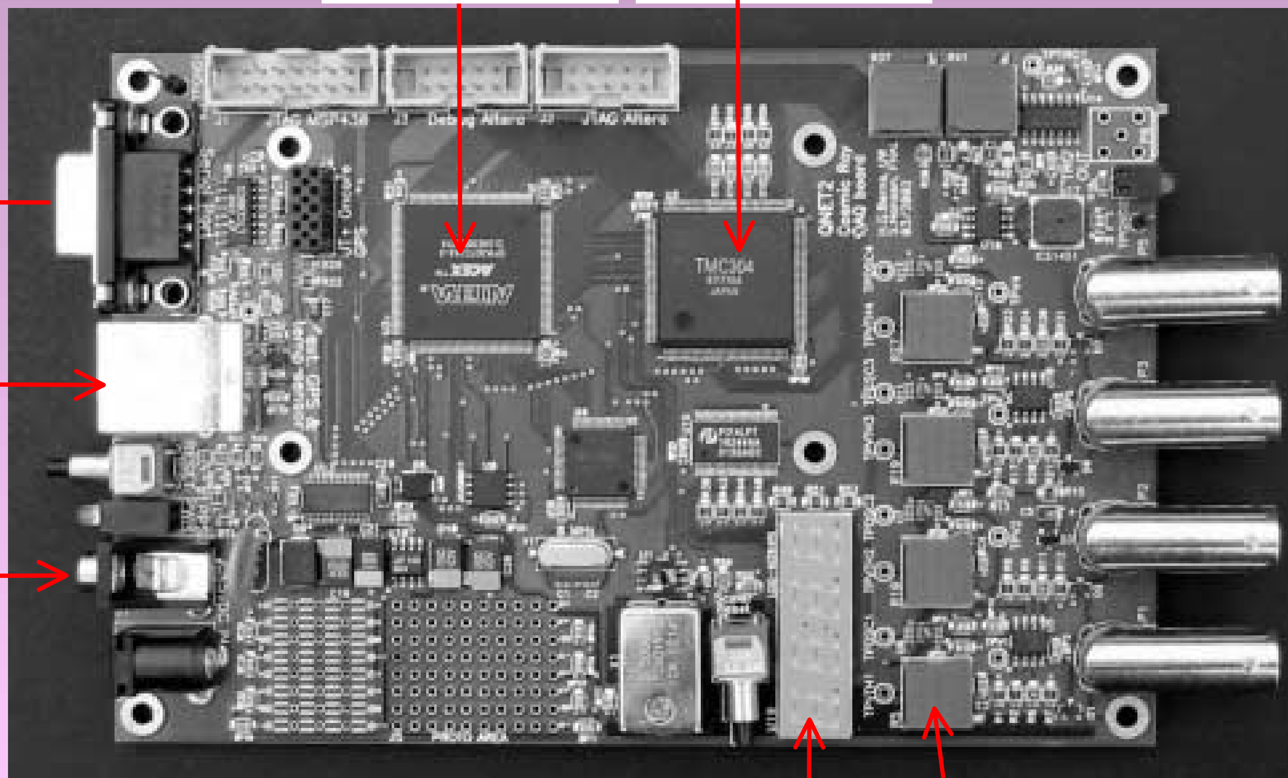
Programmable logic device

Time-to-digital converters

To PC serial port

GPS receiver input

5 Volt DC power



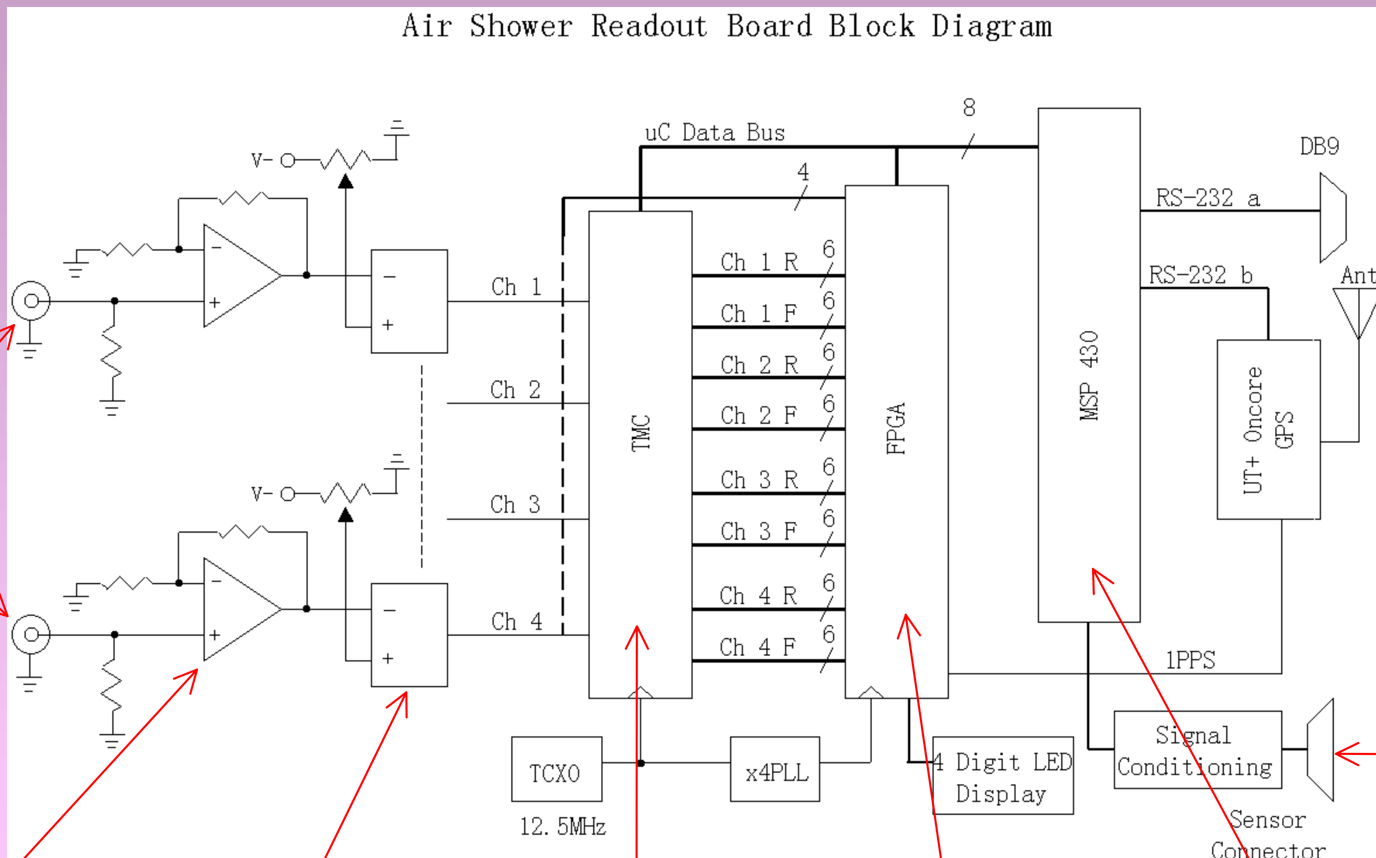
Four analog PMT inputs

Event counter

Discriminator threshold adjust

- 50 Mhz (20 nsec) clock interpolates between 1 pps GPS ticks for trigger time
- TDC's give relative times of 4 inputs with 75 psec resolution

