FLASH

FLuorescence in ***A***ir from ***SH***owers

(SLAC E-165)

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SLAC

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*Fl*uorescence from *A*ir in *Sh*owers (FLASH)

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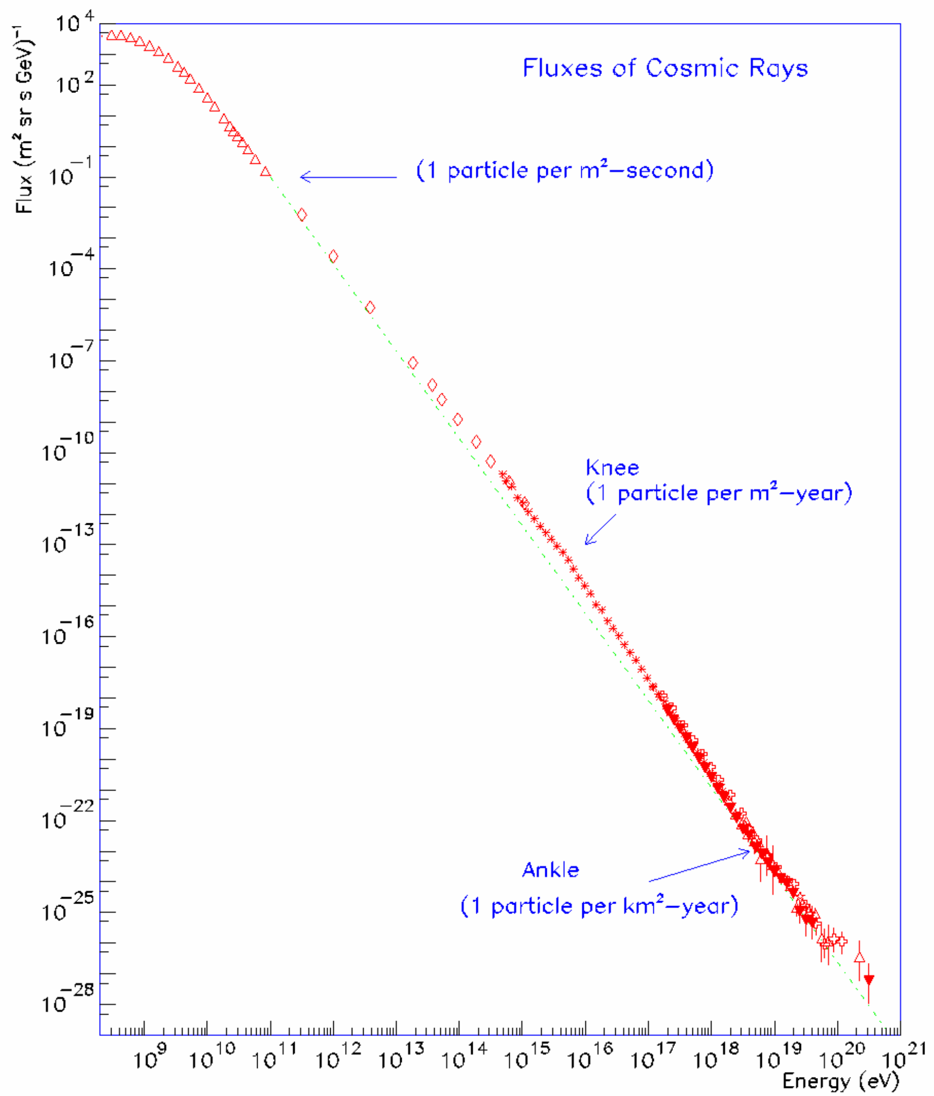
* Collaboration Spokespersons

Ultra High Energy Cosmic Rays

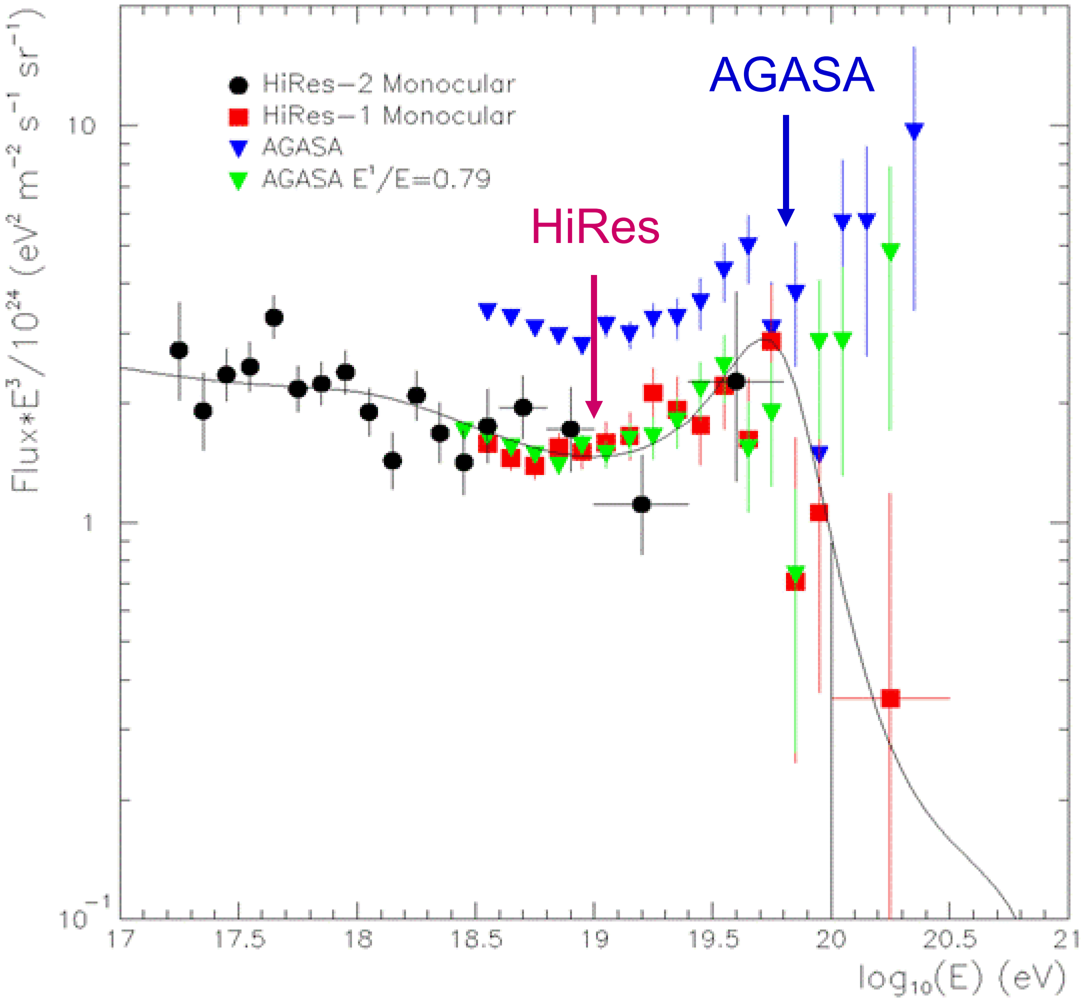
- Cosmic Rays have been observed with energies beyond 10^{20} eV
- The ***flux*** (events per unit area per unit time) follows roughly a ***power law:*** $\sim E^{-3}$
- Changes of power-law index at “knee” and “ankle”.

⇨ Onset of different origins/compositions?

