Separating p's, π's, and K's

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Design criteria for tuning a high energy TRD:

- X-rays are emitted at energies below $\gamma\omega_1$.
- Highest frequency maximum in interference pattern occurs near

$$\omega_{max} = l_1\omega_1^2/2\pi c$$

- 3) Total TR yield ~ γ up to saturation energy

$$\gamma_s = 0.6\ \omega_1(l_1 l_2)^{1/2}/c$$

- 4) Total number of photons

$$N_\gamma \sim 2Z^2\ \alpha\ \omega_1\ \gamma\ N_{eff} / 3\ \omega_{max} \quad \text{below saturation}$$

$$\sim 2Z^2\ \alpha\ \omega_1\ \gamma_s\ N_{eff} / 3\ \omega_{max} \quad \text{at saturation}$$

(where *Neff* is effective number of foils)

$$\sim \pi/2\ \ Z^2\alpha\ L\ \omega_1/\gamma_s \qquad \text{where } L = N(l_1+l_2)$$

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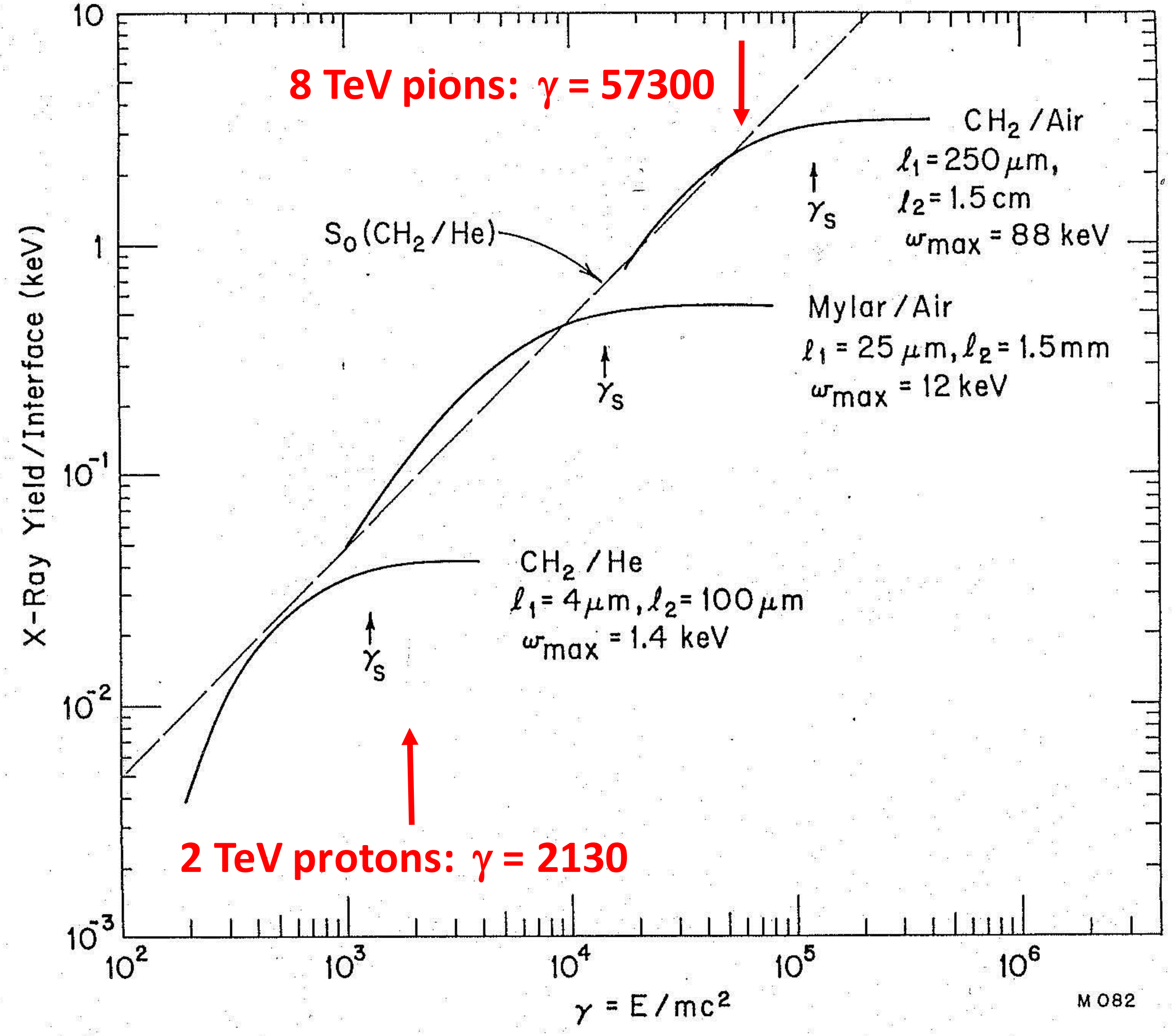
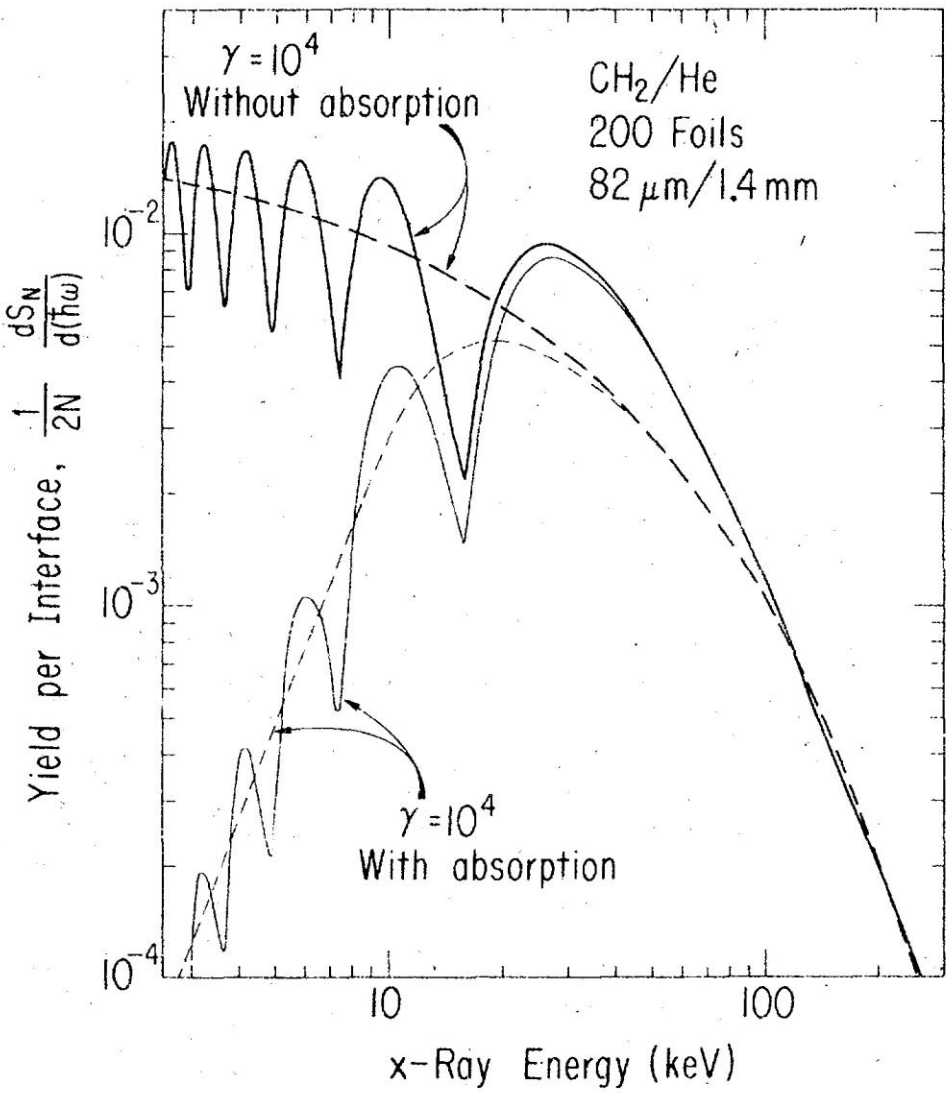
For a fixed length detector, as γ_s goes up, # of photons decreases unless ω_1 increases.



