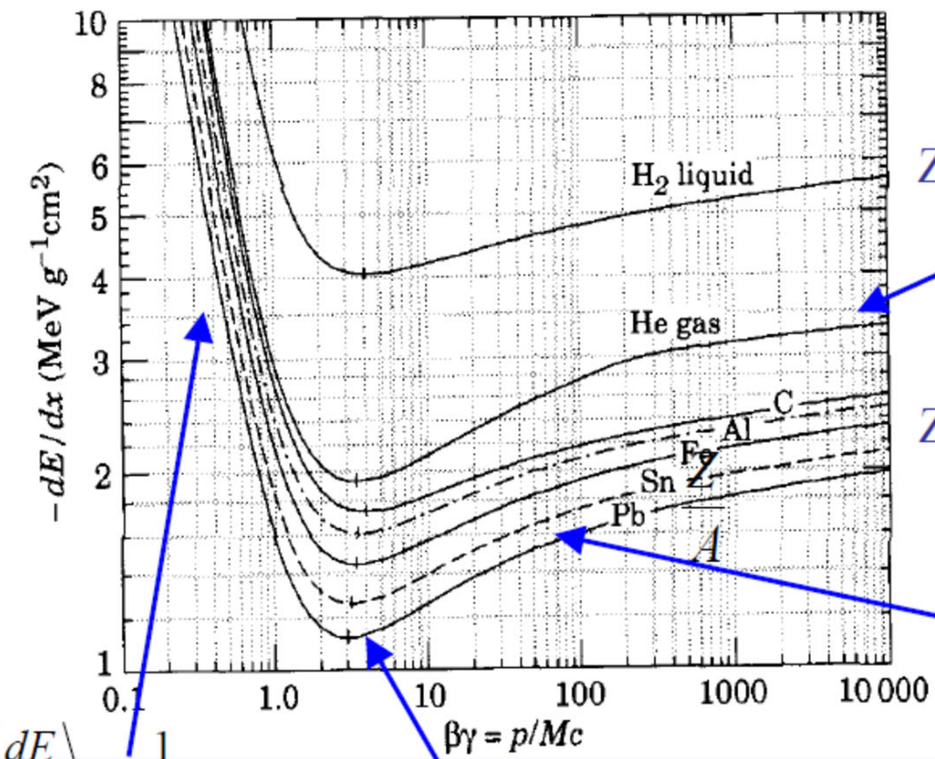


$Z/A = 1$

"Fermi plateau"

$Z/A \sim 0.5$

$\frac{Z}{A}$

$\left\langle \frac{dE}{dx} \right\rangle \propto \ln \beta^2\gamma^2$

"relativistic rise"

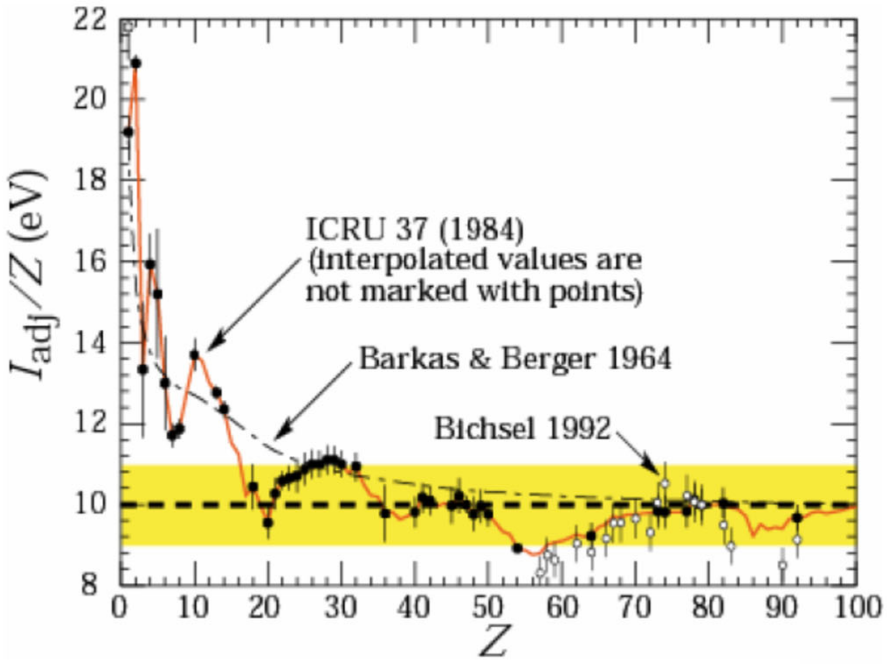
$\left\langle \frac{dE}{dx} \right\rangle \propto \frac{1}{\beta^2}$

