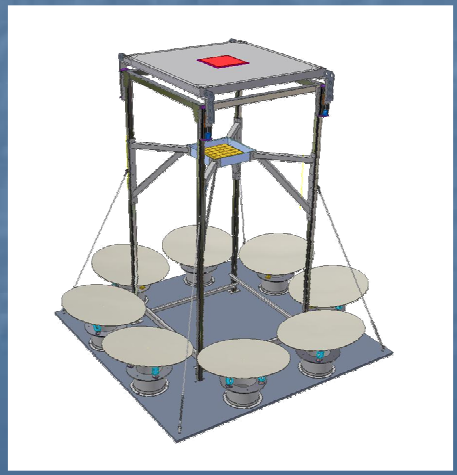
High Resolution Measurements of Cosmic-Ray Air Showers with the Track Imaging Čerenkov Experiment



Elizabeth Hays

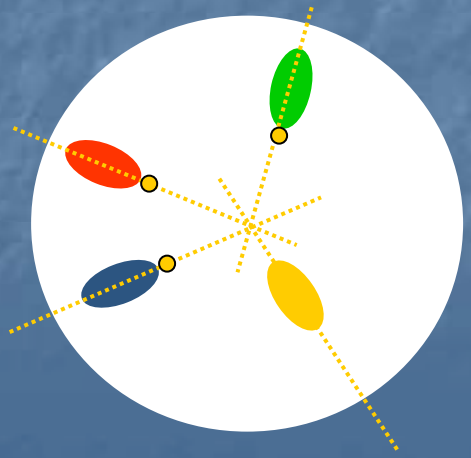
U. Chicago and
Argonne National Lab

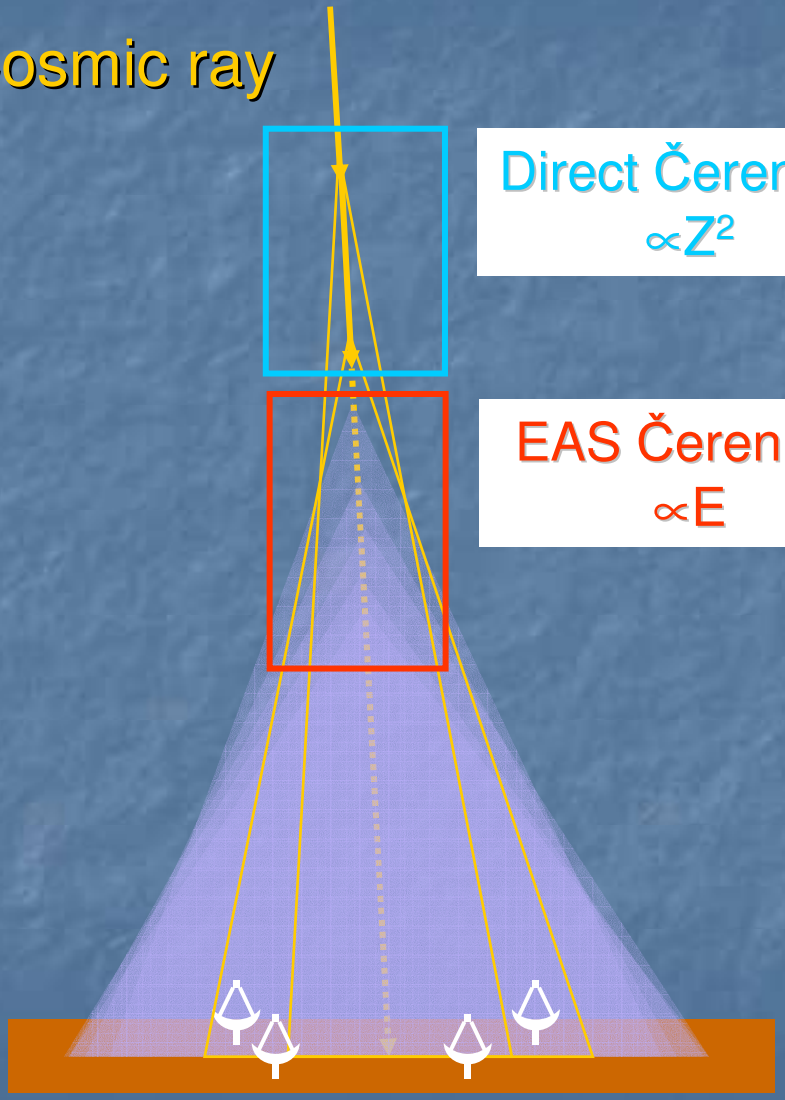
Overview

- Instrument specifications for imaging *direct* Čerenkov light
- TrICE prototype instrument description
- Multi-anode PMT (MAPMT) camera
- Preliminary results

