The FLASH Thick Target Experiment: Direct Measurement of Air Fluorescence Yield in Electromagnetic Showers

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Collaborators

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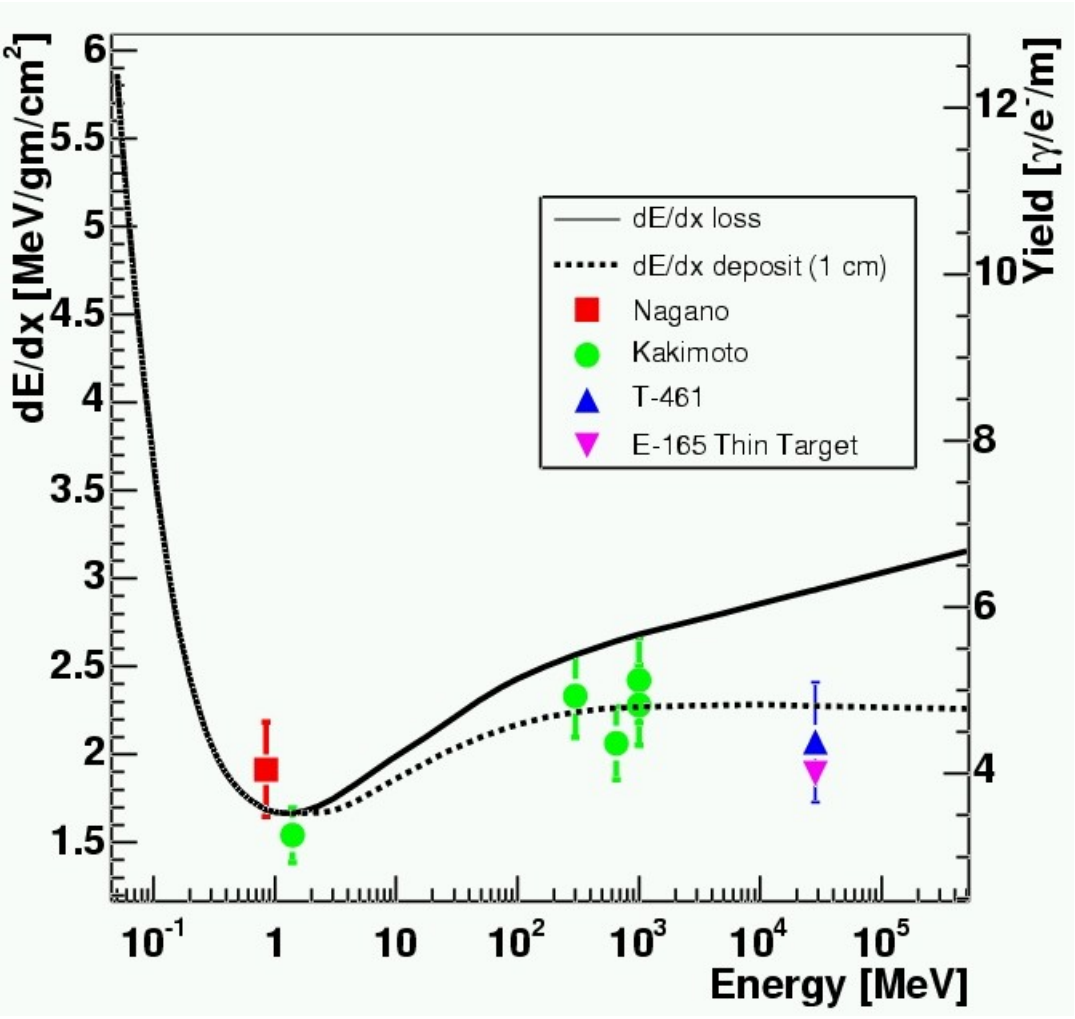
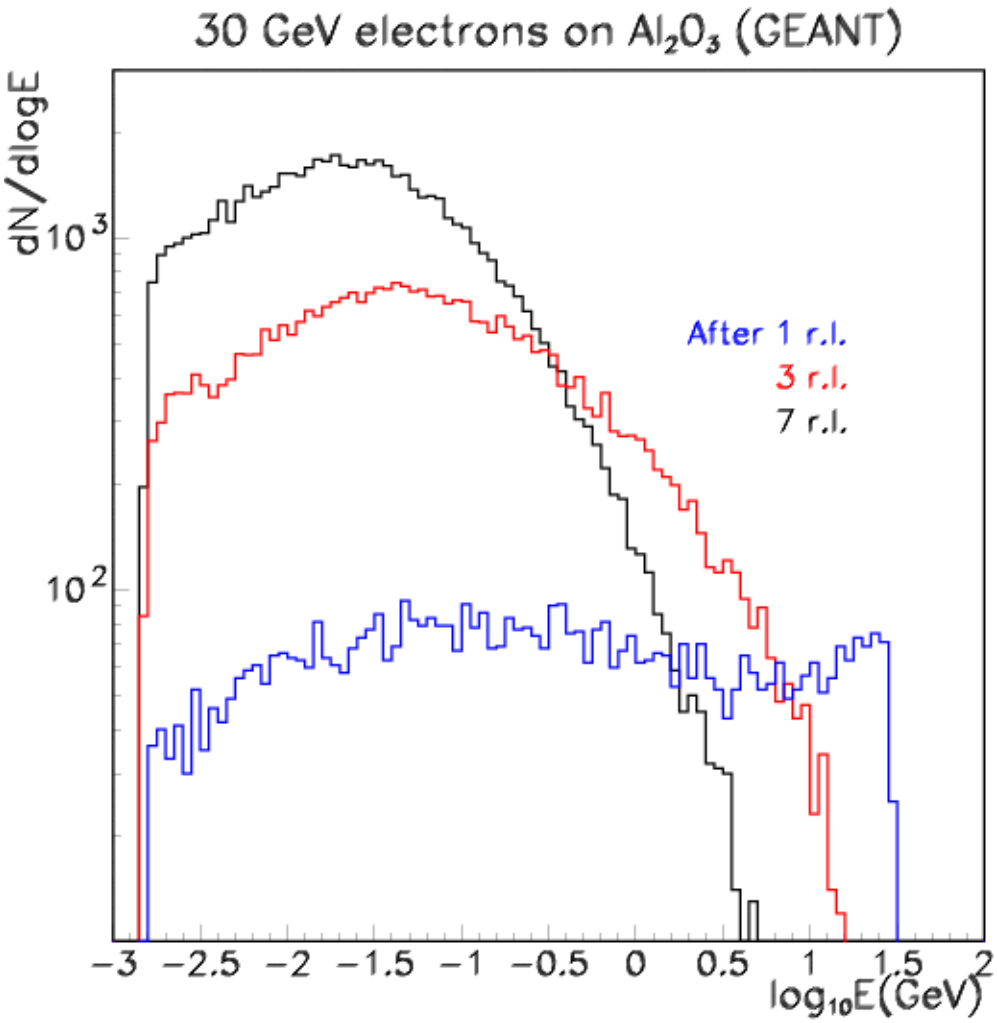
Summary: Air Fluorescence Yield Measurements