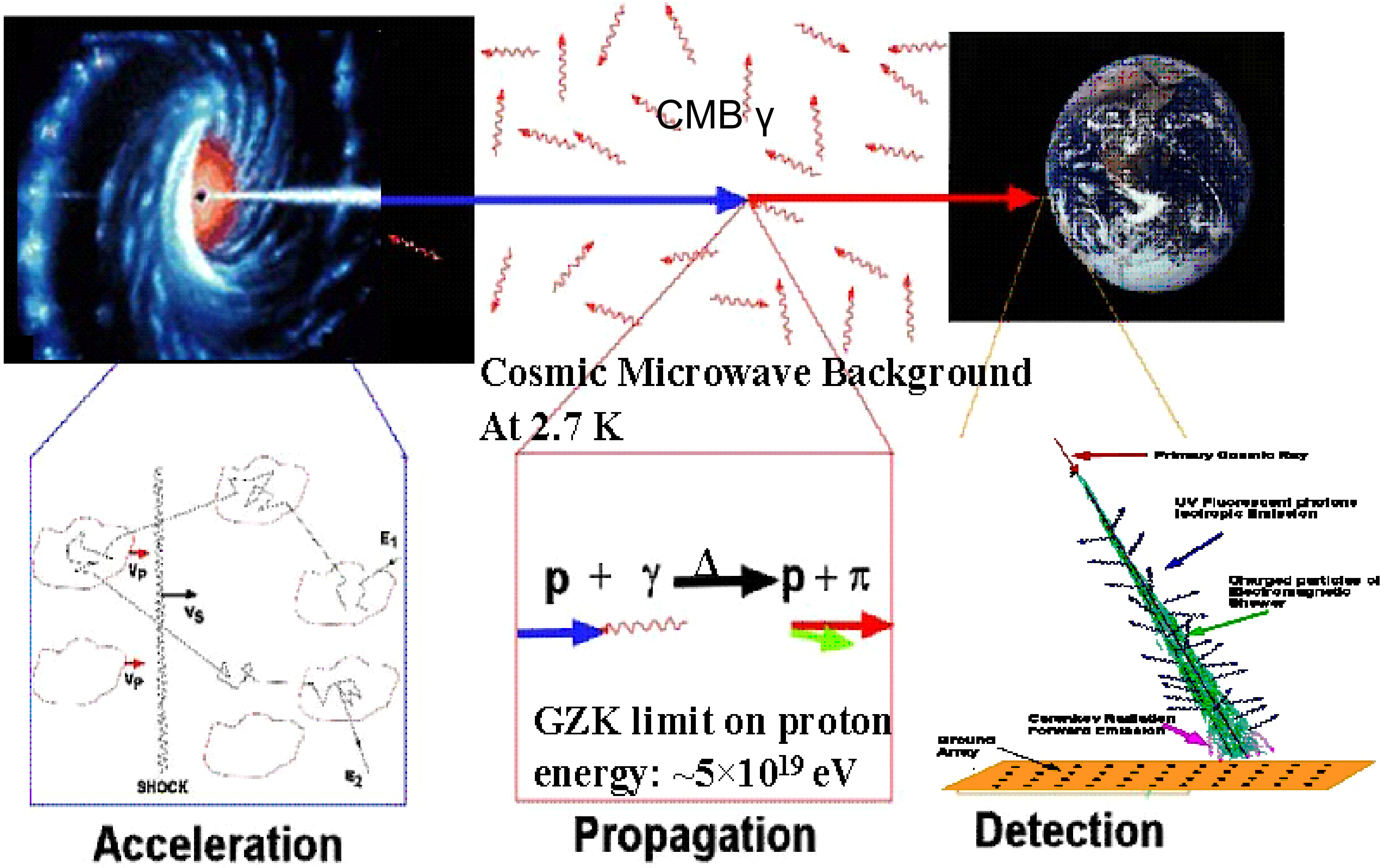
⇨ Where does the spectrum stop?



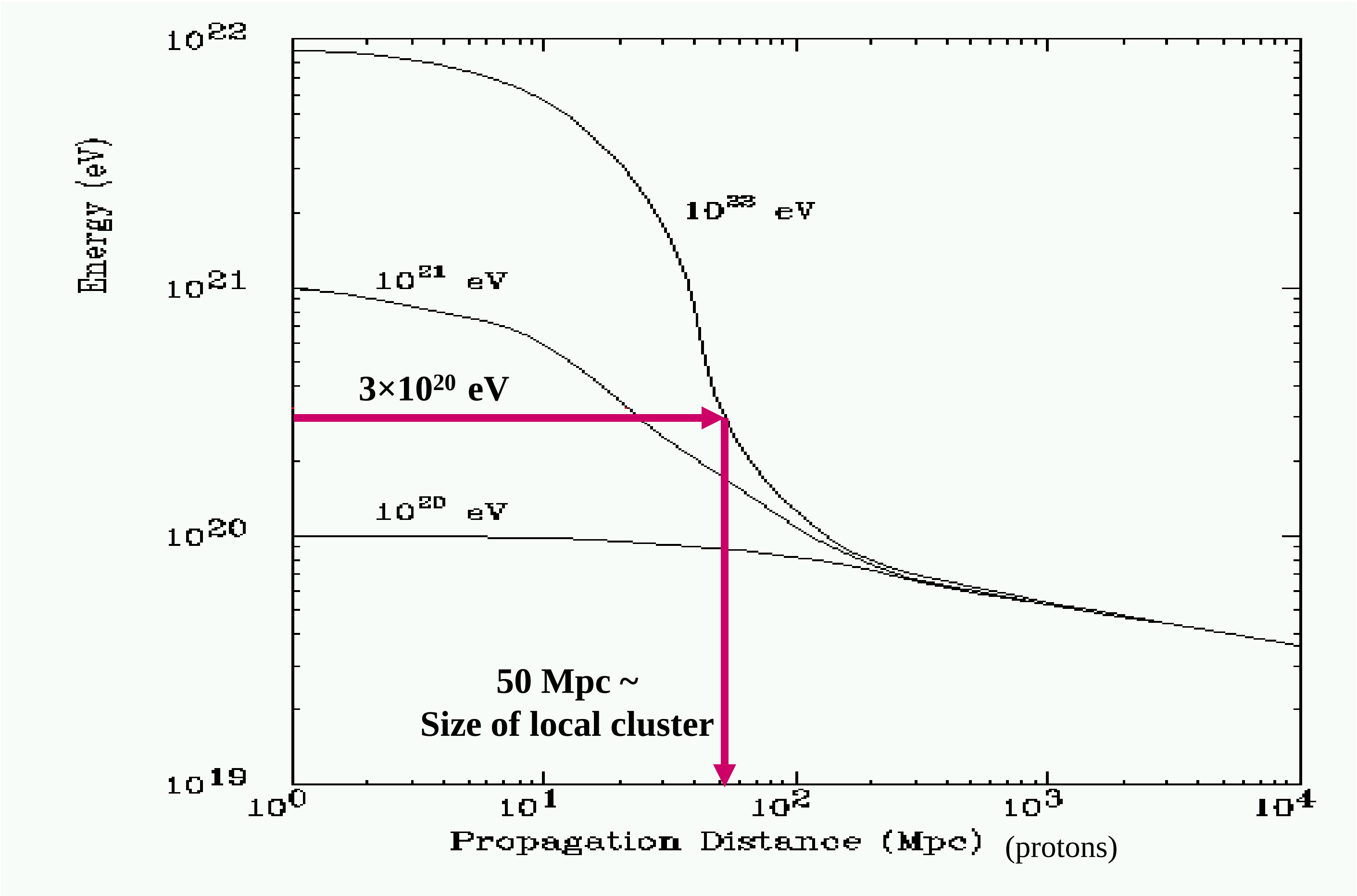
Discrepancy Between Two UHECR Experiments