8 TeV pions: $\gamma = 57300$

2 TeV protons: $\gamma = 2130$



Separating electrons and pions
SLAC, 1973

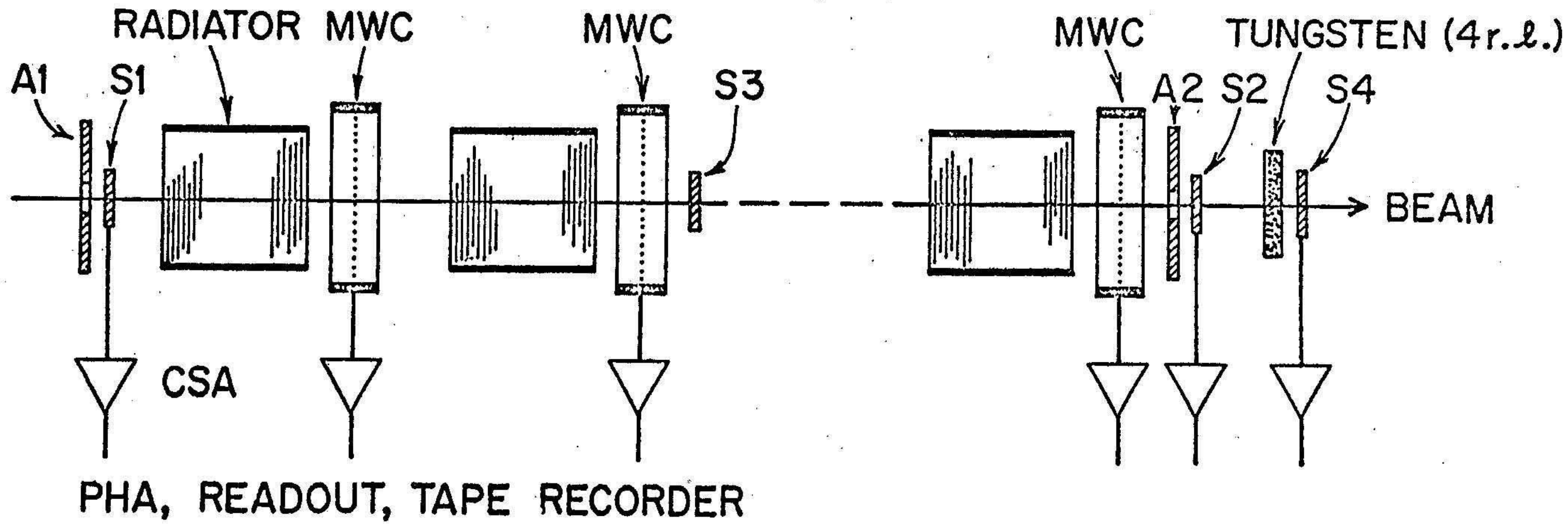
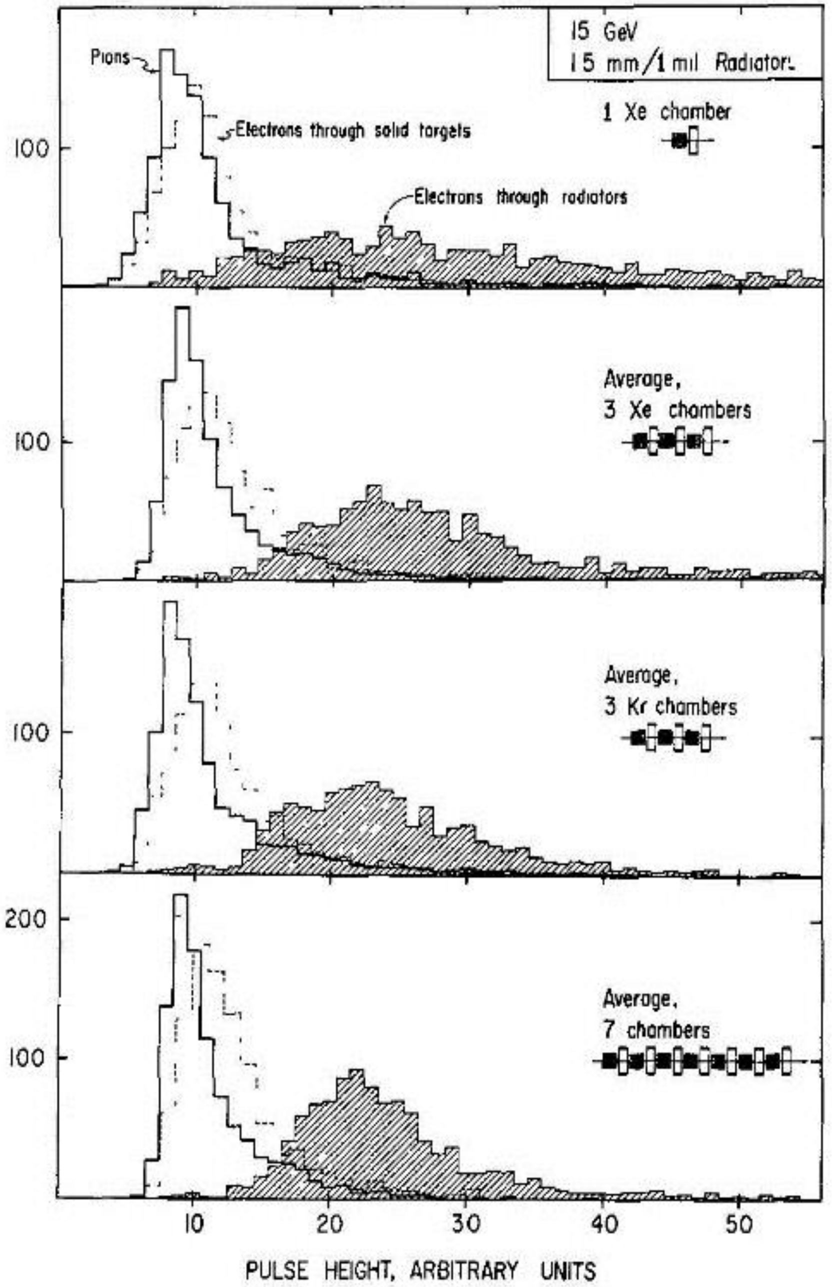


