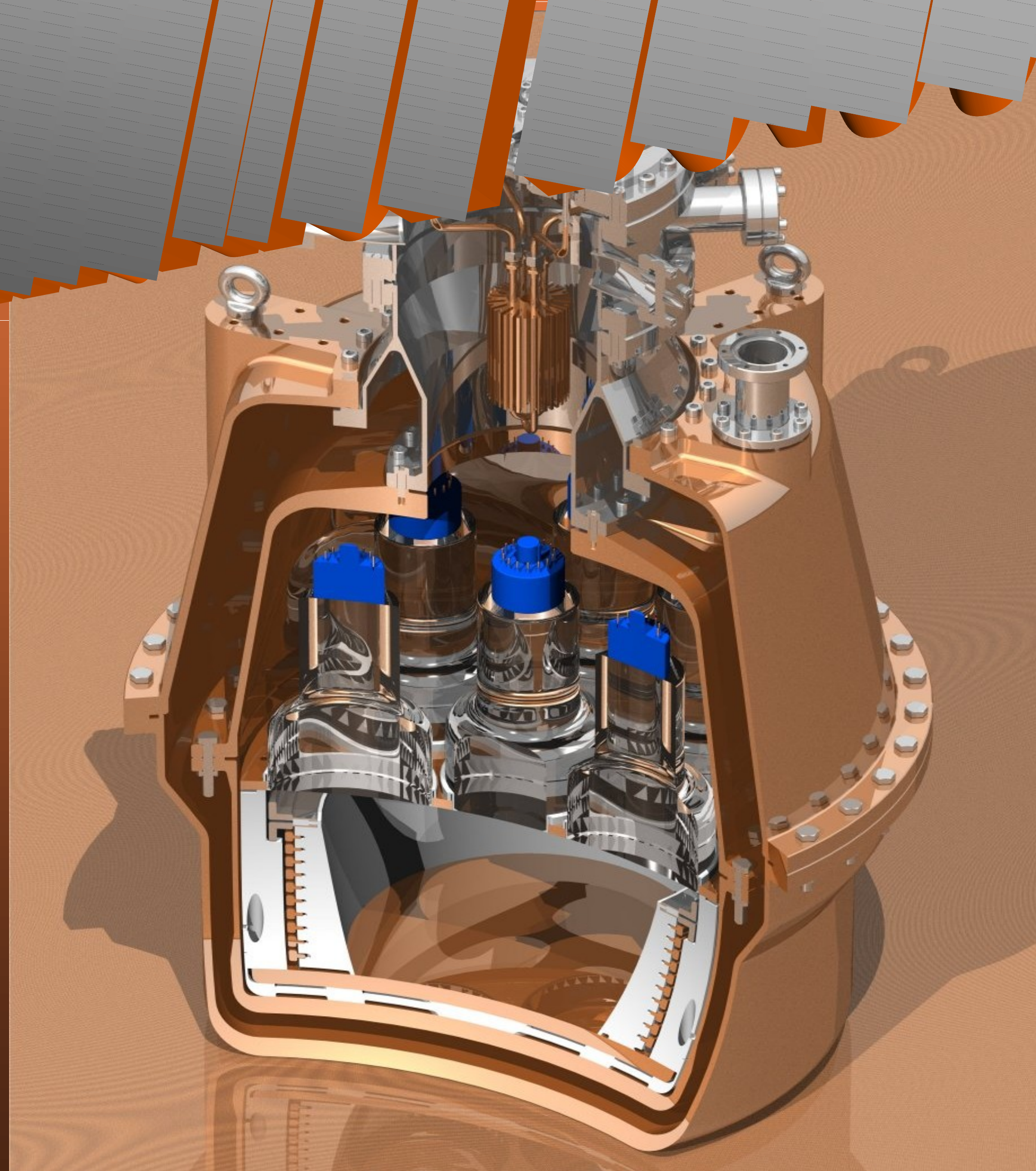
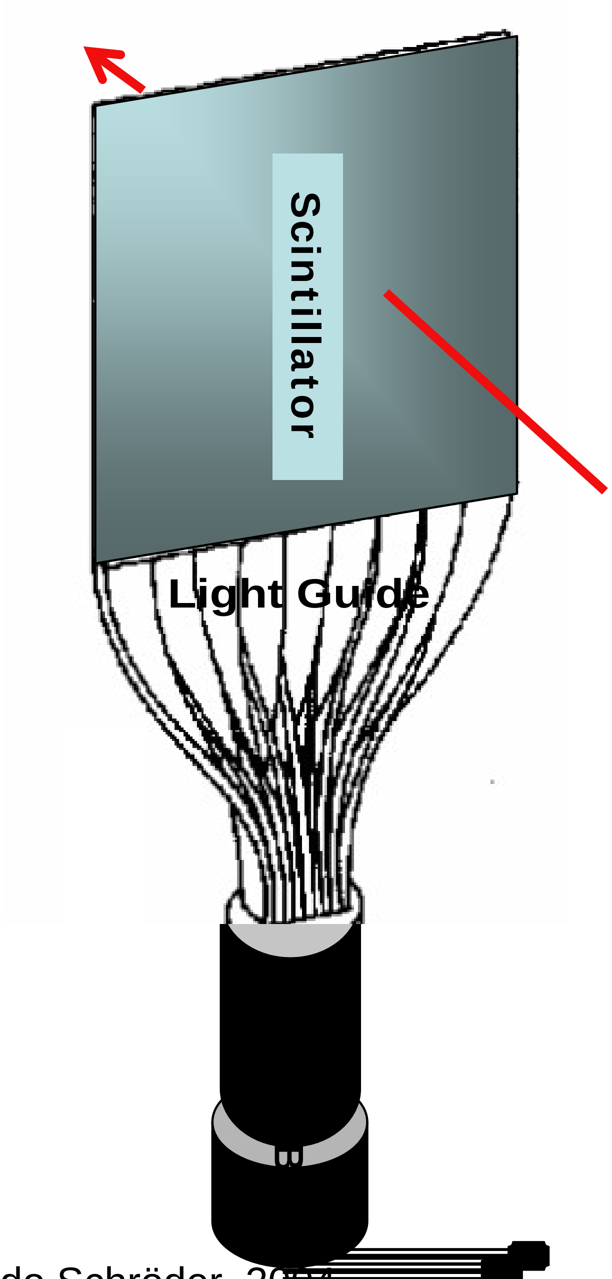


ZEPLIN III

Construction of Scintillation Counters



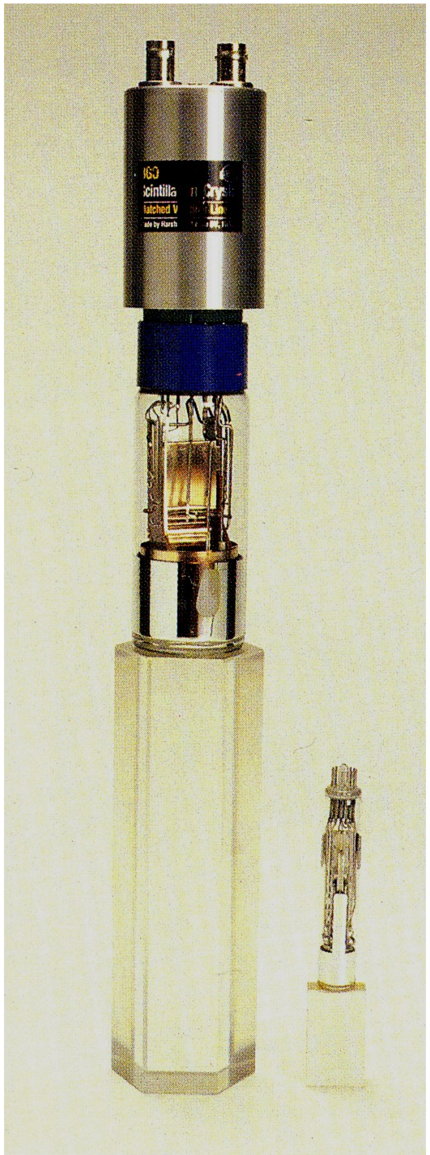
- Scintillator $(q\ (\Delta E) \rightarrow h\nu)$
- Light guide (*collect, direct*)
- Photomultiplier $(h\nu \rightarrow e^-)$
- Base (*power, readout*)

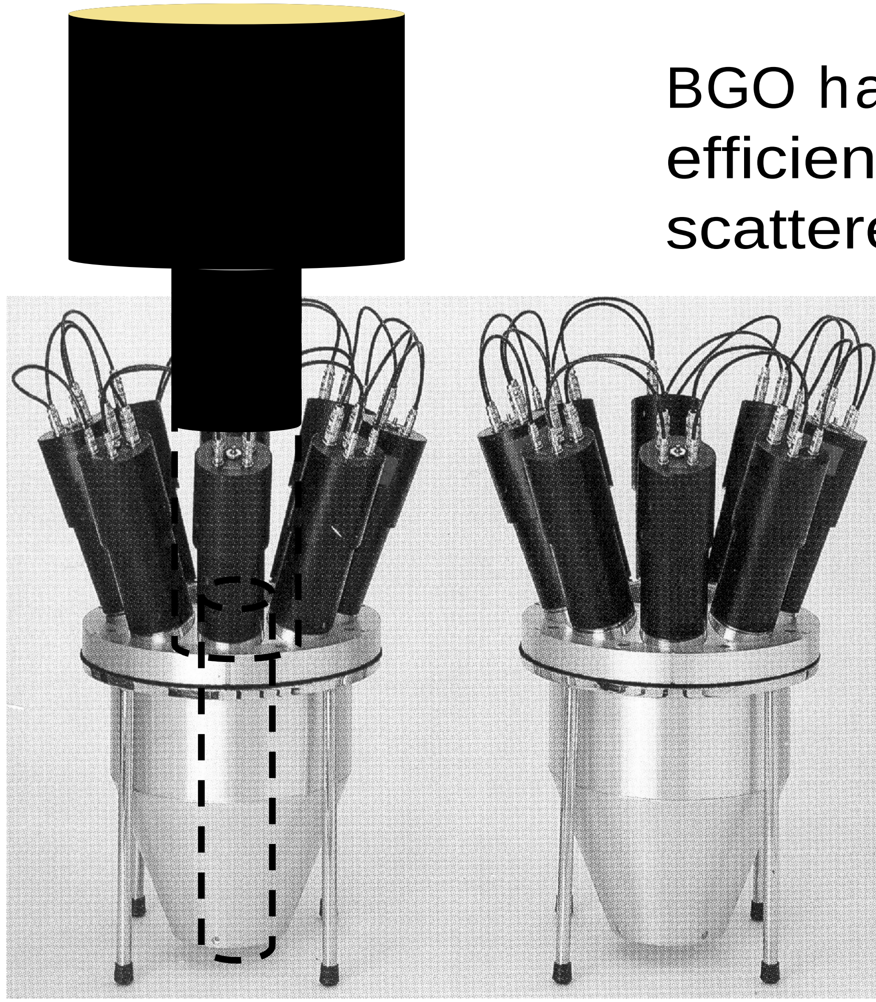
Scintillating Materials

Inorganic
- *gas (Ar, Xe,...)*
- *liquid (He, Xe,...)*
- *solid (NaI, CsI, BGO, BaF_2..)*