UHECR: From Source to Detector



Greisen-Zatsepin-Kuzmin Cutoff

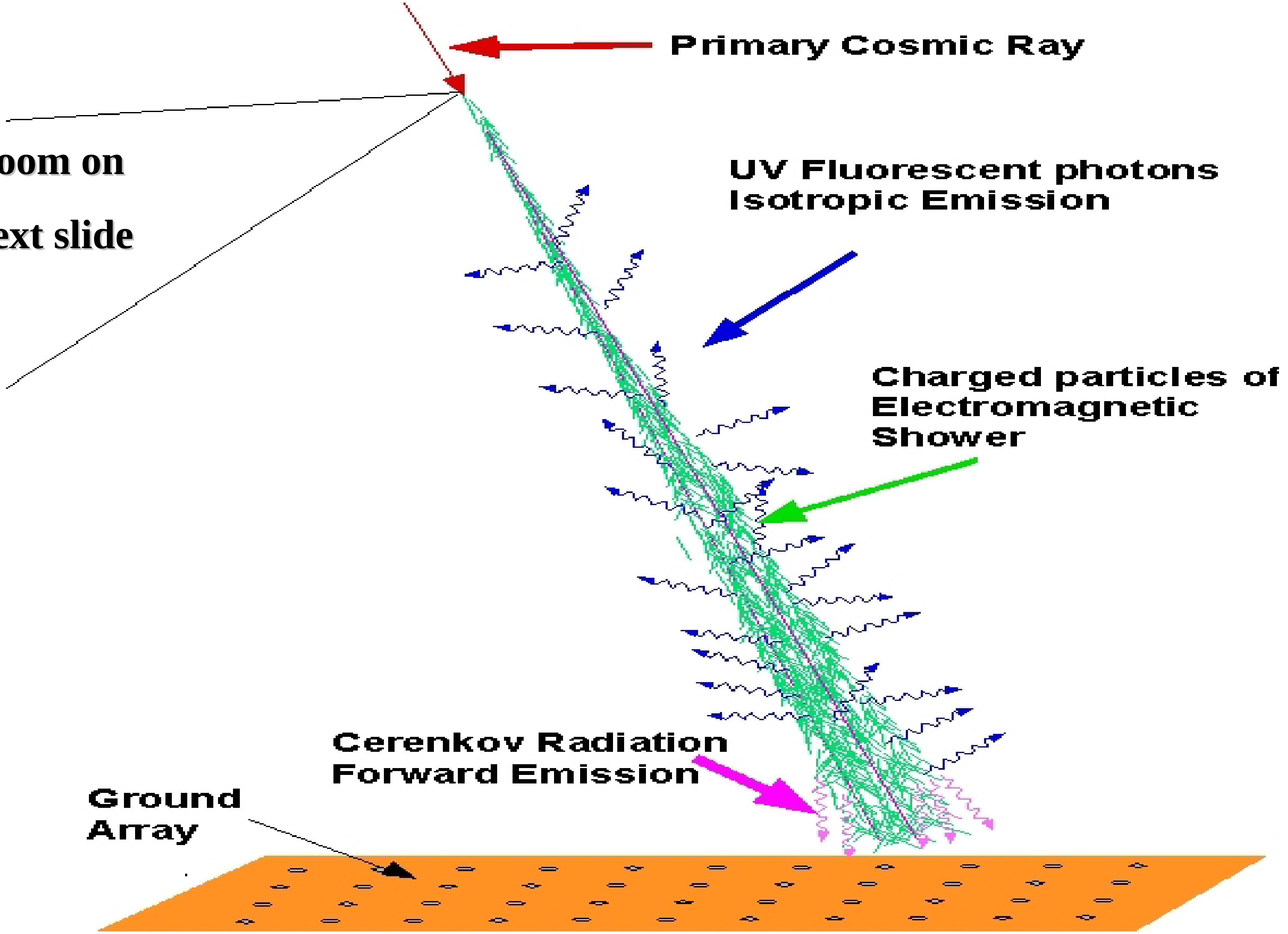


- Protons above 6×10^{19} eV will lose sizable energy through CMB
- Super-GZK events have been found with no identifiable local sources

