Progress Report

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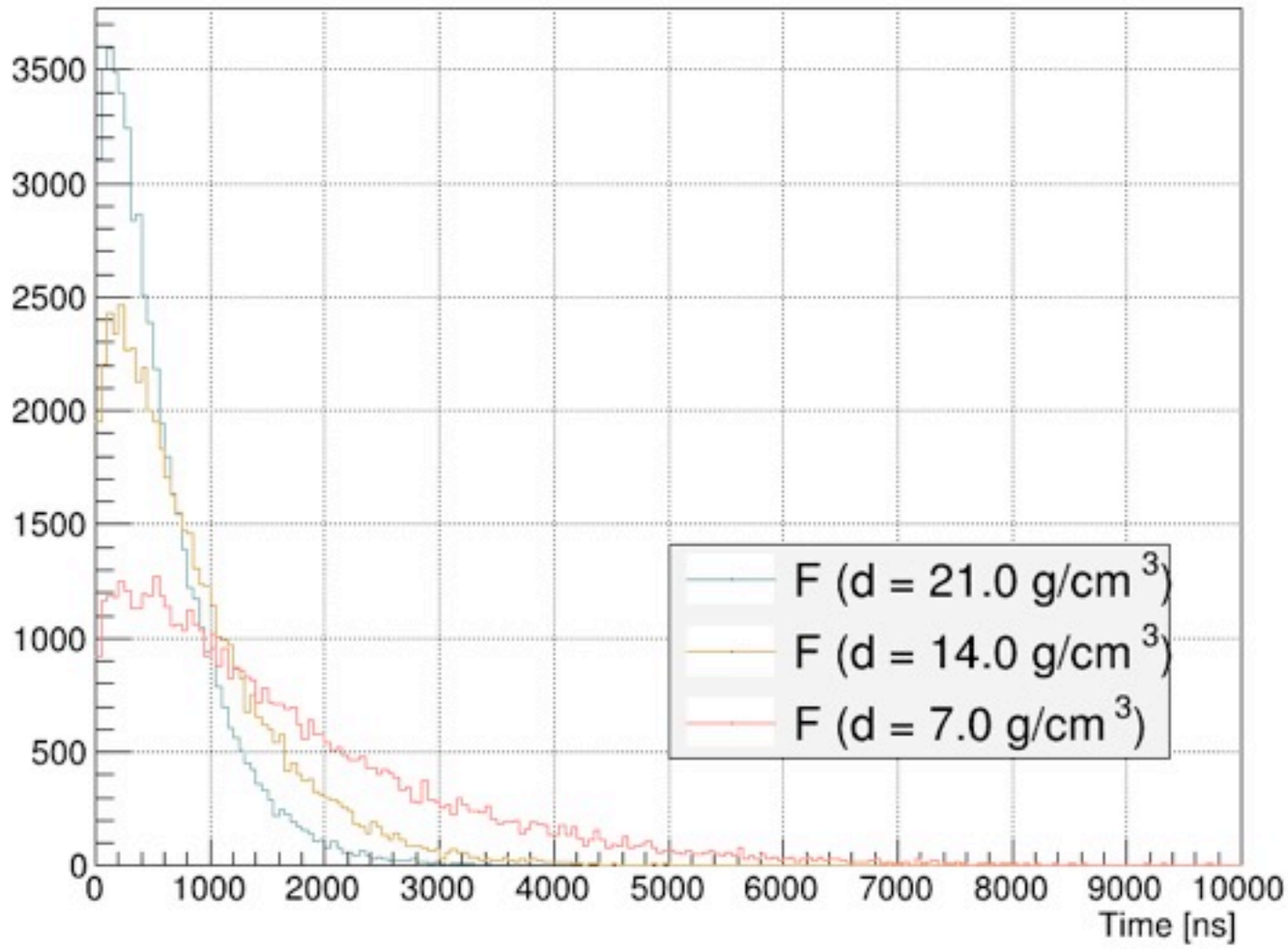
July 19th, 2013

Creation time of photons from neutron capture in F (5 GeV pi-)

Density (g/cm3)	# of photons (avg. per evt.)	# of atoms/cm3 (x 10^23)	# of atoms*cross section (x 10^21)
7.0	53.835	2.22	2.13
14.0	54.509	4.44	4.26
21.0	54.260	6.66	6.39

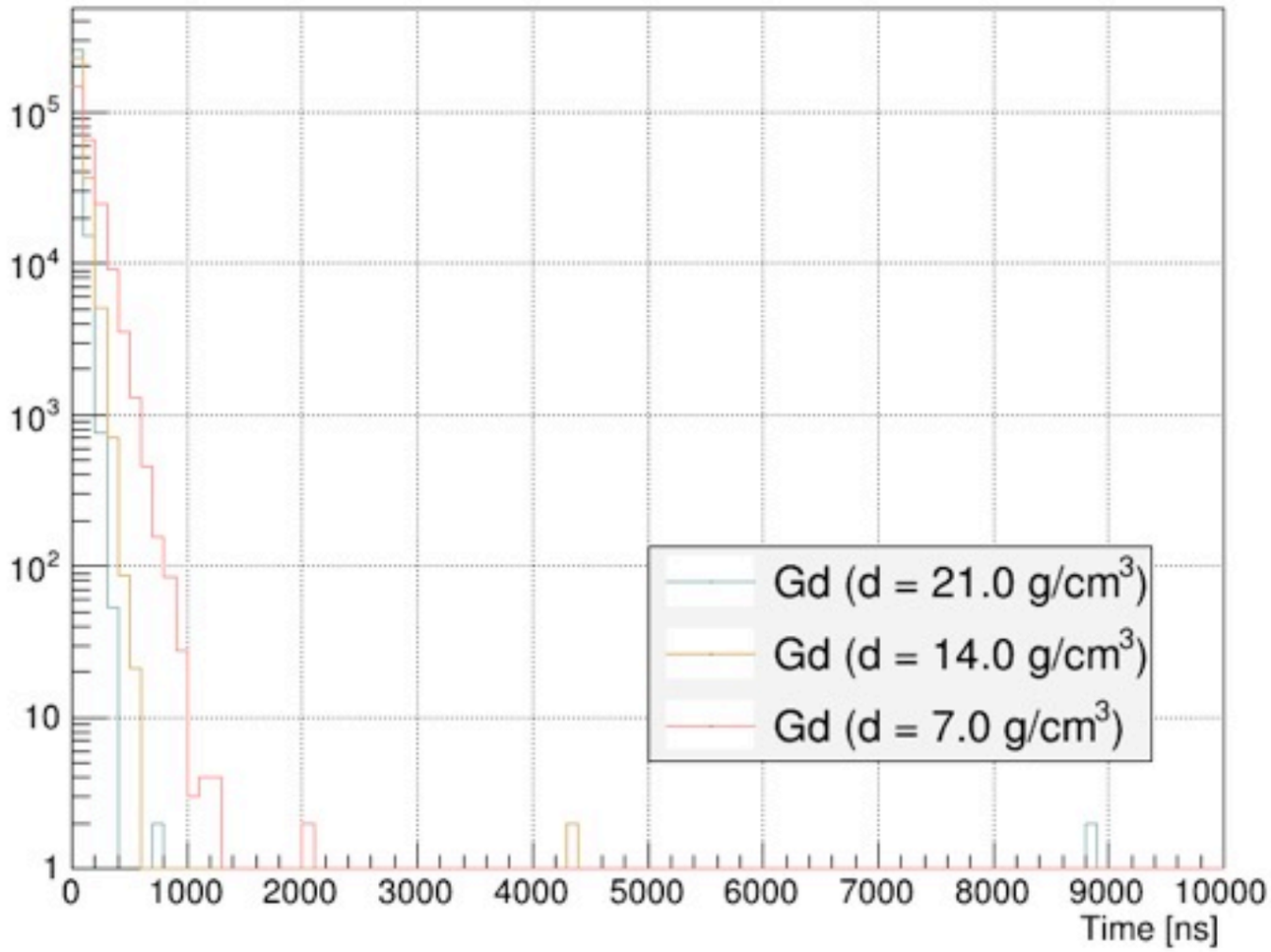
Density ~ 1.696 g/cm3 (@ 293K)
Molar mass ~ 18.99 (g/mol)
Neutron capture cross section -> 0.0096



Creation time of photons from neutron capture in Gd (5 GeV pi-)

Density (g/cm3)	# of photons (avg. per evt.)	# of atoms/cm3 (x 10^23)	# of atoms*cross section (x 10^21)
7.0	252.373	0.268	1,313,200
14.0	268.195	0.554	2,714,600
21.0	273.233	0.804	3,940,628