Organic
- *liquid (xylene, benzene,..)*
- *solid (polystyrene,..)*

BGO Detectors

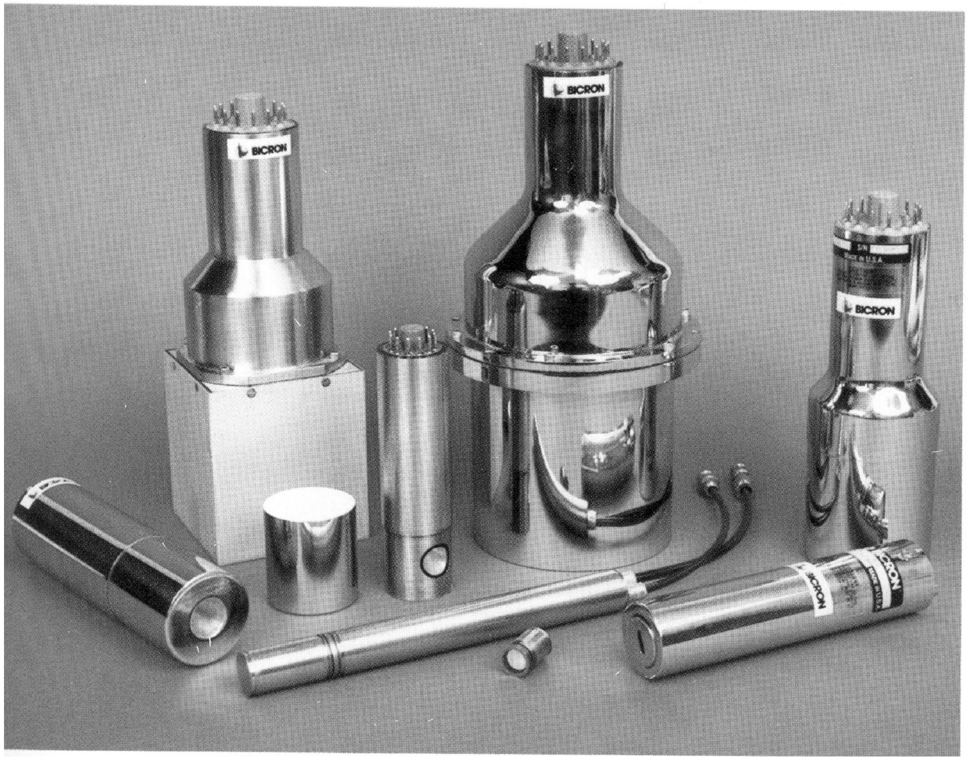




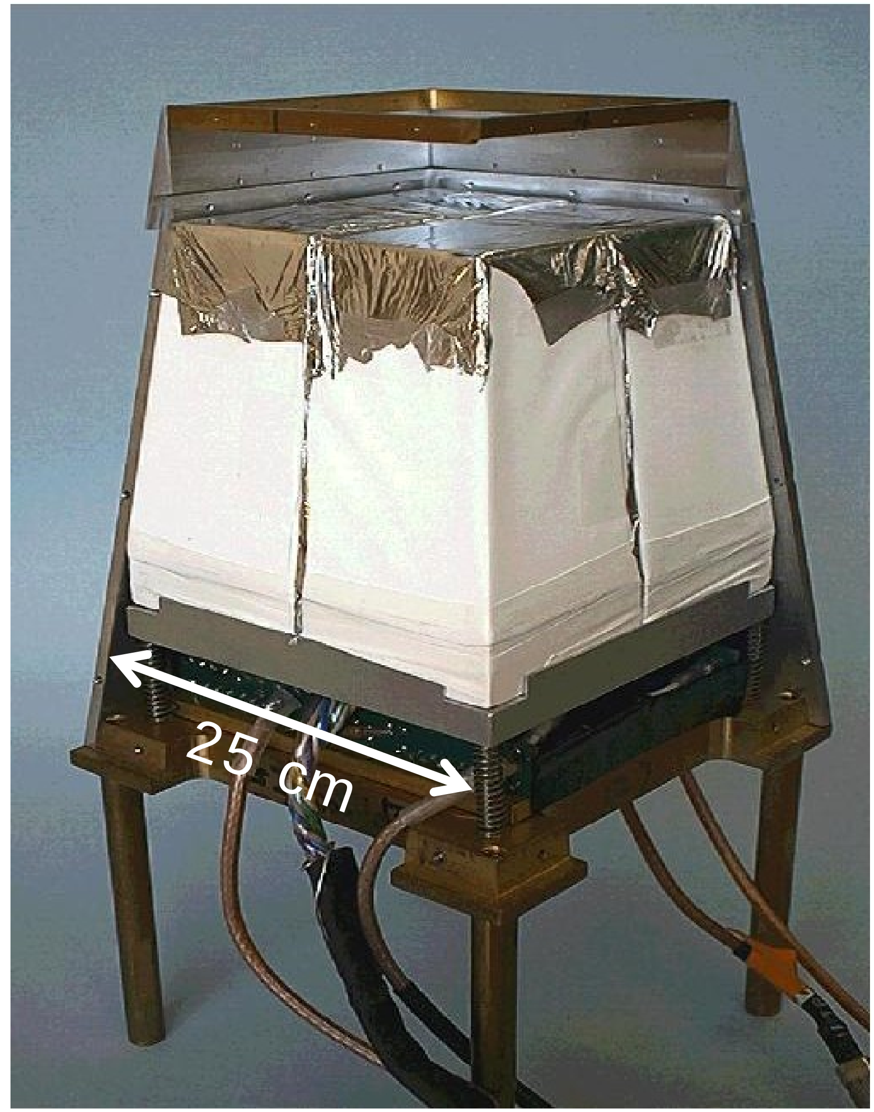
BGO has high density, efficiency for Compton scattered photons

Anti-Compton Shield detectors for high-resolution γ spectroscopy

NaI(Tl) and CsI(Tl) Scintillation Detectors

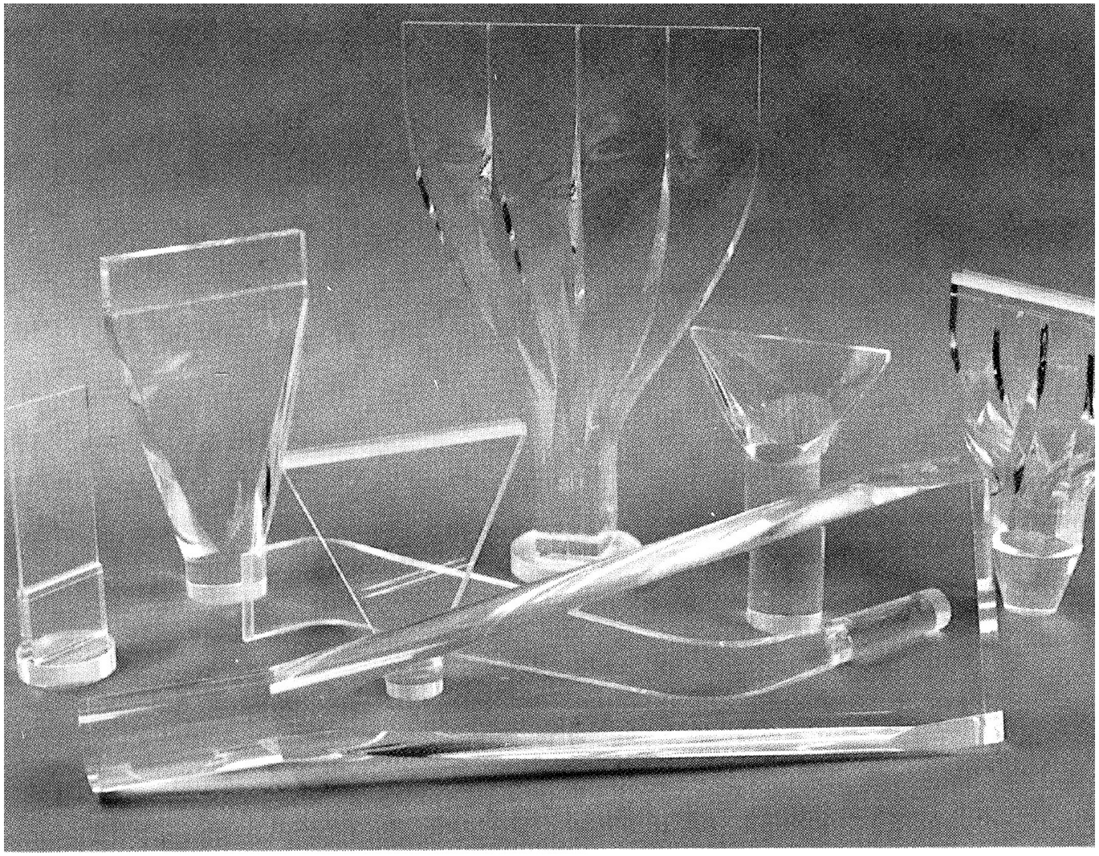


Commercial NaI(Tl) detectors:
Integral lines. (Harshaw)



Segmented CsI(Tl) detectors
for LASSA array (deSouza)

Light Guides



Liouville Theoreme: constant phase space volume (decrease cross section of guide → loss of intensity)

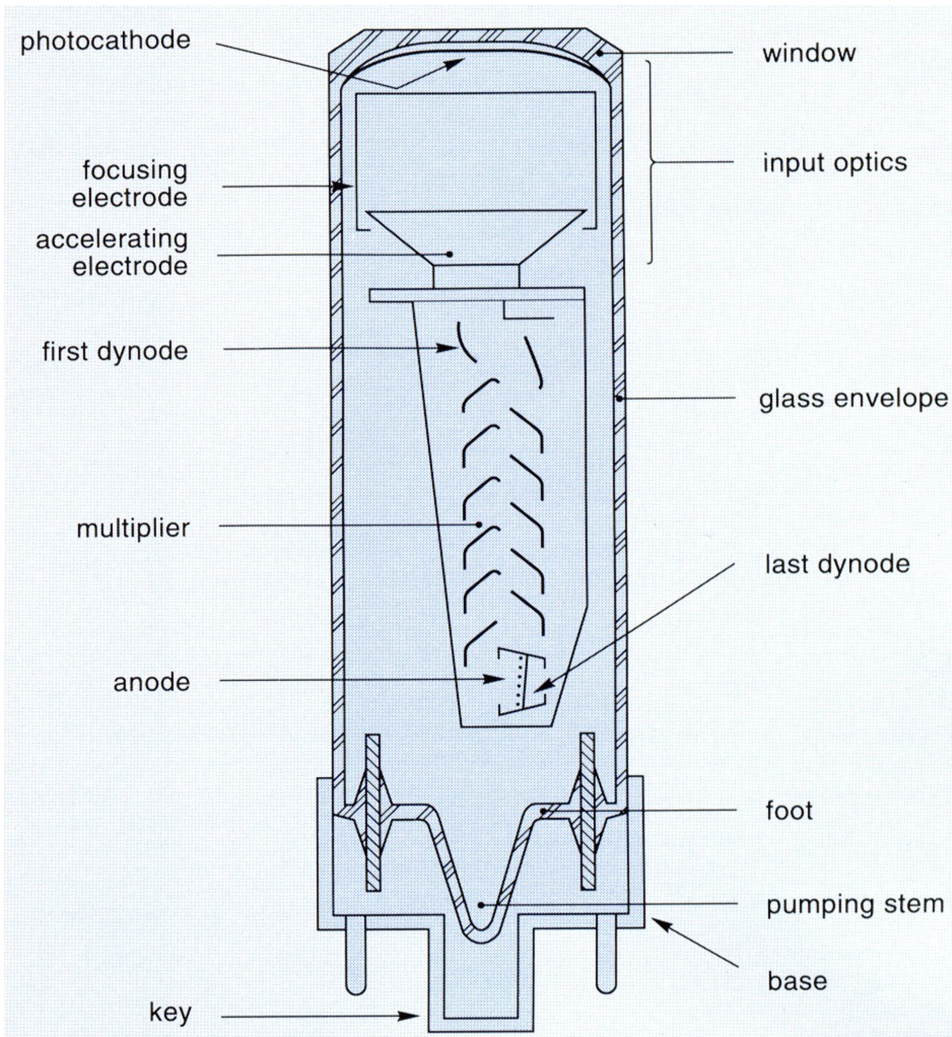
Bending radius r large enough for total internal reflection

$$n^2 - 1 > \left(d/2r + 1\right)^2$$

n=refractive index
d=diameter of guide

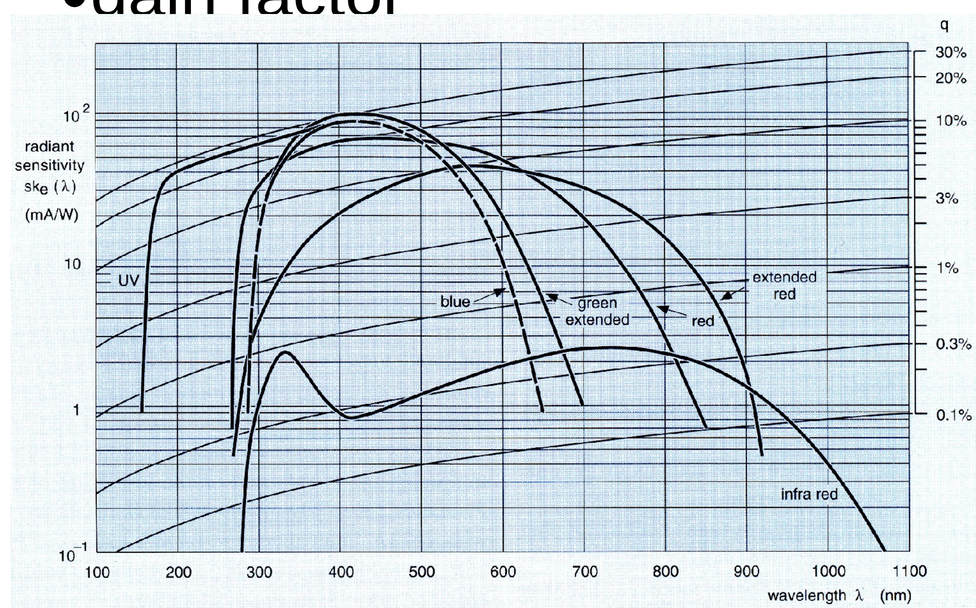
Electronic Photo-Multipliers

Philips 56 AVP



Criteria for choice:

- match photo cathode to scintillator light
- quantum efficiency
- rise time
- entrance window (glass, quartz,..)
- gain factor



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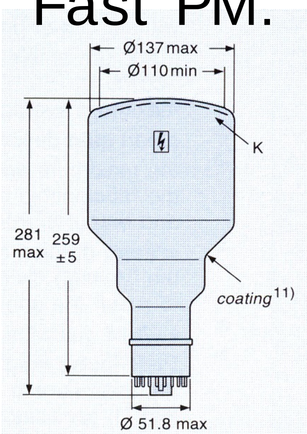
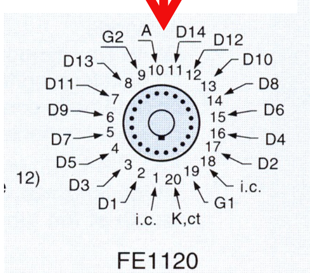
PM Operation