"kinematical term"

$\beta\gamma \approx$ 3-4

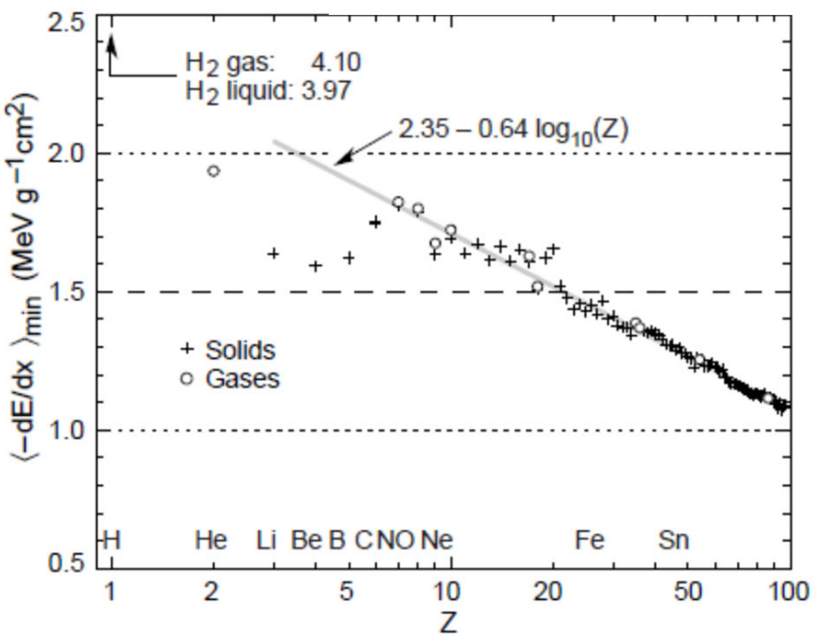
minimum ionizing particles, MIPs

$$-\frac{dE}{dx} = \rho K z^2 \frac{Z}{A} \frac{1}{\beta^2} \left[\ln \frac{2mc^2\beta^2\gamma^2}{I} - \beta^2 - \frac{\delta(\gamma)}{2} \right]$$



ICRU 37 (1984)
(interpolated values are
not marked with points)
Barkas & Berger 1964
Bichsel 1992
I_{adj}/Z (eV)
Z