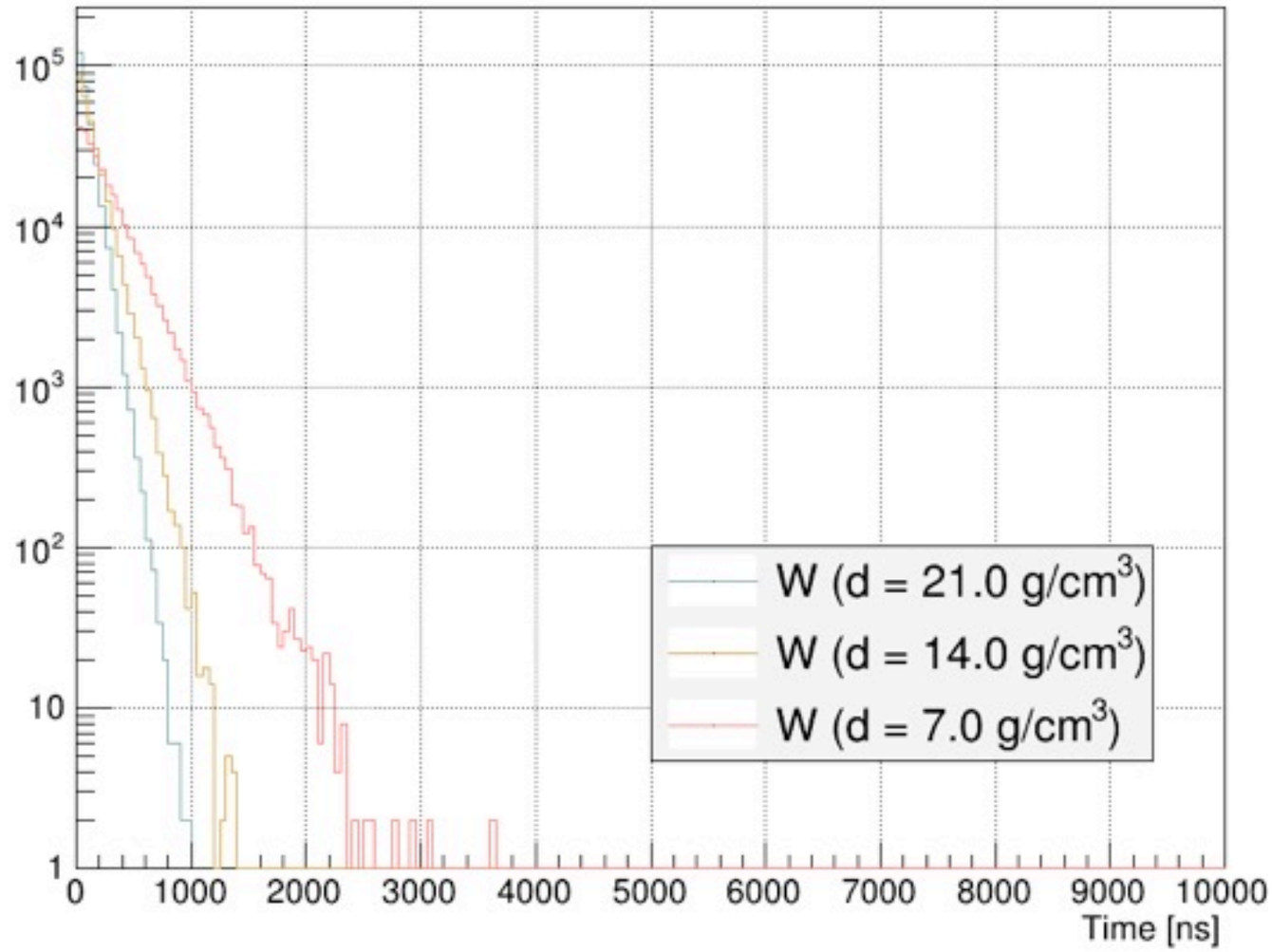
Density ~ 7.90 g/cm3
Molar mass ~ 157.25 (g/mol)
Neutron capture cross section -> 4.9 x10^4 (barn)



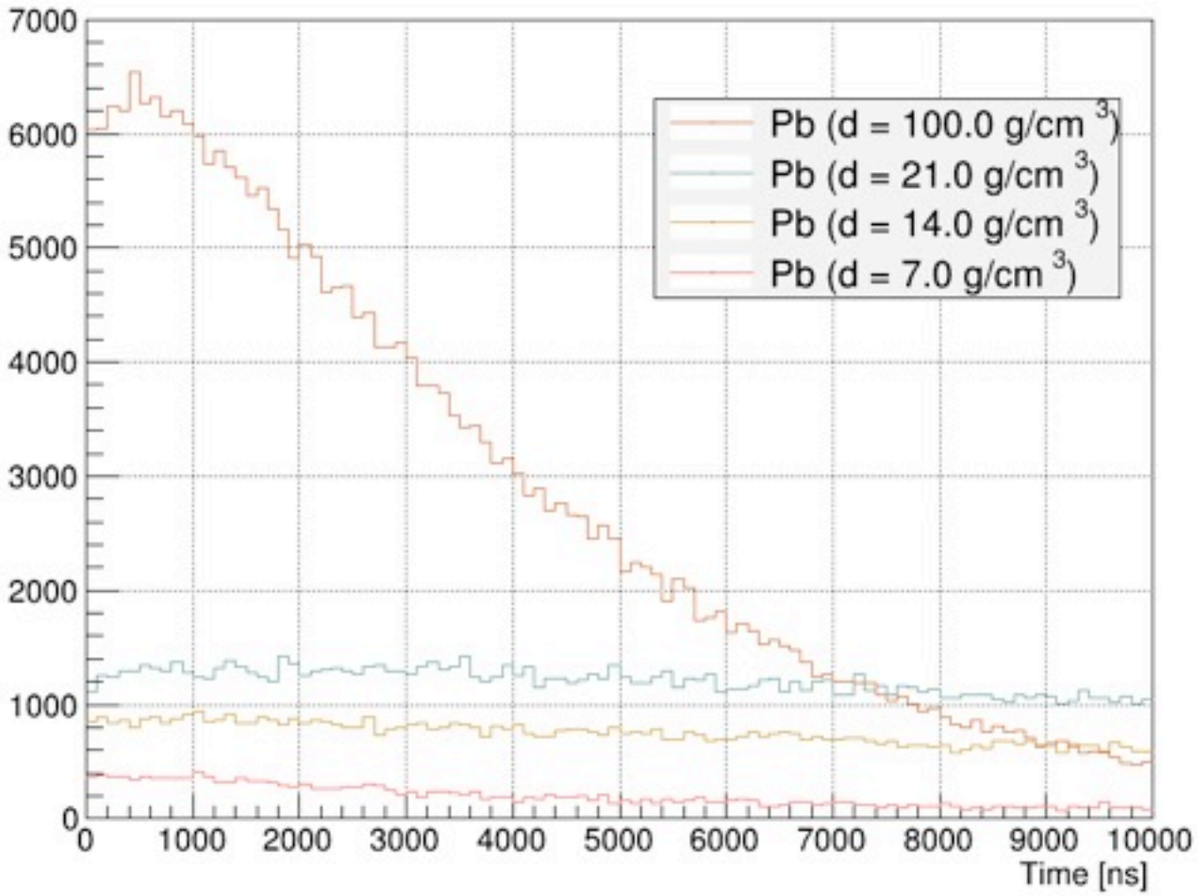
Creation time of photons from neutron capture in W (5 GeV pi-)

Density (g/cm3)	# of photons (avg. per evt.)	# of atoms/cm3 (x 10^23)	# of atoms*cross section (x 10^21)
7.0	265.204	0.223	411.12
14.0	288.757	0.458	844.552
21.0	294.481	0.687	1266.82

Density ~ 19.25 g/cm3
Molar mass ~ 183.8410 (g/mol)
Neutron capture cross section -> 18.44 (barn)



Creation time of photons from neutron capture in Pb (5 GeV pi-)



Density (g/cm3)	# of photons (avg. per evt.)	# of atoms/cm3 (x 10^23)	# of atoms*cross section (x 10^21)
7.0	19.655	0.21	3.59
14.0	75.11	0.406	6.94
21.0	120.807	0.610	10.43
100.0	284.377	2.90	49.59

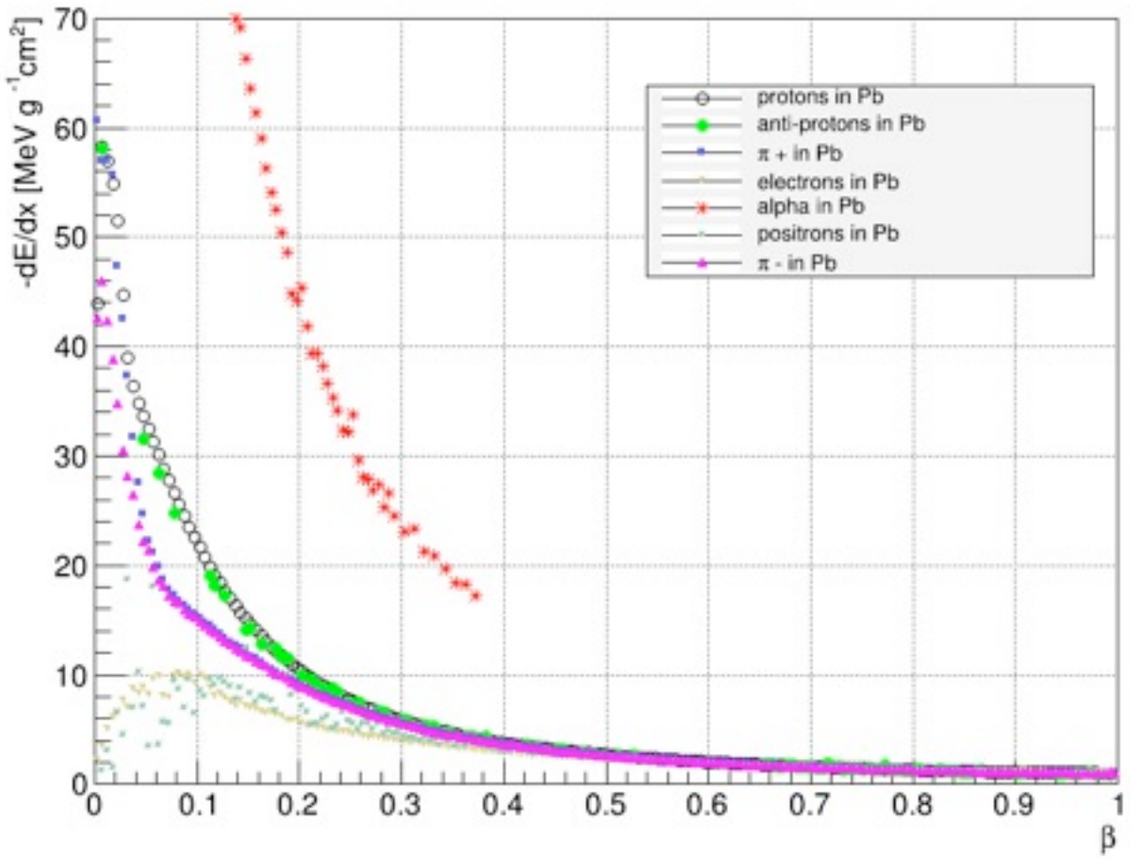
Density ~ 11.34 g/cm3
Molar mass ~ 207.21 (g/mol)
Neutron capture cross section -> 0.171 (barn)