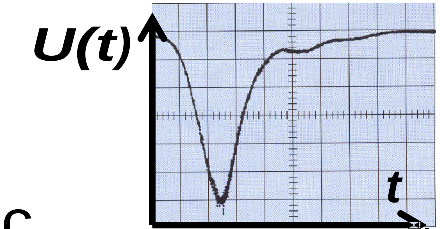
Fast PM: pulse rise time ~ 2ns, gain: $3 \cdot 10^7$

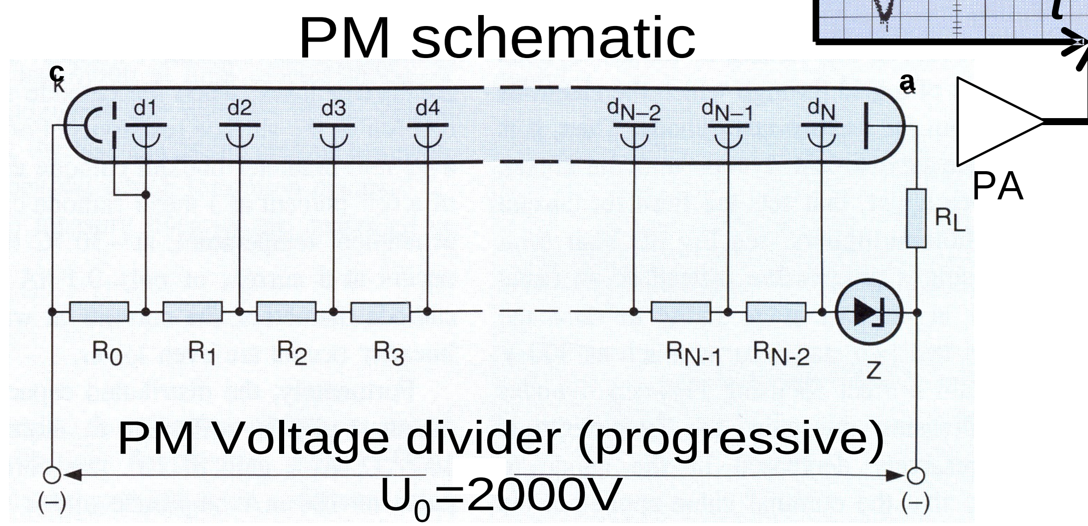


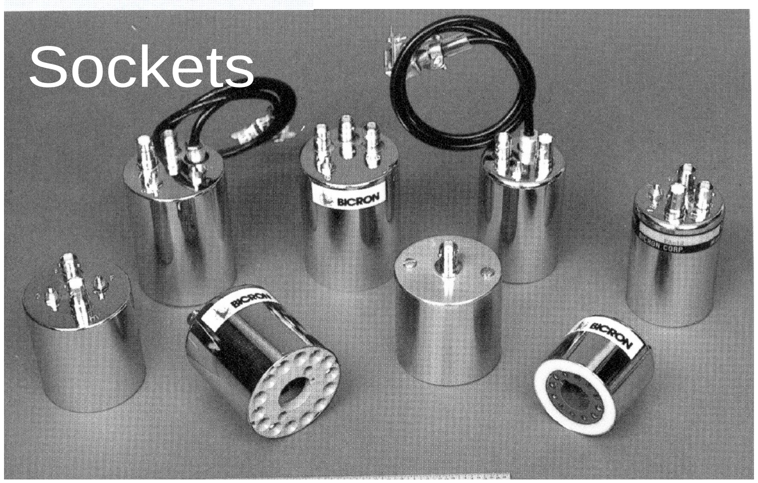
Philips XP2041
5″ dia cathode
14 dynodes
+ focussing
electrodes



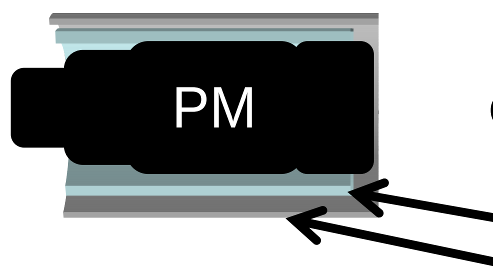
Socket FE1120
pin connections





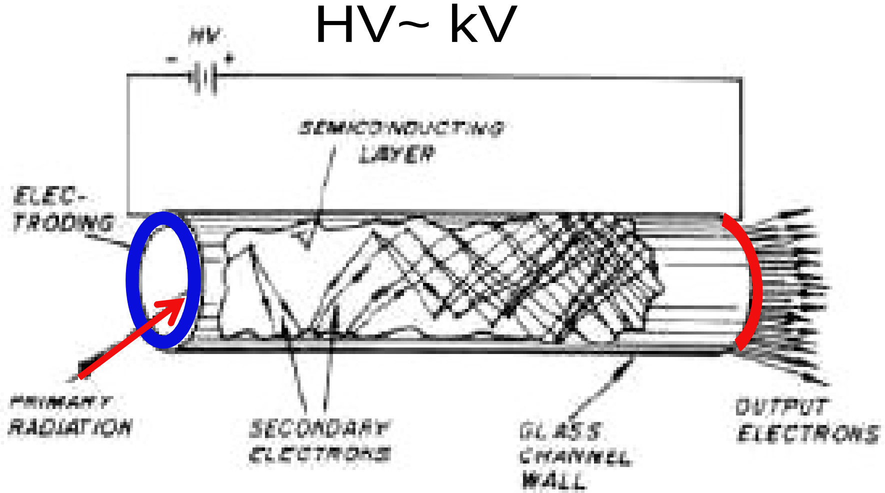


mu-metal shield
tube provides
protection from
external B field.



Channel Electron Amplifiers

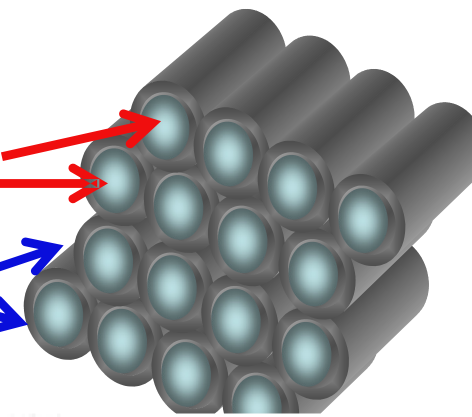
HV~ kV



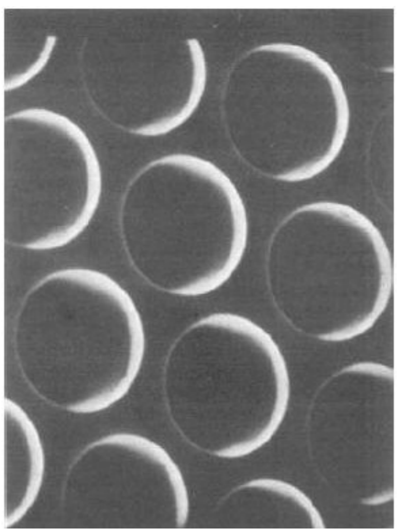
Glass fiber tube (straight o curved), few 10μm dia. etched, inside coating LiF, MgF_2,KCl,CsI,..

soft core glass

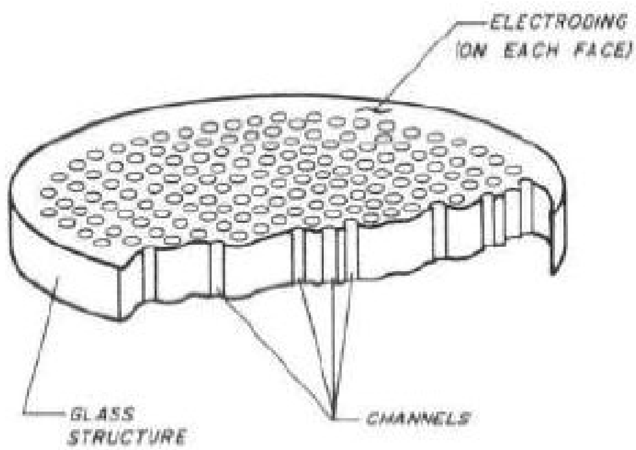
lead glass cladding



Stacked tubes

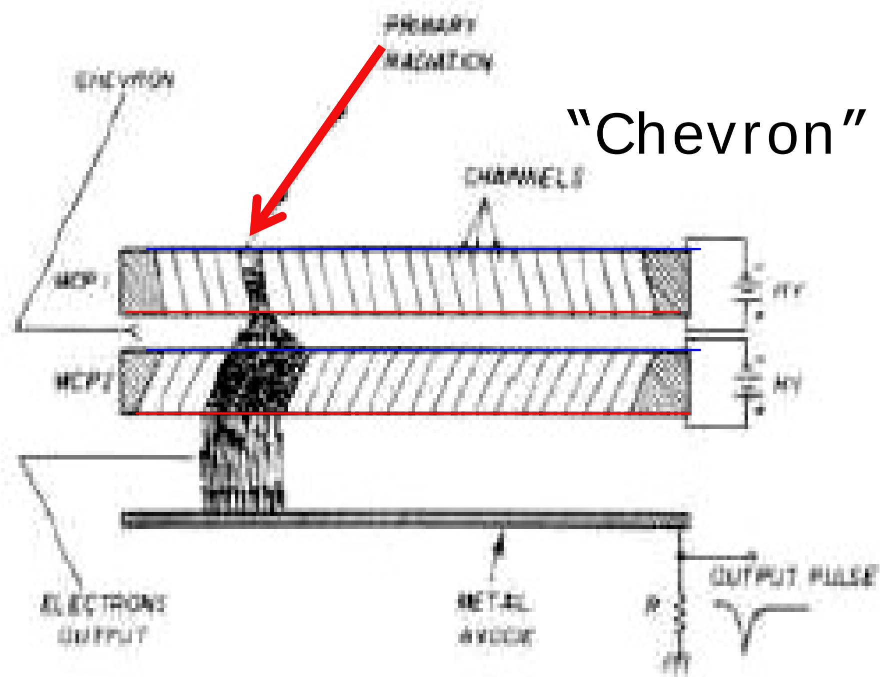


MCP face



Multi-Channel Plate

“Chevron”



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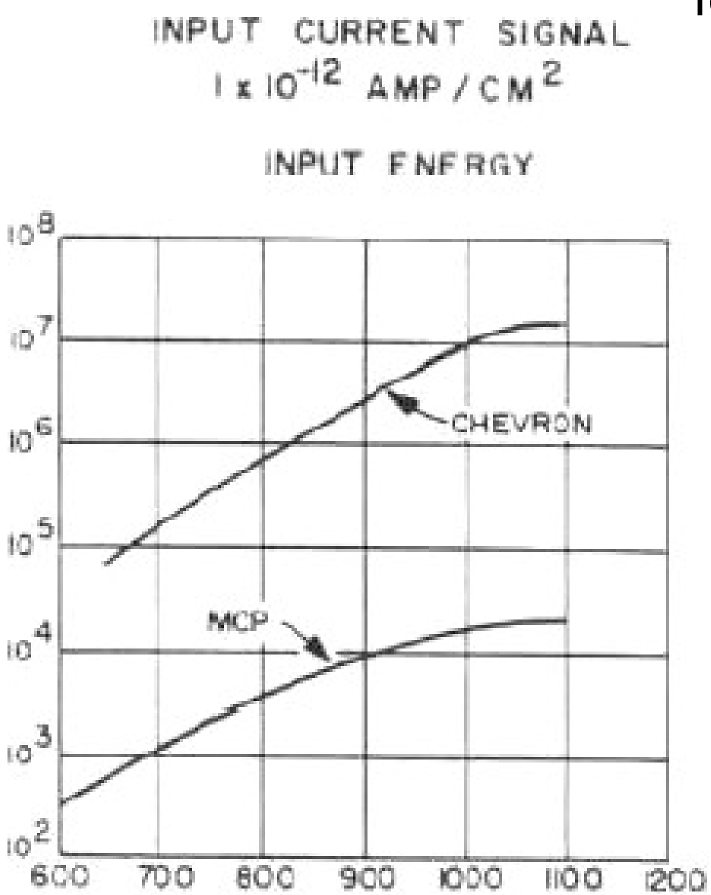
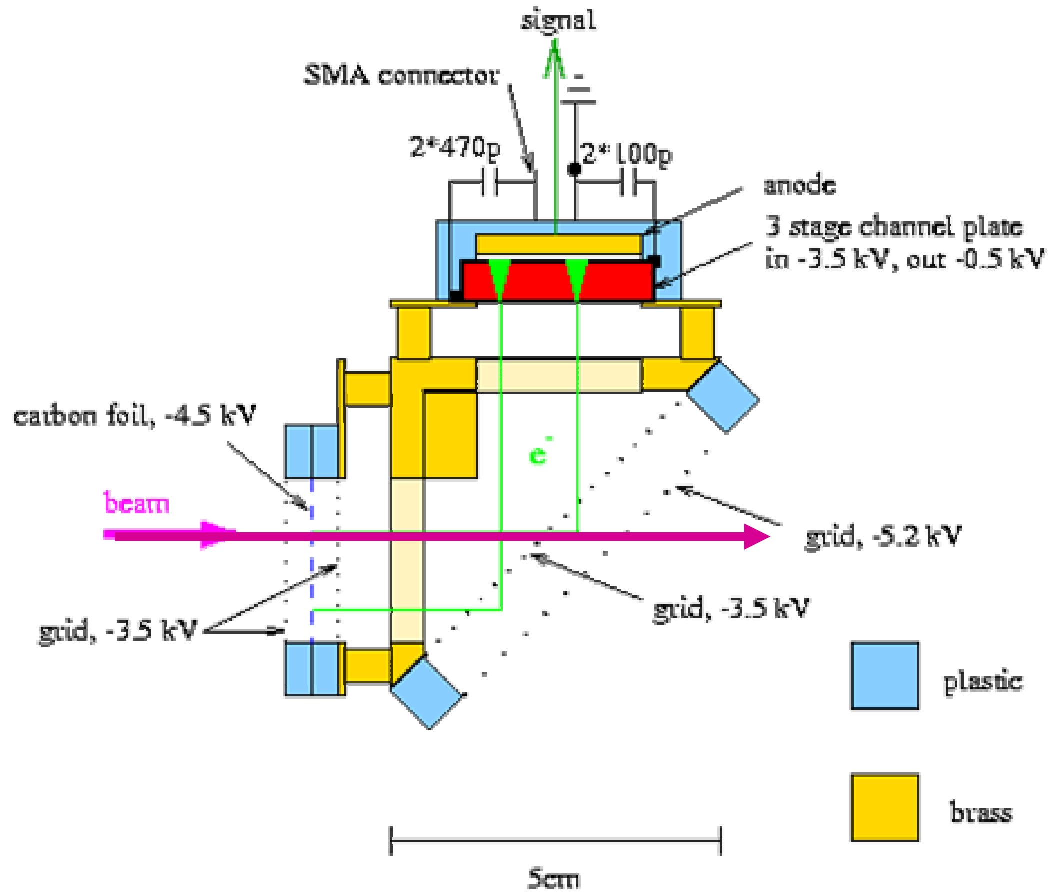
Applications of Channel Plate Multipliers