Figure 5



$$P_1 = P_e^{(1)}(x_1)\, P_e^{(2)}(x_2) \ldots P_e^{(n)}(x_n).$$

Similarly, the probability that a pion will produce this same set of signals is:

$$P_2 = P_\pi^{(1)}(x_1)\, P_\pi^{(2)}(x_2) \ldots P_\pi^{(n)}(x_n).$$

If we wish to decide whether or not the event defined by the pulse heights characterizes an electron or pion, we can define the quantity

$$P_e = P_1/(P_1+P_2).$$

This quantity defines the probability of interpretation of the event as an electron. (This definition assumes equal a priori probability for electrons and pions.) Similarly, the quantity

$$P_\pi = P_2/(P_1+P_2) = 1-P_e$$

is the probability of interpretation of the event as a pion.

Example radiator/detector configuration:

20 modules

$N = 50$ mylar foils, $\omega_1 = 24.4$ eV

foil thickness $l_1 = 50\ \mu$, spacing $l_2 = 4$ mm

$\omega_{max} = 24.4$ keV $\gamma_s = 3.3 \times 10^4$

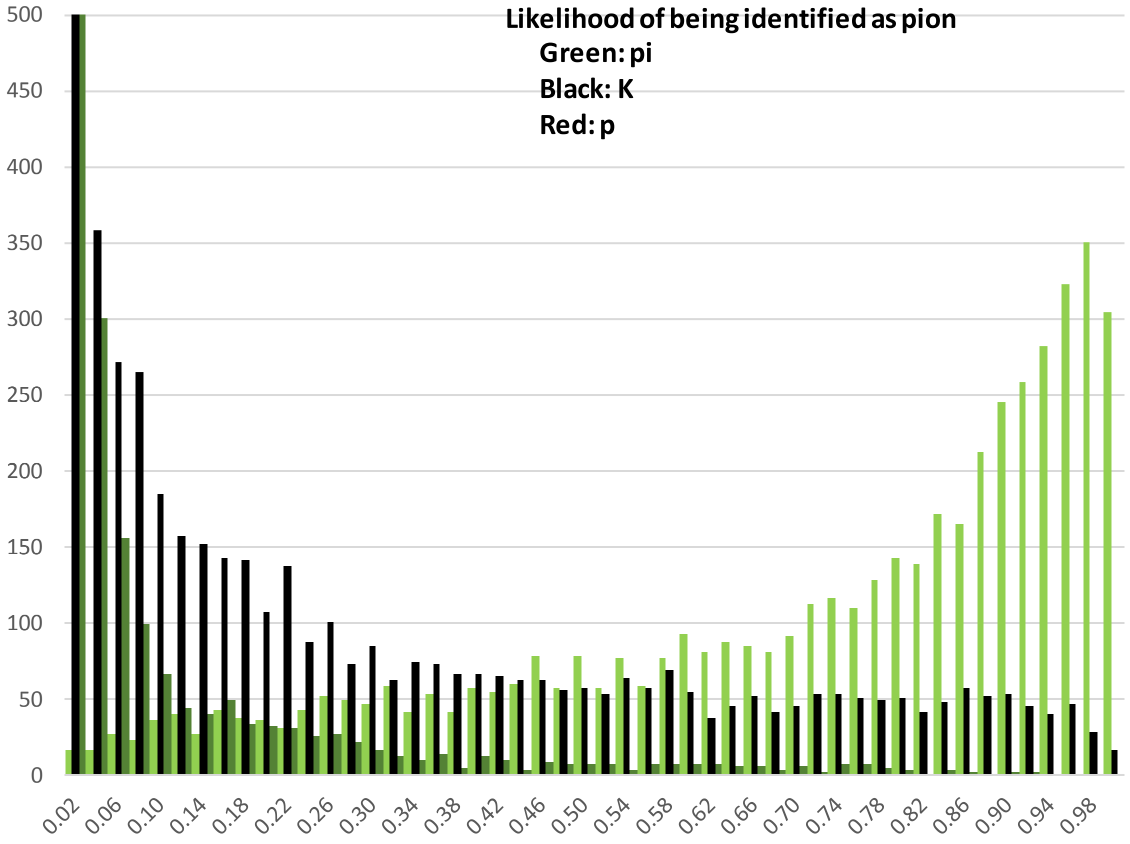
Total length 4 m Thickness 7 g

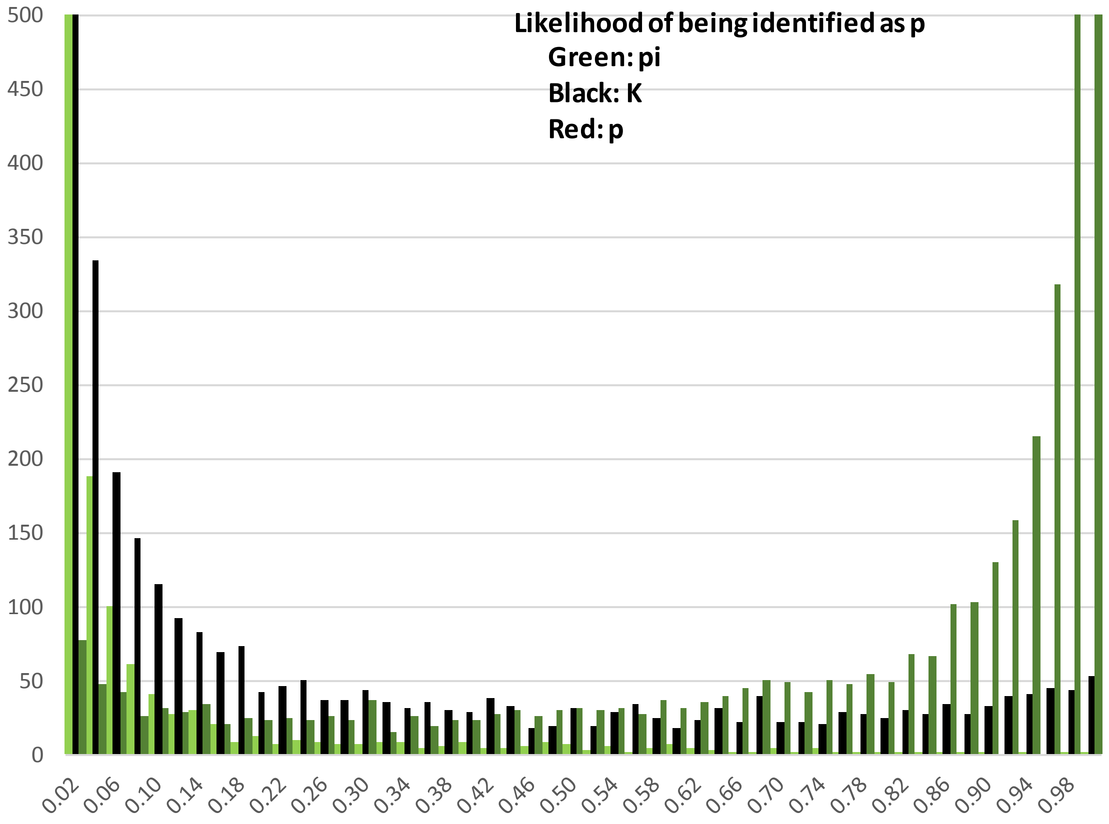
Modules 1-10: 1 cm Xe Modules 11-20: 2 cm Xe

Include Compton + photoelectric cross sections

Account for feedthrough from one module to next

Assume TR and dE/dx detected together, do not (yet) account for dependence on position along the beam





52% pion efficiency
3% of K’s incorrectly identified as π’s
0.2% of p’s incorrectly identified as π’s

74% proton efficiency
2% of K’s incorrectly identified as p’s
0.3% of π’s incorrectly identified as p’s

Example radiator/detector configuration #2:

20 modules

$N = 75$ teflon foils, $\omega_1 = 28.5$ eV

foil thickness $l_1 = 50\ \mu$, spacing $l_2 = 4$ mm

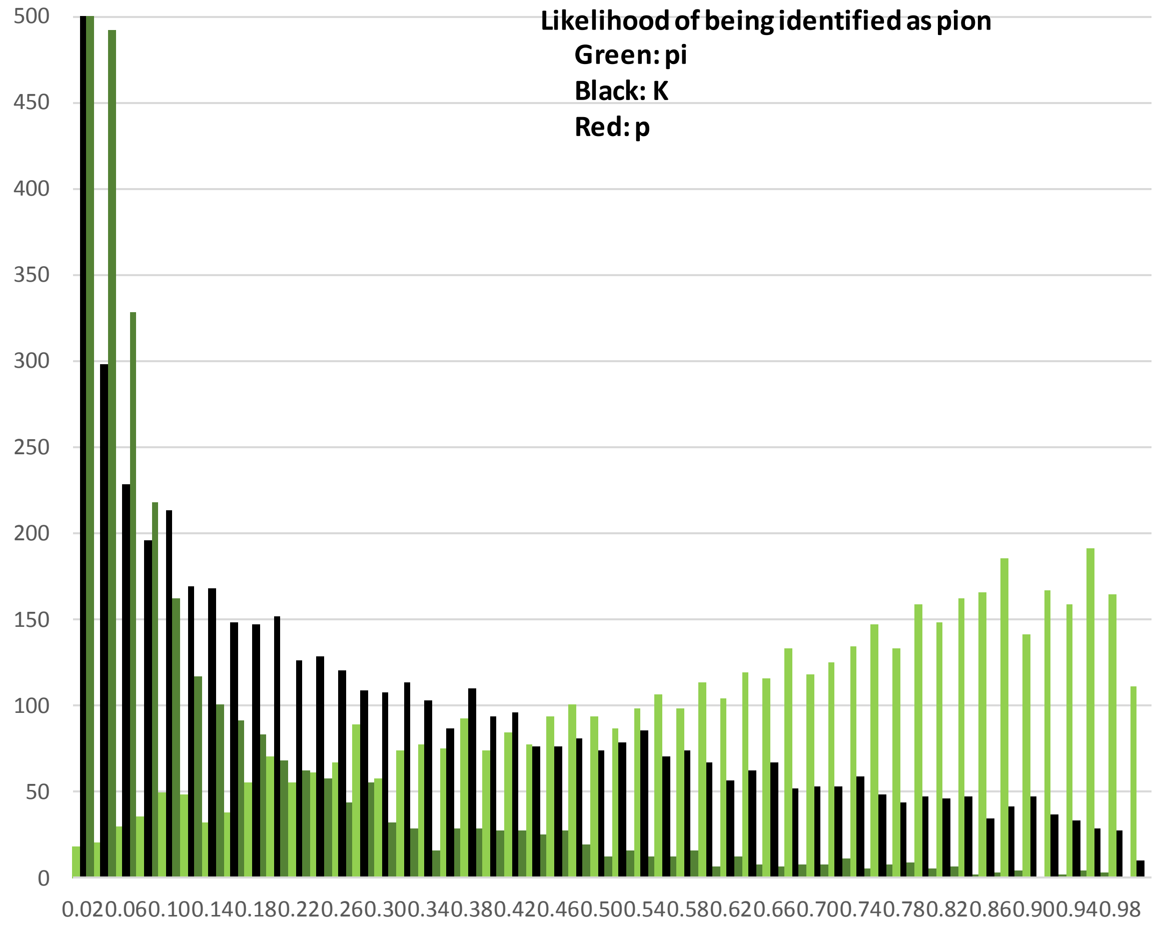
$\omega_{max} = 32.7$ keV $\gamma_s = 3.9 \times 10^4$