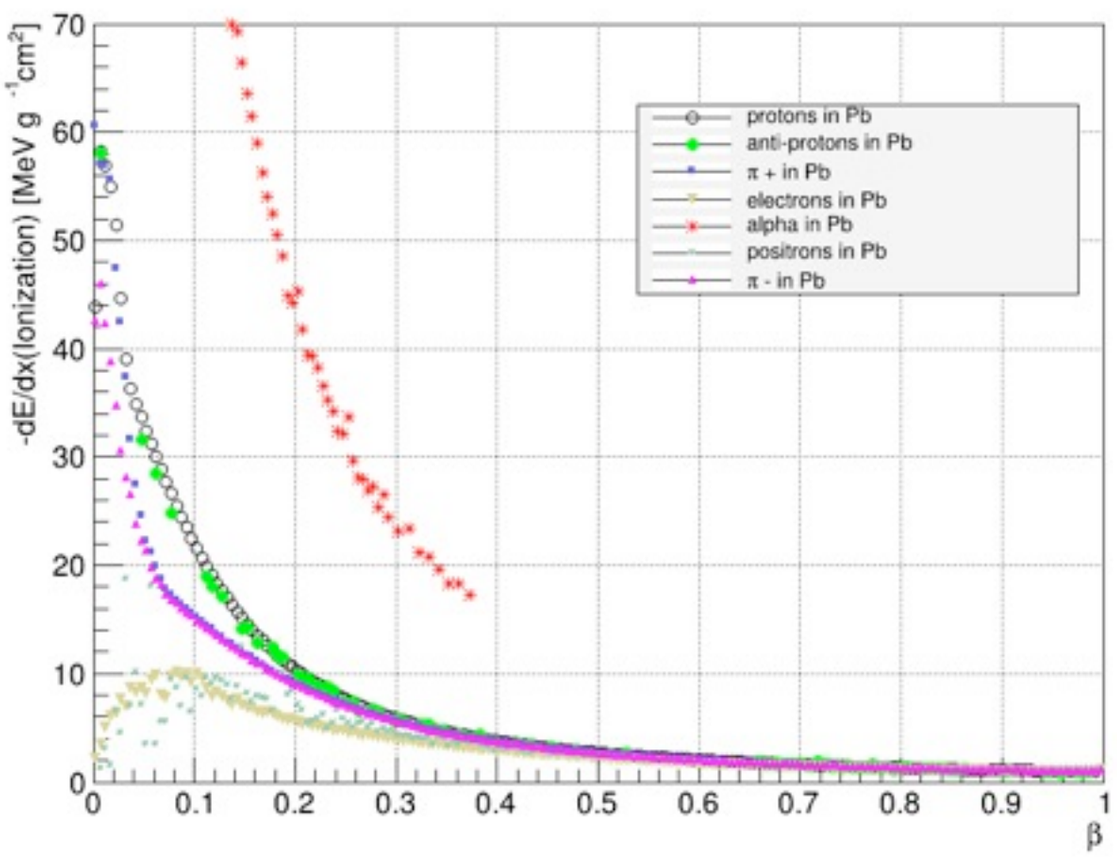
	# of photons (avg. per evt.)	# of atoms/cm3 (x 10^23)	# of atoms*cross section (x 10^21)
7.0 (Pb)	19.655	0.21	3.59
14.0 (Pb)	75.11	0.406	6.94
21.0 (Pb)	120.807	0.610	10.43
100.0 (Pb)	284.377	2.90	49.59
7.0 (W)	265.204	0.223	411.12
14.0 (W)	288.757	0.458	844.552
21.0 (W)	294.481	0.687	1266.82
7.0 (Gd)	252.373	0.268	1,313,200
14.0 (Gd)	268.195	0.554	2,714,600
21.0 (Gd)	273.233	0.804	3,940,628
7.0 (F)	53.835	2.22	2.13
14.0 (F)	54.509	4.44	4.26
21.0 (F)	54.260	6.66	6.39