high gain=high efficiency, fast response. Use for timing (TOF-Start/Stop)

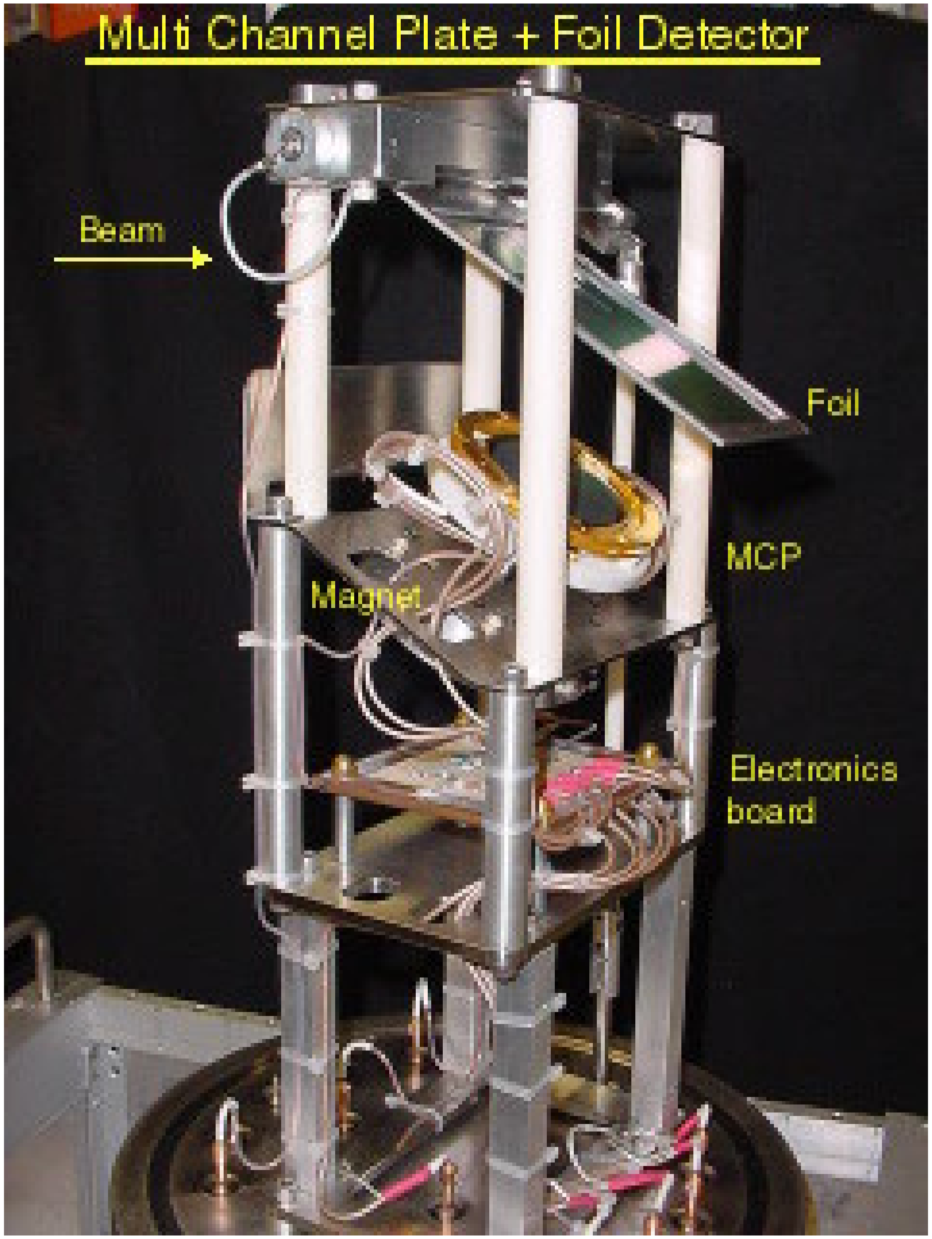




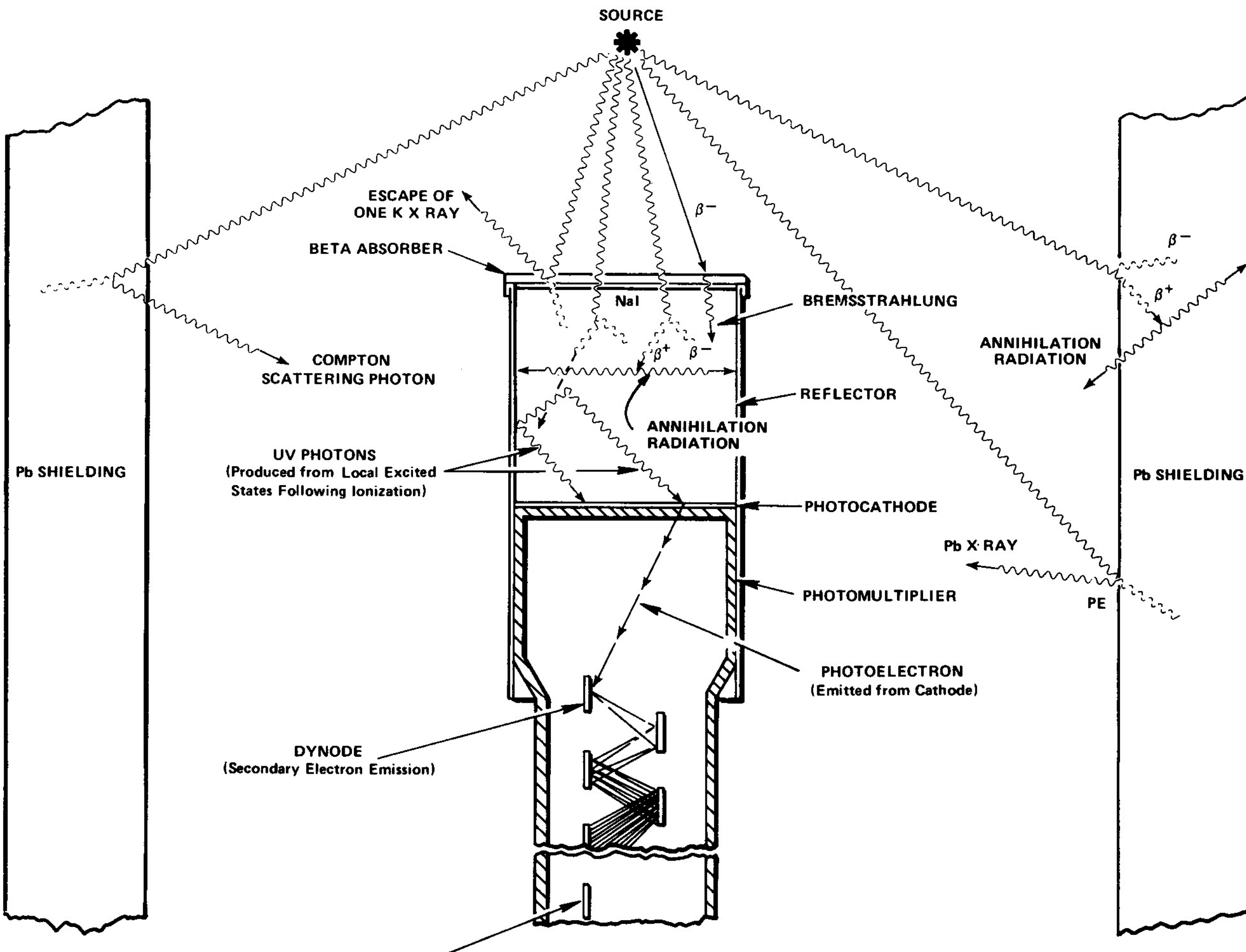
HI beam releases δ electrons in C foil, multiplied with multi-stage chevron

Examples of MCP e-Multipliers

Chevron mounted: El-Mul Technologies Ltd.



Environment of γ Scintillation Measurement



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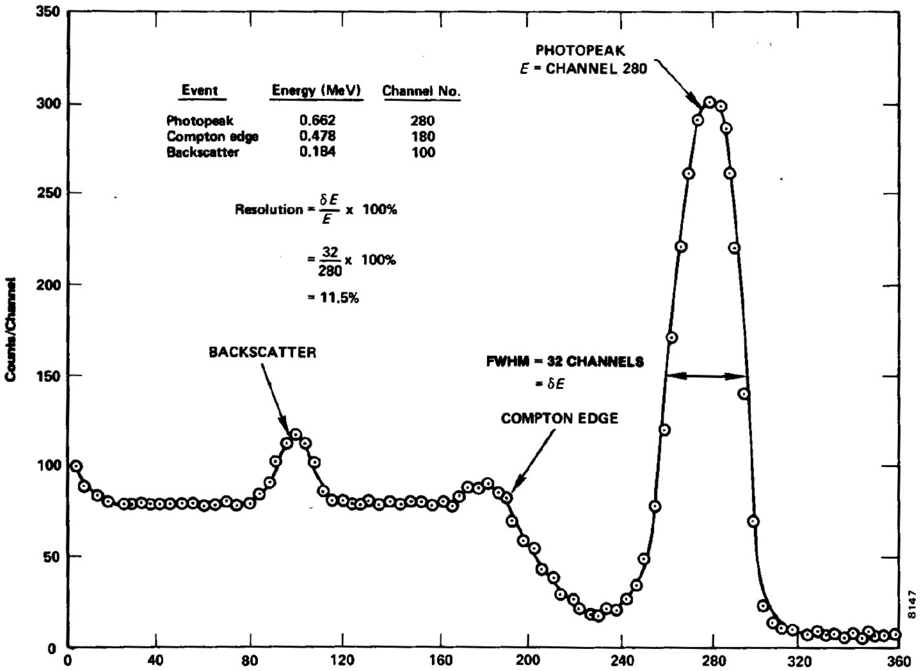
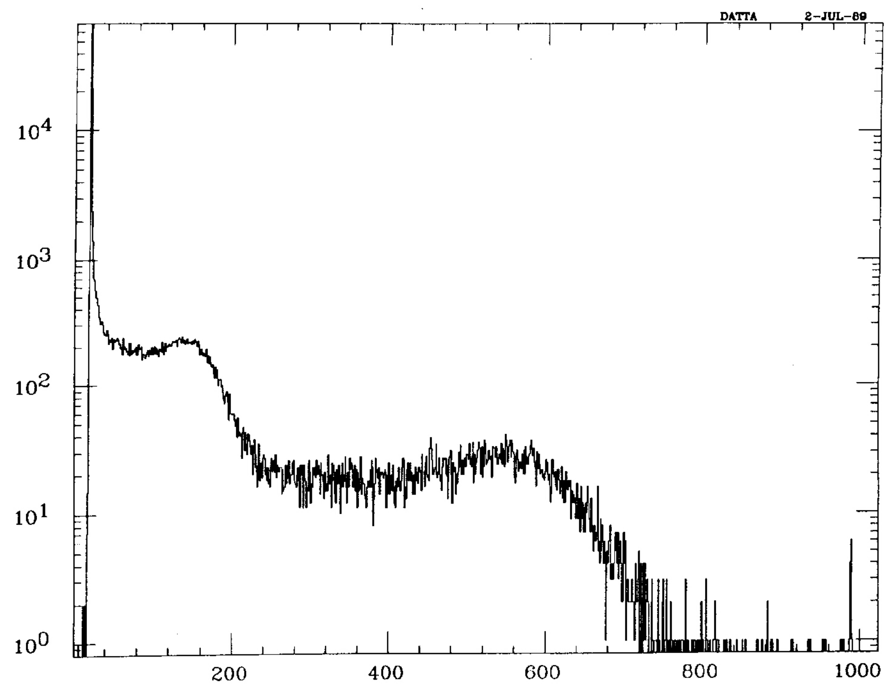
Photon Response