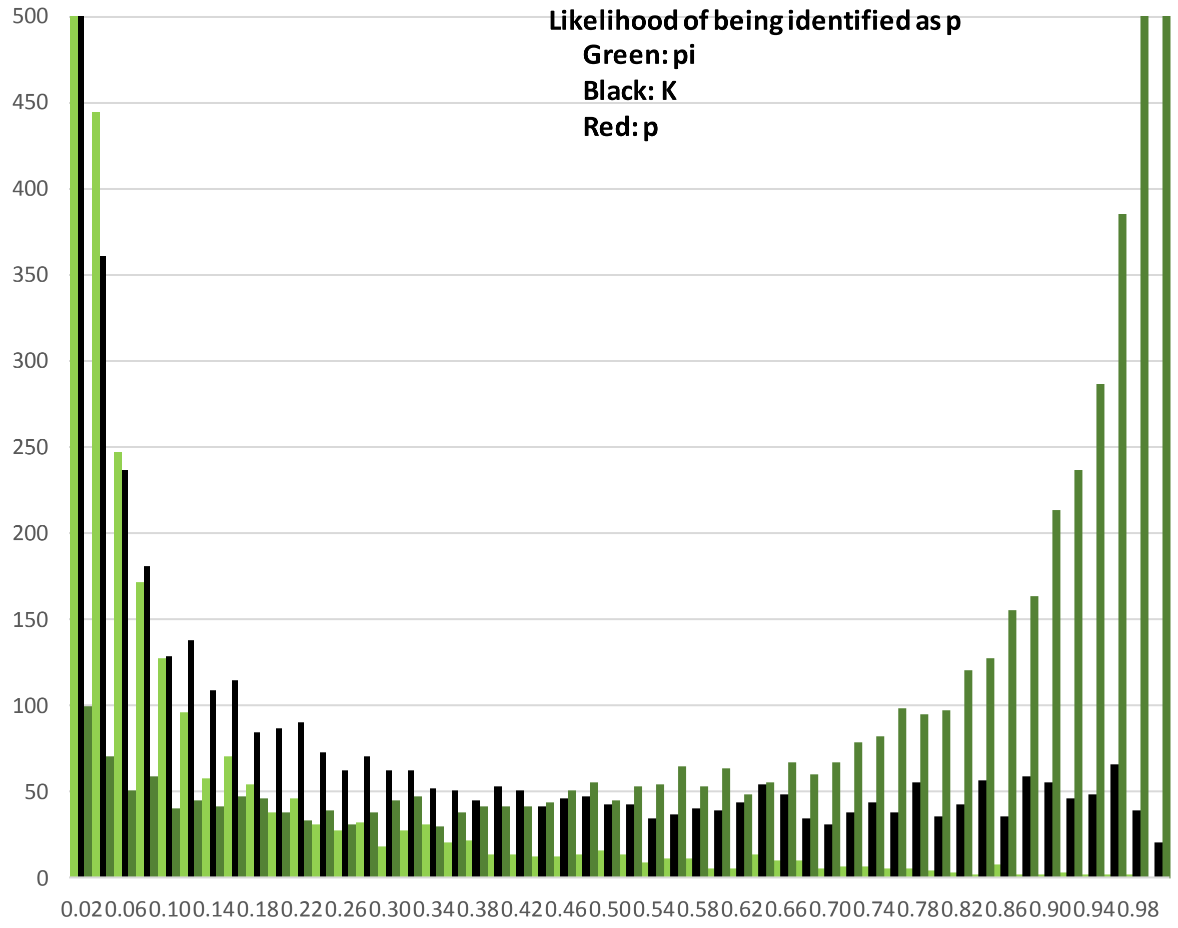
Total length 6.3 m Thickness 20 g

Modules 1-10: 1 cm Xe Modules 11-20: 2 cm Xe

Include Compton + photoelectric cross sections

Account for feedthrough from one module to next





35% pion efficiency
0.9% of K’s incorrectly identified as π’s
0.6% of p’s incorrectly identified as π’s

58% proton efficiency
0.6% of K’s incorrectly identified as p’s
0.7% of π’s incorrectly identified as p’s

Example radiator/detector configuration #3:

20 modules

$N = 50$ teflon foils, $\omega_1 = 28.5$ eV

foil thickness $l_1 = 50\ \mu$, spacing $l_2 = 6$ mm

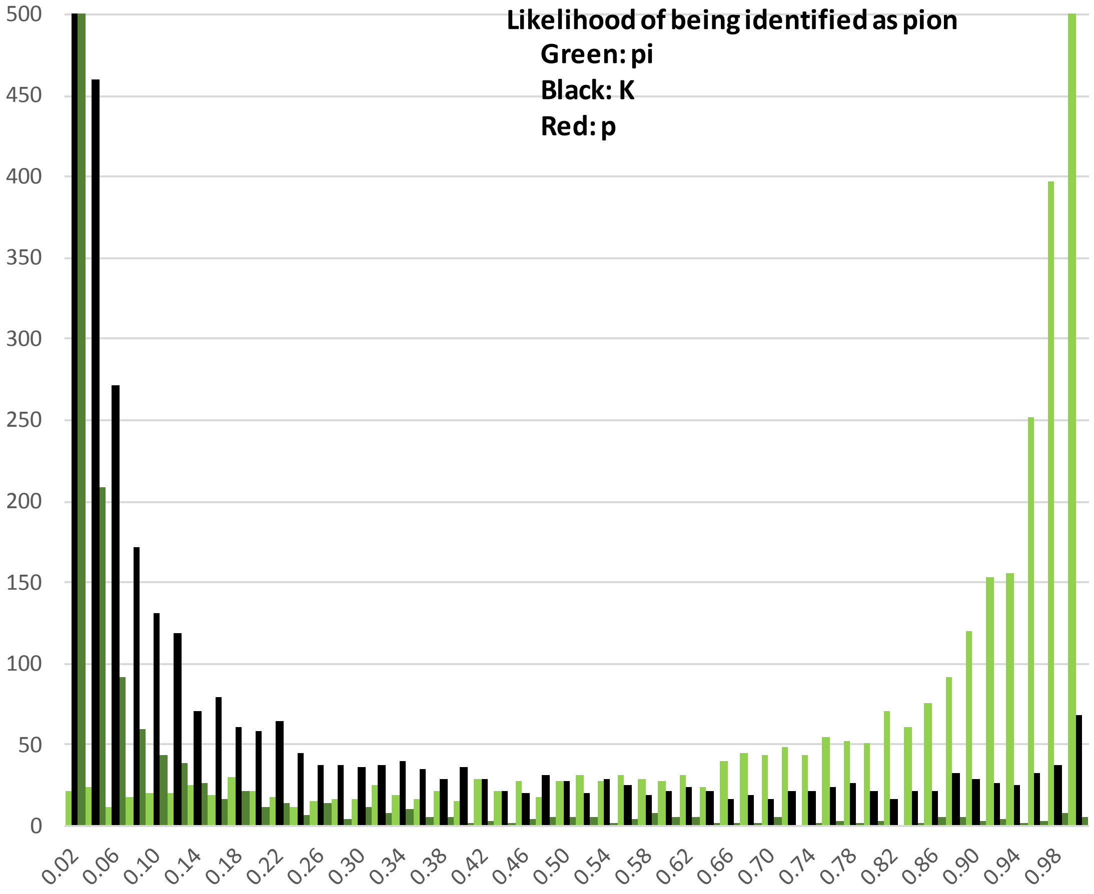
$\omega_{max} = 32.7$ keV $\gamma_s = 4.8 \times 10^4$