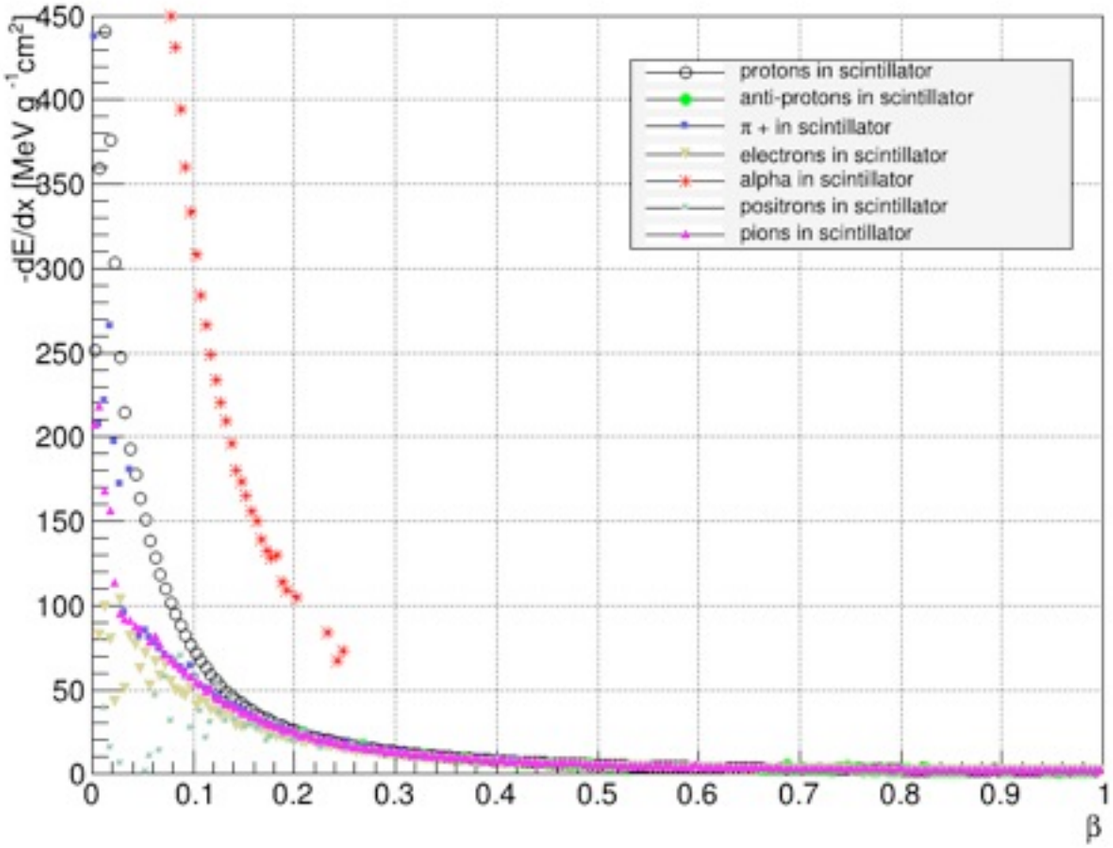
dE/dx for charged particles

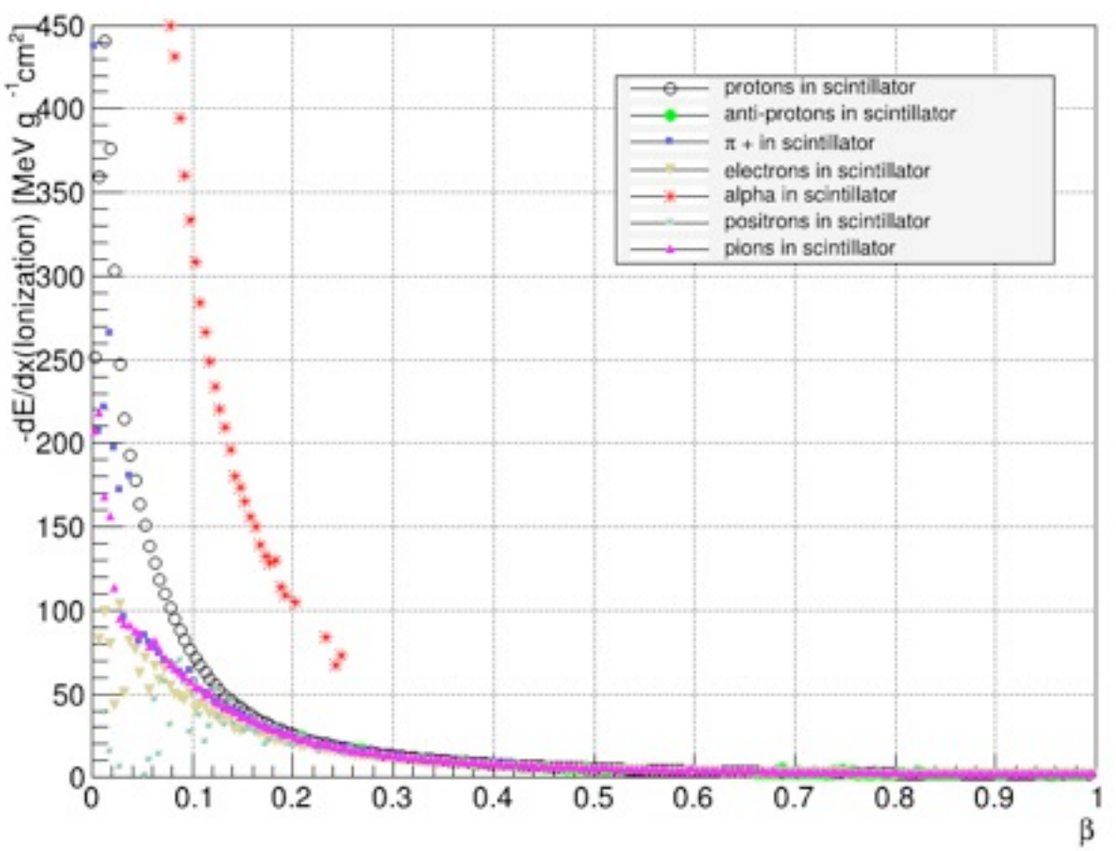
Pb4mm + Scint1mm
15 GeV incident pi-

dE/dx as a function of beta for charged particles