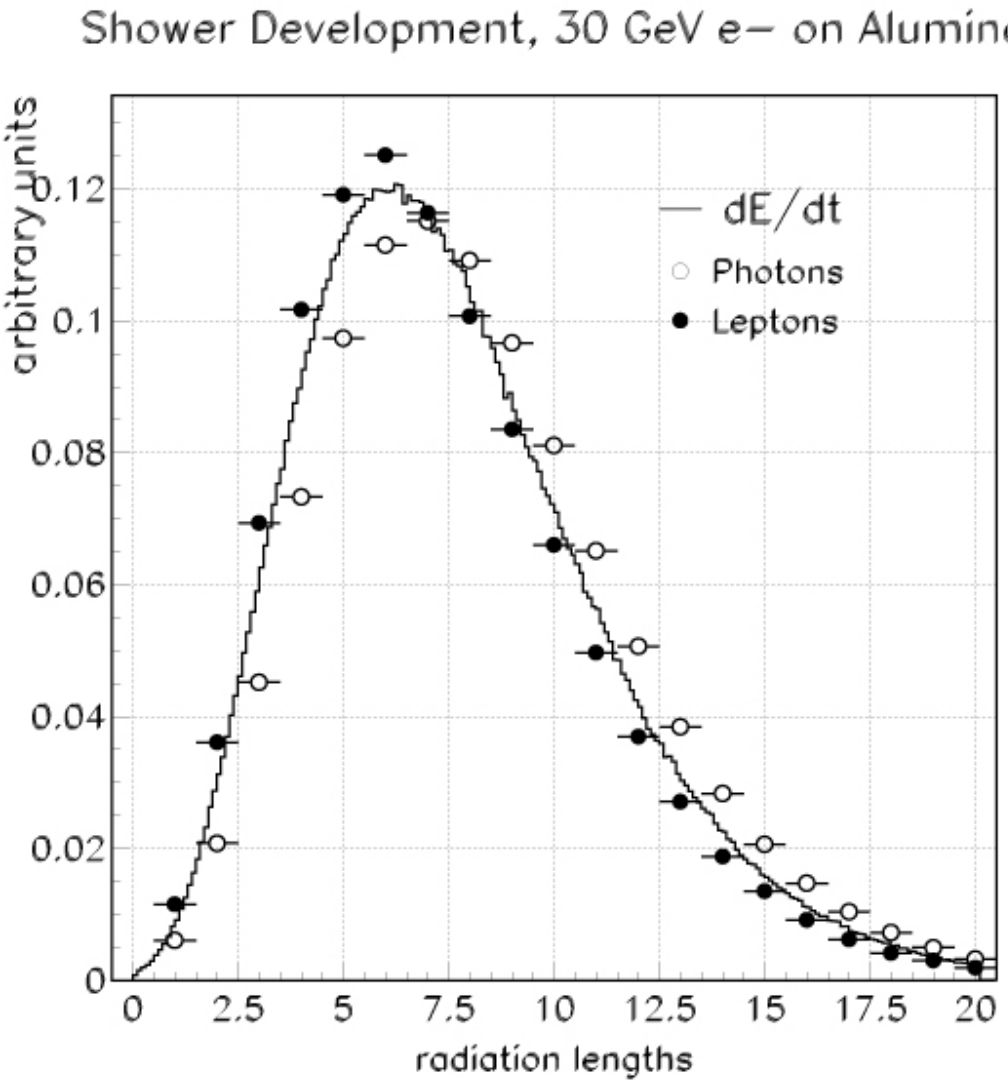
- Kakimoto *et al.*, NIM A372 (1996)
- Nagano *et al.*, Astroparticle Physics 20 (2003)
- Belz *et al.*, astro-ph/0506741
- Huentemeyer *et al.*, Proceedings 29th ICRC

Thick Target Run Motivation

- Understand how fluorescence yield depends on the incident particle energy, to ~100 keV.
- Check hypothesis that nitrogen fluorescence is proportional to energy deposition dE/dT; a key assumption in airshower modeling.
- Mean electron energies near shower max are very similar for 30 GeV electrons and 10^{19} eV protons: SLAC is the right location!