Direct Čerenkov Emission

- Charged cosmic rays generate Čerenkov light before first interaction – direct Čerenkov
- At TeV-PeV energies DČ detectable on the ground
- Separate DČ and EAS components to measure composition





Instrument Requirements

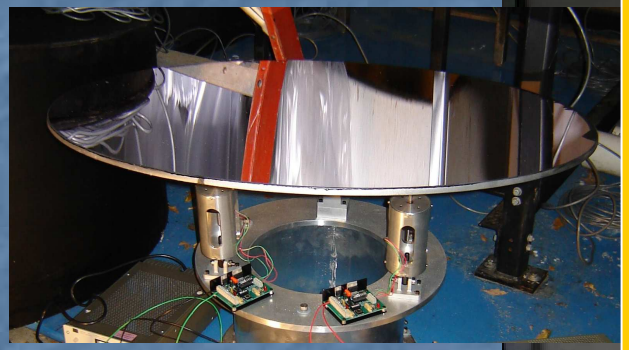
- From Kieda, Swordy, and Wakely (2001)
  - DČ signal is compact in space and time
  - Imaging Atmospheric Čerenkov Telescopes (IAČTs) could separate DČ light from extensive air shower light
    - **0.01°** angular resolution on sky
    - **0.5 ns** time resolution
- Caveats
  - Depends on primary charge and energy
  - Depends on impact parameter
- Current IAČTs
  - Most commonly ~0.15° pixel spacing
  - 2 ns FADC (VERITAS)

TrICE People

Argonne National Laboratory:	K. Byrum, G. Drake, E. Hays, E. Kovacs, S. Magill, L. Nodulman, R. Wagner
University of Chicago:	R. Northrop, S. Swordy, S.P. Wakely, S.A. Wissel
University of Utah:	D. Kieda
Loyola University:	J. Cunningham

The TrICE Prototype

Sited at Argonne National Lab (outside Chicago, IL)