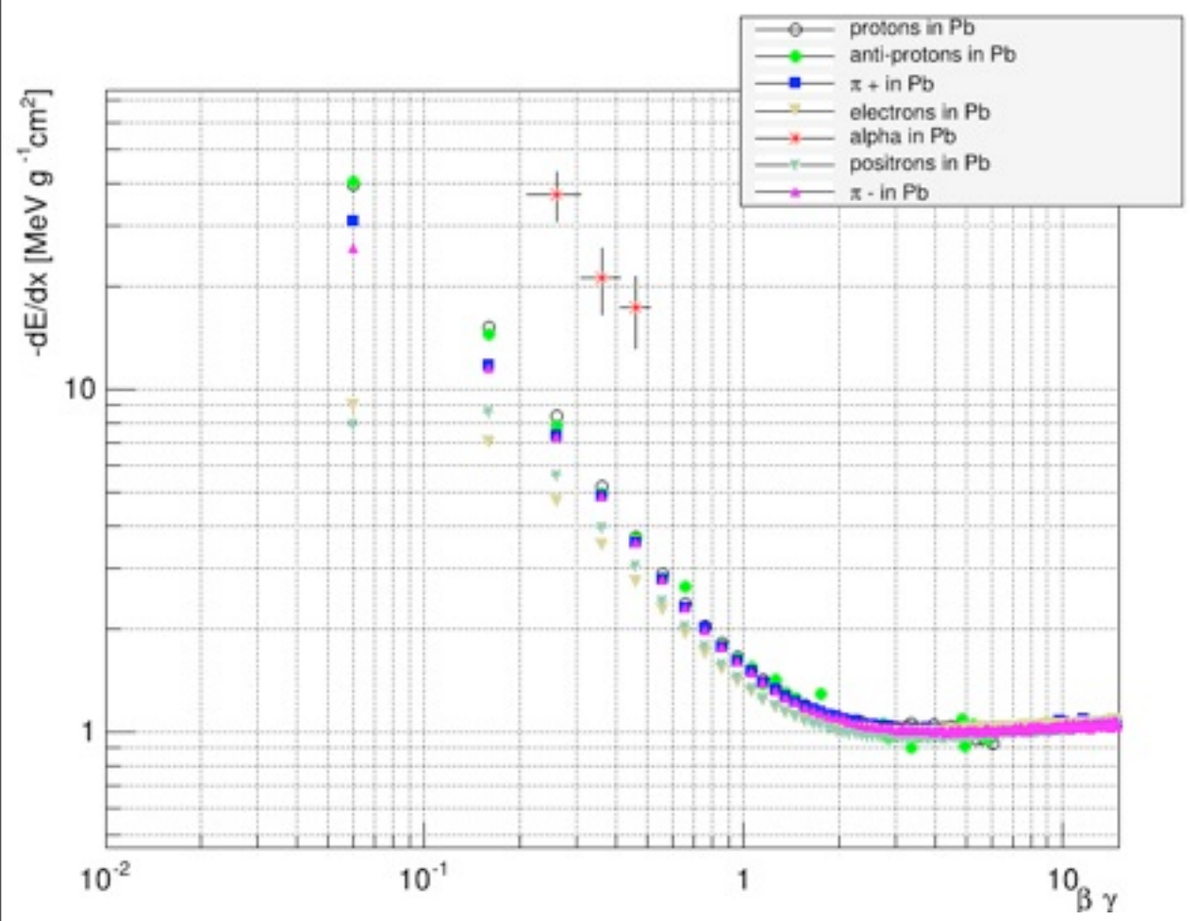


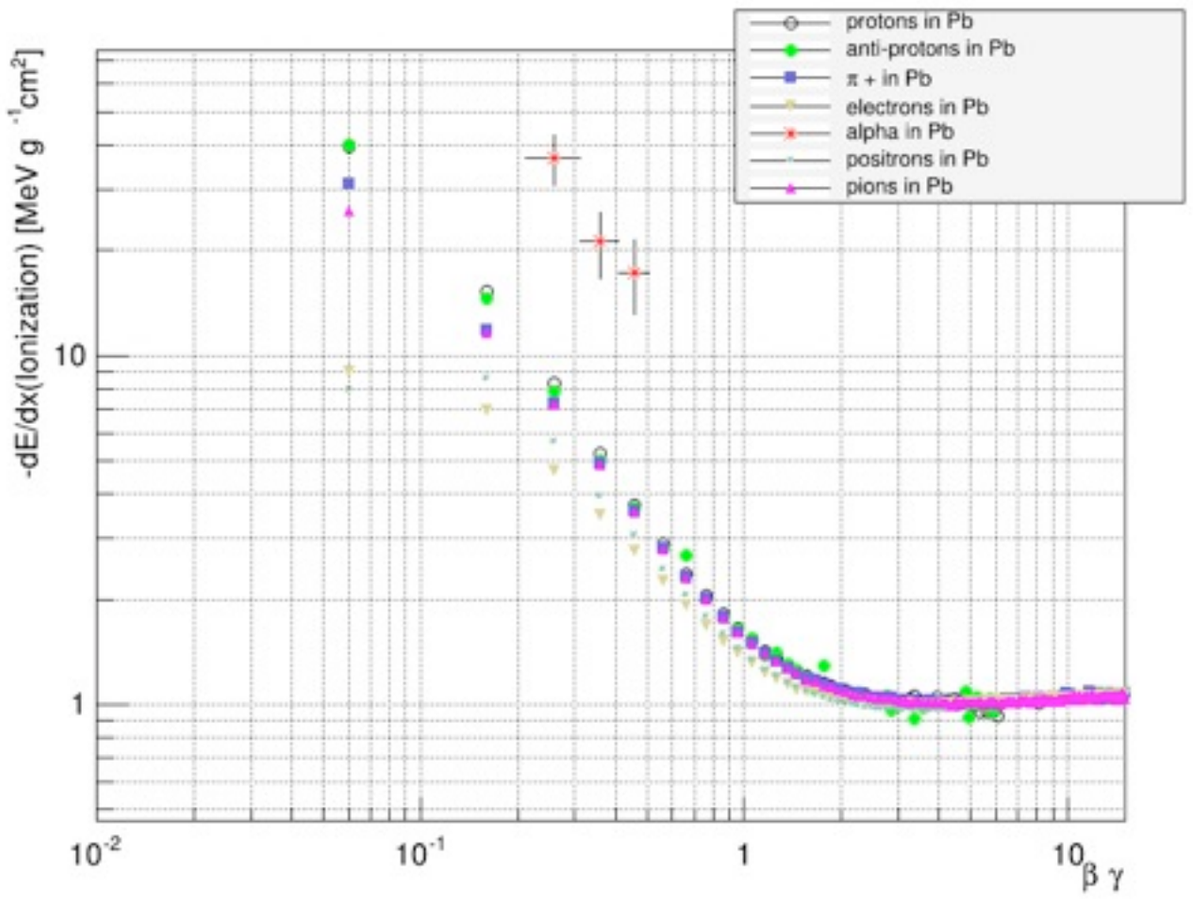


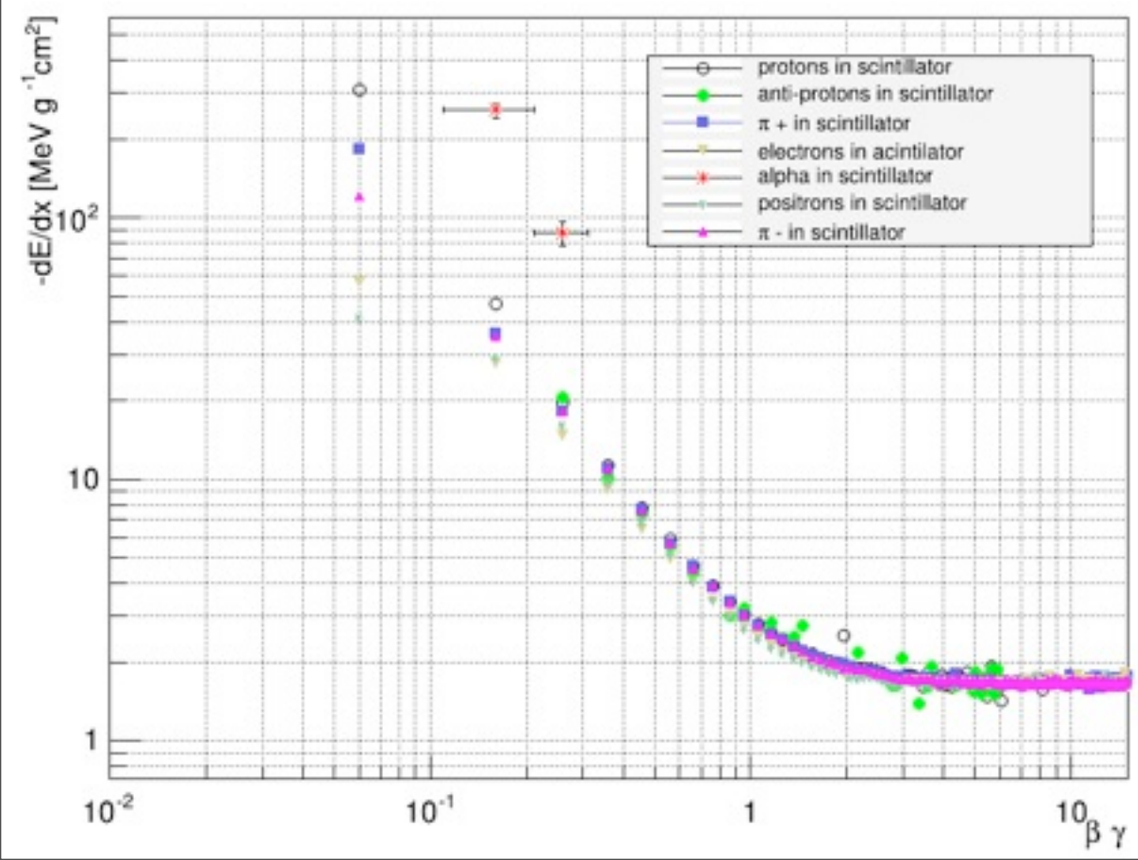


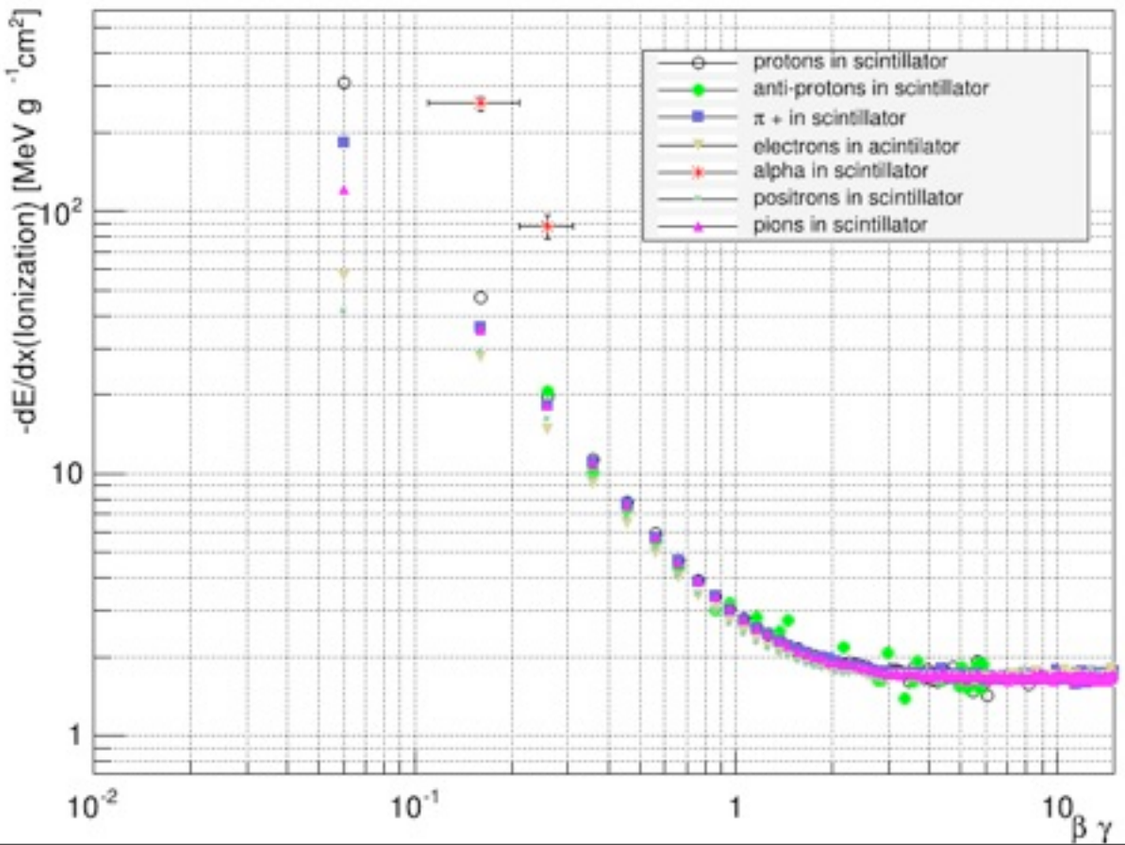