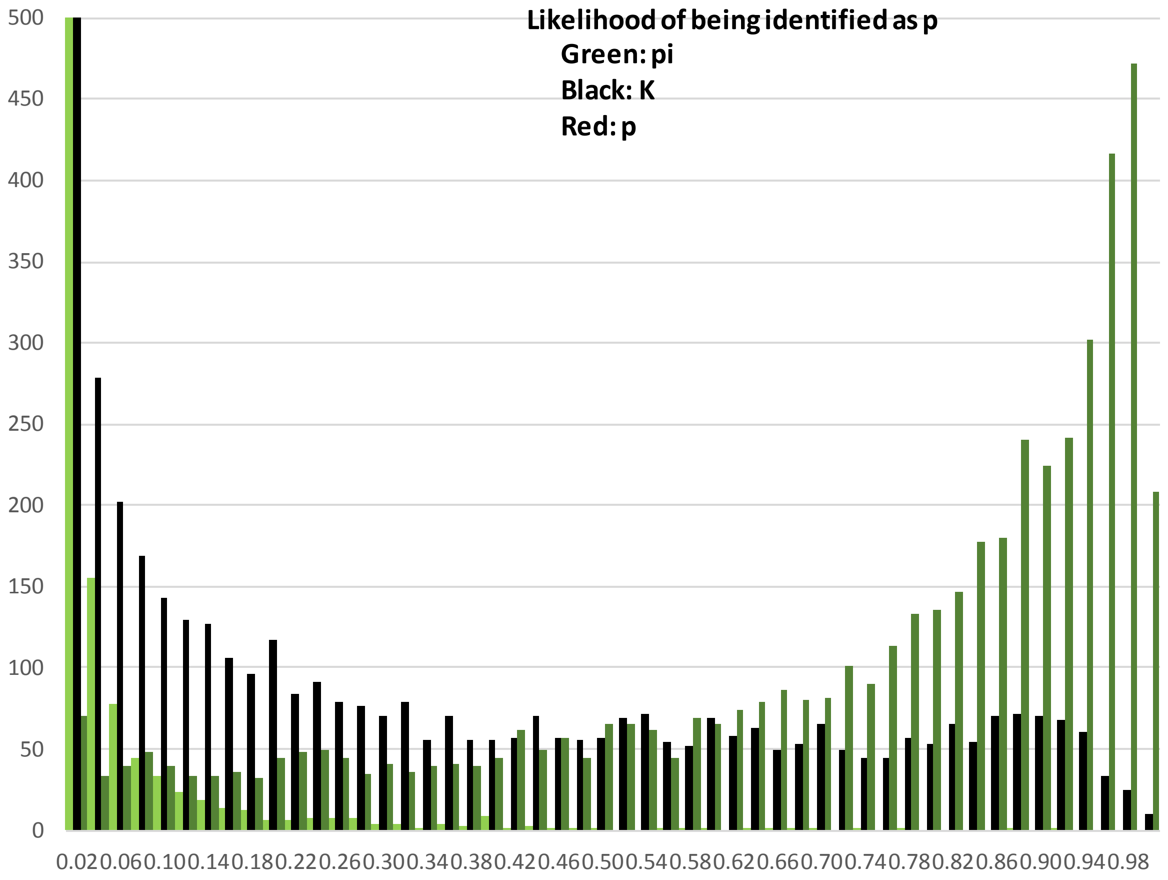
Total length 6.3 m Thickness 11 g

Modules 1-10: 1 cm Xe Modules 11-20: 2 cm Xe

Include Compton + photoelectric cross sections

Account for feedthrough from one module to next





78% pion efficiency

2.2% of K's incorrectly identified as π's

0.02% of p's incorrectly identified as π's

55% proton efficiency

4.2% of K's incorrectly identified as p's

0.8% of π's incorrectly identified as p's

Compton Scatter TRD

TR x-rays emitted with angle ~ 1/γ

→ difficult to spatially separate from ionization signal

Two Paths to take

1. Don’t separate:

Layer with thin gas (xenon) detector can detect photons well below ~30 keV

Detection length sufficiently thin to keep ionization signal not much larger than TR signal

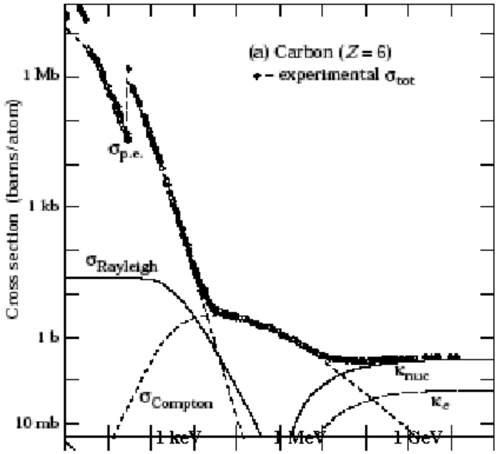
Maximal efficiency requires keeping ω’s to be low and radiator foils to be thin

2. Separate via Compton Scattering

Employ 250 μm Al foils to push TR x-ray energies > ~50 keV where Compton scattering begins to dominate

Al radiator foils can then Compton scatter TR photons, separating them from ionization deposition

Detect scattered high-energy photons with scintillator (CsI) efficiently



See

Measurement of Compton Scattered Transition Radiation at High Lorentz Factors, G. Case et al., hep-ex/0209038

Compton Scattered Transition Radiation from Very High Energy Particles, M. Cherry & G. Case, astro-ph/02060663

Plasma frequency depends on density.