CROP data acquisition electronics card



Analog inputs

GPS

Barometer, temperature

Amplifiers

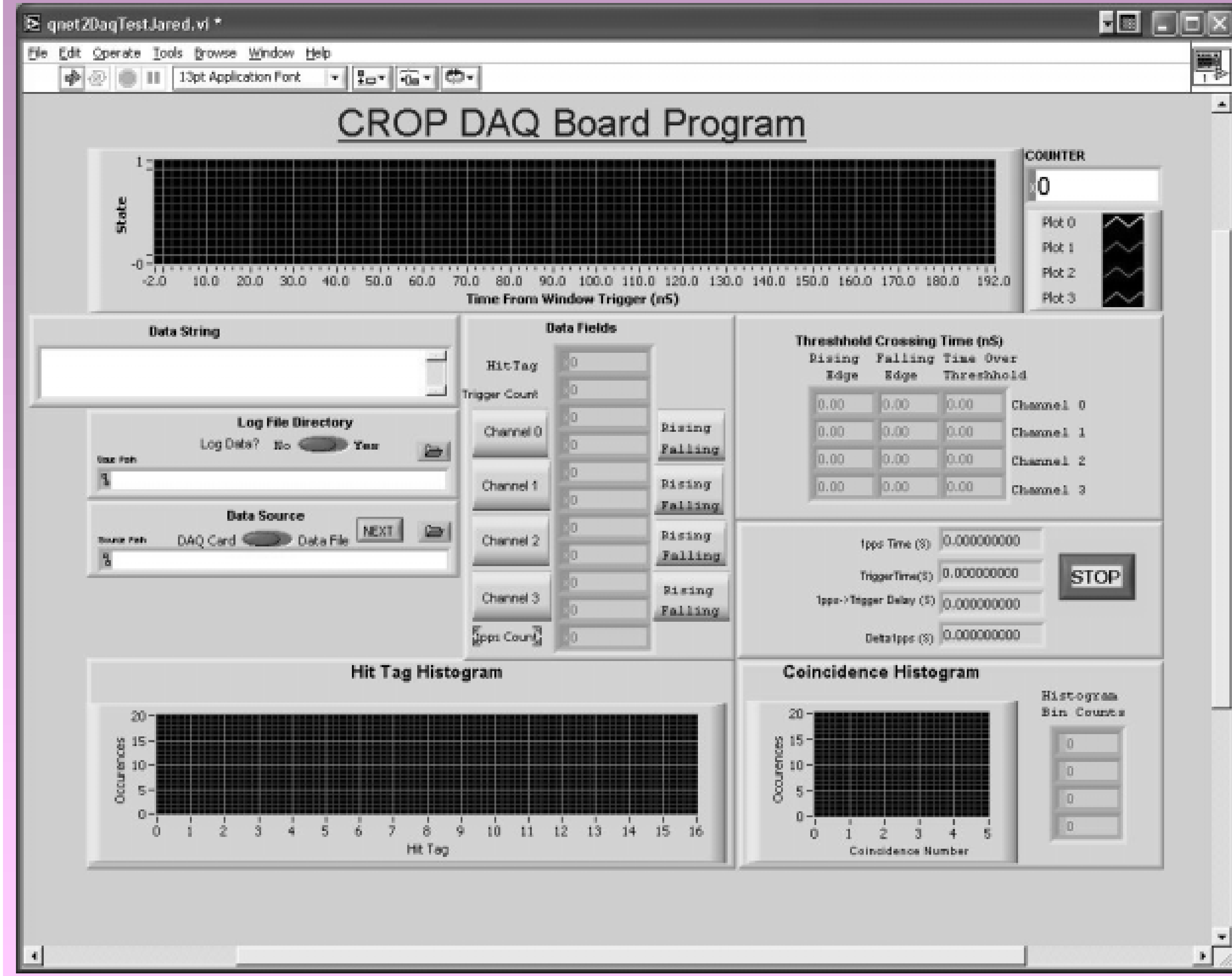
Discriminators

TDC Time-to-digital converter

Programmable gate array

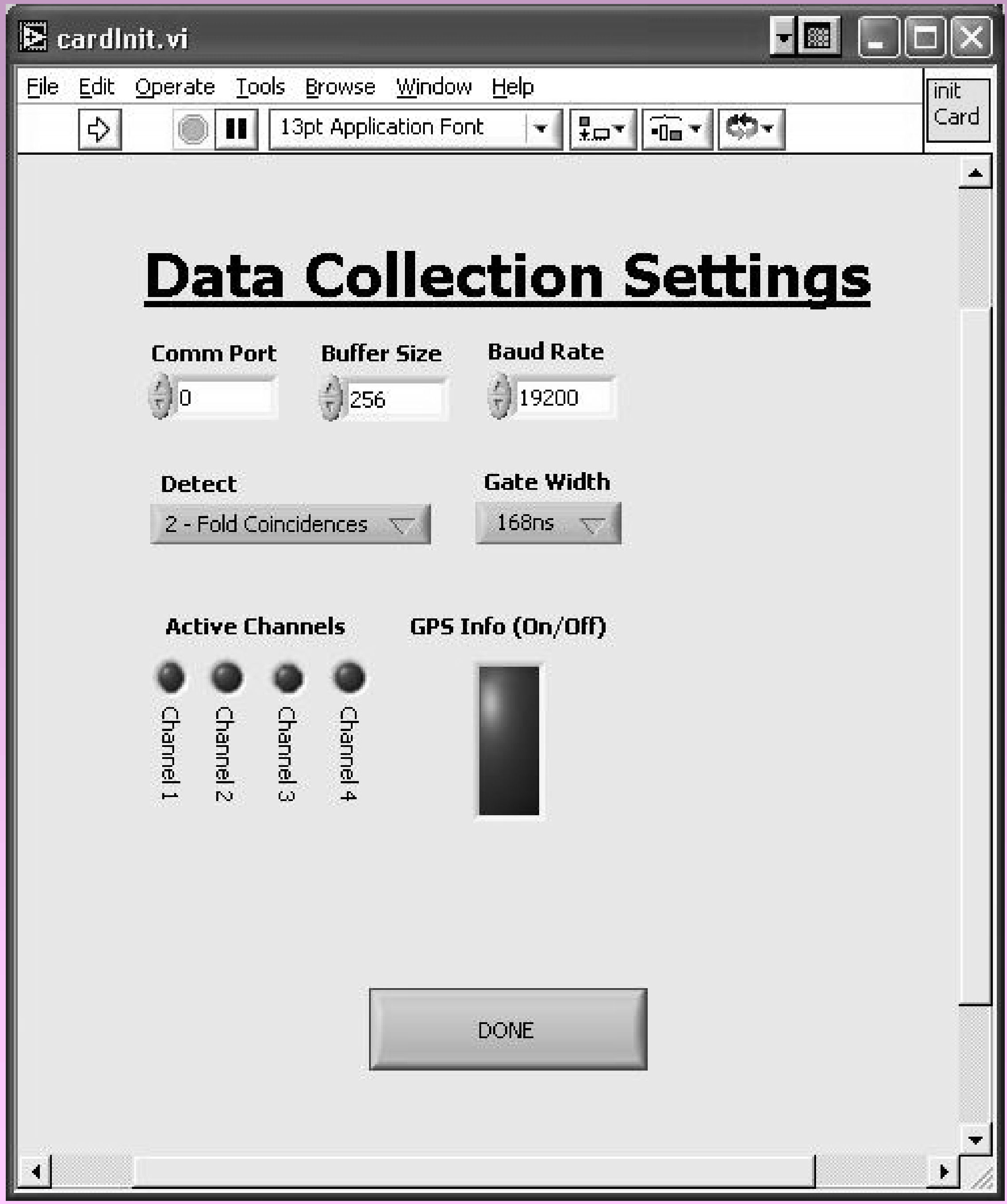
Programmable microcontroller