dE/dx as a function of beta*gamma for charged particles

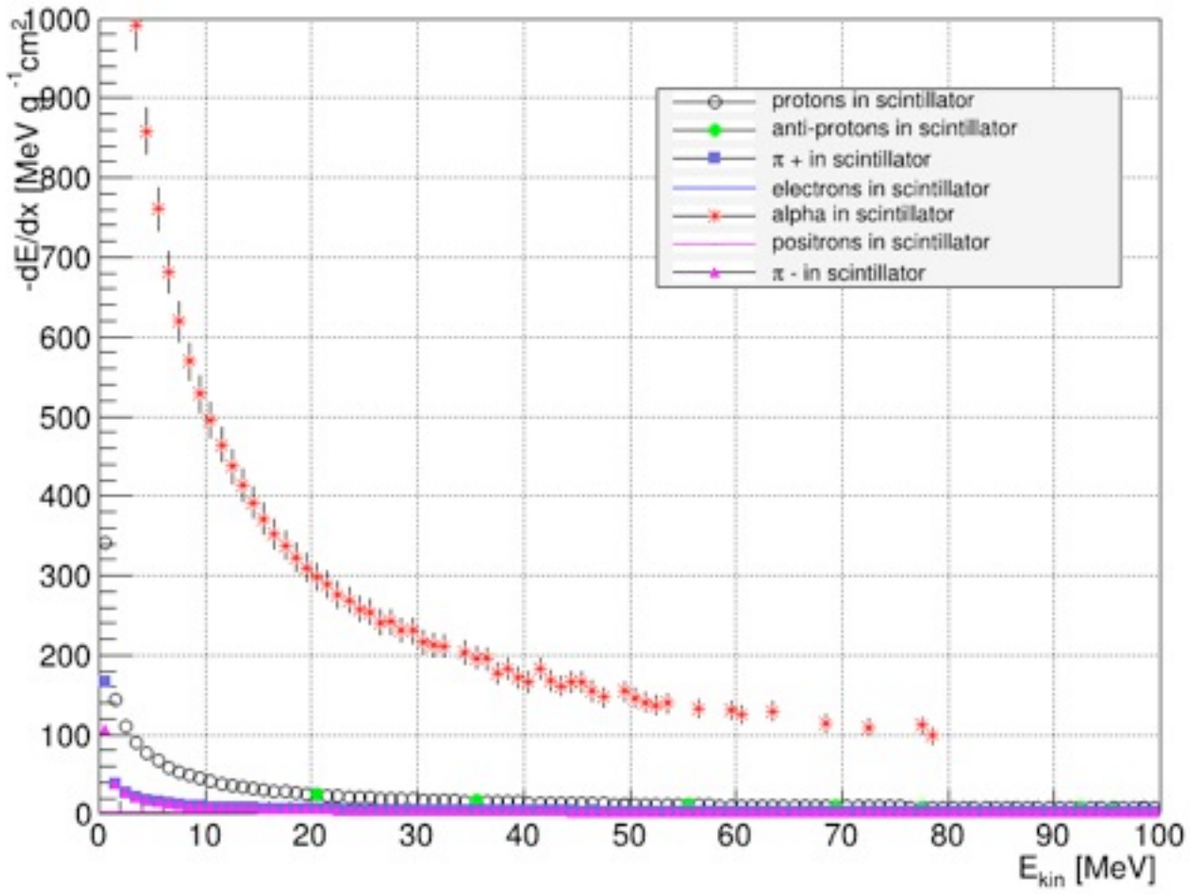


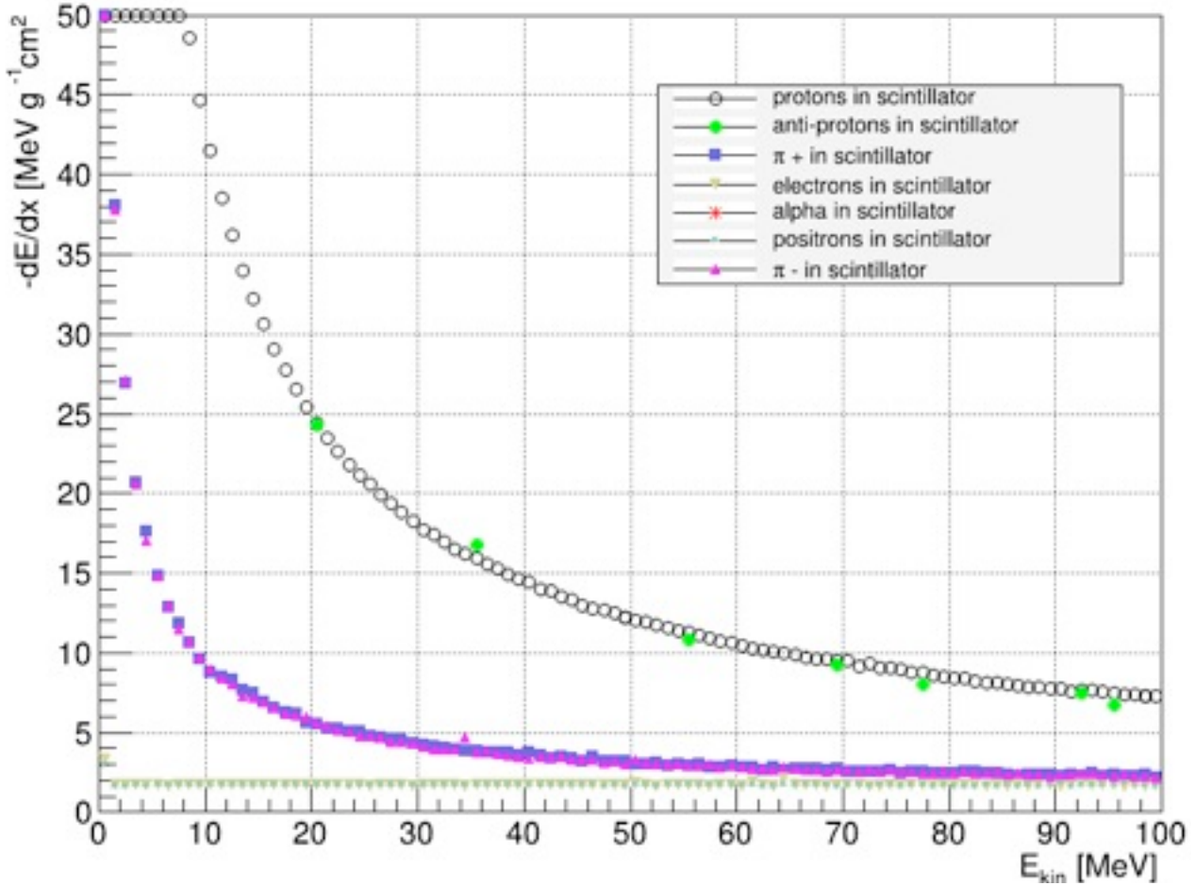


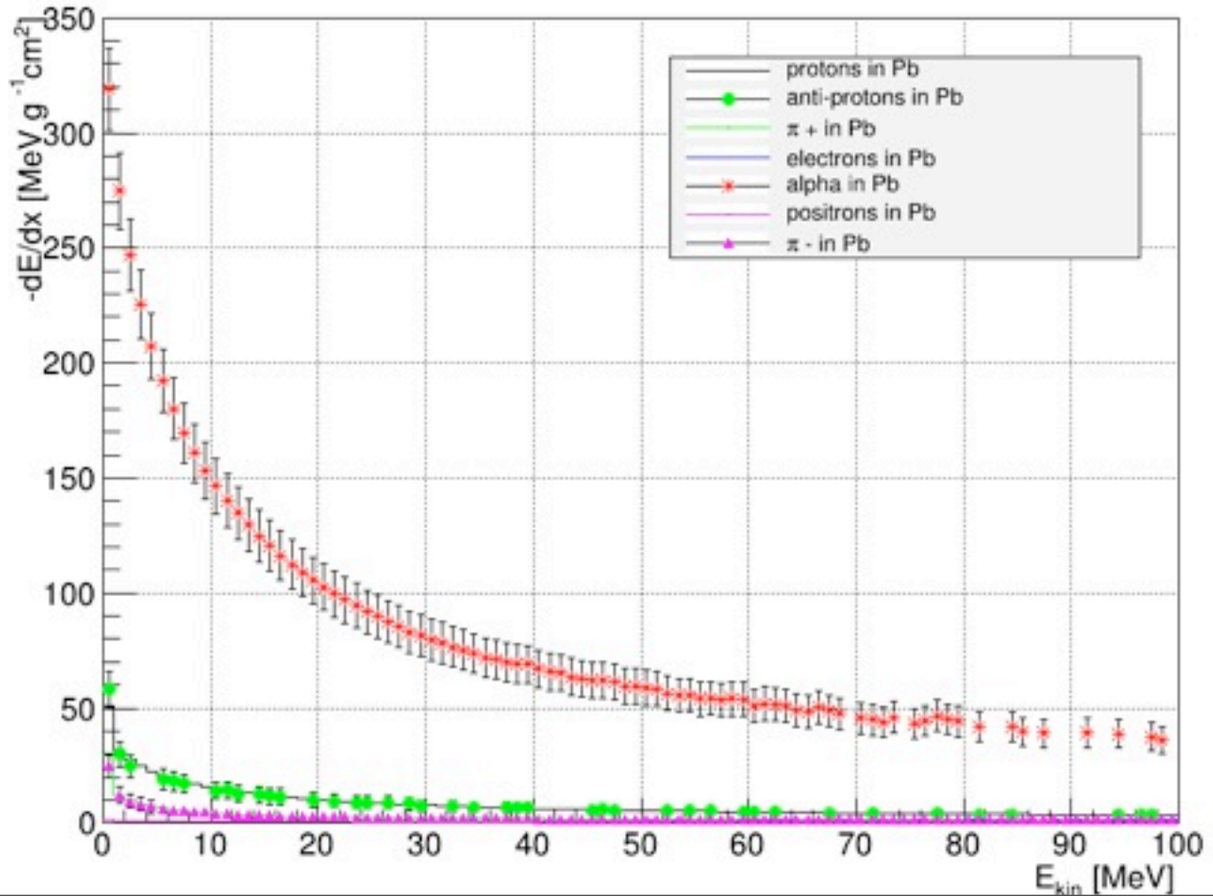