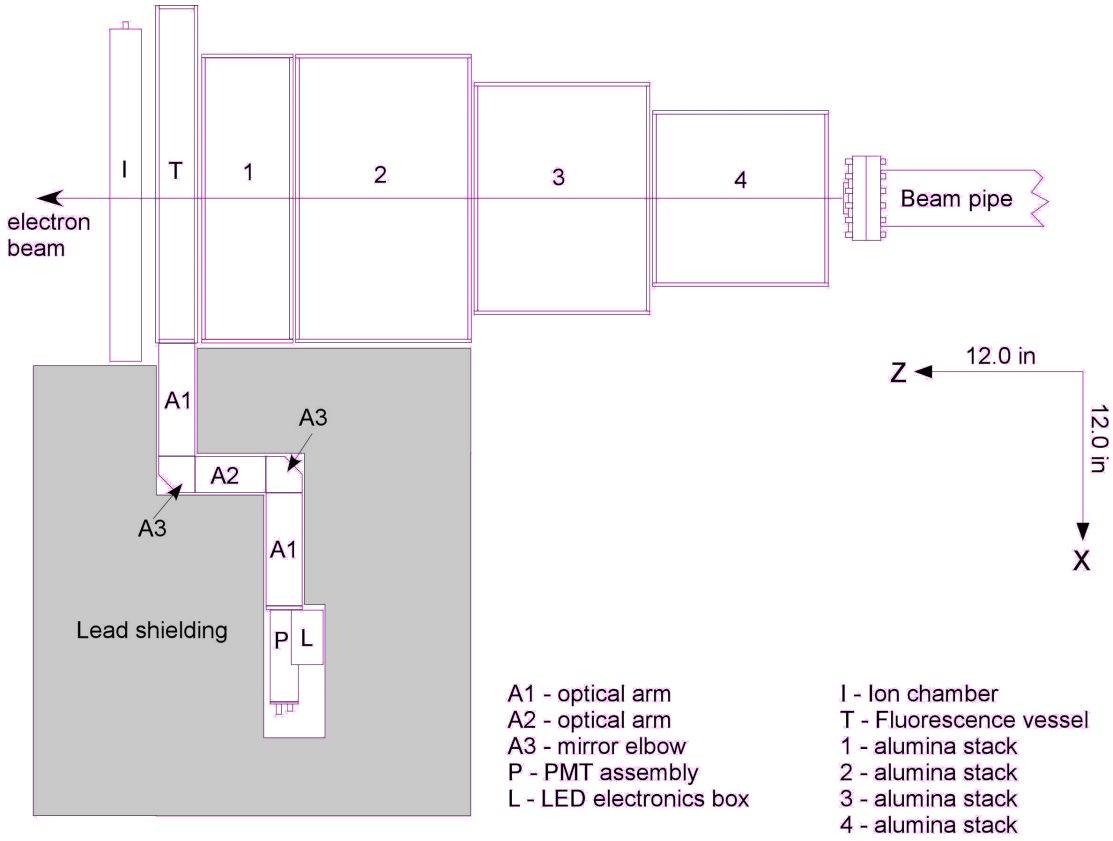


Thick Target Run Motivation



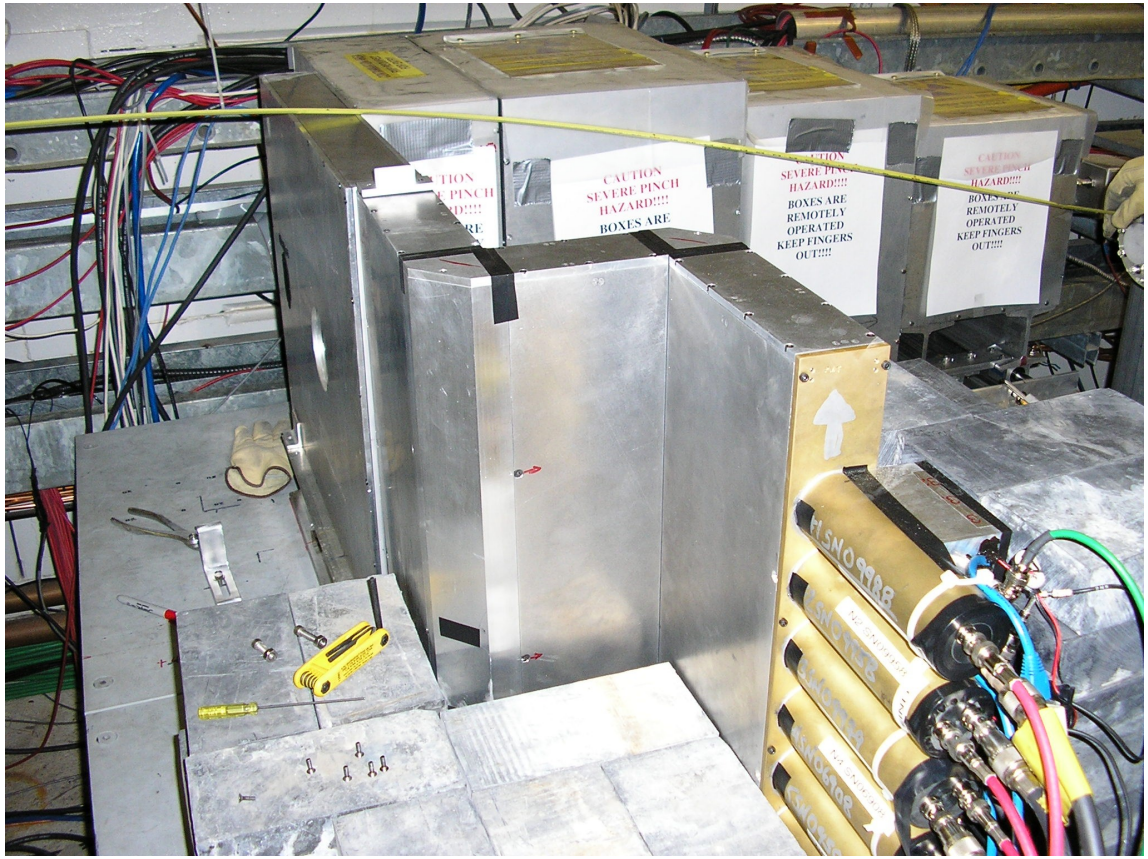
- Strategy: produce a shower with similar characteristics to electromagnetic airshower in the lab.
- Test observed yields against EGS and GEANT simulations, predicted energy loss curves.

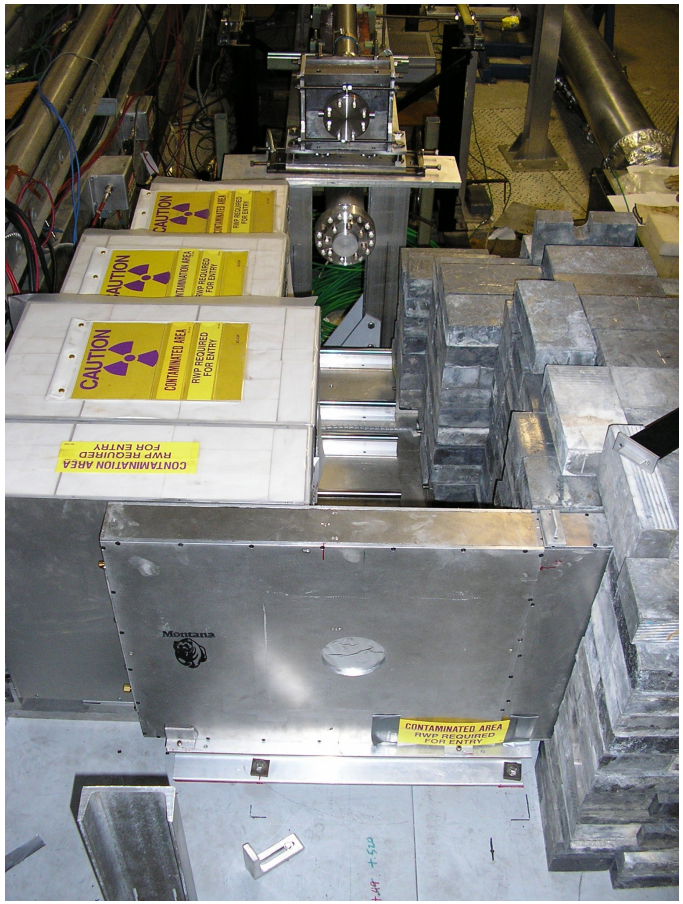
Thick Target Fluorescence Vessel and Ion Chamber



- Goal: Sum fluorescence light produced in a “slice” of an EM shower.
- Reduce scattered and non-fluorescence (Cherenkov) contributions to collected light
- Reduce backgrounds from stray particles hitting light detectors
- Drop-in mechanical shutter, (background studies) and filter holder.