Extensive Air Showers

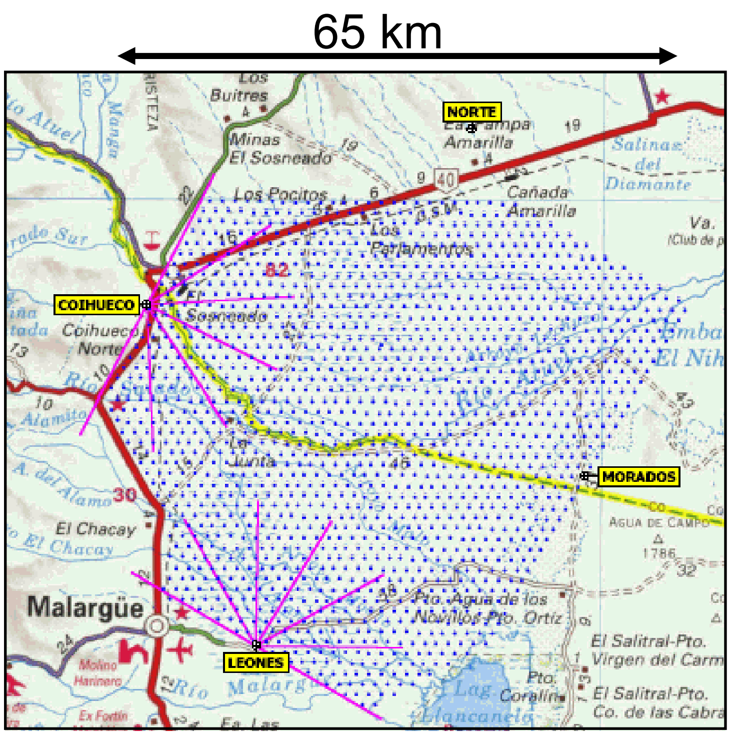
Zoom on

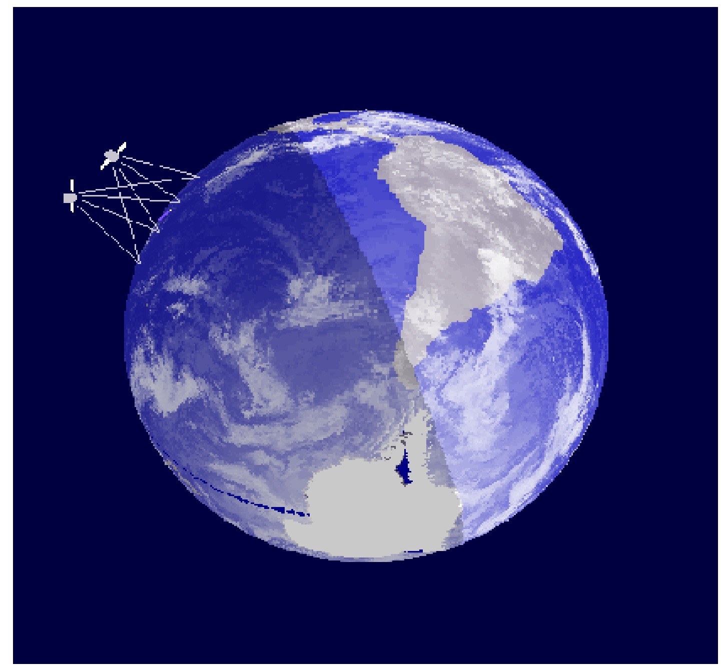
next slide



FLASH useful for future UHEC Experiments

- Ground-Based: The Pierre Auger Observatory
- Space-Based: EUSO, OWL/AirWatch





- Hybrid detection
- Relies purely on Fluorescence

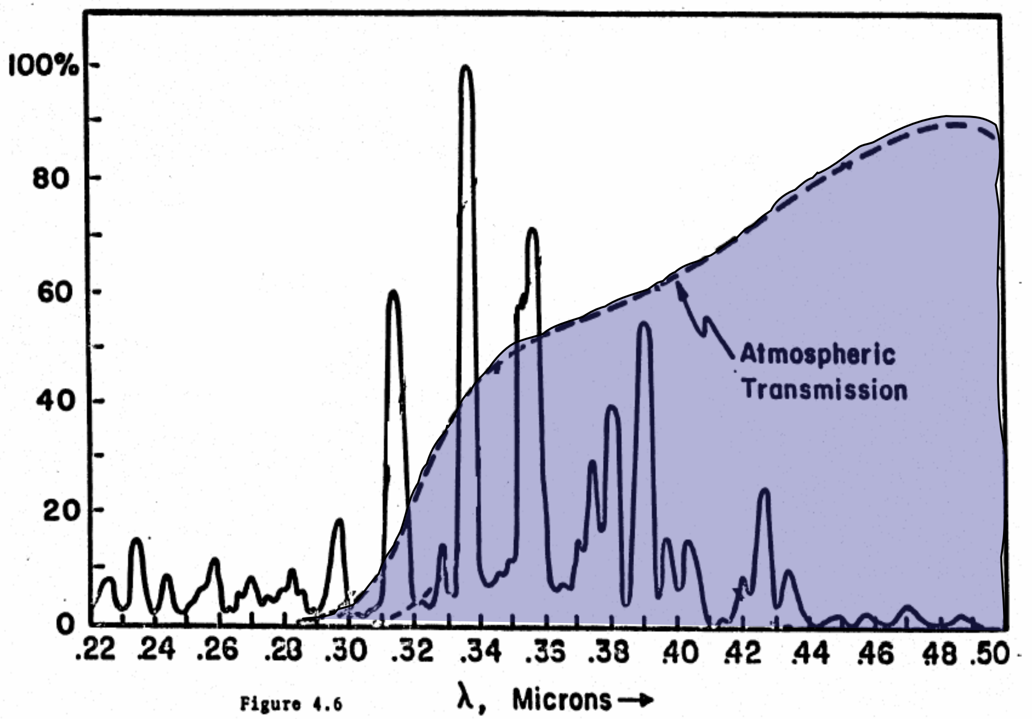
Issues of Fluorescence

- Detailed shape of the fluorescence spectrum
  - Spectrally resolve fluorescence yield
  - Use narrow band filters or spectrometer
- Pressure dependence of the fluorescence yield
  - Total and individual line pressure dependence
- Effects of impurities on fluorescence yield
  - CO_2, Ar and H_2O
- Effects of electron energy distribution on yield

Importance of Spectral Distribution

- At large distances of up to **30 km**, which are typical of the highest energy events seen in a fluorescence detector, knowing the **spectral distribution** of the emitted light becomes essential due to the λ^{-4} attenuation from **Rayleigh scattering**.

Bunner (1967)



Previous Fluorescence Measurements

- A.N. Bunner, PhD thesis, Cornell (1967)
  - Compiled a spectrum from many sources.
  - Unknown systematic errors.
- F. Kakimoto et al., NIM (1996)
  - Measured 3 narrow band lines not a spectrum.
- M. Nagano, FIWAF presentation (2002)

Why Measuring Fluorescence at SLAC?

- Extensive Air Showers (EAS) are predominantly a superposition of EM sub-showers.
- FFTB beam-line provides energy equivalent showers from ~10^{15} to ~10^{20}eV.
  - 10^{7}-10^{10} electrons/pulse at 28.5 GeV.

Objectives

- Spectrally resolved measurement of fluorescence yield to better than 10%.
- Investigate effects of electron energy.
- Study effects of atmospheric impurities.
- Observe showering of electron pulses in air equivalent substance (Al_2O_3) with energy equivalents around 10^{18} eV.

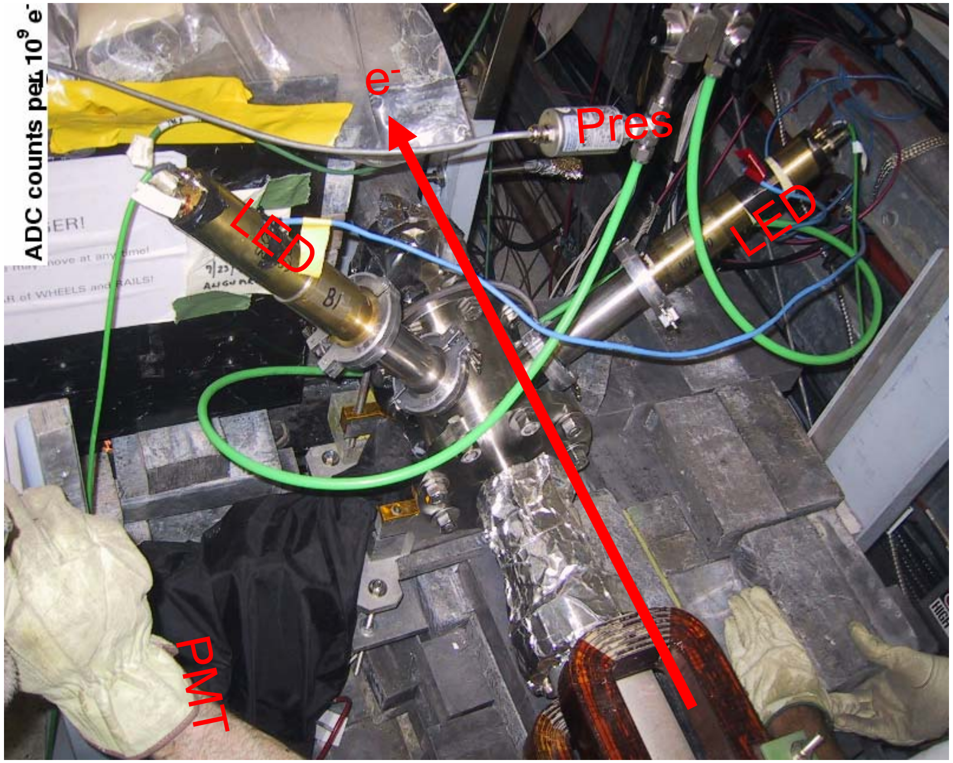
THIN TARGET STAGE

- Pass electron beam through a thin-windowed air chamber.
  - Measure the yield over wide range of pressures at and below atmospheric.
  - Measure the total fluorescence yield in air.
  - Measure emission spectrum using narrow band filters or spectrometer.
  - Effects of N_2 concentration. Pure N_2 to air. Also H_2O, CO_2, Ar, etc.