^{137}Cs- γ spectrum with inorganic scintillator (NaI)



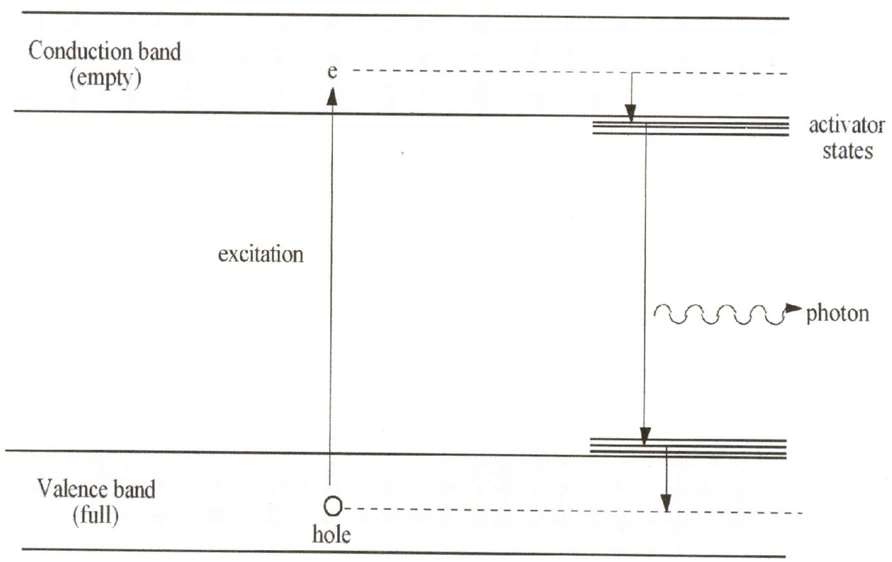
Light Output (Energy)

^{22}Na- γ spectrum with organic scintillator (NE213)



Light Output (Energy)

Scintillation Mechanism: Inorganic Scintillators



Excitation electronic:
VB → CB (or below)
Trapping of e- in activator states (Tl) doping material, in gs of activator band e transition emits lower $E\gamma$, not absorbed.

Primary ionization and excitations of e- or excitons (e^-,h^+) → sequential deexcitation with different time constants.

Advantage: high density, stopping power → good efficiency

Disadvantage: slow response – μs decay time, "after glow", some are hygroscopic

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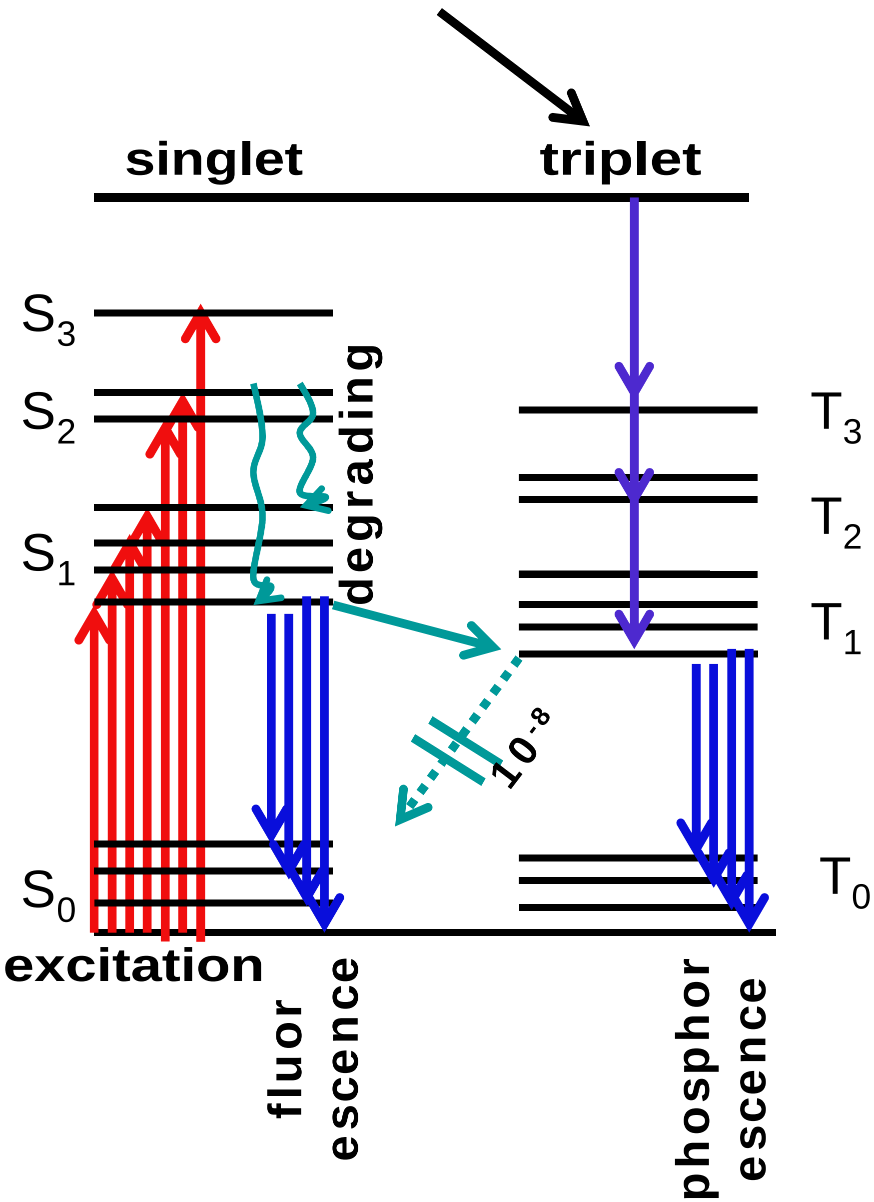
Scintillation Mechanism: Organic Scintillators



Excitation of molecular states determined by π electrons: singlets (↾⇂) and triplets (↿↾). Form vib. band heads

Trapping of e- in triplet states, slow decay to S_0 g.s.

Triplet excited (3:1) via ion recombination.

Decay via collisions
TT → SS+phonons (τ~ 300 ns)

E1 excitation/rad. less transitions depends on ionization density (A,Z,E)

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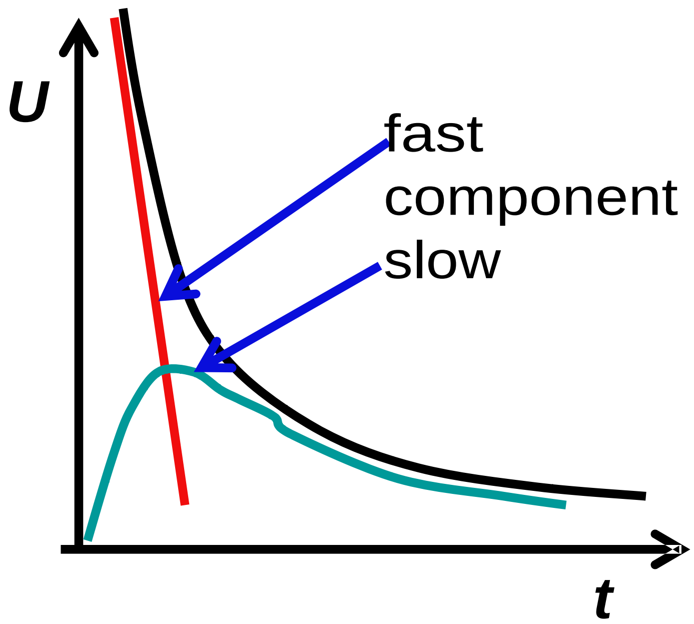
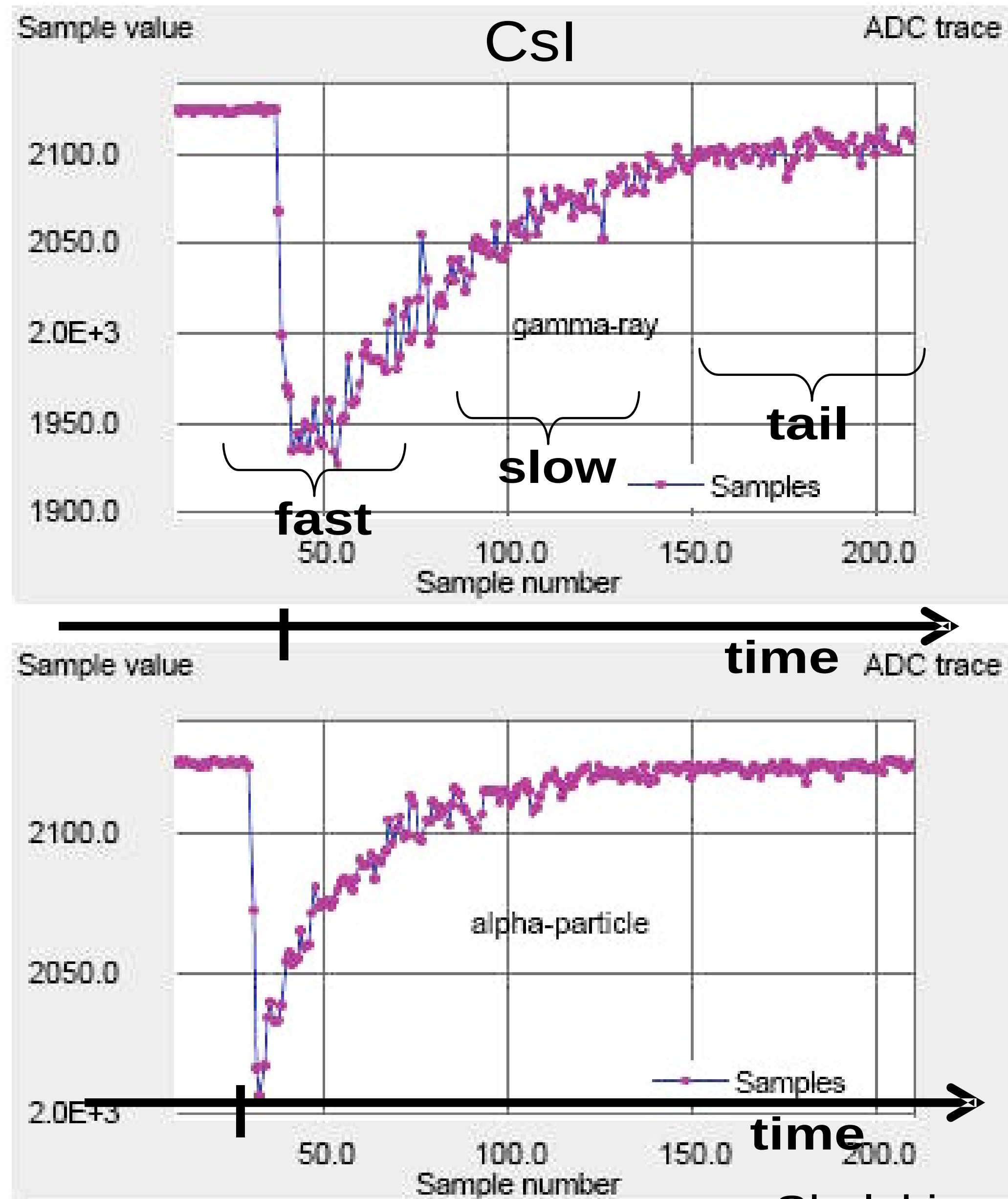
Light Output Response