Thick Target Fluorescence Chamber *in situ* (Summer 2004)

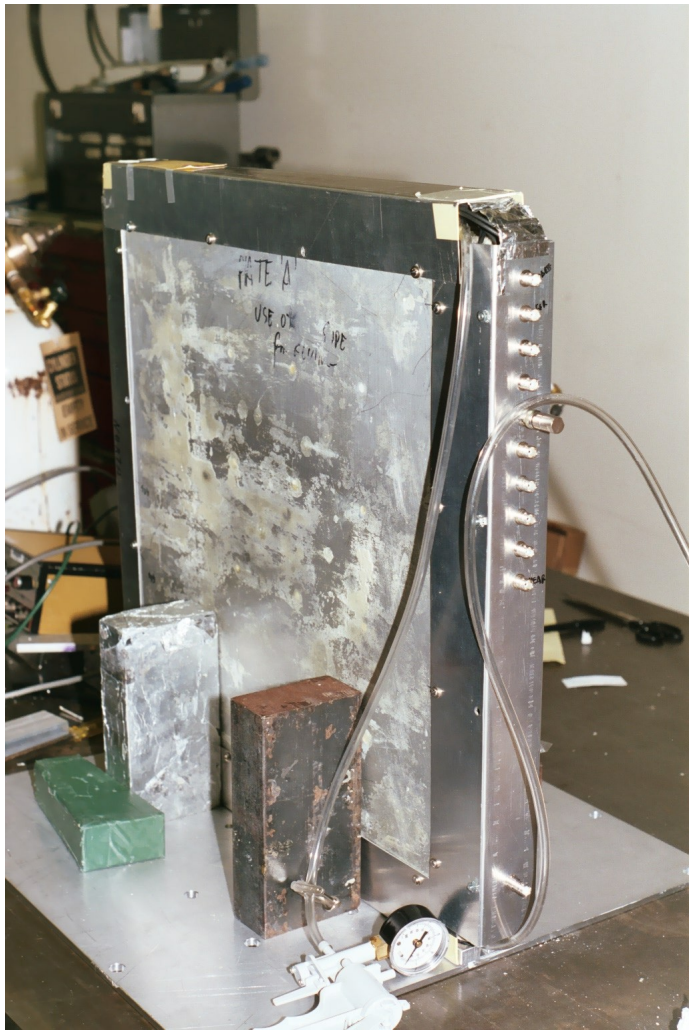




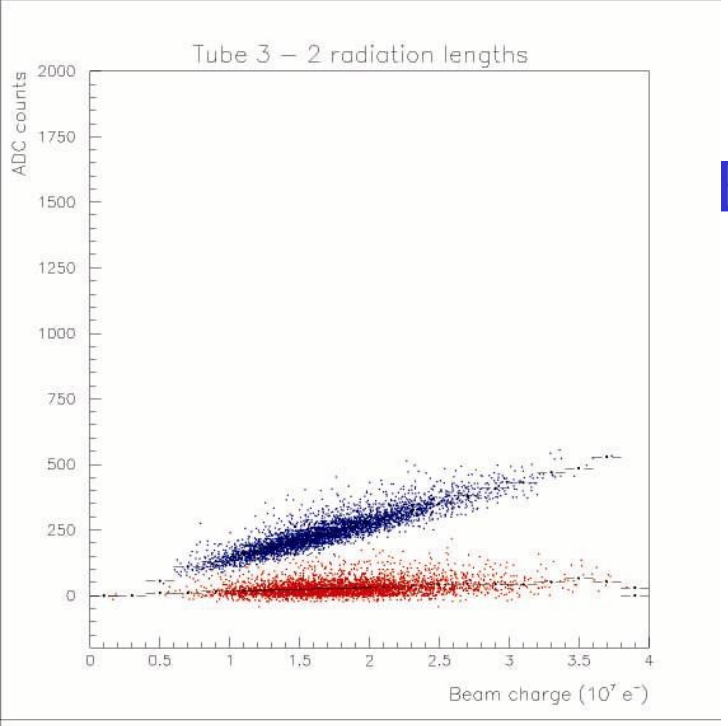
Direct Detection of Shower Particles: Ion Chamber

- Direct measurement of ionization produced by beam particles.

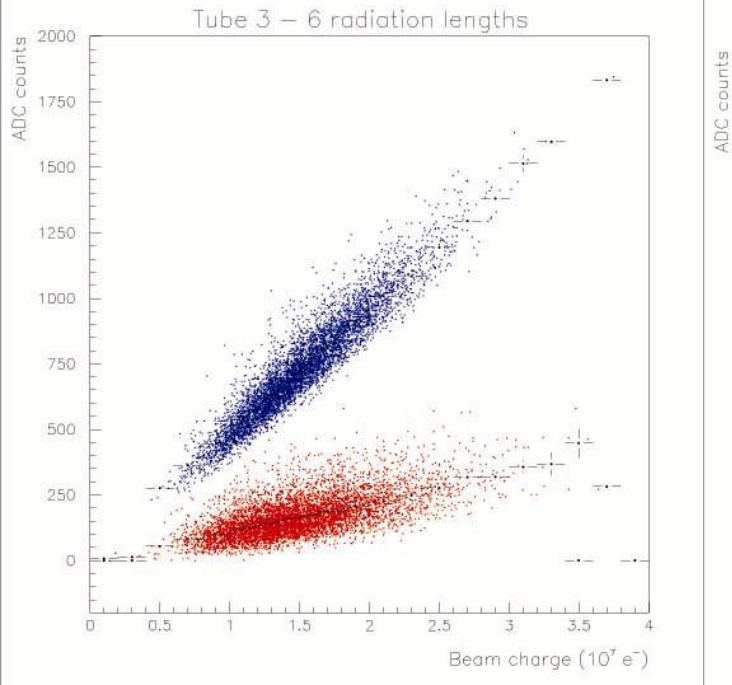
- Collected simultaneously with fluorescence data; important crosscheck of data and simulation.