Monitoring Program for Data Acquisition Card

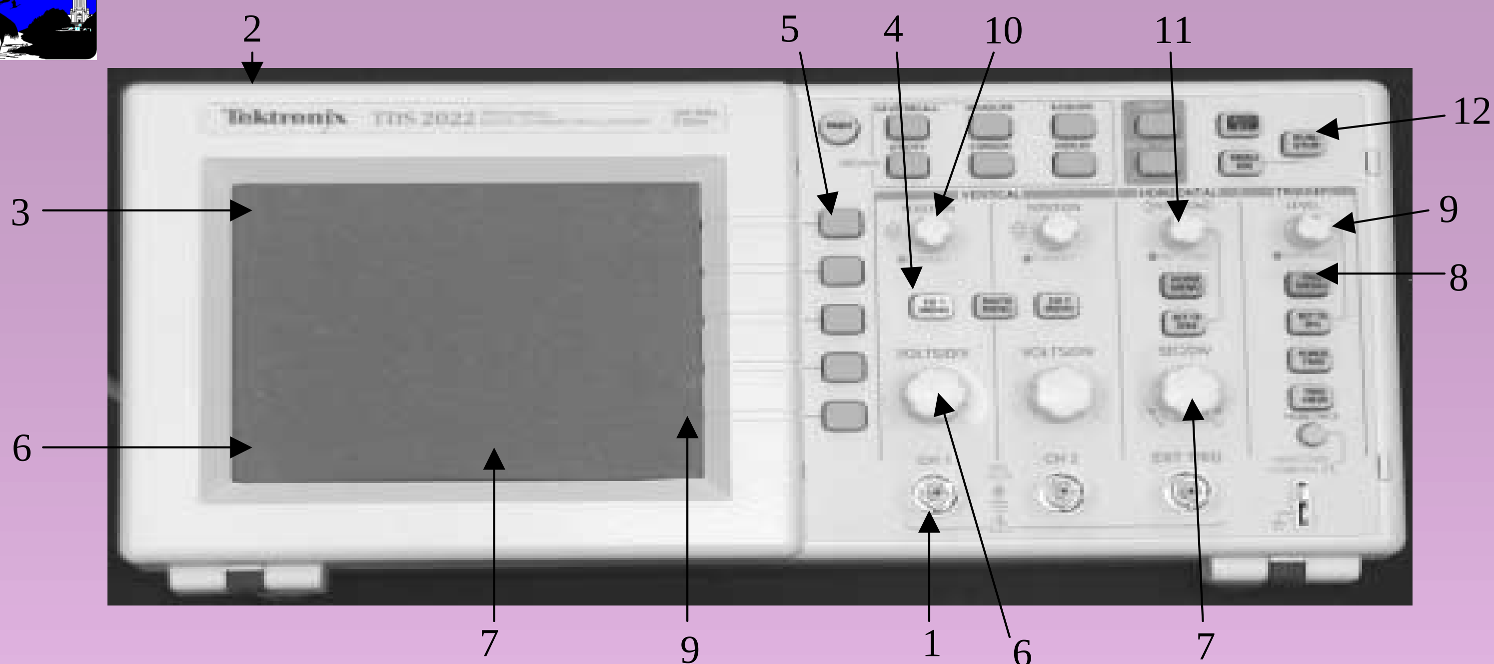


- LabView running on a PC
- At-a-glance monitoring of incoming data
- Jared Kite

Labview Window for Setting Data-Taking Conditions



Oscilloscope Lesson for Tektronix TDS 2022 (T. Evans)