FLASH Experimental Design

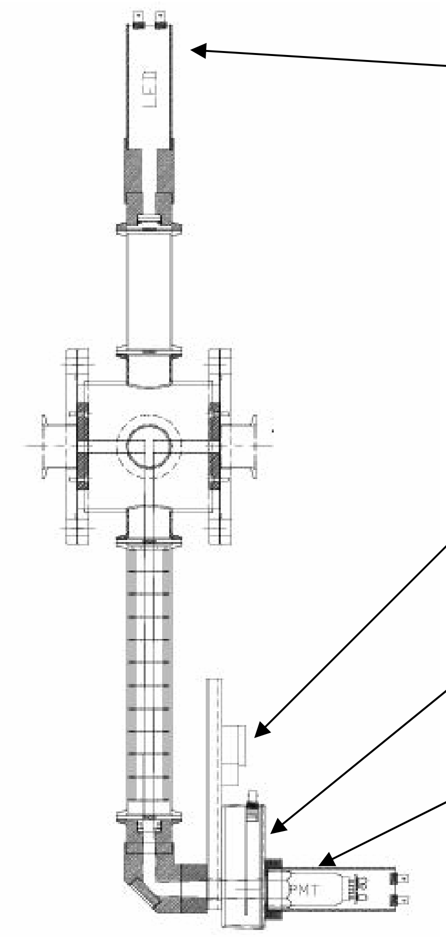
Thin Target Stage

- Electron beam passes (5×10^7-5×10^9 e^-/pulse) through a chamber of air. 1x1 – 2x2 mm beam spot.
- HiRes PMTs are used to measure the fluorescence signal.
- 1 cm gap well defined by interior tubes.
- Interior blackened and baffled.



FLASH Experimental Design

Thin Target Stage



- Opposing LED calibration source.
- Remotely controllable filter wheel.
- Post filter LED calibration sources (4)
- Signal PMT.
- Symmetric system allows for 2 of each.

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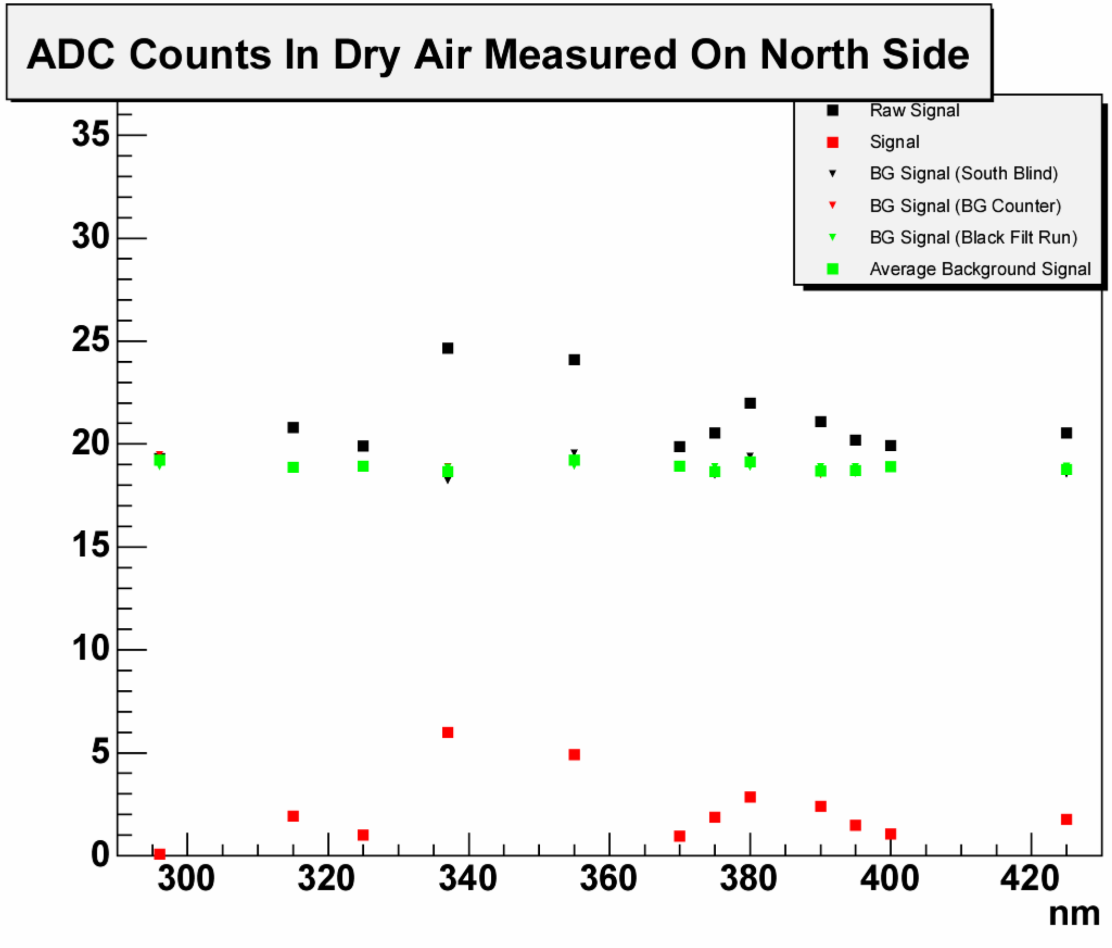
Background Subtraction



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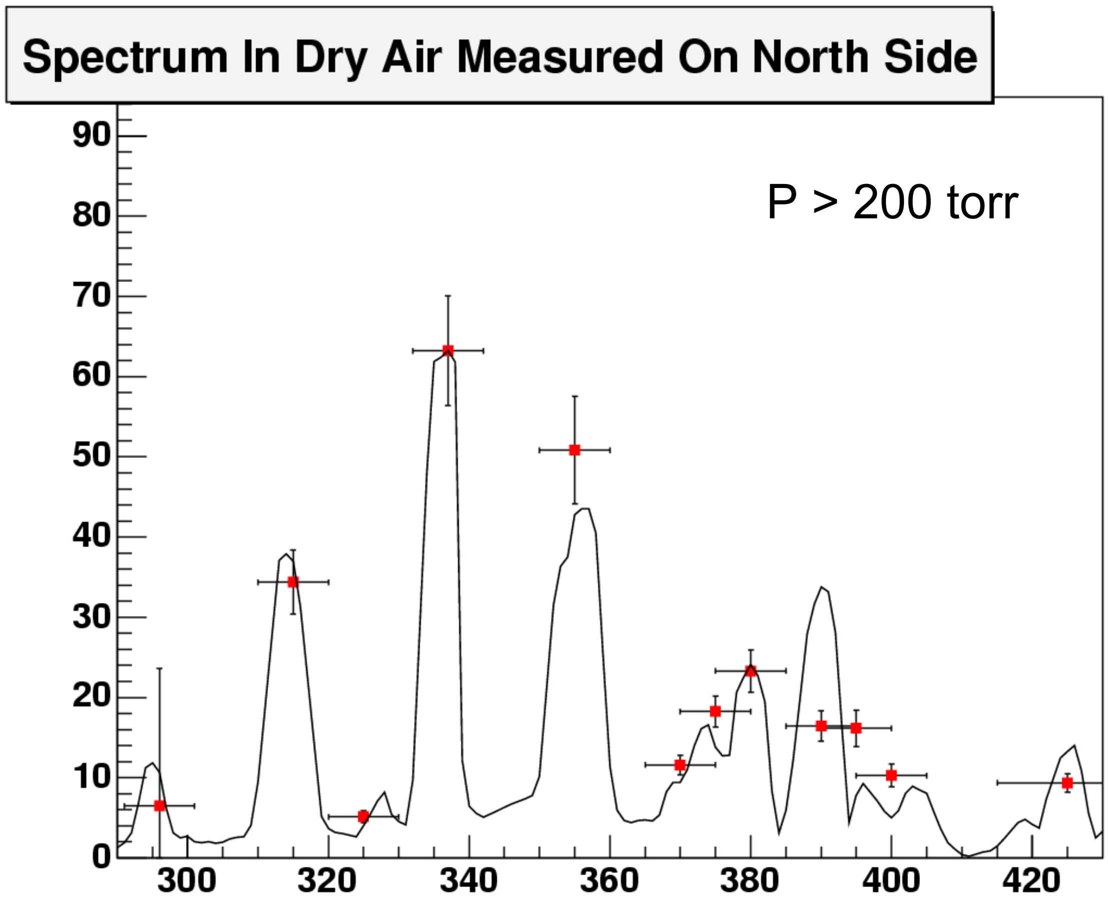
Fluorescence Spectrum Using Filters