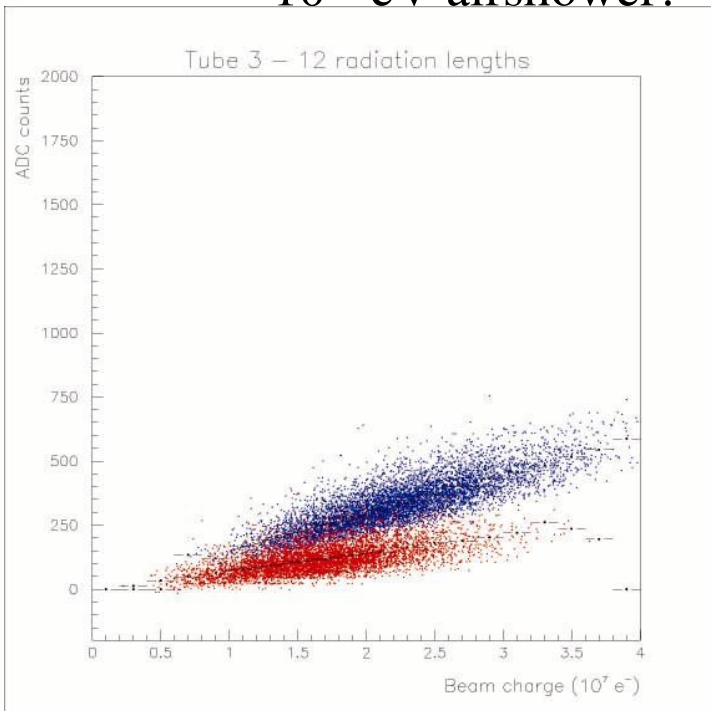


Fluorescence; Signal and Background

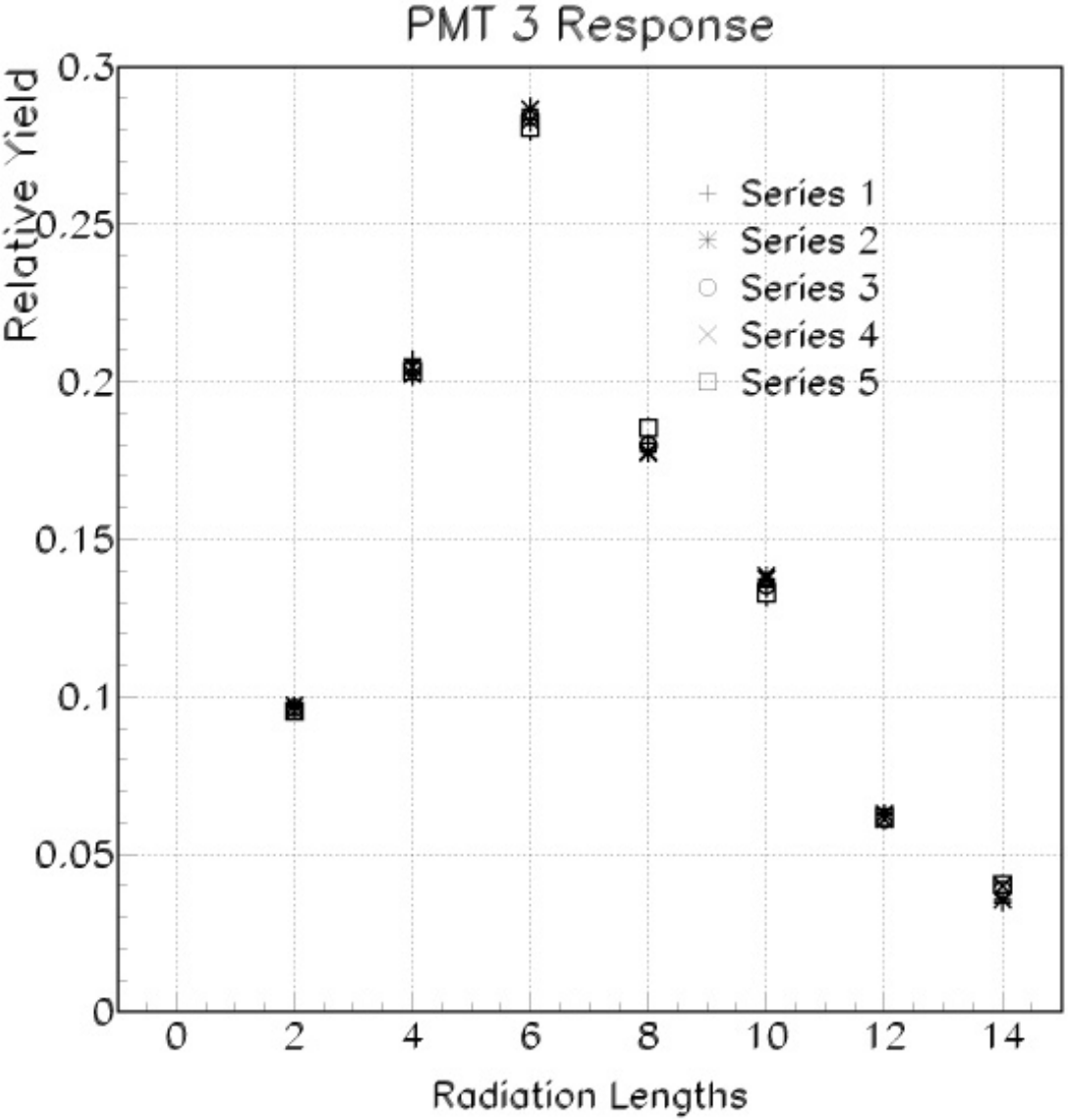


- PMT ADC Counts vs. Beam Charge (blue)
- Background subtraction (red)
- Fit slope in linear region
- Note:3x10^7 30 GeV electrons = 10^{18} eV airshower!