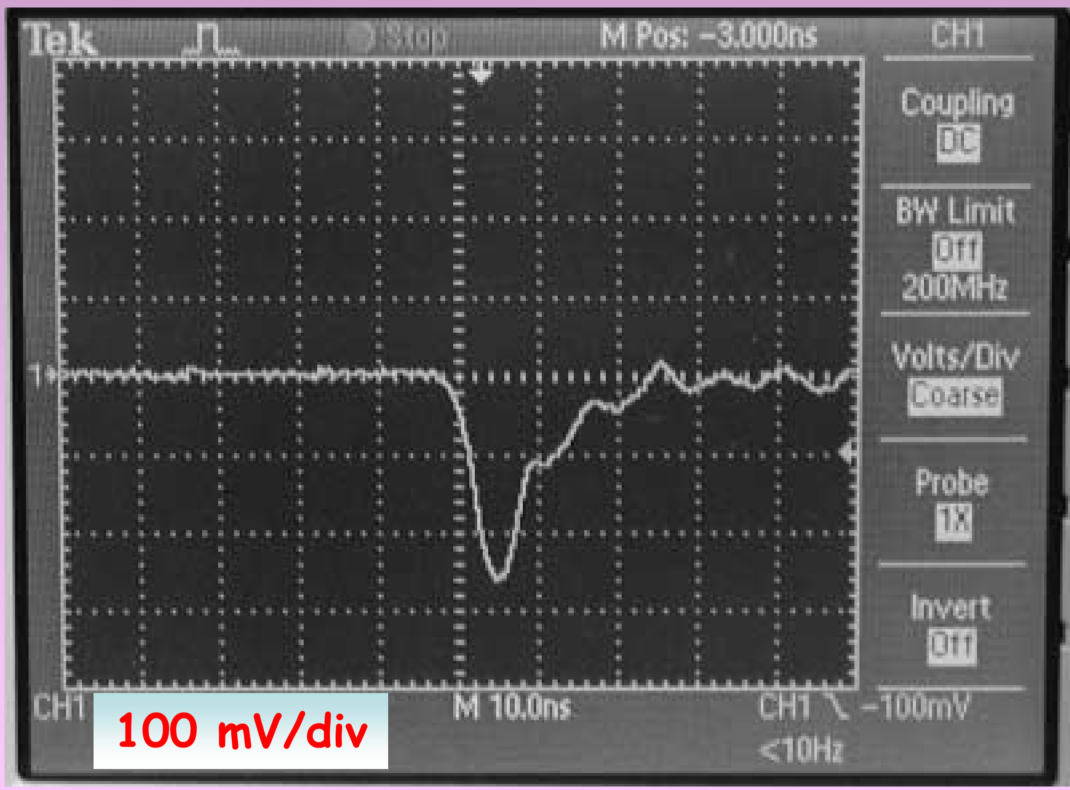


1. Connect the scintillator cable with a 50-ohm “T” into Ch 1 adapter
2. Turn the oscilloscope on by depressing the power button.
3. The display should show a graph and some sort of signal, example:
4. If no signal, make sure to select the Ch 1 menu.
5. You can change the settings by depressing the buttons to the right of the display, should read:
6. Make sure the volts/div is set around 100 mV (shows on display bottom left corner), examples:
7. Make sure the sec/div is set around 10.0 ns (shows on display bottom middle), examples:
8. Select trigger menu, change settings by depressing buttons to the right of the display, should read:
9. To view only the signal with certain mV (generally greater than 50 mV) use the trigger knob to move cursor on vertical axis (shows on display bottom right corner underneath menu), examples:
10. To change position of signal in vertical direction use the vertical knob for Ch1.
11. To change position of the signal in horizontal direction use the horizontal position knob.
12. To freeze view of single signal depress the RUN/STOP button (press again to resume continuous signal) example of a good signal:

Plugging in a cable with a 50-ohm terminator

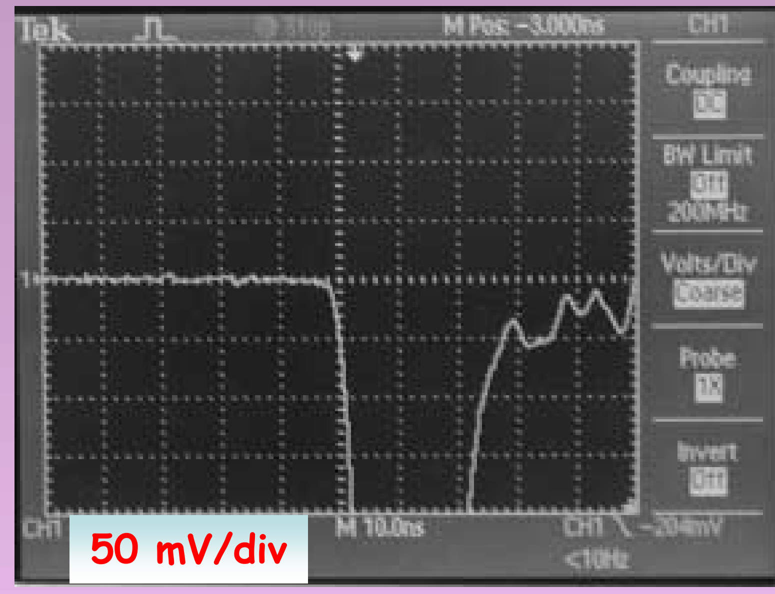
Adjusting the oscilloscope's vertical scale

What you DO want:

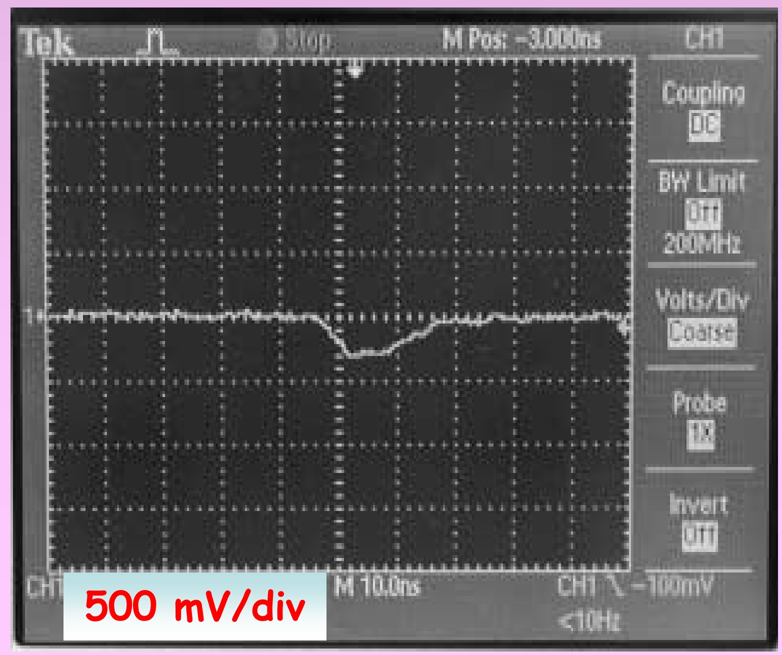


What you DON'T want:

A



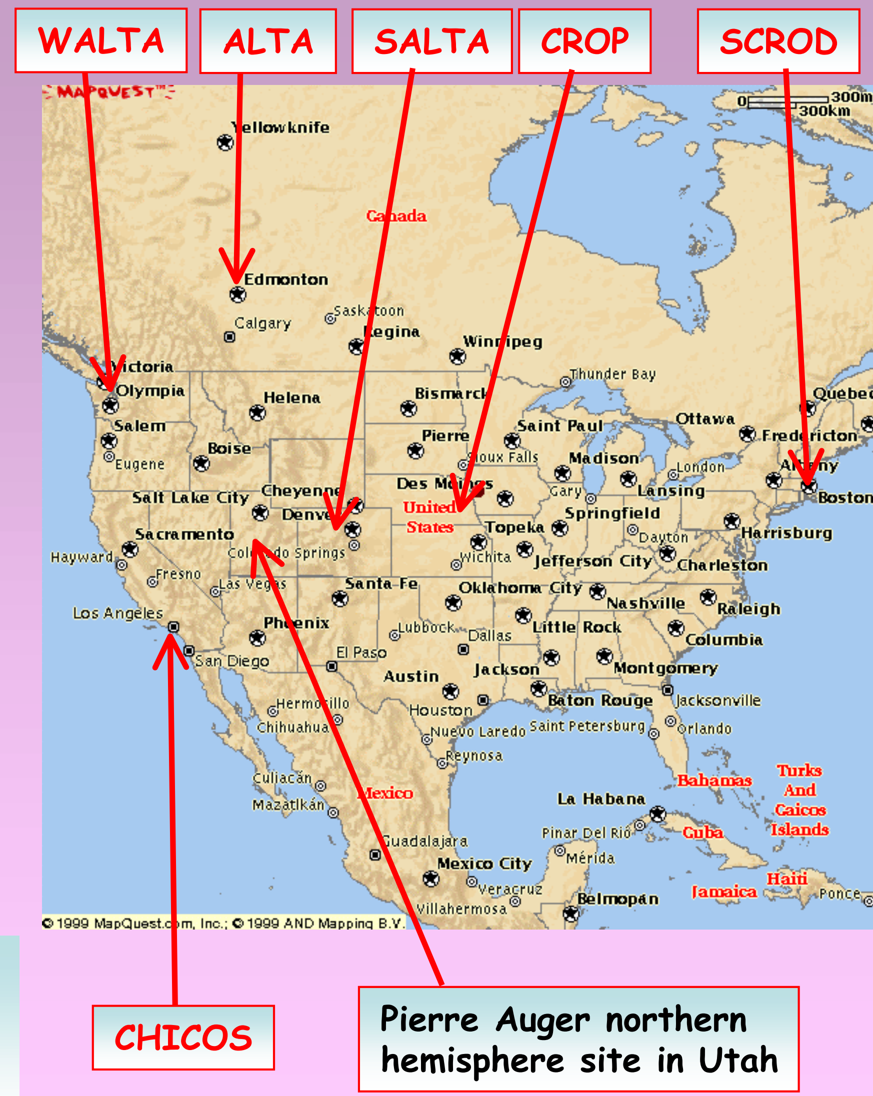
B



What happens when the mV/division is too small (A) or too big (B)?

NALTA

The North American Large-Scale Time-Coincidence Array



http://csr.phys.ualberta.ca/nalta/

- Includes links to individual project Web pages

QuarkNet

Sites in the U.S.

The Washington-Area Large-Scale Time-Coincidence Array

http://www.phys.washington.edu/~walta

Seattle area map showing schools

- CROP's closest relative
- Run by University of Washington, Seattle
  Jeff Wilkes, et al.
- WALTA also uses refurbished CASA detectors
- WALTA and CROP collaborating with Fermilab on data-acquisition electronics card
- Funding limited, but boost came by turning QuarkNet associate teacher workshop into WALTA workshop, August 2001

WALTA/QuarkNet One-week Summer Workshop
University of Washington
August 2001

Seattle teachers and WALTA staff

Refurbishing CASA scintillators

WALTA/QuarkNet Summer Workshop

Graduate student Heather Zorn giving oscilloscope lesson to teachers

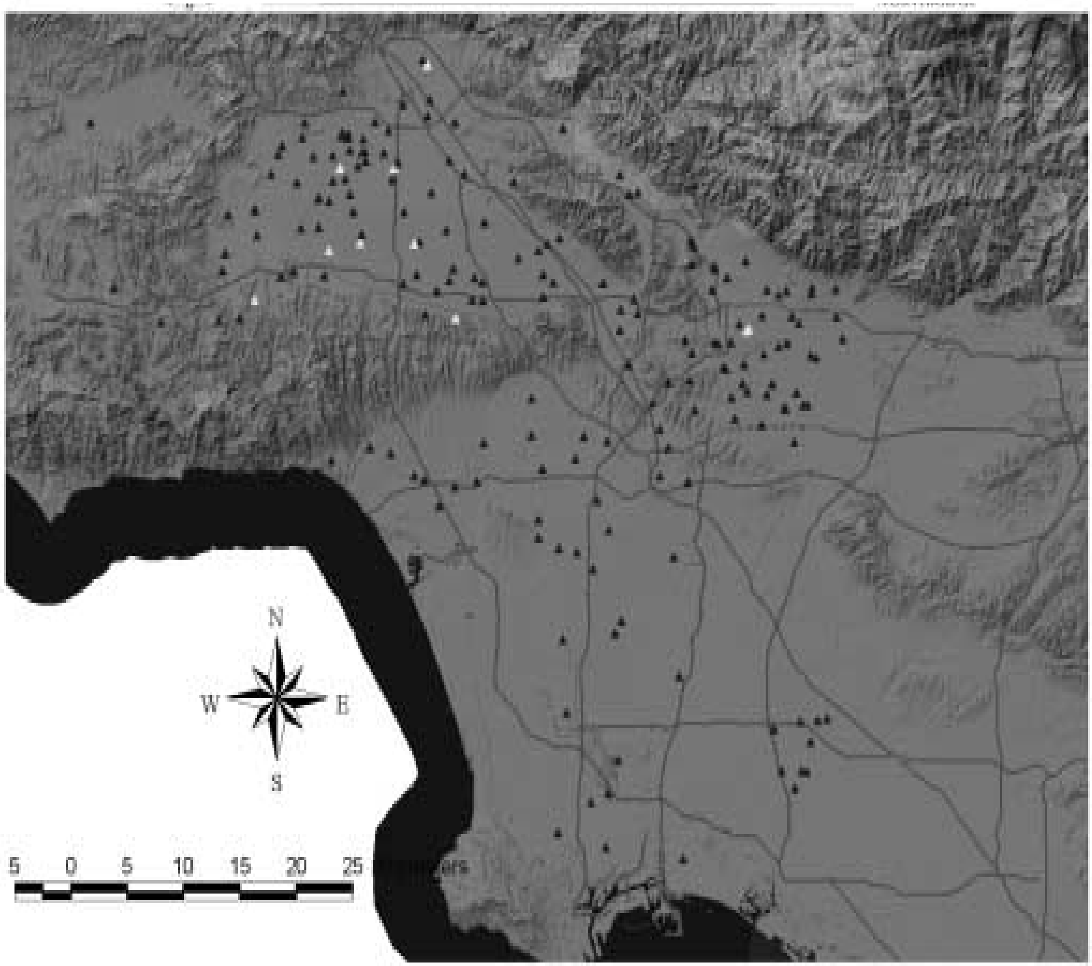
Working with NIM electronics

Rates from a two-layer telescope

California HIgh school Cosmic ray ObServatory

C H I C O S

Los Angeles Area Schools



(Animation by L.A. school teacher)

Institutions

- LA area schools
- California Institute of Technology
- California State University, Northridge
- University of California, Irvine