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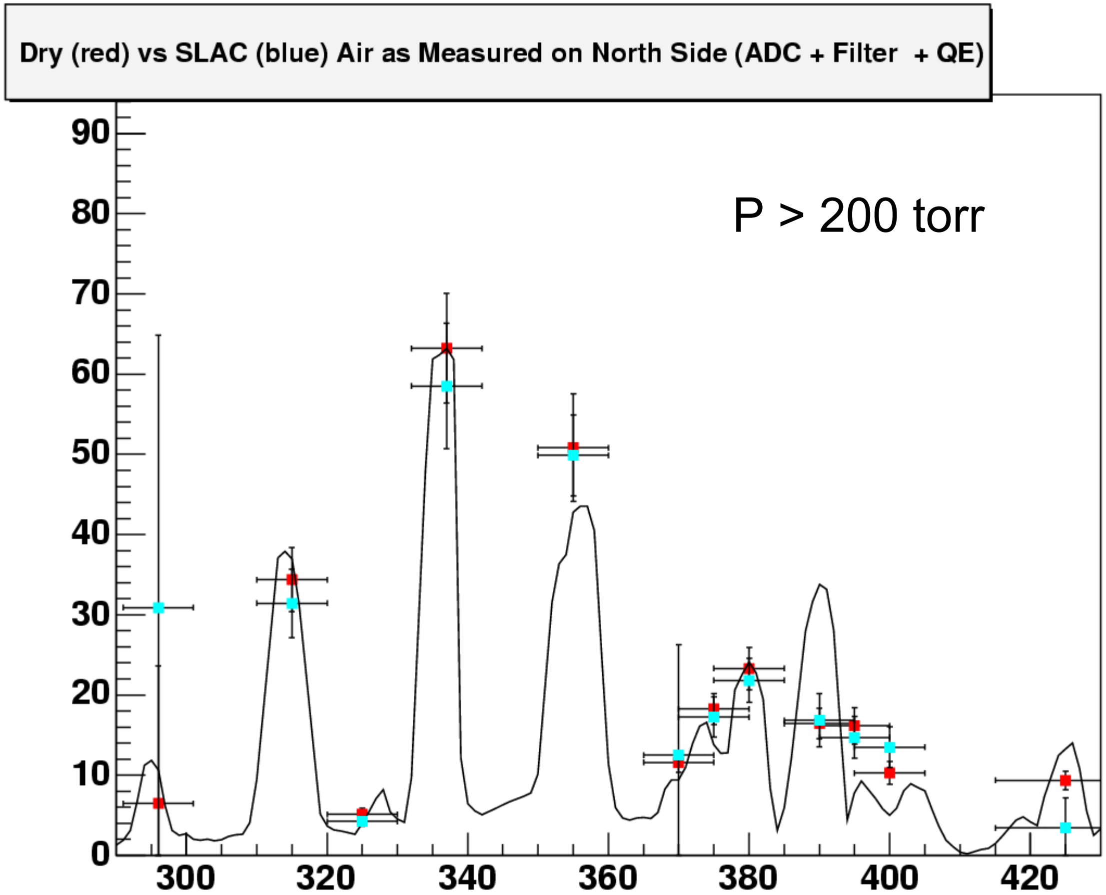
Effect of Humidity



Around 5% lower but within error. Expectation from Theory is that 1% H_2O gives 6% reduction in yield.

SLAC Air is 1.3 % H_2O.