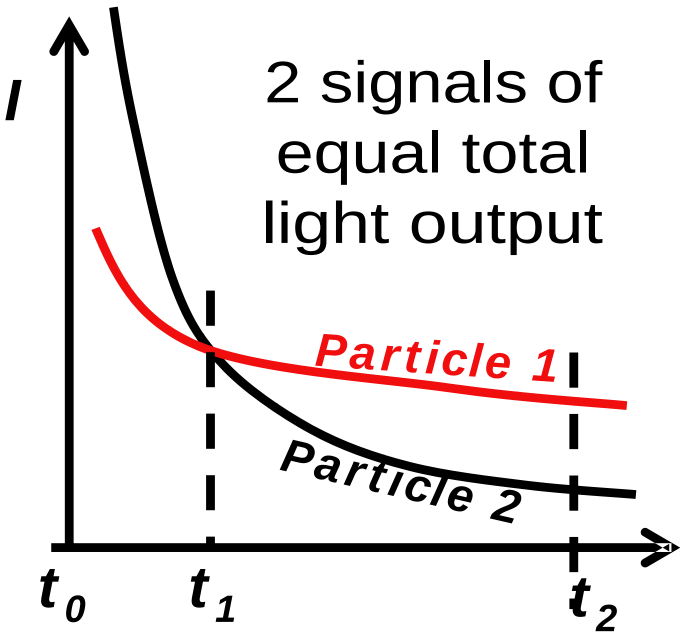


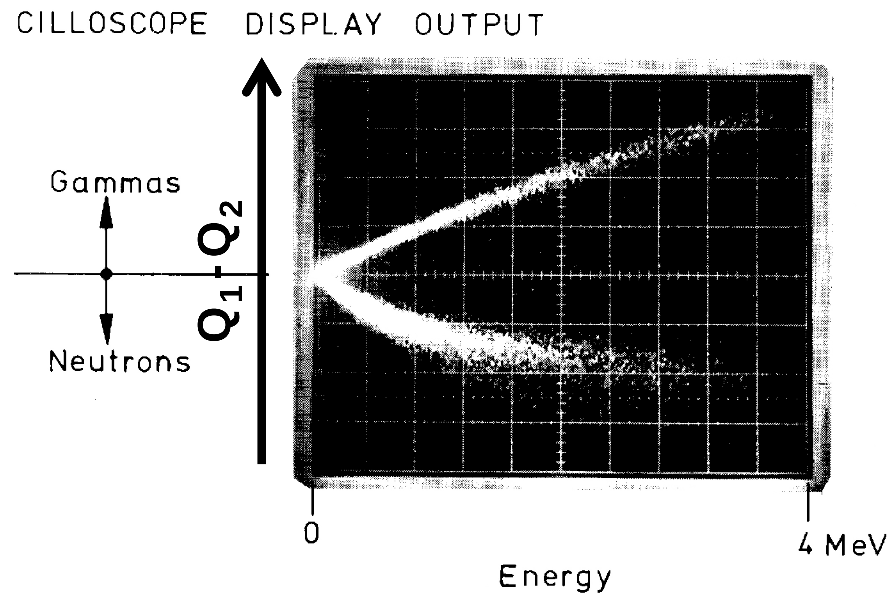
Skulski, pc

Different radiation leads to different mix of fast and slow → ID

Pulse shape discrimination retained electronically →

Pulse Shape Analysis

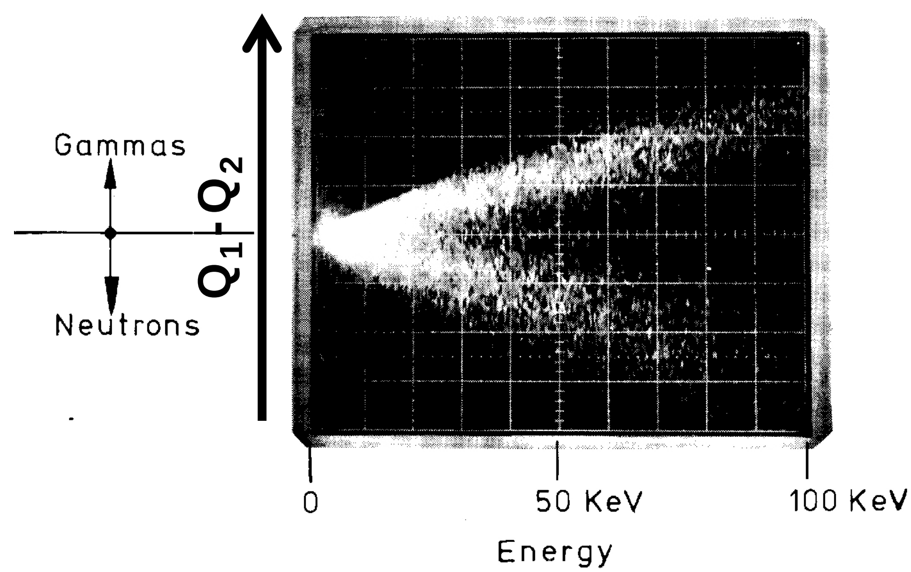




$$Q_1 = \int_{t_0}^{t_1} I(t)dt$$

fast
component
slow

$$Q_2 = \int_{t_1}^{t_2} I(t)dt$$



$$Q_1 + Q_2 = Q \propto L(Energy)$$

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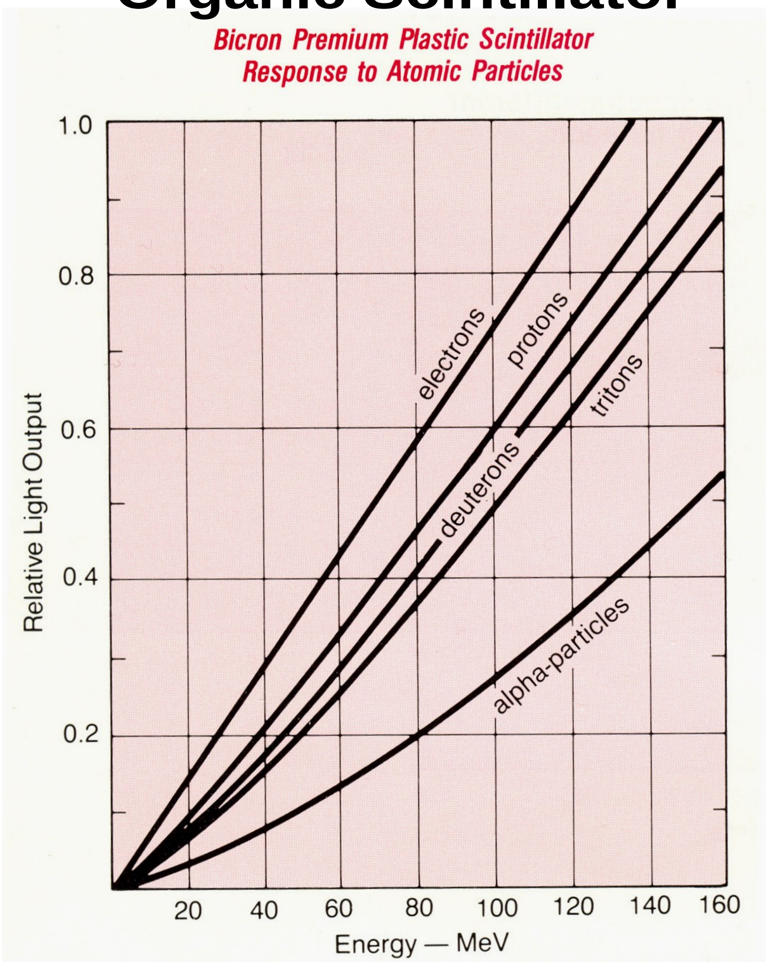
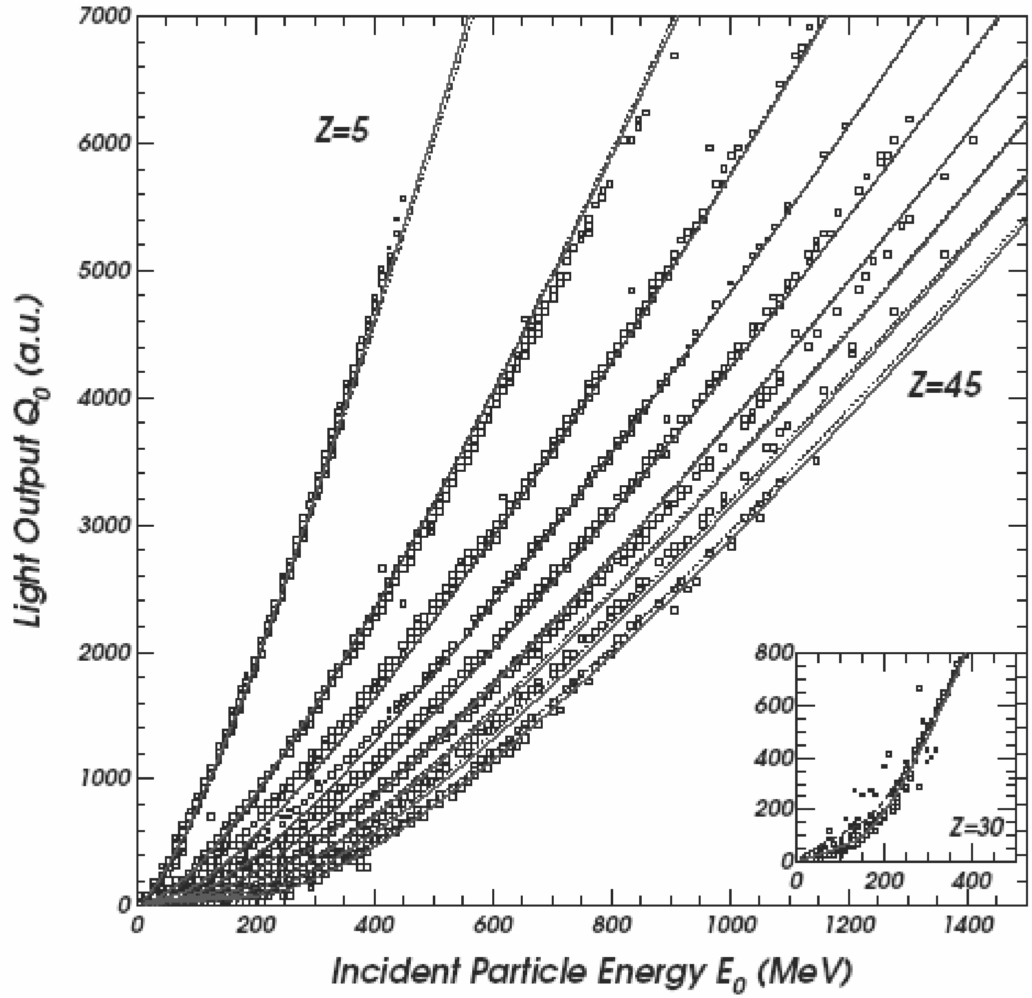
Pulse Shape Discrimination

Organic Scintillator



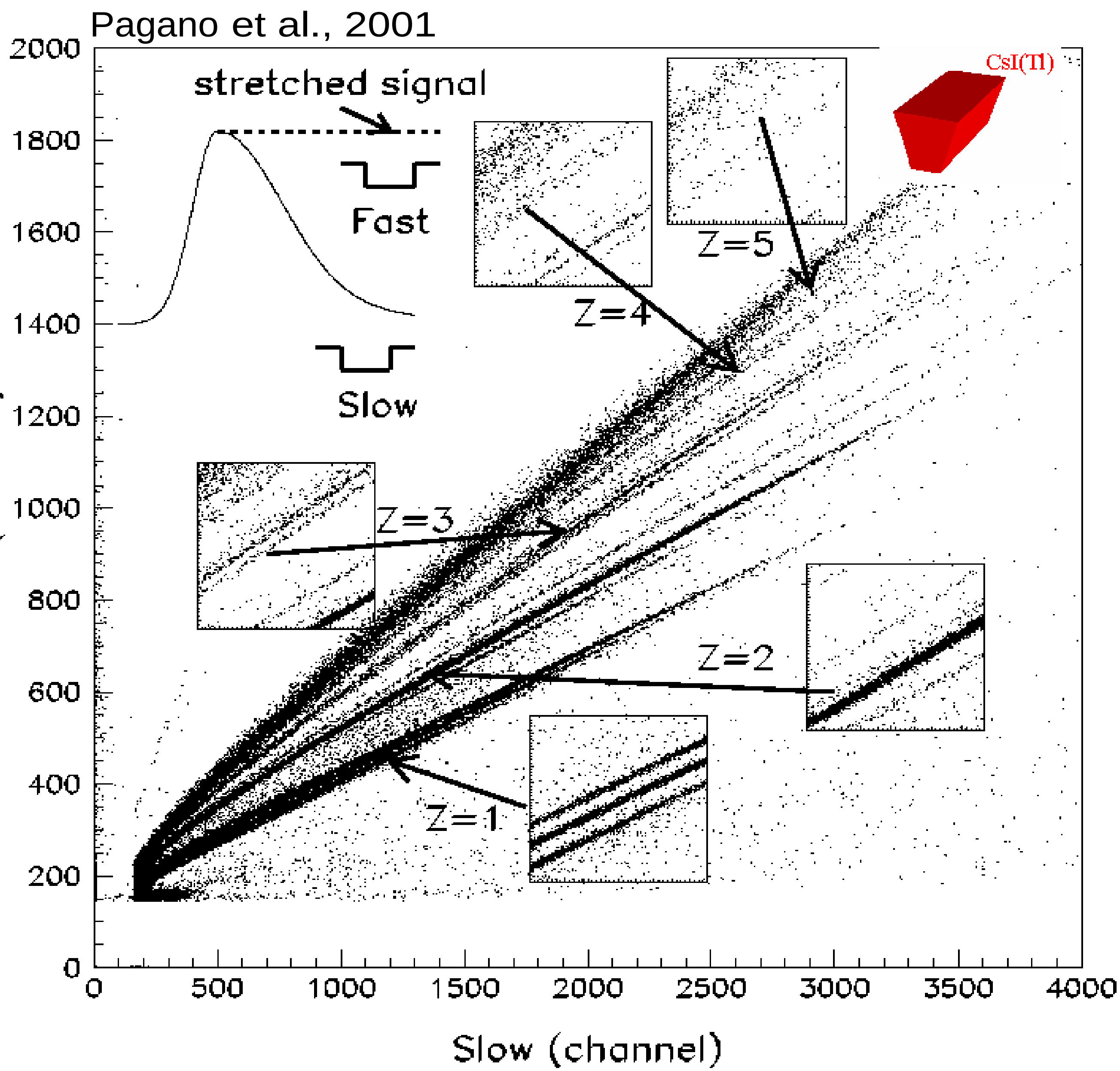
Bicron Corp.