Funding

- Caltech
- NSF Nuclear Physics

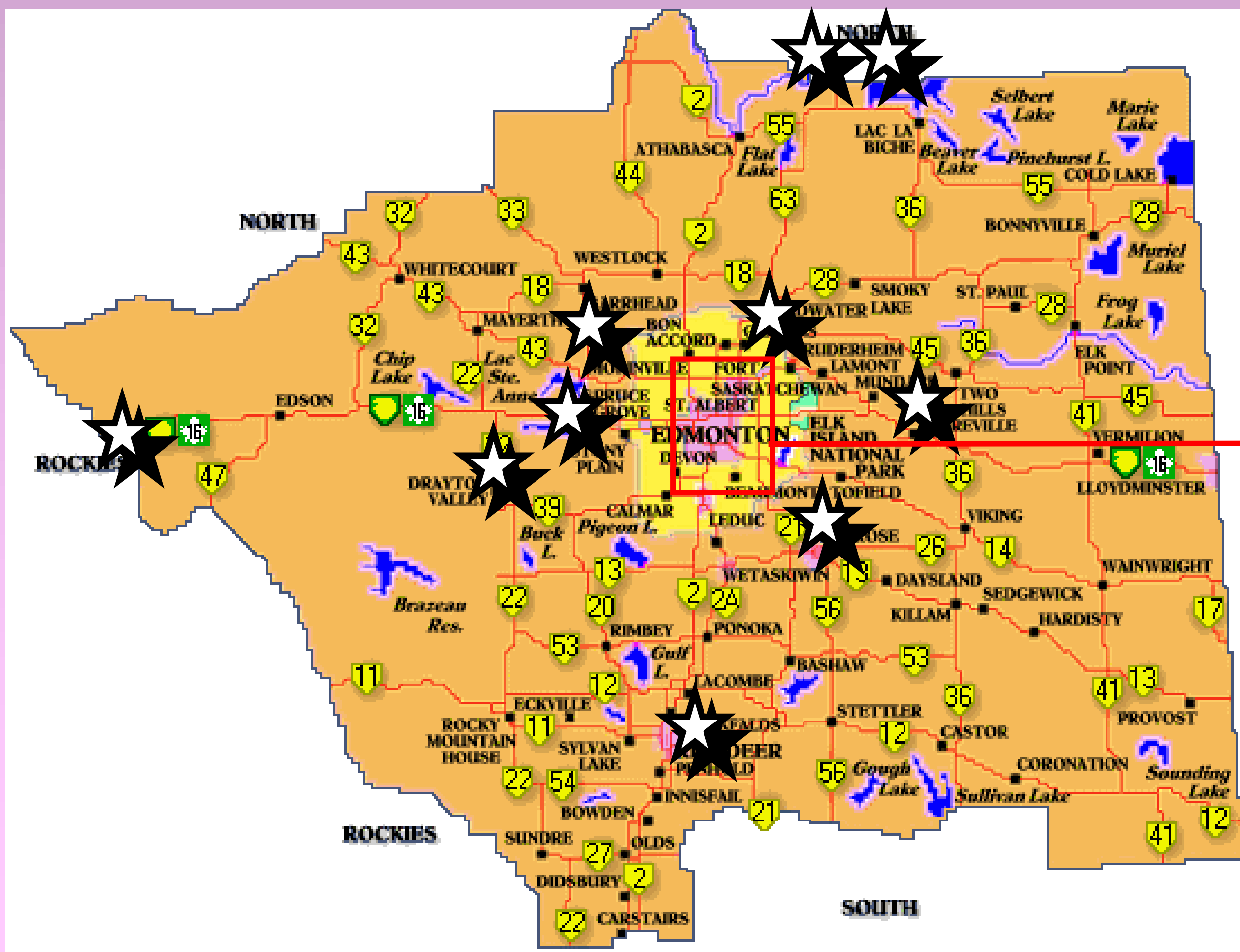
California HIgh school Cosmic ray ObServatory

C H I C O S

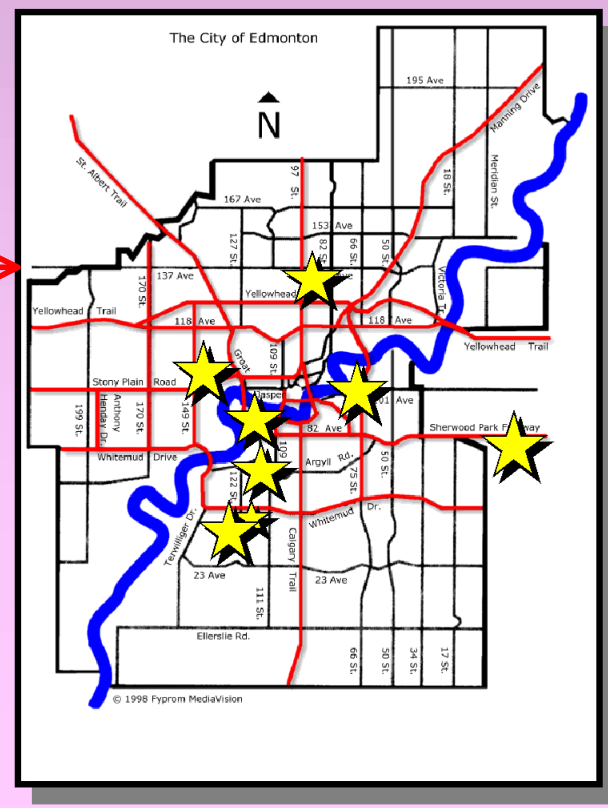
- 164 detector stations recovered
- 2 detectors per school foreseen
- About 39 schools in process of being outfitted

ALTA: The Alberta Large-Scale Time-Coincidence Array

- Run by the University of Alberta, Edmonton
- Jim Pinfold, John McDonald, et al.
- Funding: Canadian research and education organizations and corporate sponsorship