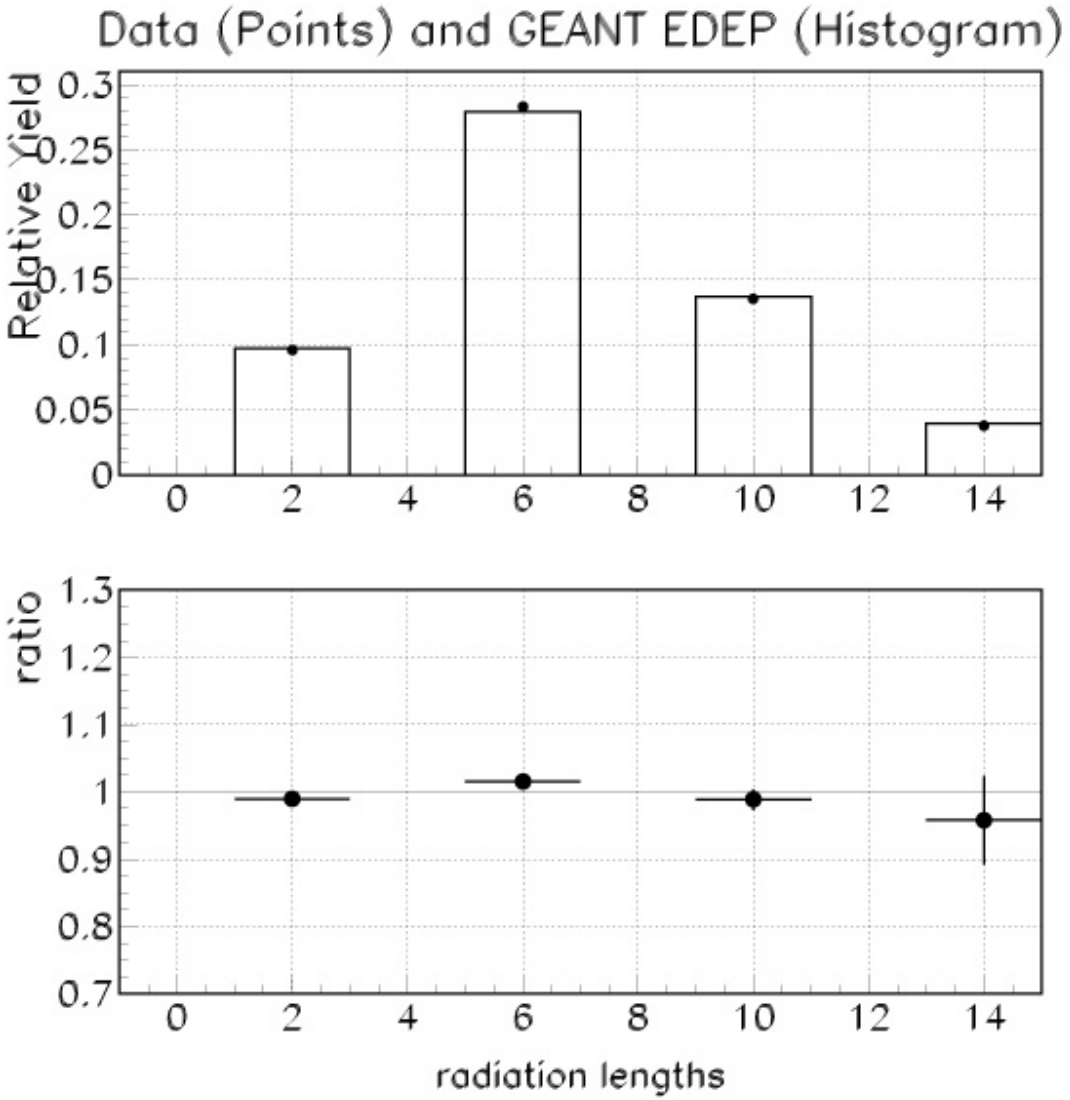
Signal vs Shower Depth



- Uncorrected signal minus background
- Five series of runs overlaid on this plot
- Variations consistent with statistics
- Very stable method!
  - ±0.8% at 6 r.l.
  - ±7% at 14 r.l.

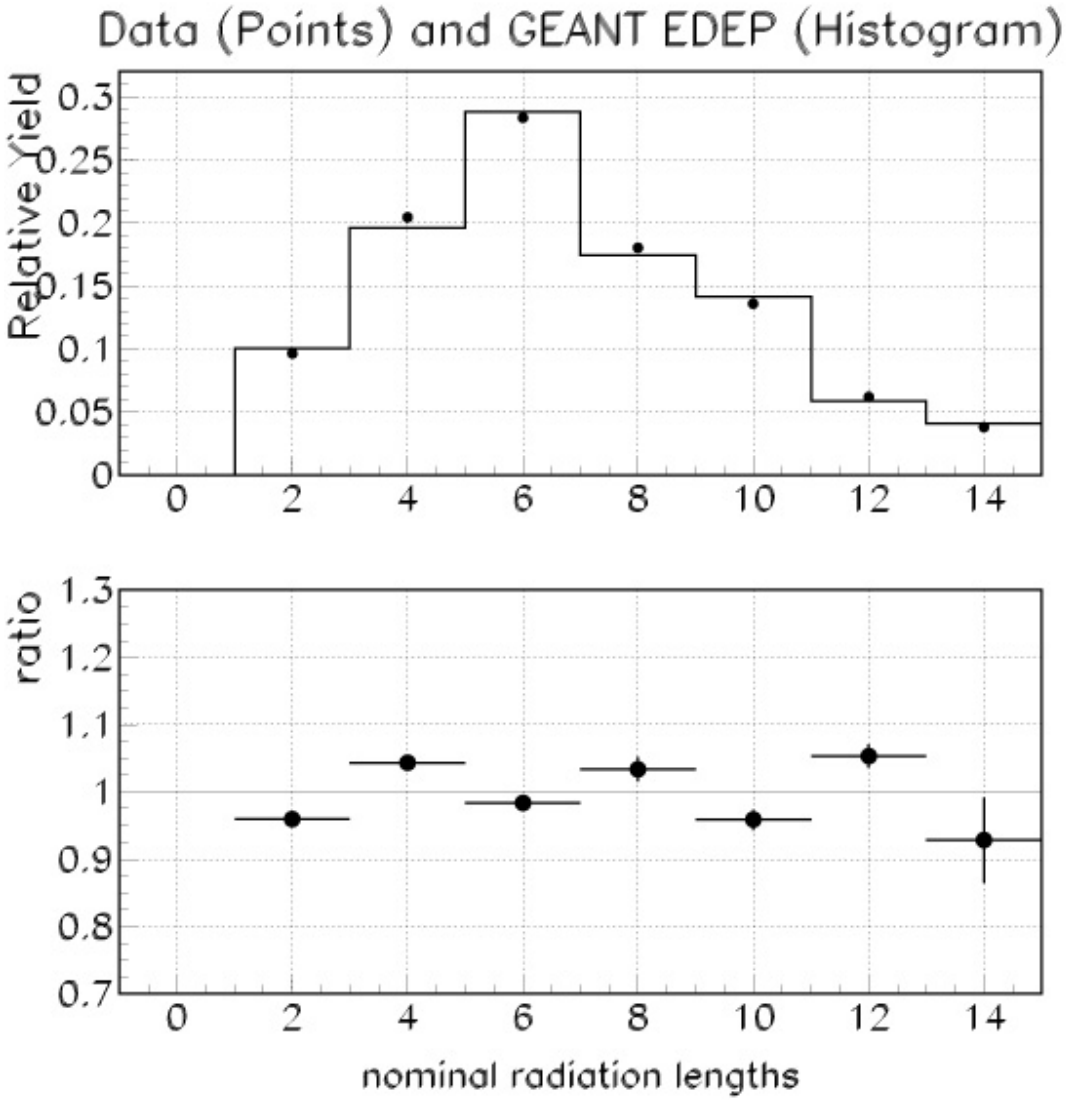
Comparison to GEANT 3.2

- Check hypothesis that fluorescence yield is proportional to energy deposition.
- Plot fluorescence signal and GEANT energy deposition at 2, 6, 10, 14 radiation lengths.
- Excellent agreement: ±1%