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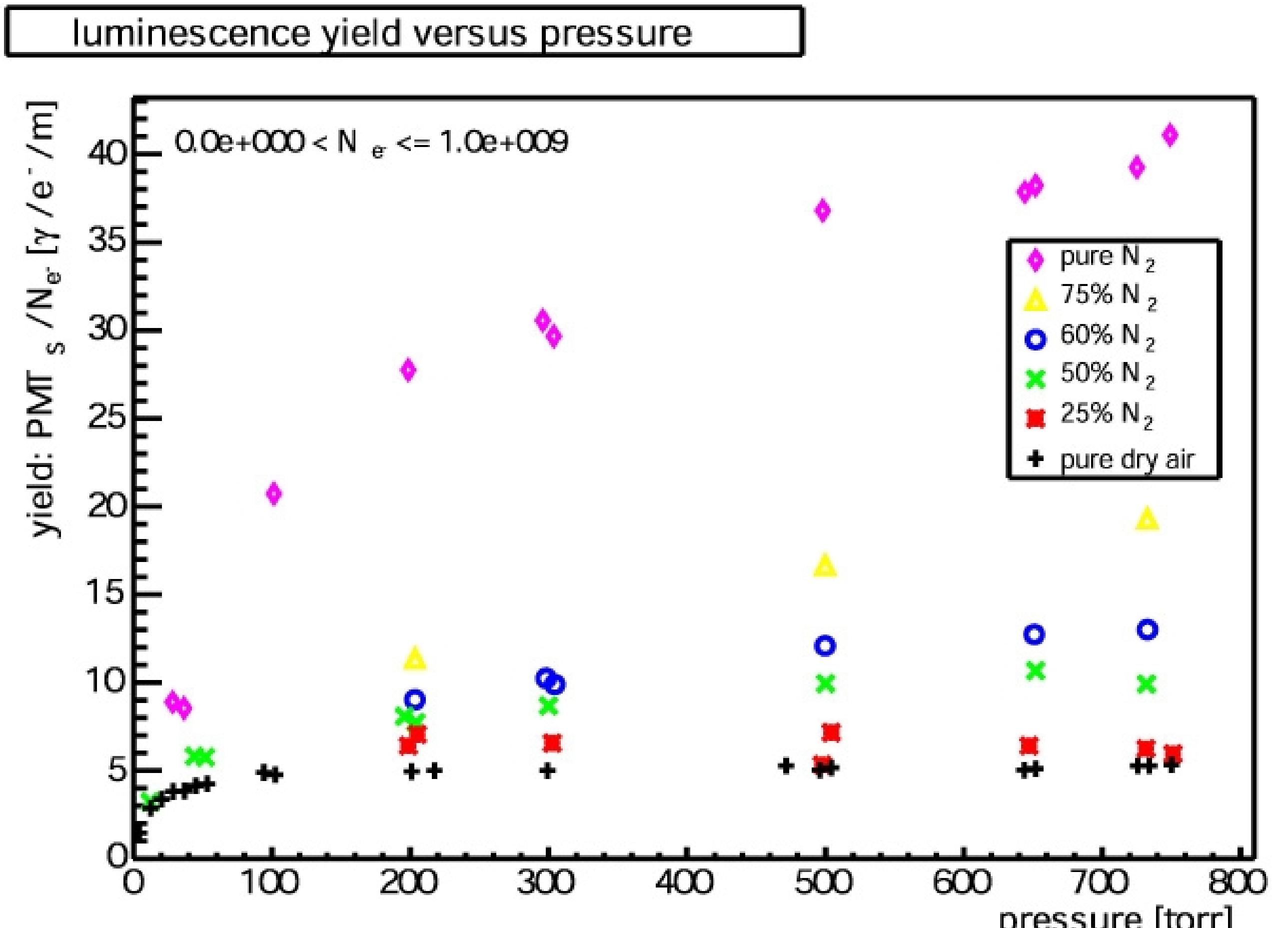
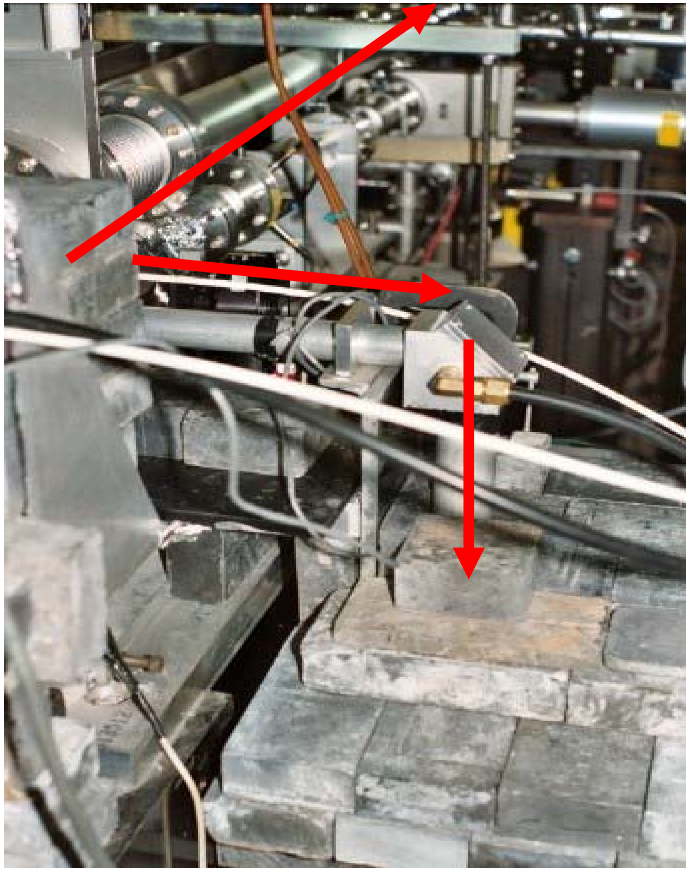
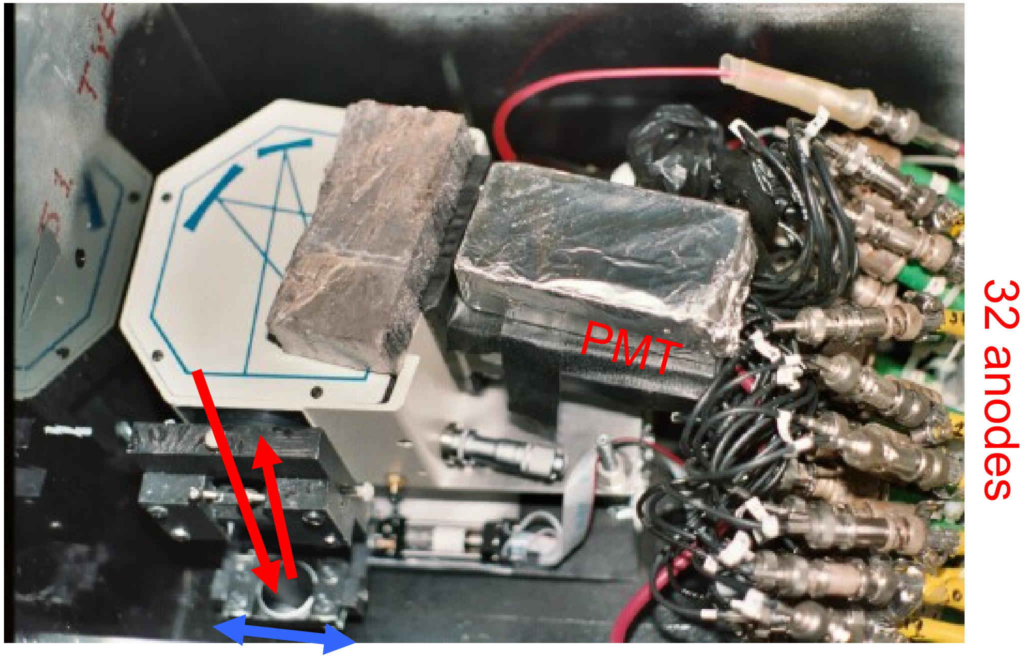
Effect of Contamination



FLASH Spectrograph

To cross check the fluorescence spectrum measurement made using narrow band filters.





Almost zero noise.
Noise looks like Bunner!