As plasma frequency goes up, so does X-ray absorption, particle interaction probability, delta ray background

Plasma frequency depends on density.

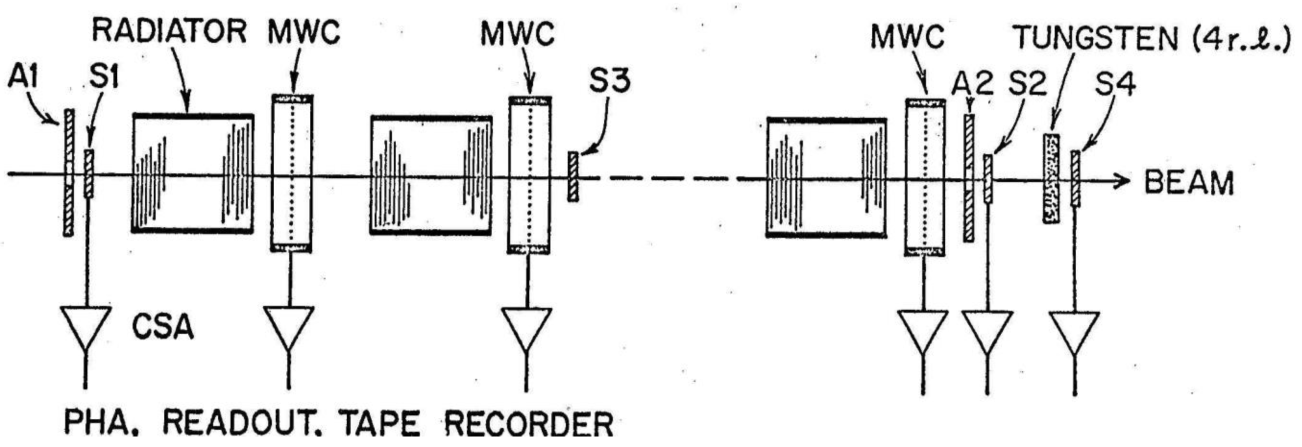
As plasma frequency goes up, so does X-ray absorption, particle interaction probability, delta ray background

… and Compton scattering.

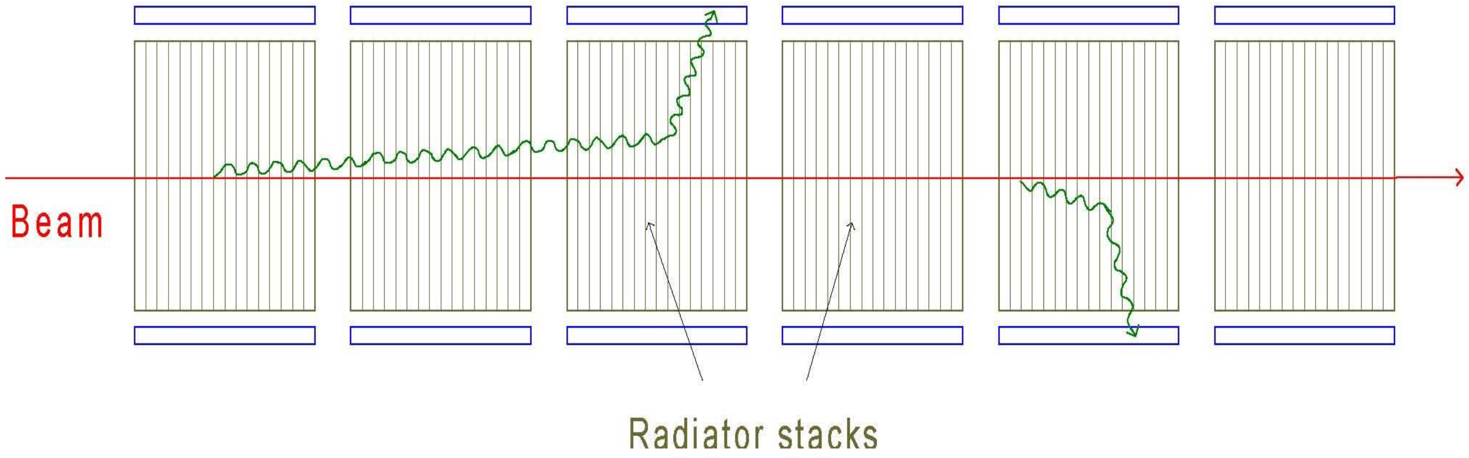
In a standard configuration, X-rays are emitted forward and detected together with dE/dx.

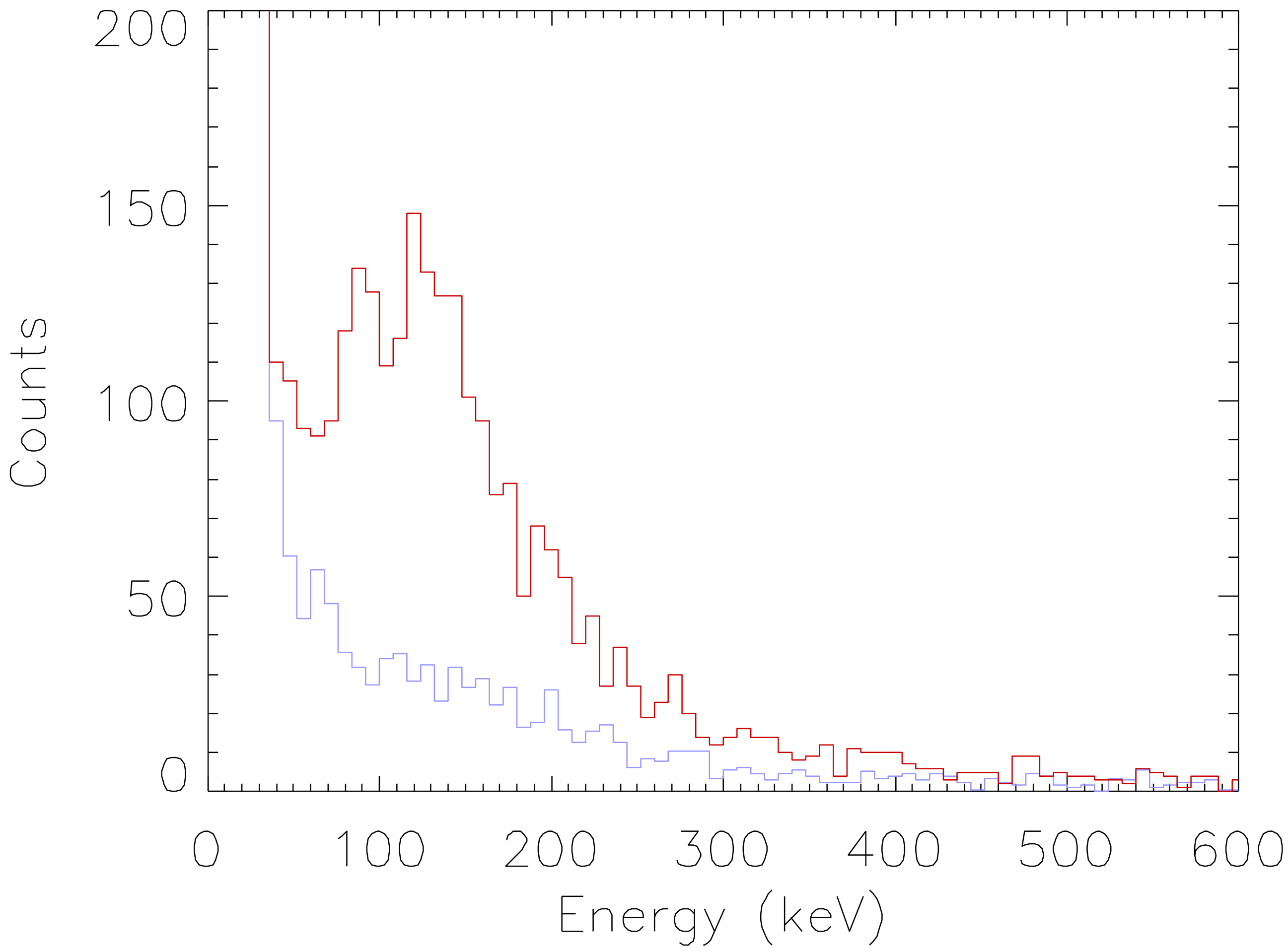
Compton scattering allows the X-rays to separate from the dE/dx.