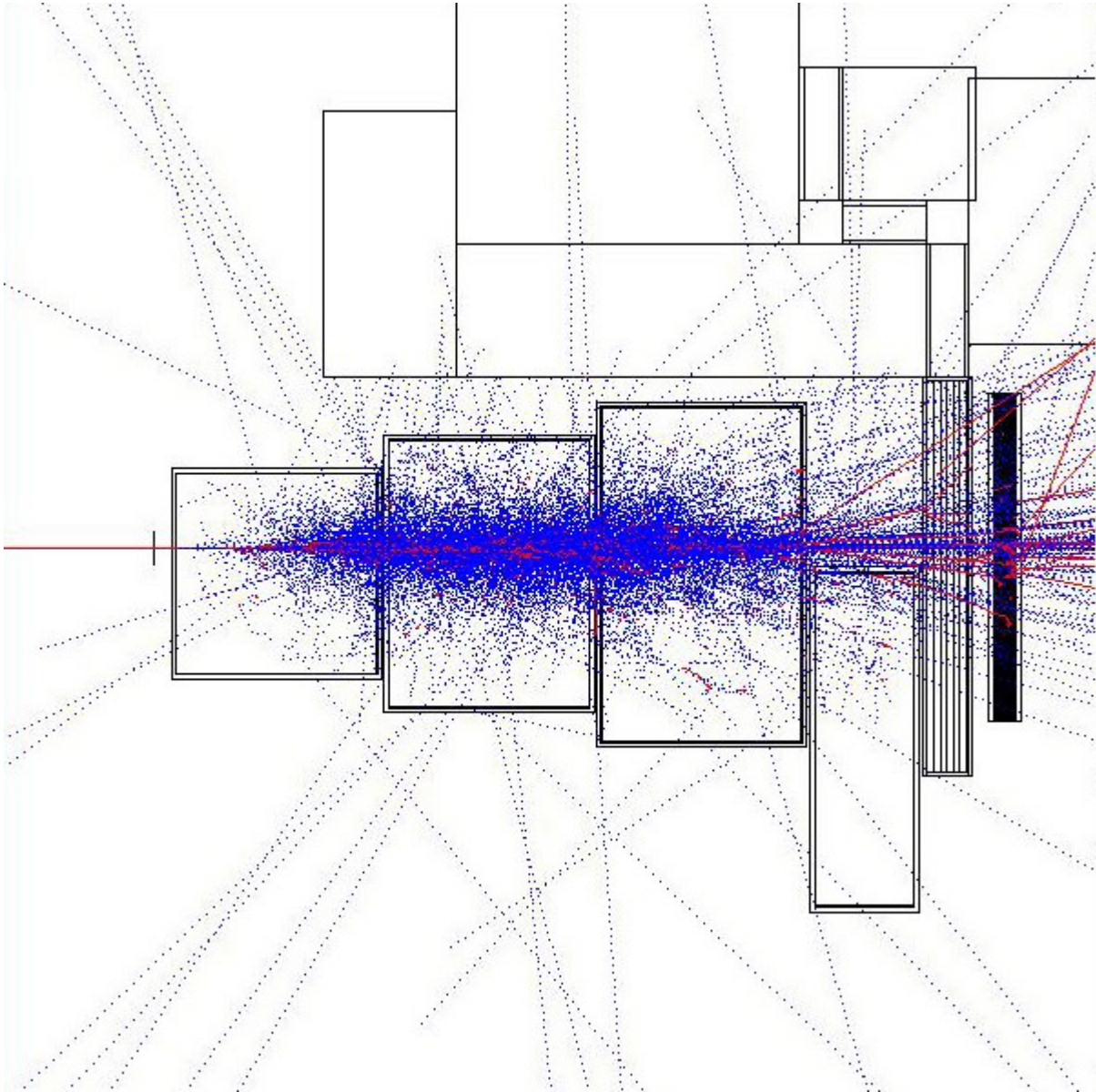
Comparison to GEANT 3.2

- Check hypothesis that fluorescence yield is proportional to energy deposition.
- Plot fluorescence signal and GEANT energy deposition at 2, 4, 6, 8, 10, 12, 14 radiation lengths.
- Agreement: ±5%
- Anomaly at 4, 8, 12?



What's happening?

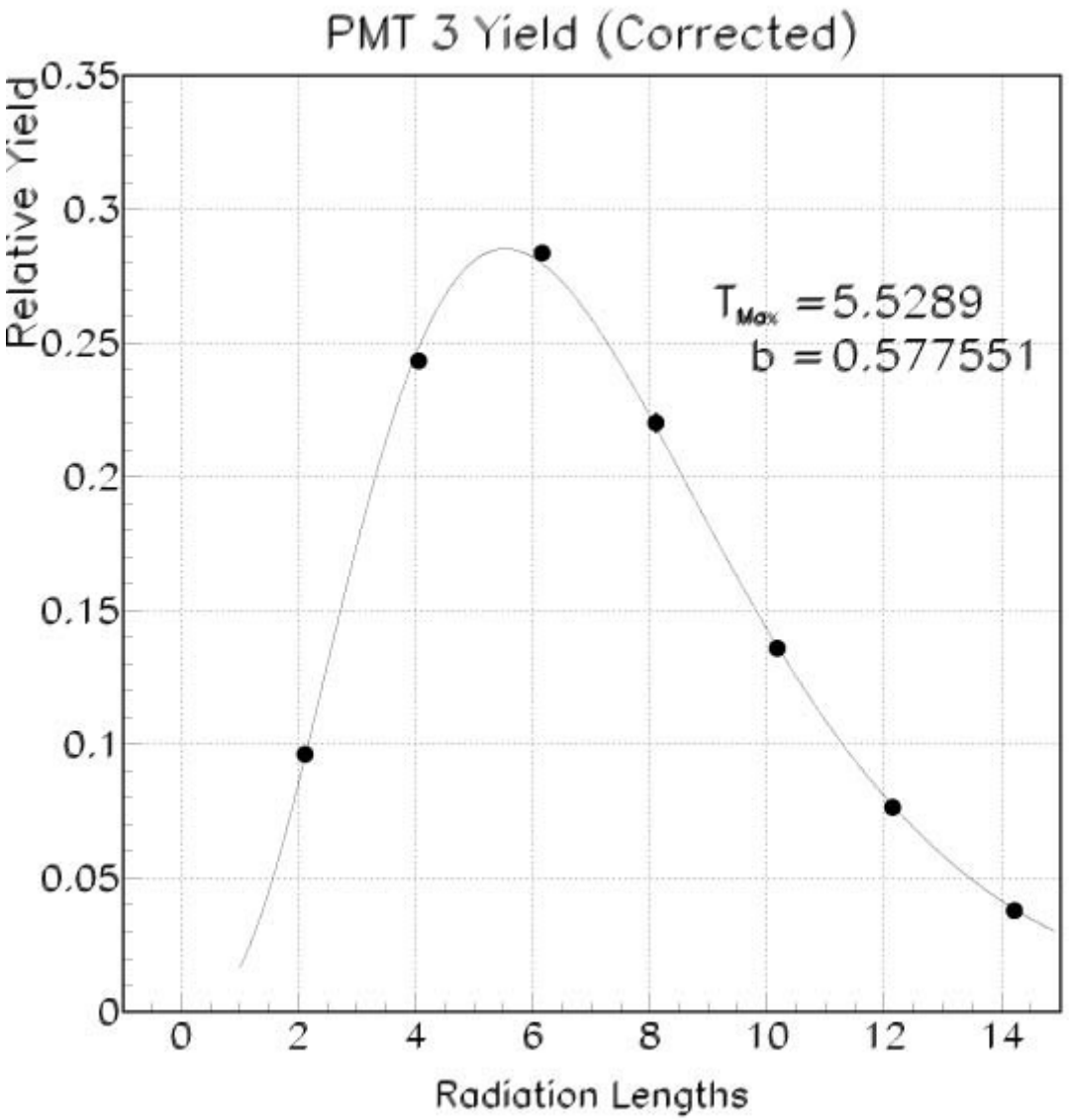
- 2 radiation length block partially interacts with shower particles.
- Reduces particle/light yield at 4, 8, and 12 r.l.
- Well simulated (ion chamber).