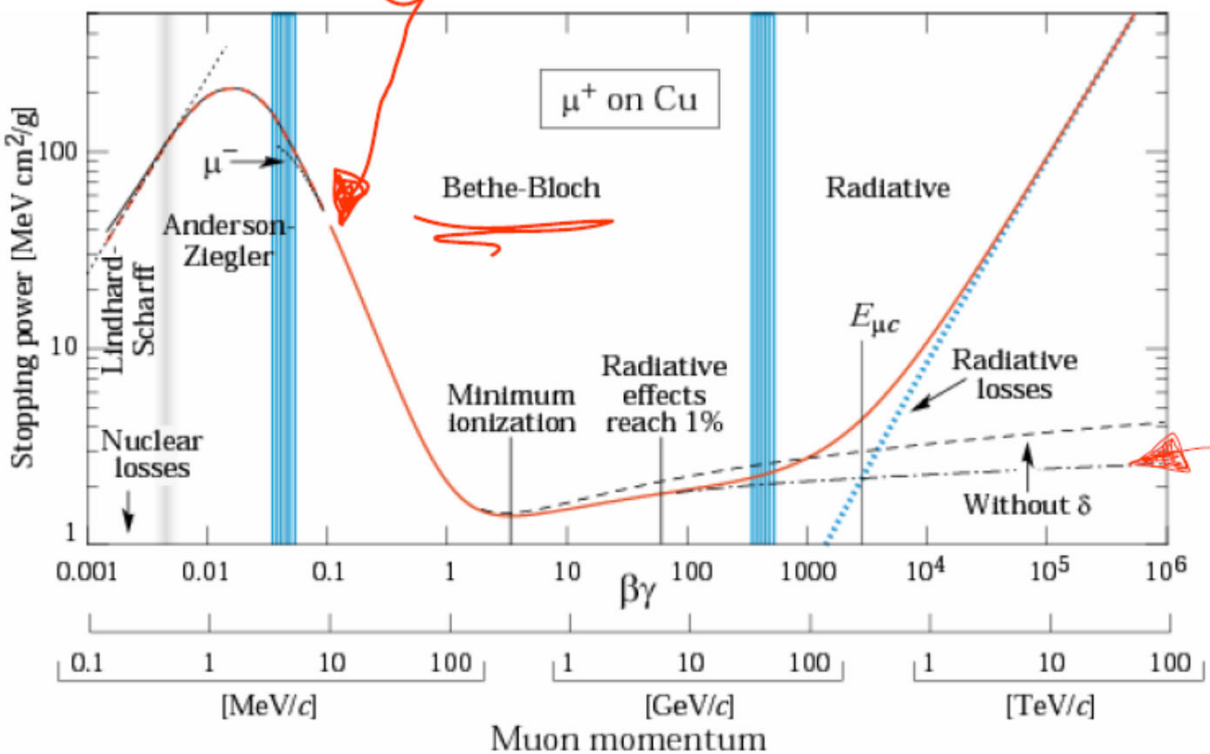
10 ± 1 eV



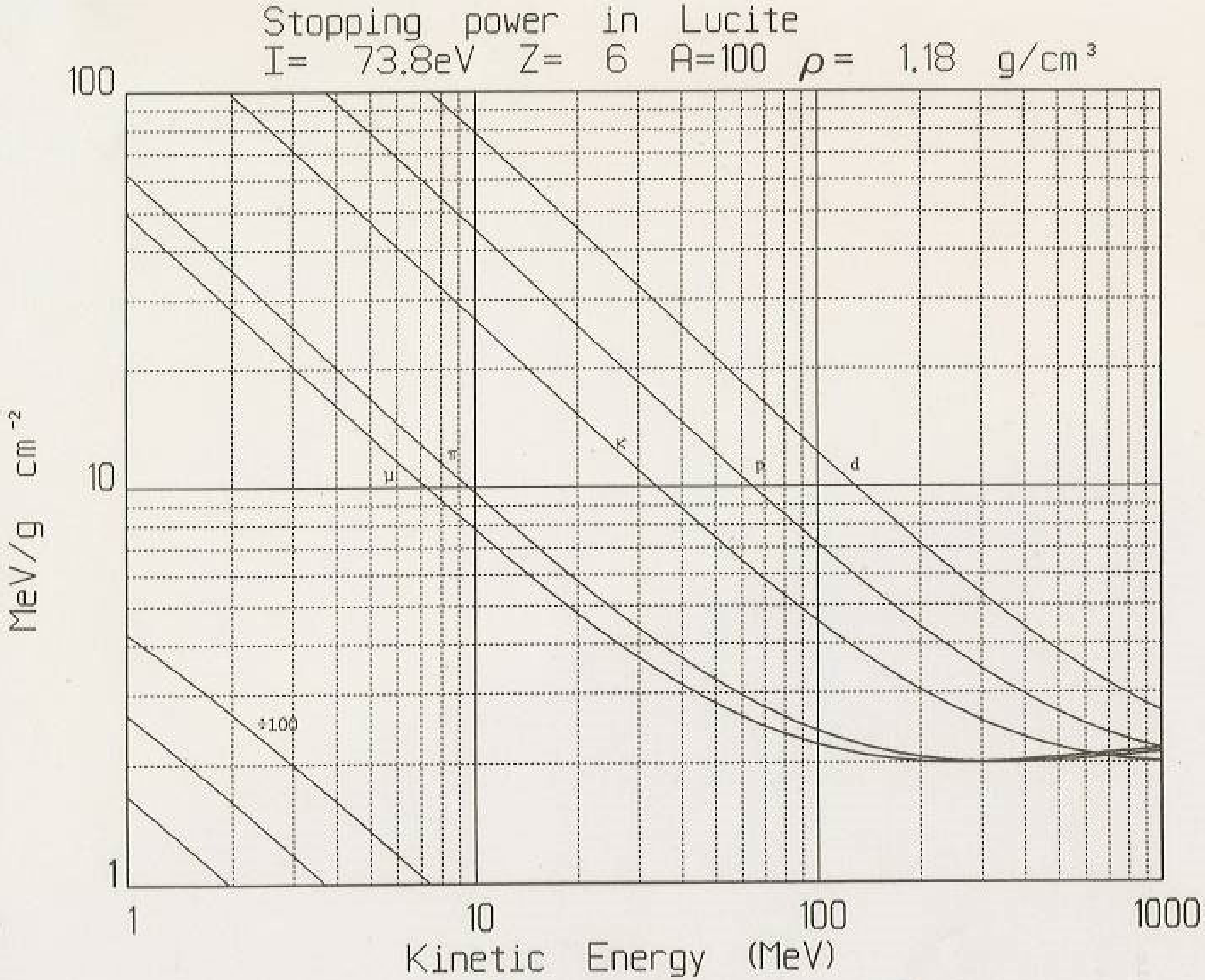
H_2 gas: 4.10
H_2 liquid: 3.97
2.35 – 0.64 $\log_{10}$(Z)
+ Solids
○ Gases
$\langle -dE/dx \rangle_{min}$ (MeV $g^{-1}cm^2$)
H He Li Be B CNO Ne Fe Sn
Z

Material	Z	A	Z/A	dE/dx min ($MeVcm^2/g$)	Density (g/cm^3)
H_2 (liquid)	1	1.008	0.992	4.034	0.0708
He	2	4.002	0.500	1.937	0.125
C	6	12.01	0.500	1.745	2.27
Al	13	26.98	0.482	1.615	2.70
Cu	29	63.55	0.456	1.403	8.96
Pb	82	207.2	0.396	1.123	11.4
W	74	183.8	0.403	1.145	19.3
U	92	238.0	0.387	1.082	19.0
Scint.			0.538	1.936	1.03
BGO			0.421	1.251	7.10
CsI			0.416	1.243	4.53
NaI			0.427	1.305	3.67

$$\frac{dE}{dx} = Kz^2 \frac{Z}{A}\frac{1}{\beta^2}\left[\frac{1}{2}\ln\frac{2m_e c^2 \beta^2 \gamma^2 T_{\max}}{I^2} - \beta^2 - \frac{\delta}{2}\right]$$



Stopping power (≡⟨dE/dx⟩) for positive muons in copper as a function of βγ $=p/Mc$ over nine orders of magnitude in momentum (12 orders of magnitude in kinetic energy). Solid curves indicate the total stopping power.


Stopping power in Lucite
I= 73.8eV Z= 6 A=100 ρ= 1.18 g/cm³
MeV/g cm⁻²
100
10
1
μ
π
K
p
d
÷100
1
10
100
1000
Kinetic Energy (MeV)