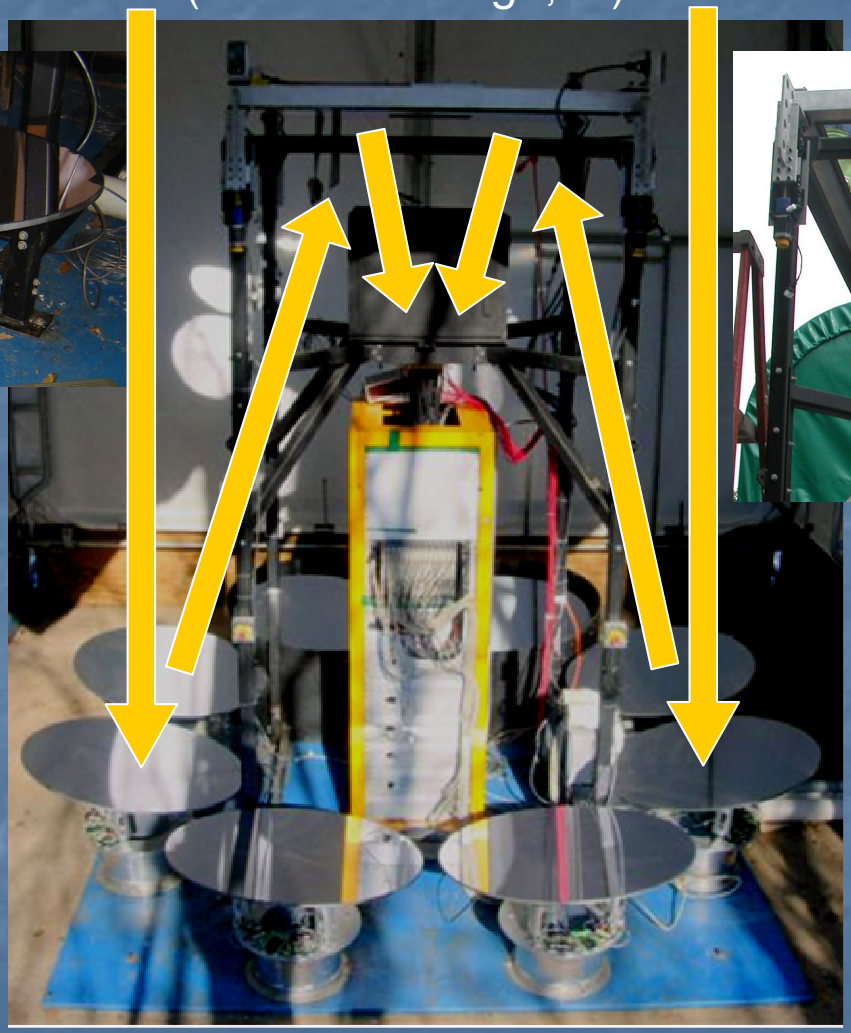


MINOS prototype electronics modules

53 MS/s (18.9 ns) pipeline ADC

Dynode & external TTL trigger inputs

Data acquisition via single-board CPU



Primary optics
8 spherical mirrors

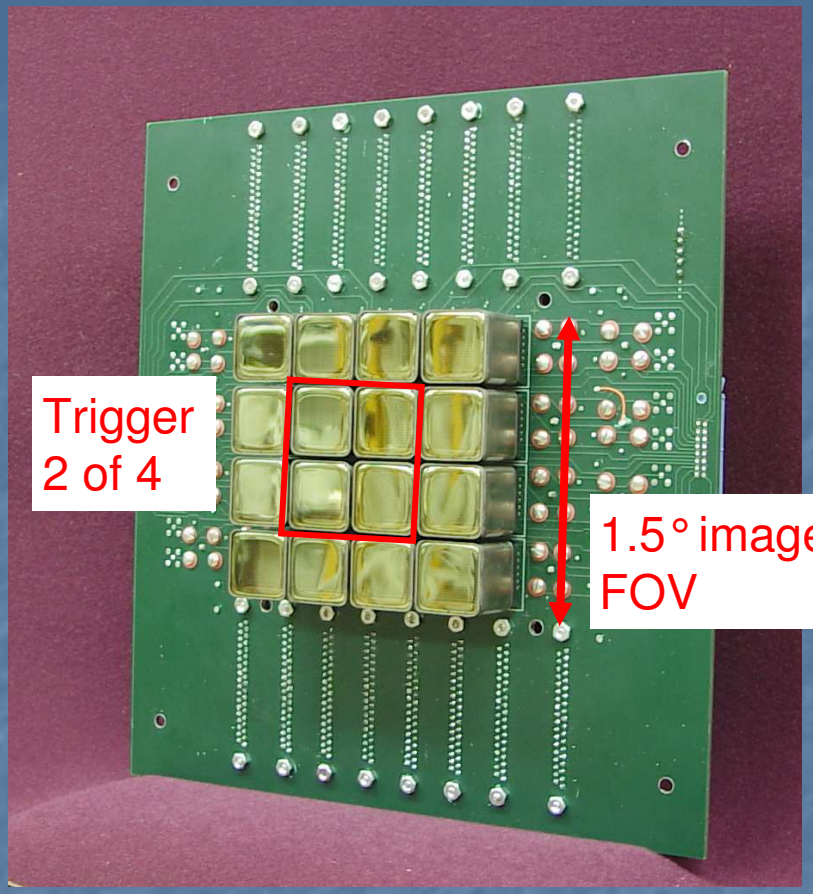
Secondary optics
Plane mirror

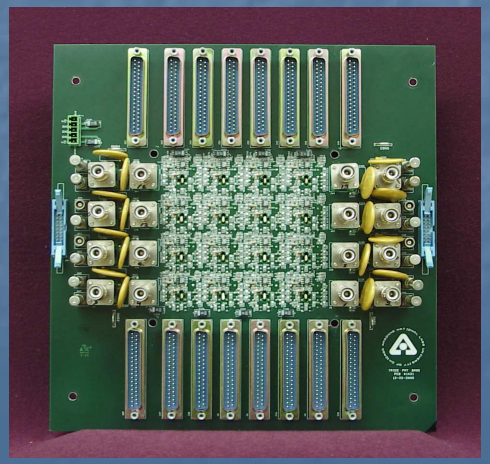
Trigger optics
Fresnel lens

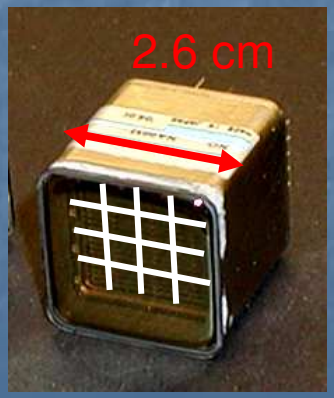
See S.A. Wissel poster, “Status of TrICE”