Longitudinal Fluorescence Profile

- Corrections applied to light yields at 4, 8, 12 radiation lengths
- Fit dE/dT shower max at 5.5 radiation lengths agrees well with critical energy model prediction.
- Curve:

$$\frac{dE}{dt} = E_0 b \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)}$$



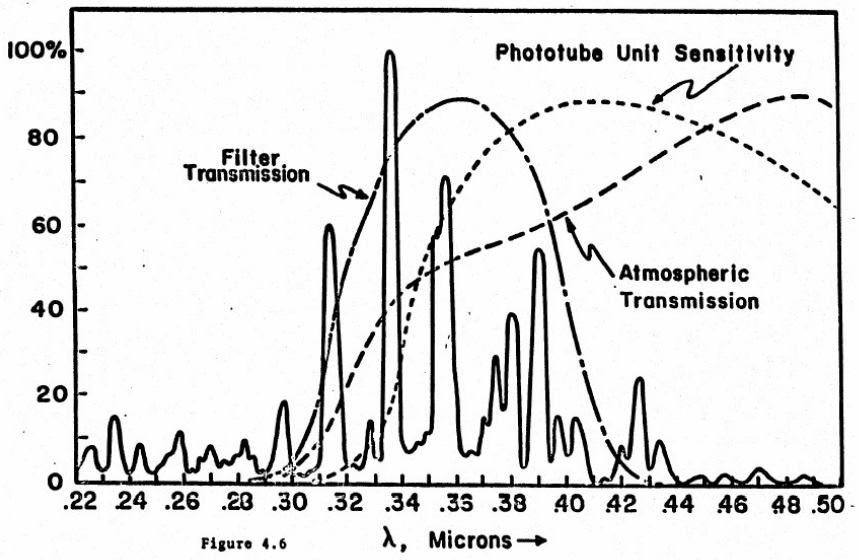
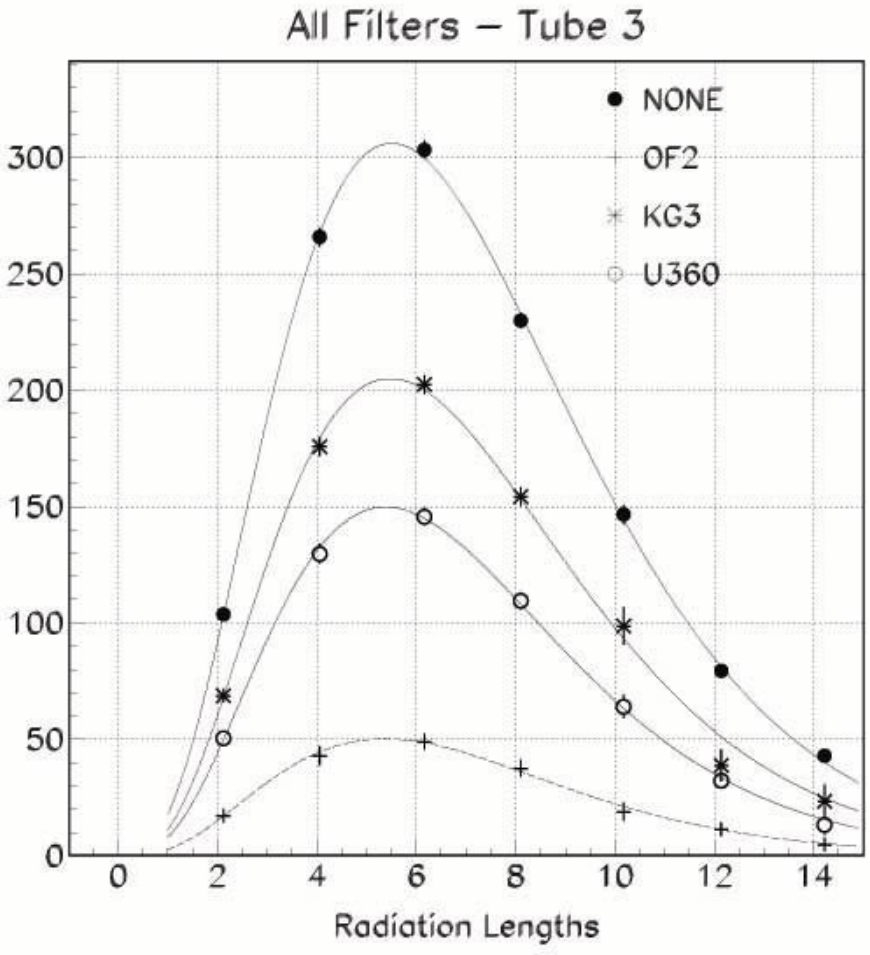


Figure 4.6

- Using band-pass filters, we can isolate the contributions of several different wavelength bands to the overall light yield.
- Shape of fluorescence profile unchanged

Filter	Band
"None"	$310 < \lambda < 400$ nm
OF2	$370 < \lambda < 400$ nm
KG3	$330 < \lambda < 390$ nm
U360	$330 < \lambda < 380$ nm



FLASH Thick Target: Conclusions

- Excellent data collected in thick-target mode summer 2004.
- Analyses indicate the results are well understood:
  - GEANT energy deposition good predictor of relative fluorescence yield versus shower depth: Relative yields agree to better than ±1% for most of the shower profile.
  - Air fluorescence yield shows good agreement with empirical dE/dt model.
  - Band-pass filter data indicates that energy deposition proportionality to fluorescence is wavelength-independent.
- Paper: astro-ph/0510375