Inorganic Scintillator CsI(Tl)



INDRA Collaboration

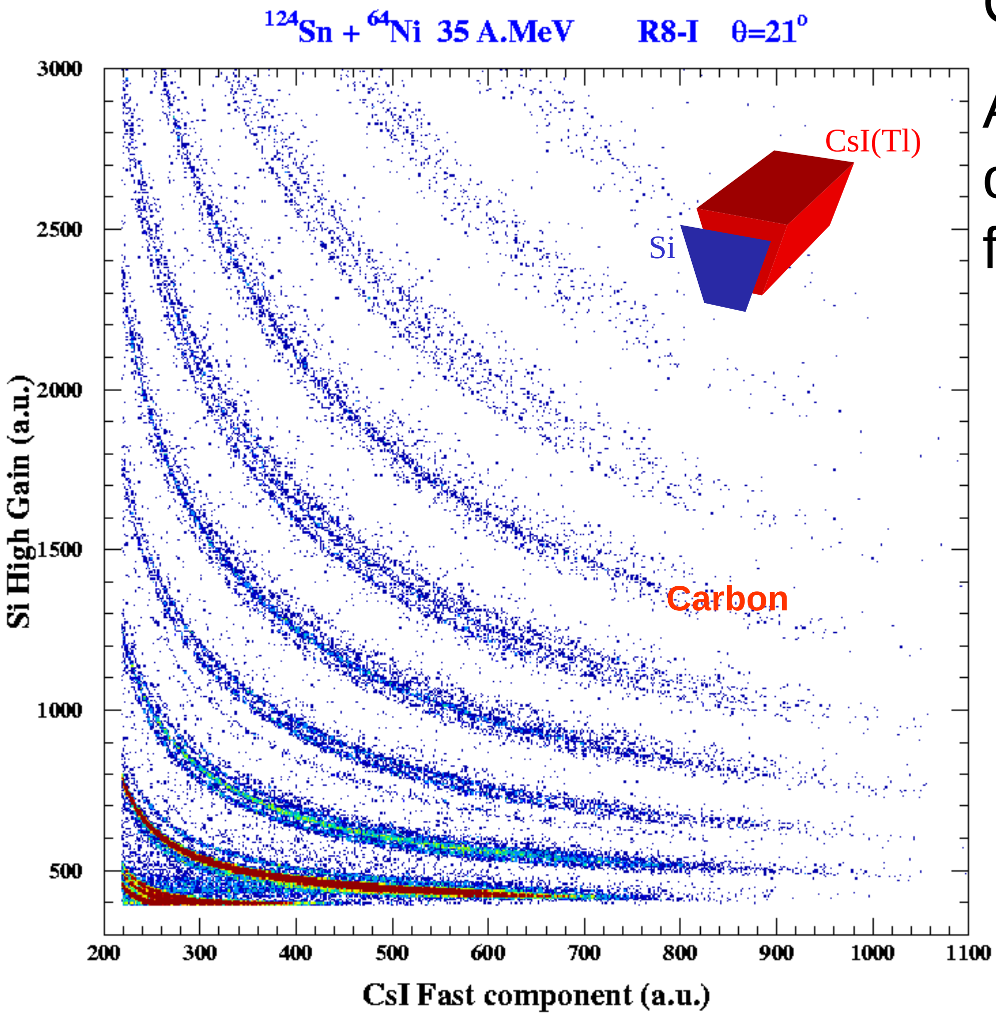
Light Charged Particle Identification: CsI(Tl)



A-Z Identification of LCP's: CsI(Tl)with photodiode read-out and pulse shape discrimination (<u>Chimera</u> 14° (ring 6I)).

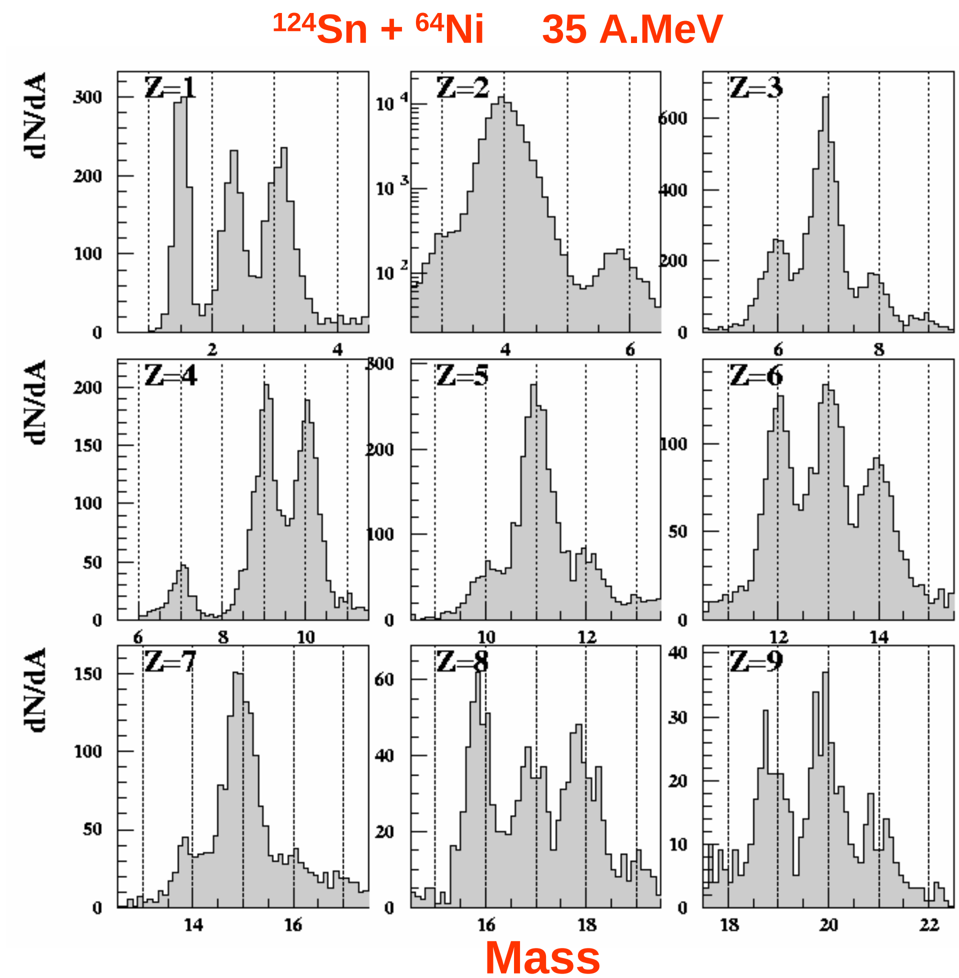
PID threshold for α and protons: 4-5 MeV proton equivalent energy. Good p,d,t discrimination > 20 MeV proton energy.

ΔE-E Isotope Identification



Combine CsI with Si ΔE

A-Z identification (up to Z=9) based on a Bethe-Bloch formula, no need for energy calibration



1) Reverse collaboration, LNS report (2001).
2) L.. Tassan Got, Preprint IPNO-DR—01-008

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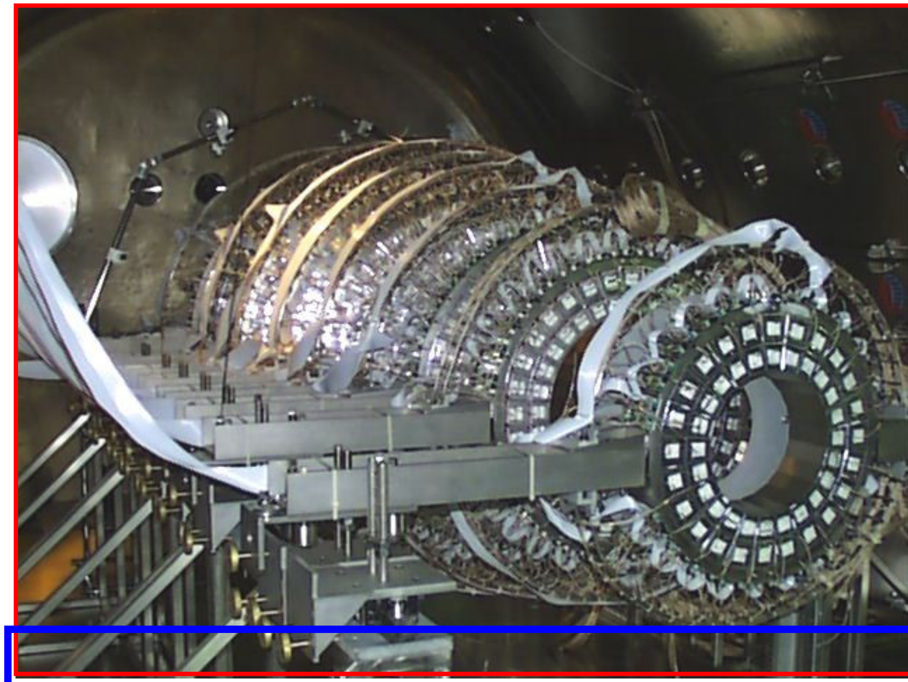
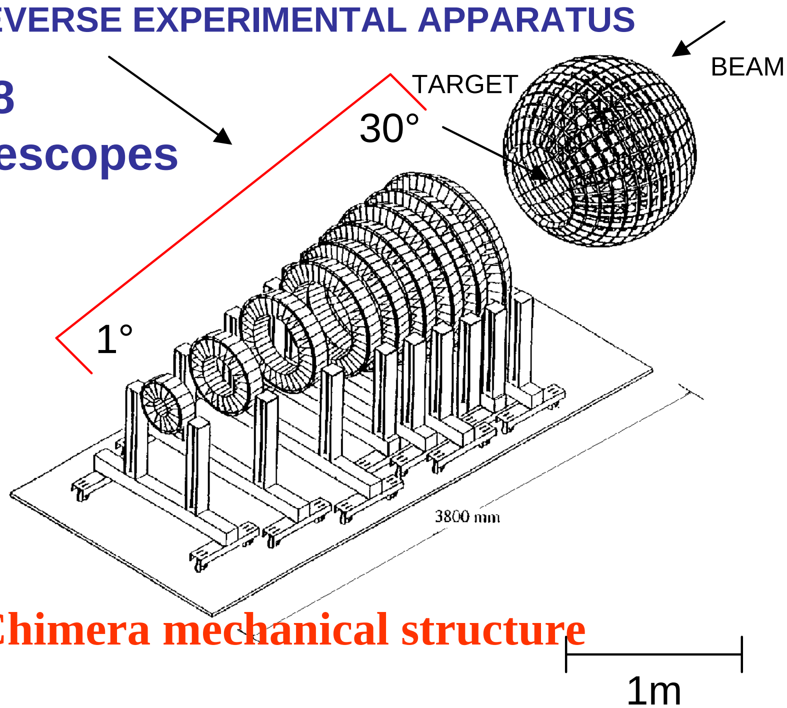
THE CHIMERA DETECTOR