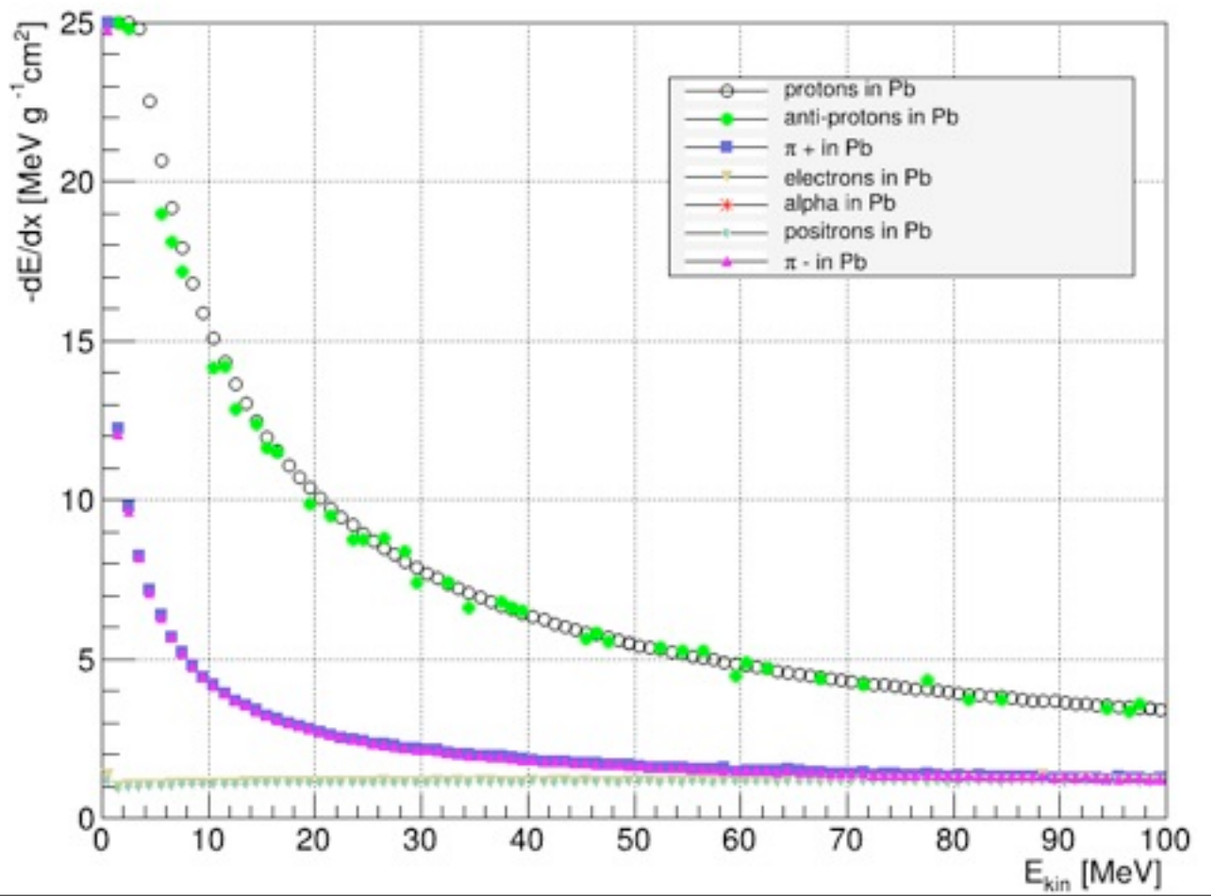


dE/dx as a function of Ekin for charged particles

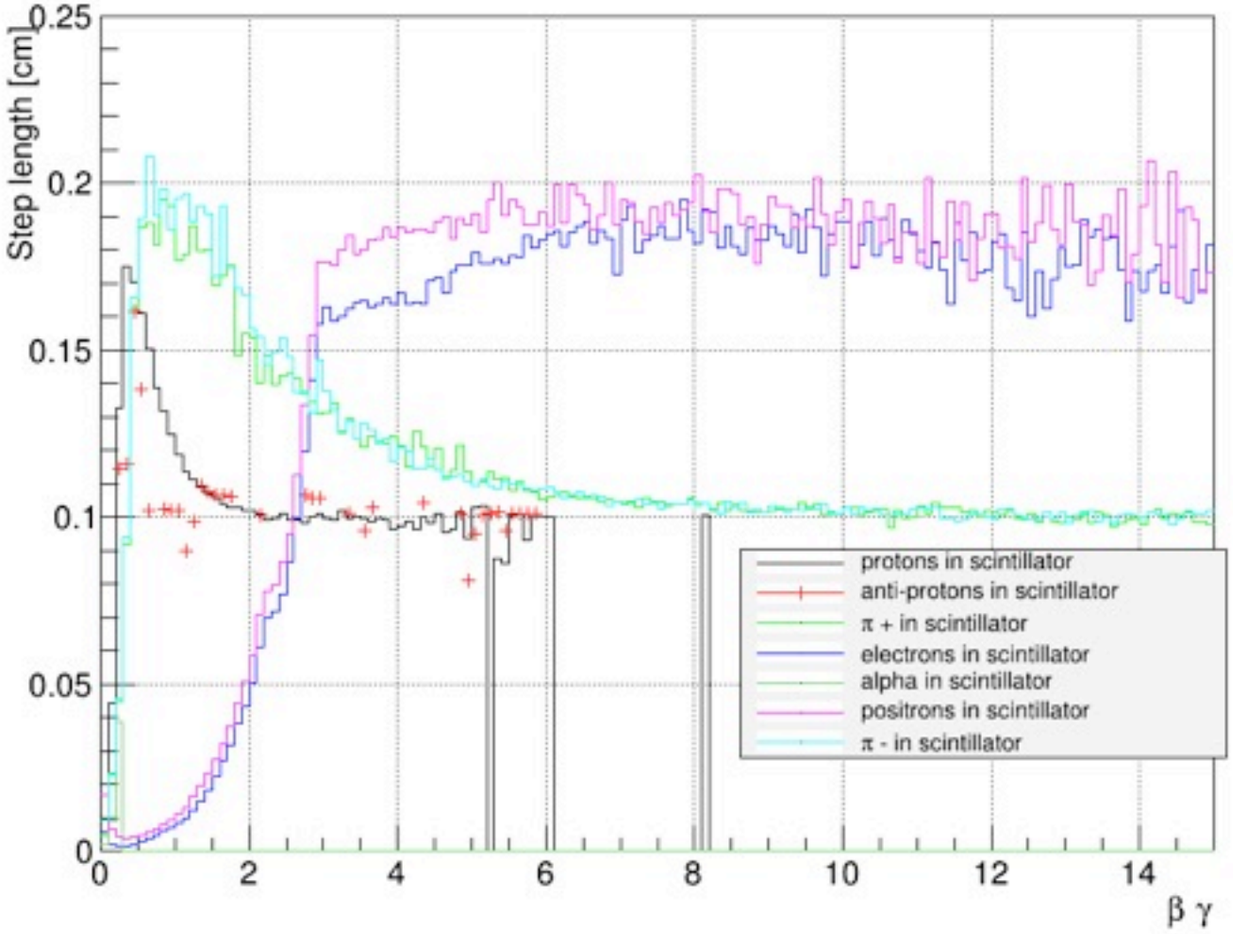


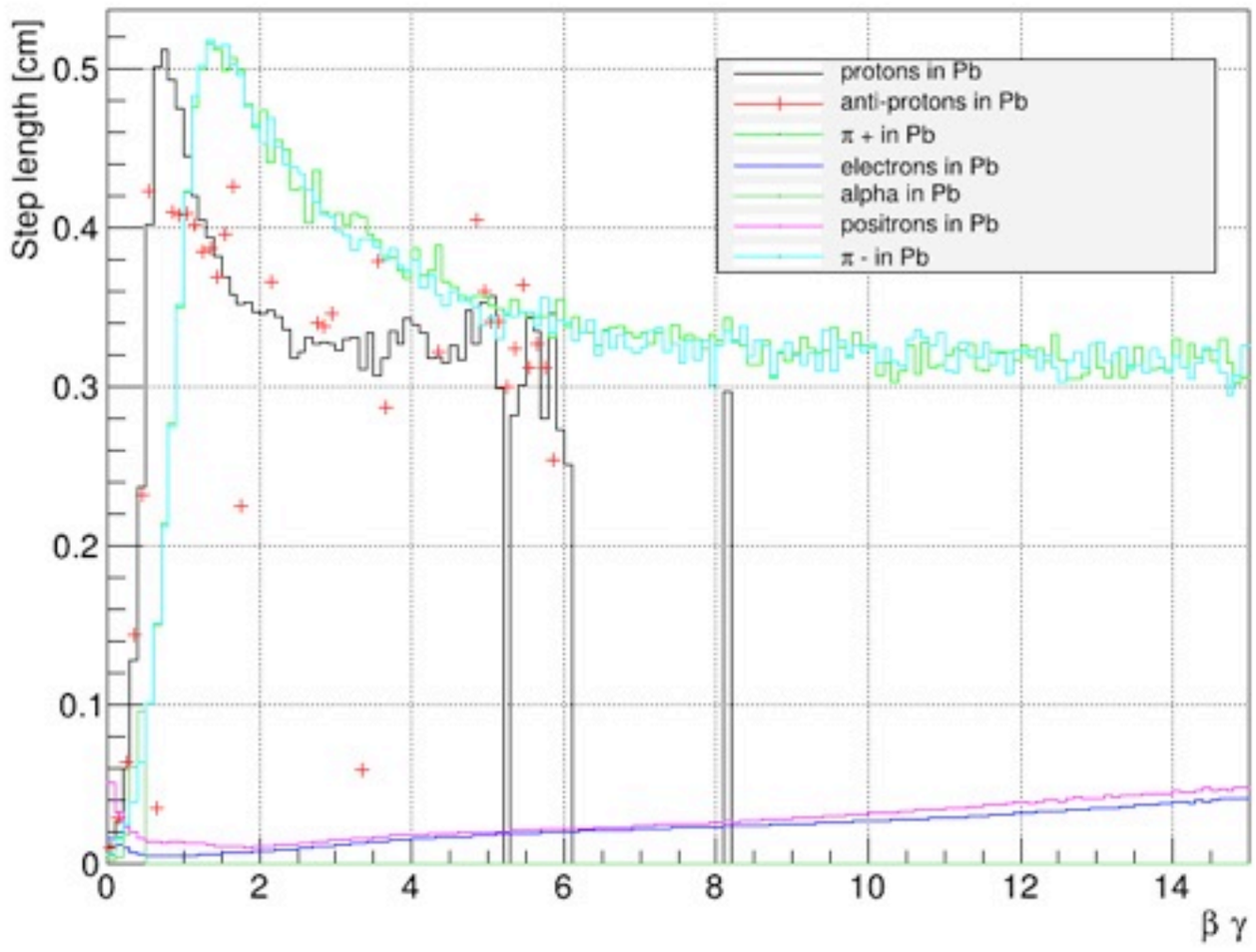