TrICE Camera

- 4 x 4 array of 16-channel Hamamatsu R8900 multi-anode photomultipliers (2.6 cm width)
- Total pixels: 256
- Pixel width: 0.086°
- Trigger FOV: 3° (Fresnel)
- Image FOV: 1.5°

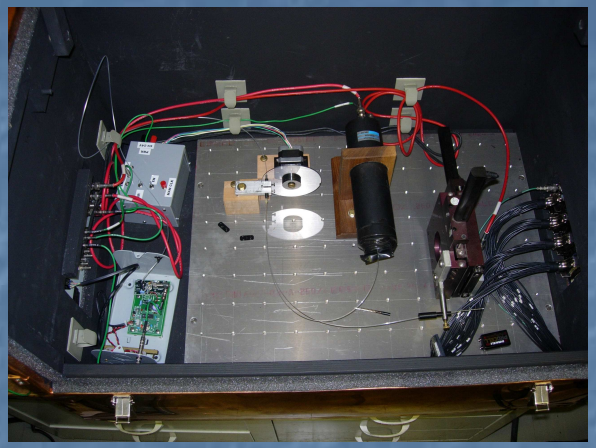




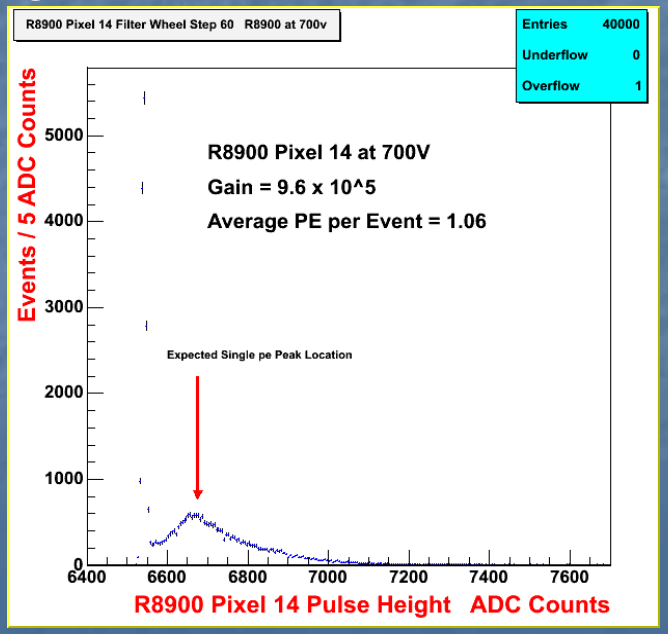


- Socket mounted
  - High voltage feed through
  - Anode / dynode signal access
  - Current monitor