“Standard” configuration – SLAC test w/plastic foils/foam, Xe

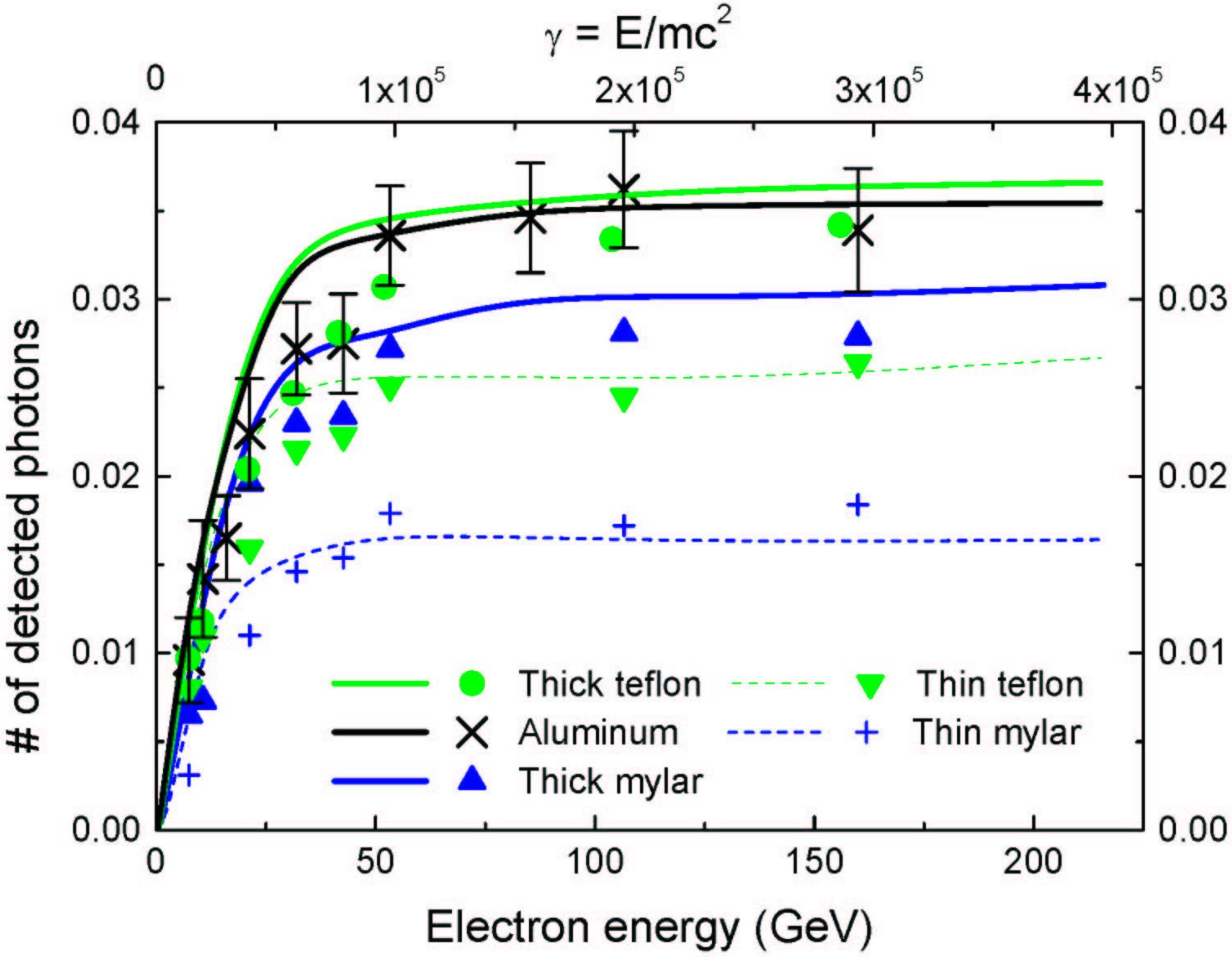


Compton scatter configuration – CERN test w/Al honeycomb, NaI





Measured spectrum, 150 GeV/c electrons with
Al honeycomb radiator (upper curve) and
solid background plates (lower curve)



Measured 35-500 keV Compton scattered intensity

Mylar, 50 foils, l_1 = 125 and 250 μm, l_2 = 3.3 mm
Teflon, 50 foils, l_1 = 125 and 250 μm, l_2 = 3.3 mm
Al, 37 foils, l_1 = 150 μm, l_2 = 5.1 mm

What is beam configuration?

Will beam configuration allow NaI/CsI scintillators along side of beam pipe to detect Compton scattered photons?

Next steps:

Include Compton scattered photons off to the side

Since much of signal is at > 30 keV, expect large Compton signal.

Analyze signal as function of location along beam

Frequency dependent – gamma dependent