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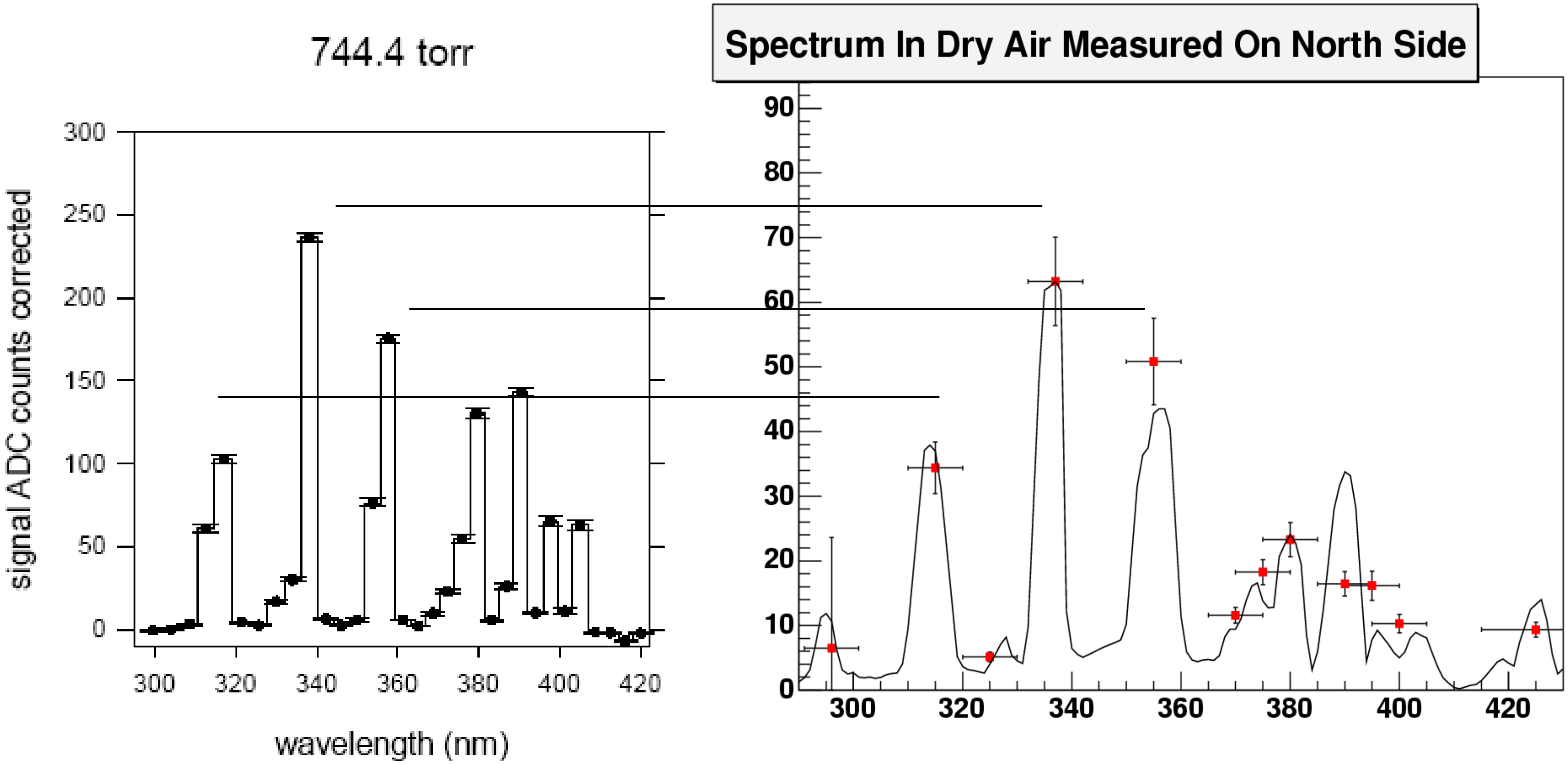
Spectrum via Spectrograph



Preliminary result: A few calibrations still pending.

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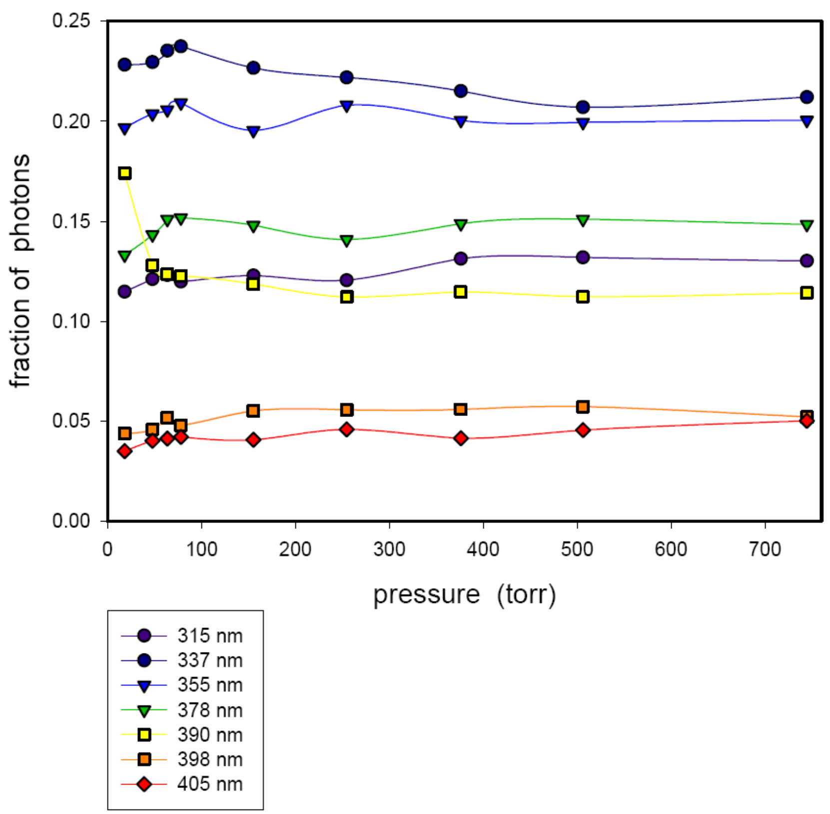
Pressure Dependence of Spectrum

Dry air: Fraction of photons in various wavelength bands



FLASH Future Runs

- We have two more runs scheduled for June and July of 2004. Both runs will be in thick target mode (described briefly on next slides).
- The third run may be a simultaneous run of thick target and spectrograph system.

FLASH Experimental Design

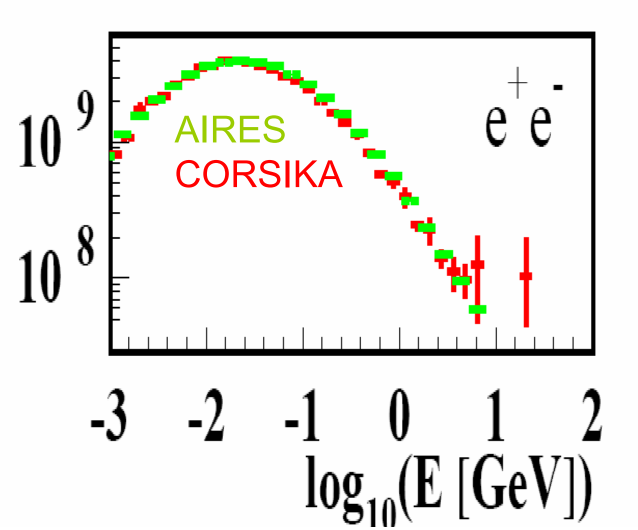
Thick Target Stage

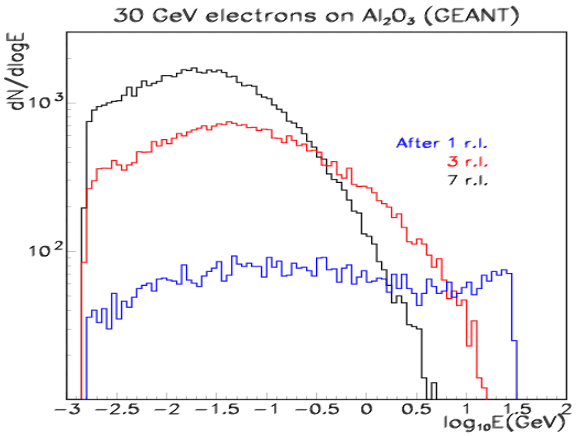
- We will shower the FFTB beam through a range of shower depths in air "equivalent" material (Al_2O_3).
- Do shower models correctly predict the fluorescence signal?
- Does the signal deviate from dE/dx?
- Are there any visible effects from the change in the distribution of electron energy?

FLASH Experimental Design

Thick Target Stage

- In addition to effects caused by impurities in the air (humidity) we also plan to study the effects of the electron energy distribution.
- 10^7 e^- showering at 30 GeV approximately reproduces a 3×10^{17} UHECR shower (near shower max).
- 2,6,10, and 14 radiation lengths.





Conclusion

- We have measured the spectrum and total yield of air fluorescence.
- We expect to resolve the spectral shape very well with our combined method of narrow band filters and spectrograph.
- Works on calibration and systematics are ongoing.
- We expect a total systematic uncertainty of 10%.
- Thick Target runs coming soon (next week!)