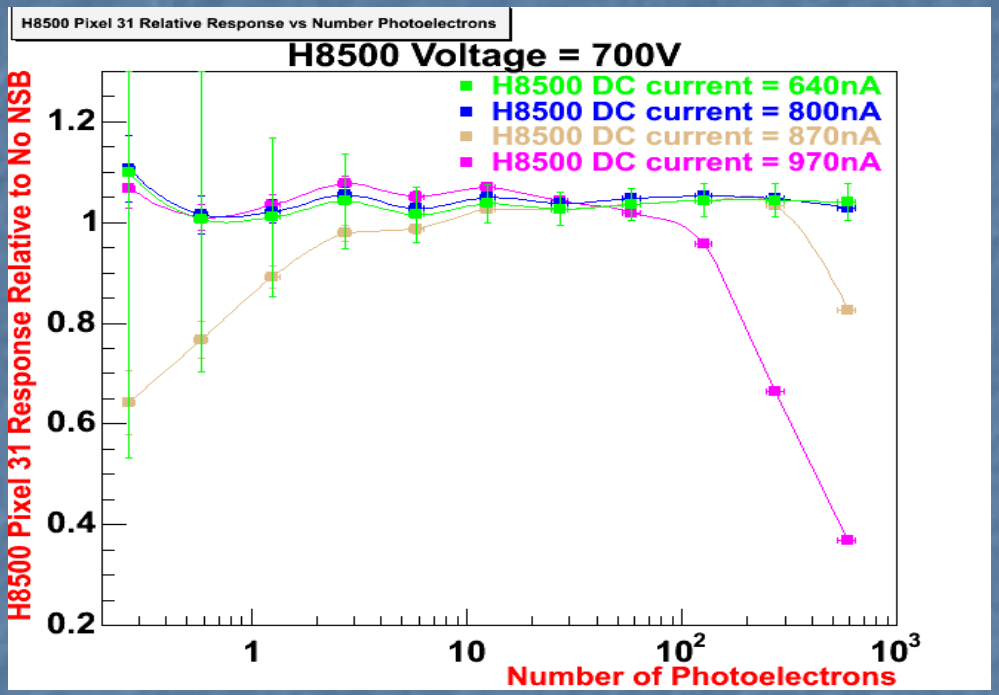
Multi-Anode PMT Studies



Single Photoelectron Resolution



Gain Linearity

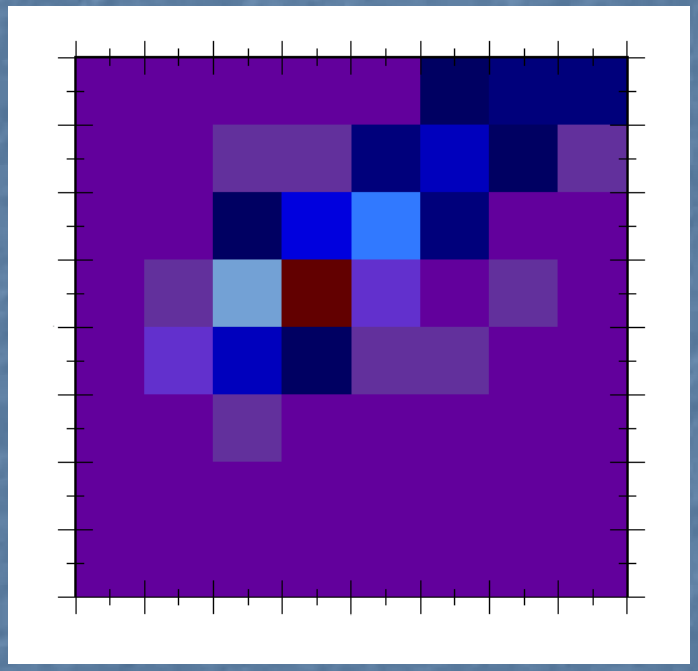


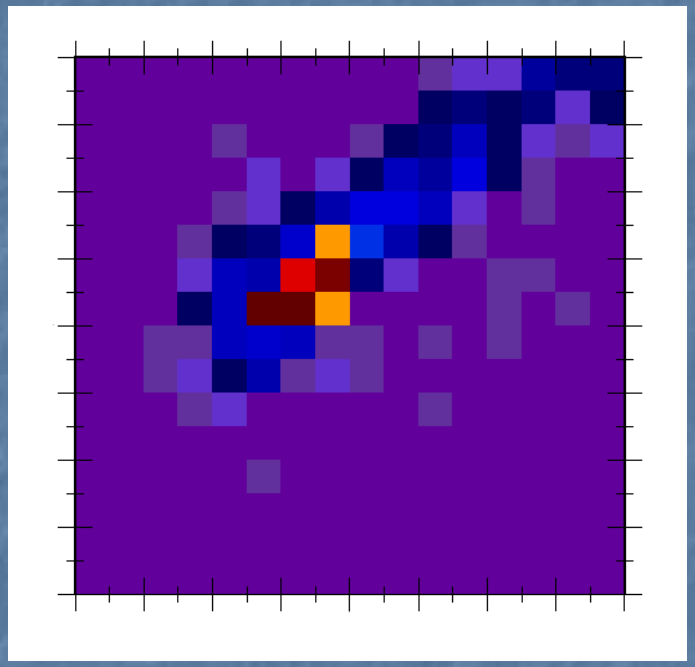
- MAPMT base modified for high-current operation
  - ~20 uA per MAPMT at 600 V
  - Operating gain ~2 x 10^5

See K. Byrum poster, "TrICE Prototype MAPMT Imaging Camera"

High Resolution Shower Images

Pixel = 0.17° x 0.17°





Pixel = 0.086° x 0.086°

Time Development

TrICE Event Movie
19 ns sampling

TrICE Event Movie
19 ns sampling

Conclusions

- Construction of TrICE prototype complete
- MAPMT camera successfully imaging cosmic-ray showers at high resolution (<0.1°)
- Analysis ongoing
- Future avenues of development
  - Fast electronics
  - Larger FOV
  - Increased collection area
  - Multiple imagers