688 telescopes

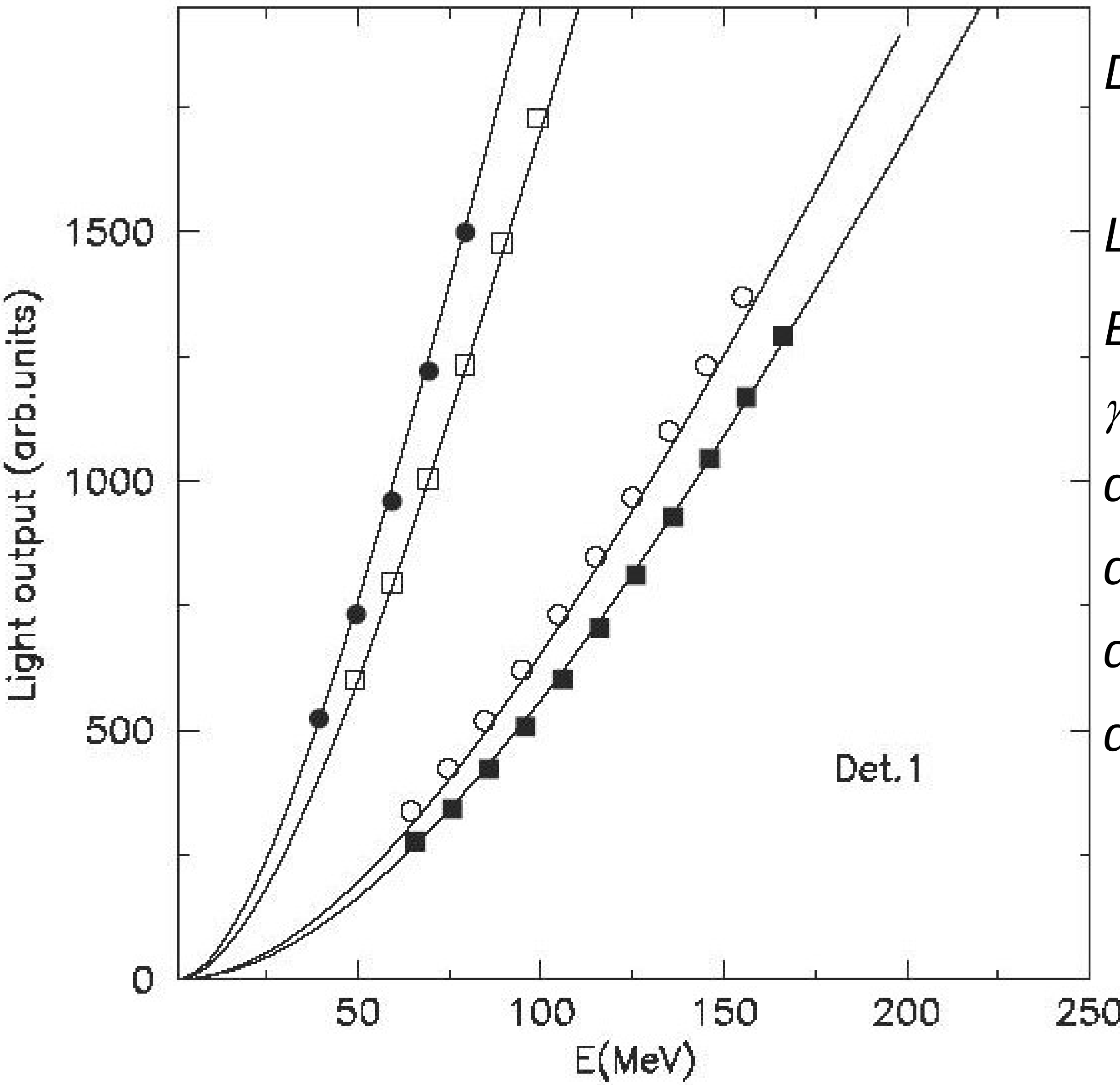
Chimera mechanical structure

CHIMERA characteristic features

Experimental Method	**ΔE-E → Charge** **ΔE-E E-TOF → Velocity, Mass** **Pulse shape Method → LCP**
Basic element	**Si (300μm) + CsI(Tl) telescope**
Primary experimental observables	**TOF δt ≤ 1 ns** **Kinetic energy, velocity** δE/E Light charged particles ≈2% Heavy ions ≤ 1%
Total solid angle ΔΩ/4π	**94%**
Granularity	**1192 modules**
Angular range	**1°< θ < 176°**
Detection threshold	**<0.5 MeV/A for H.I.** **≈ 1 MeV/A for LCP**

CsI(Tl) Light Output Parameterization

Abondanno et al., NIM A488, 604 (2002)



Data fitted $^{7}Li,\ldots,{}^{48}Ti$

$$L(E) = \gamma\left[E + E_0\left(e^{-E/E_0} - 1\right)\right]$$

$$E_0 = d_1 \cdot Z$$

$$\gamma = d_2/Z + d_3 + d_4 \cdot Z$$

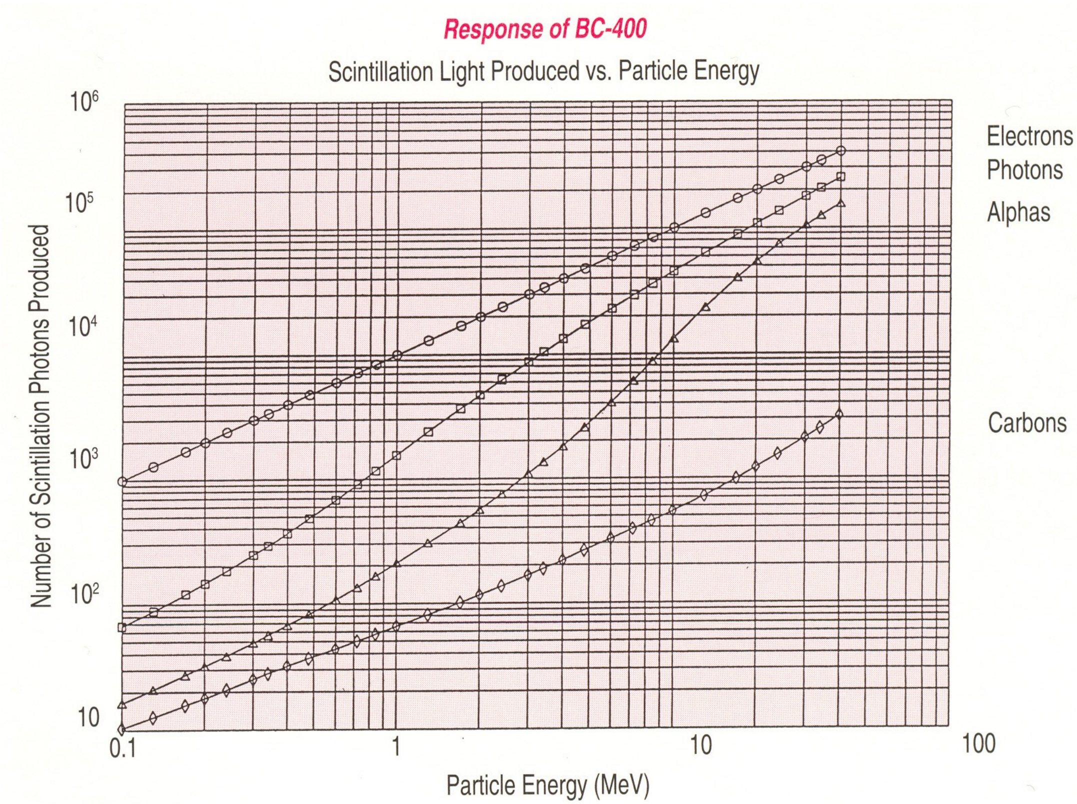
$$d_1 = (5.31 \pm 0.05)MeV$$

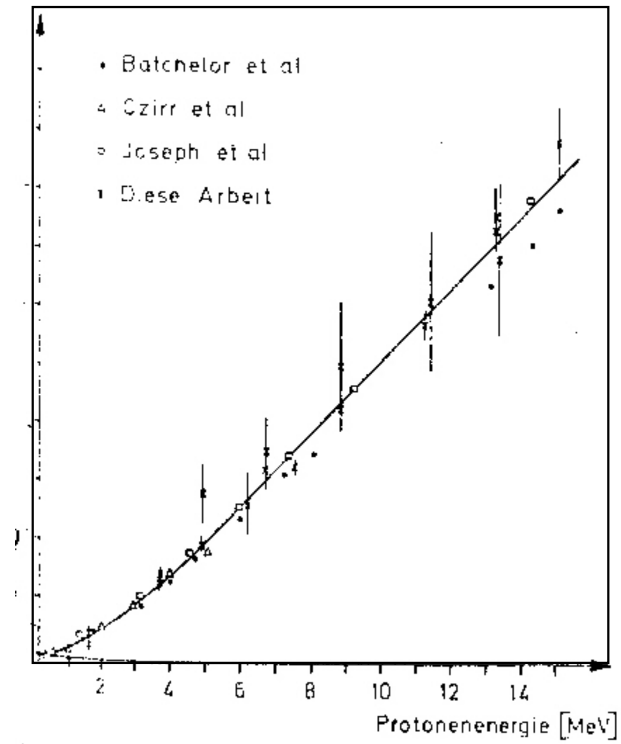
$$d_2 = (101.03 \pm 0.49)MeV^{-1}$$

$$d_3 = (7.60 \pm 0.06)MeV^{-1}$$

$$d_1 = (0.00 \pm 0.22 \cdot 10^{-3})MeV^{-1}$$

Non-Linear Light Output Response

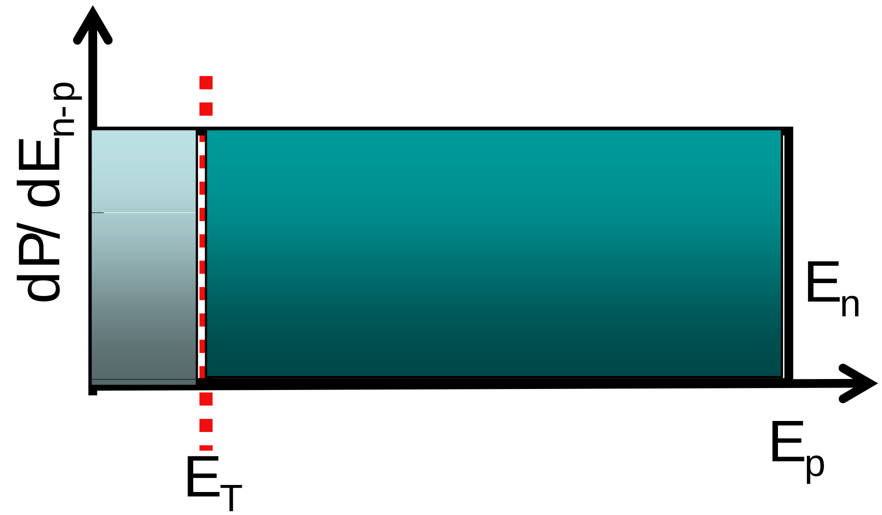




NE213 liquid scintillator: e-equivalent energies $E_e \leftrightarrow E_p$

$$E_e(E_p) = \begin{cases} \left(0.18 MeV^{-1/2}\right) E_p^{3/2} & E_p < 5.25 MeV \\ 0.63 E_p - 1.10 MeV & E_p \geq 5.25 MeV \end{cases}$$

Efficiency of p-Recoil NeutronDetectors

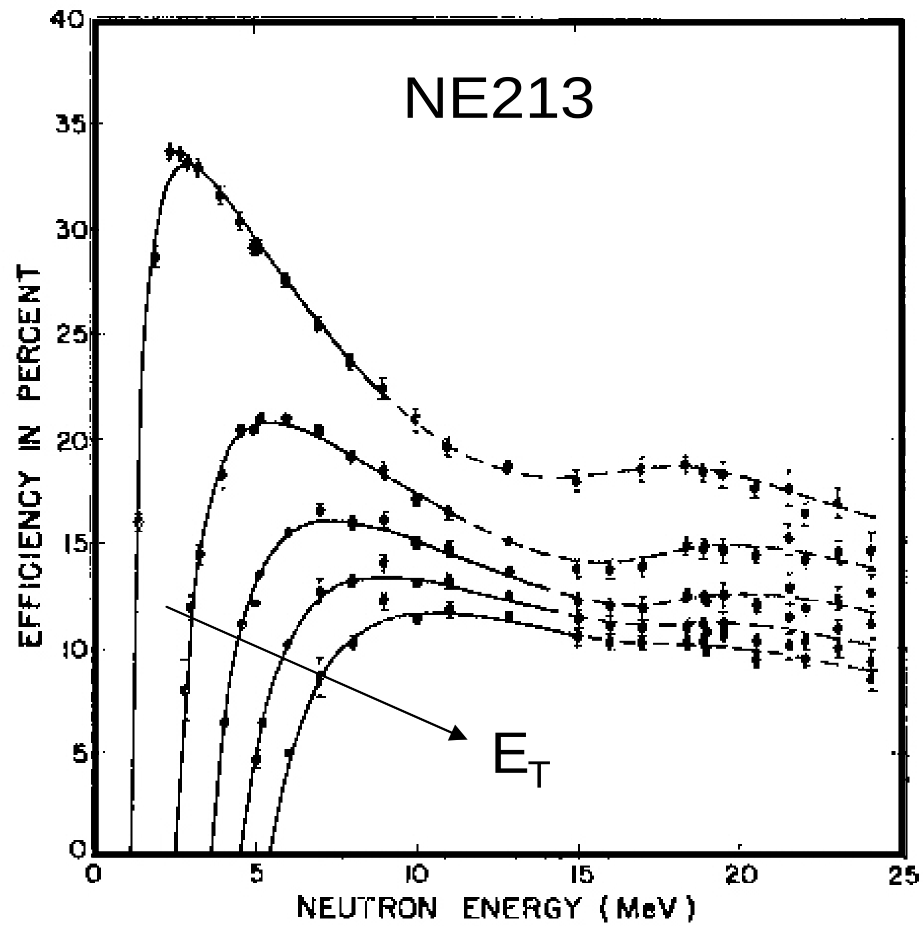


ET: Electronic detector threshold

$$\varepsilon(E_n, E_T) = \frac{F_2}{F_1 + F_2}$$

$$\approx \sigma(E_n)\left[1 - \frac{E_T}{E_n}\right]$$

$$\sigma(E_n) = \sum_{X,y} \sigma_{X(n,y)}(E_n) \quad all\ \ n - induced$$



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The End