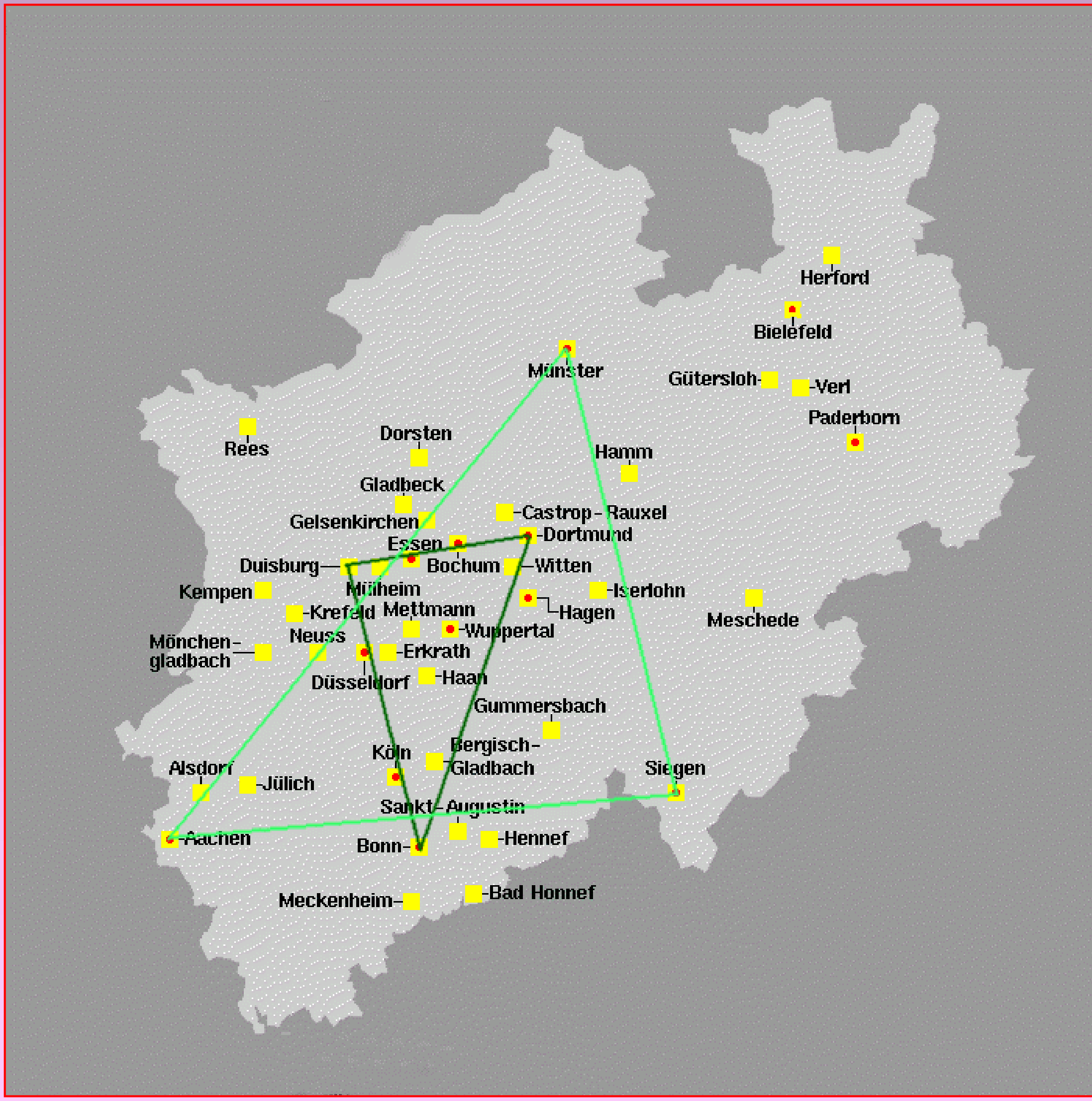


City of Edmonton



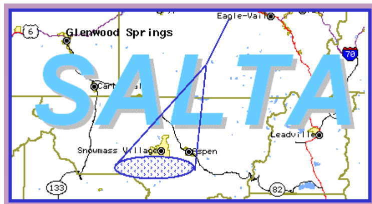
The NRW Array: NordRhein, Westfallen Array

http://nrw-array.de

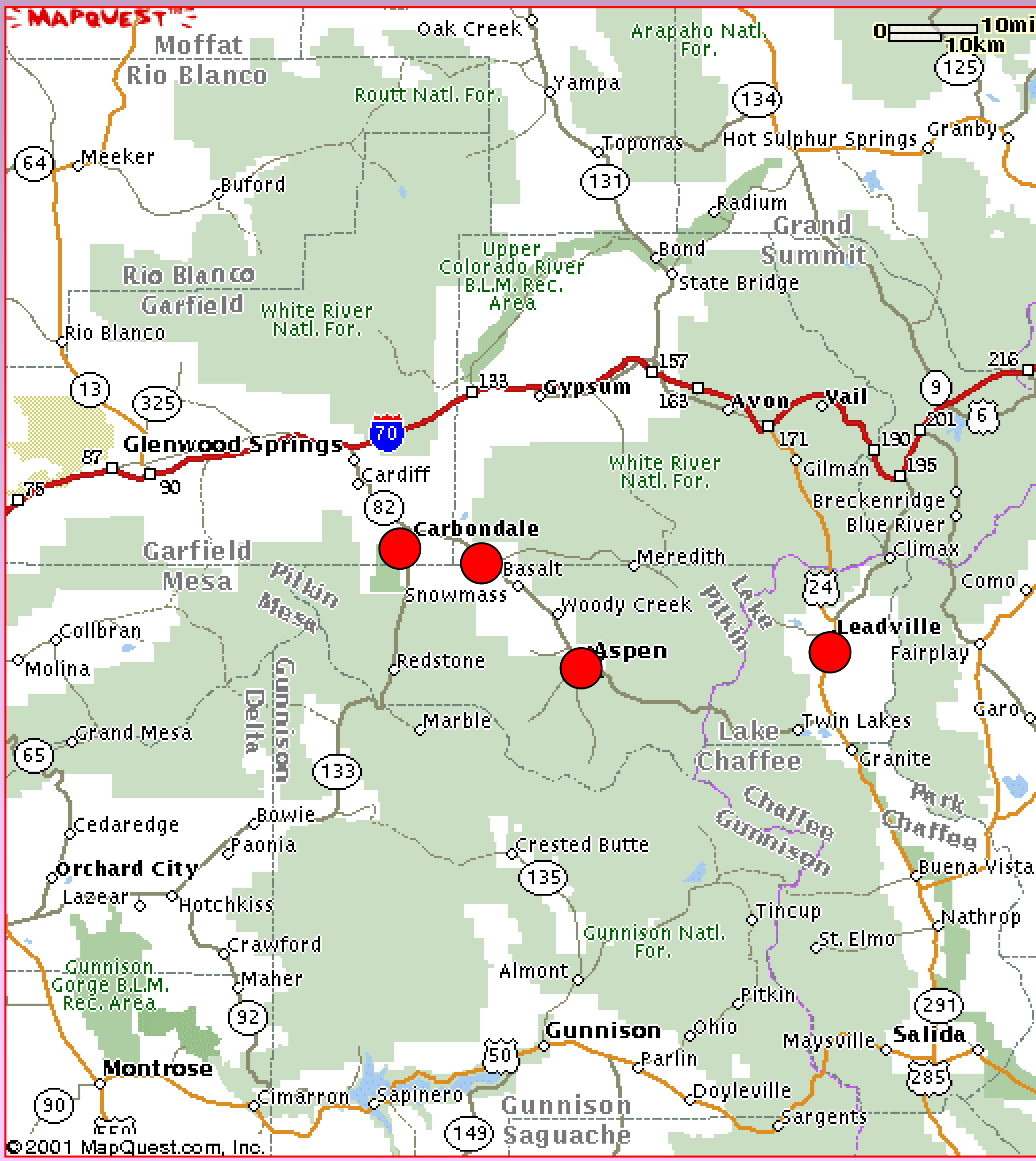


Target cities in northwestern Germany

- **Project in its early stages**
- **Headed by Karsten Eggert, CERN and Hinrich Meyer, Wuppertal**
- **Funding possibilities from German government and telecommunications industry**
- **First scintillator prototypes at a Fachhochschule in Düsseldorf**



SALTA: Snowmass Area Large Time-Coincidence Array



Colorado

- Aspen High School, Aspen, CO
- Basalt High School, Basalt, CO
- Roaring Fork Valley High School, Carbondale, CO
- Lake County High School, Leadville, CO
  The highest-elevation school in the U.S. -- 10,152 feet ASL

Illinois

- Wheaton North High School, Wheaton, IL

Austrian physicist Victor Hess on his 1912 balloon flight to study the origin of cosmic rays.

Celebrating 90 years of cosmic ray research 1912 - 2001

Sponsored by the Snowmass Area Large-scale Time-coincidence Array SALTA

Replica of Hess' Electroscope

Portable Geiger Counters

Wilkes in Hessian Outfit

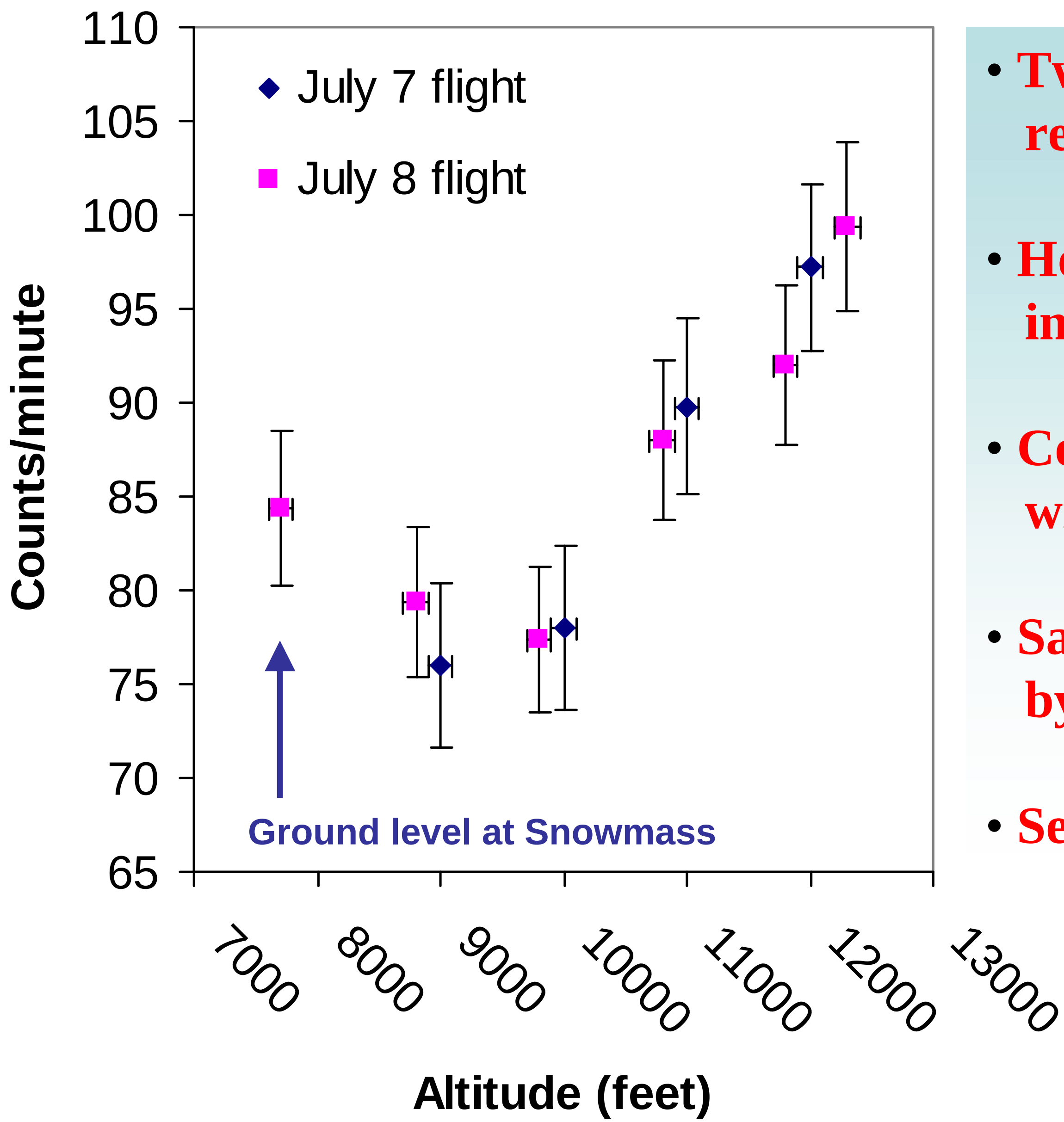
Crowd gathers to watch Victor Hess flight reenactment

Lift off !

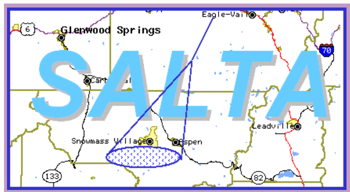
Unicorn Balloon Company, Snowmass, CO

Data transmitted live to ground via radio

Snowmass Balloon Flight 2001



- **Two flights with consistent results**
- **Hovered at 1000 ft increments in altitude for 5 minutes**
- **Cosmic ray rates measured with portable Geiger counters**
- **Same effects observed by Victor Hess**
- **See FermiNews, July 27, 2001**



SALTA Workshop, July 2001, Snowmass, CO

Polishing scintillator panel edges outside Conference Center

Applying optical cement to glue phototube

Many phototubes glued at once

SALTA Workshop, July 2001, Snowmass, CO

Final cleaning

Making detectors light-tight

Aluminum foil wrapping

SALTA group photo

CROP's Advisory Panel

Ron Bonnstetter: UNL Professor of Curriculum and Instruction

Susana Deustua: American Astronomical Society

Olivia Diaz: Former director of SciTech, Aurora, IL

Ernie Malamud: Fermilab, founding director of SciTech

Paul Mantsch: Fermilab, Pierre Auger Observatory

Gregory Neul: Inst. for Science Education, Columbia College, Chicago

John Rogers: Physics teacher, Westside High School, Omaha

Conclusions

* CROP, in its 4th year, will soon reach a major milestone: Simultaneous data-taking at all schools, offline searches for extensive air shower coincidences

* Other emerging efforts will enable the NALTA consortium to search for very long-range correlations

* Curriculum, hardware, software has been developed to facilitate the start-up of new efforts