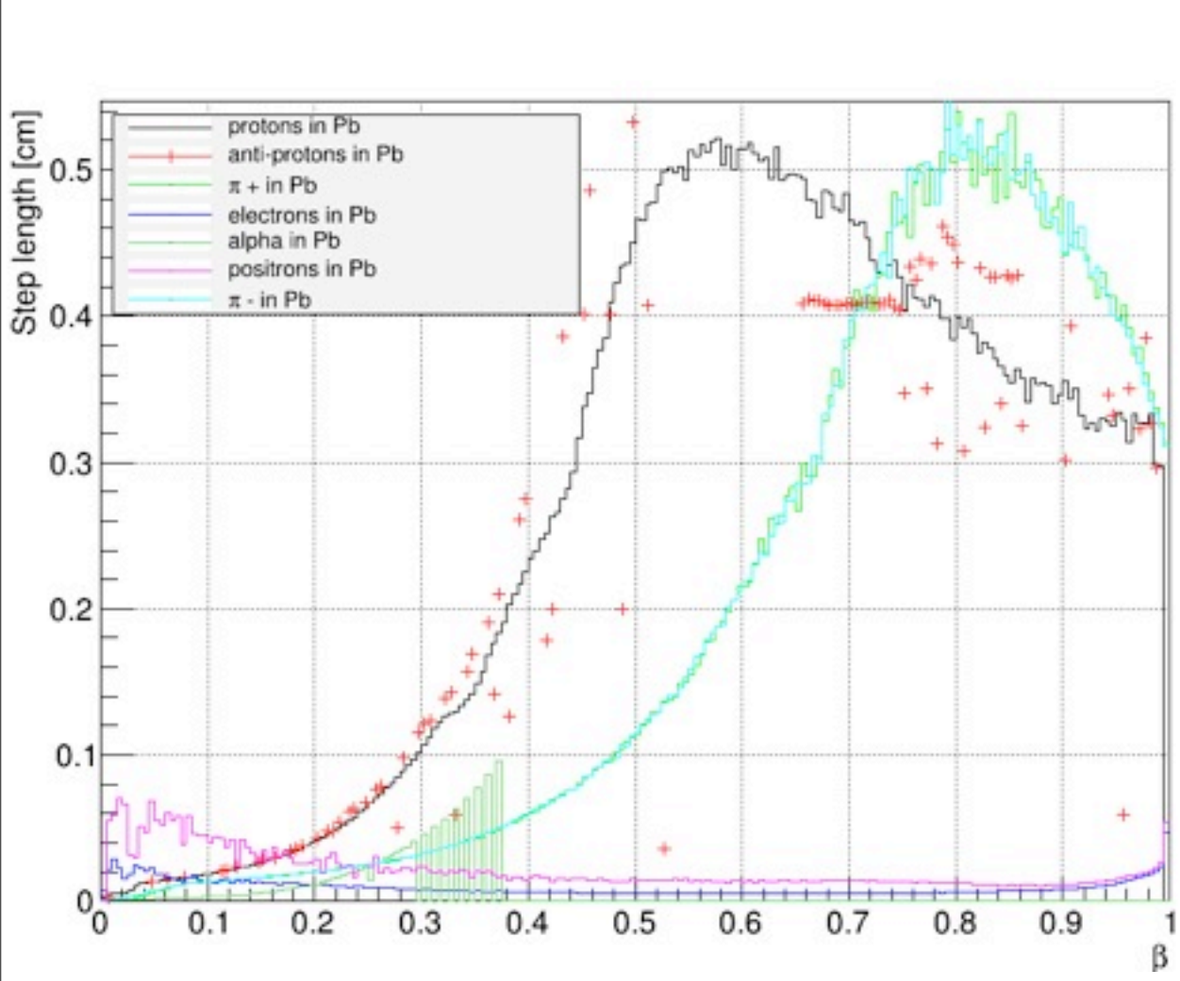


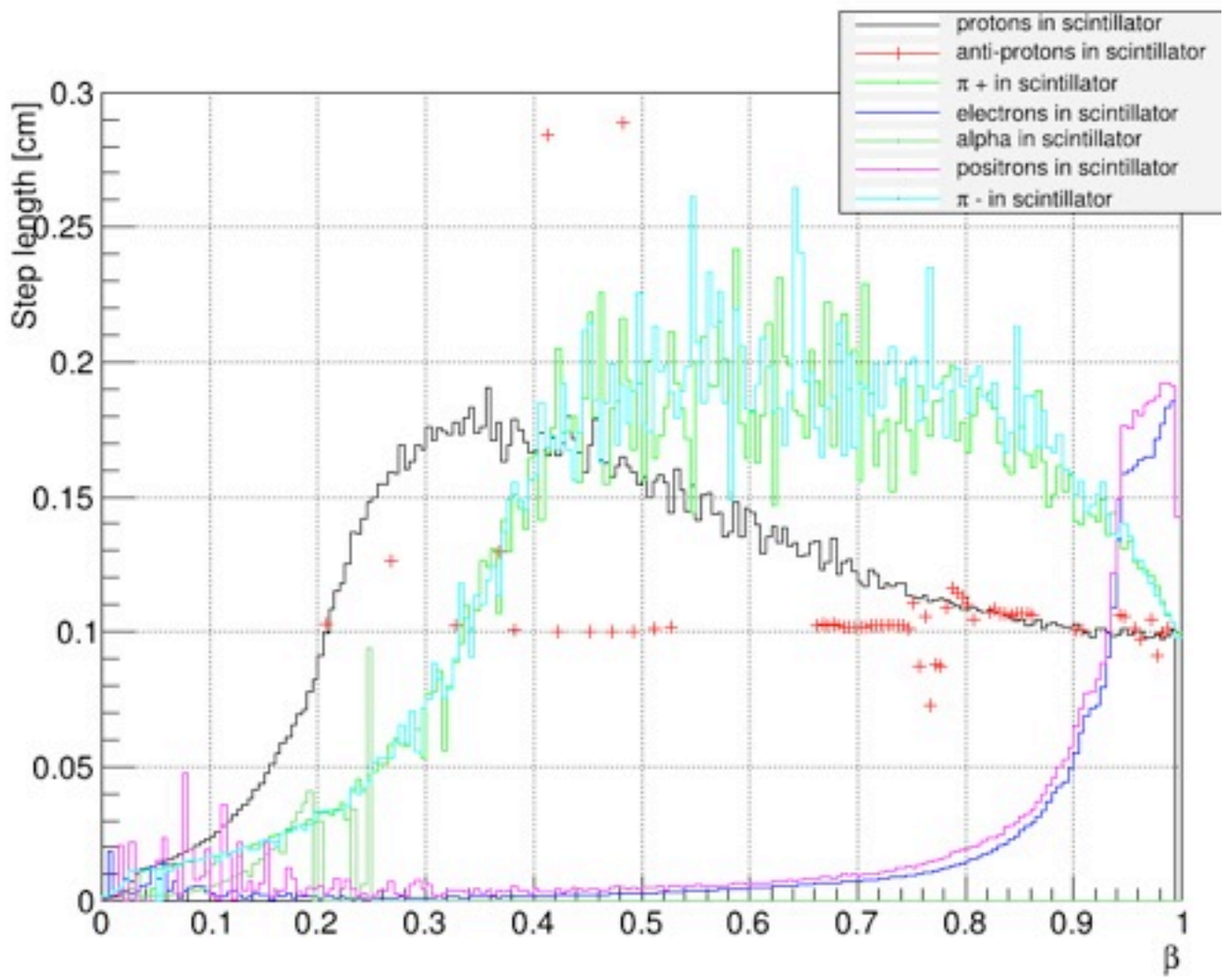
Step length as a function of beta*gamma (15 GeV incident pi-)



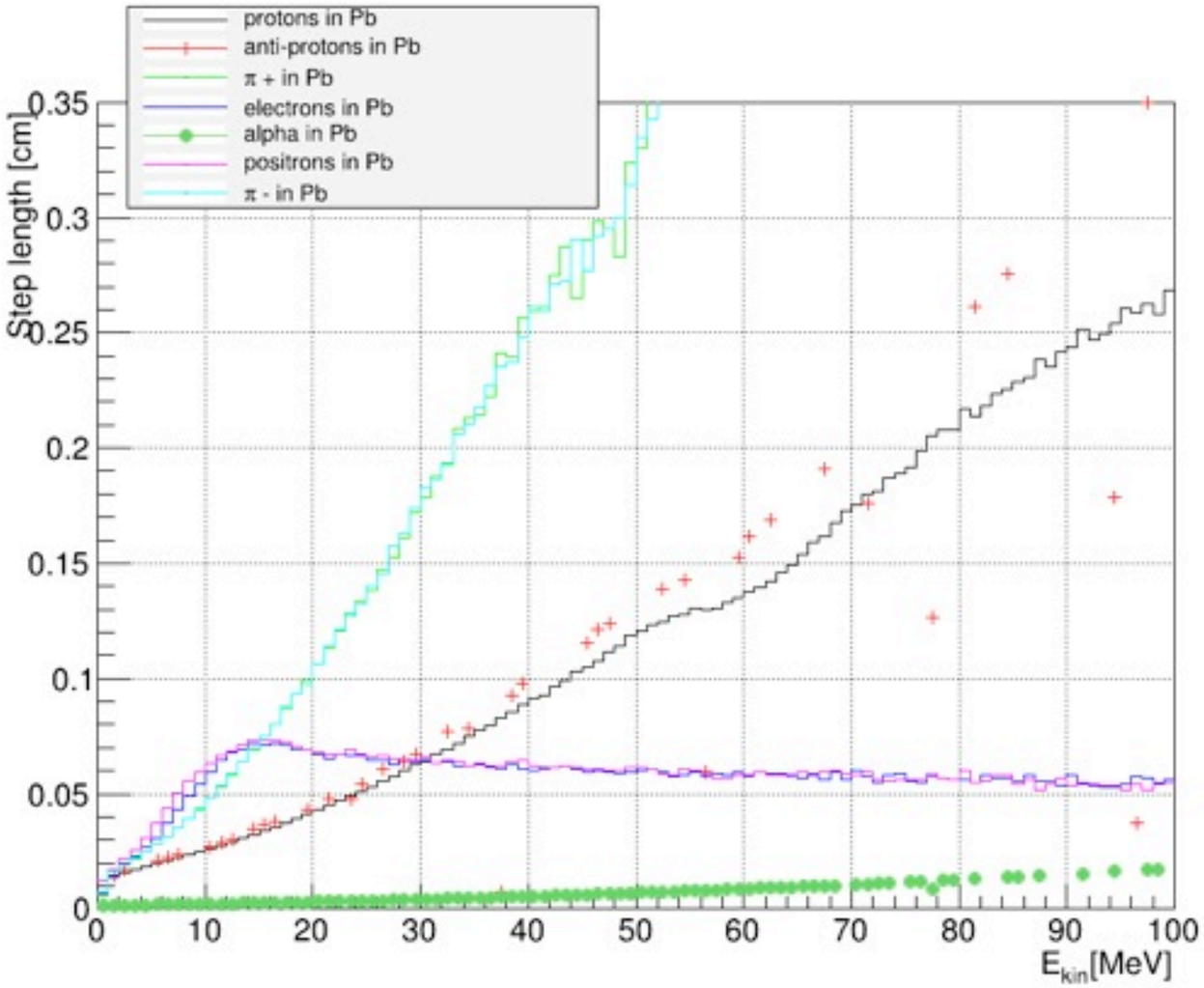


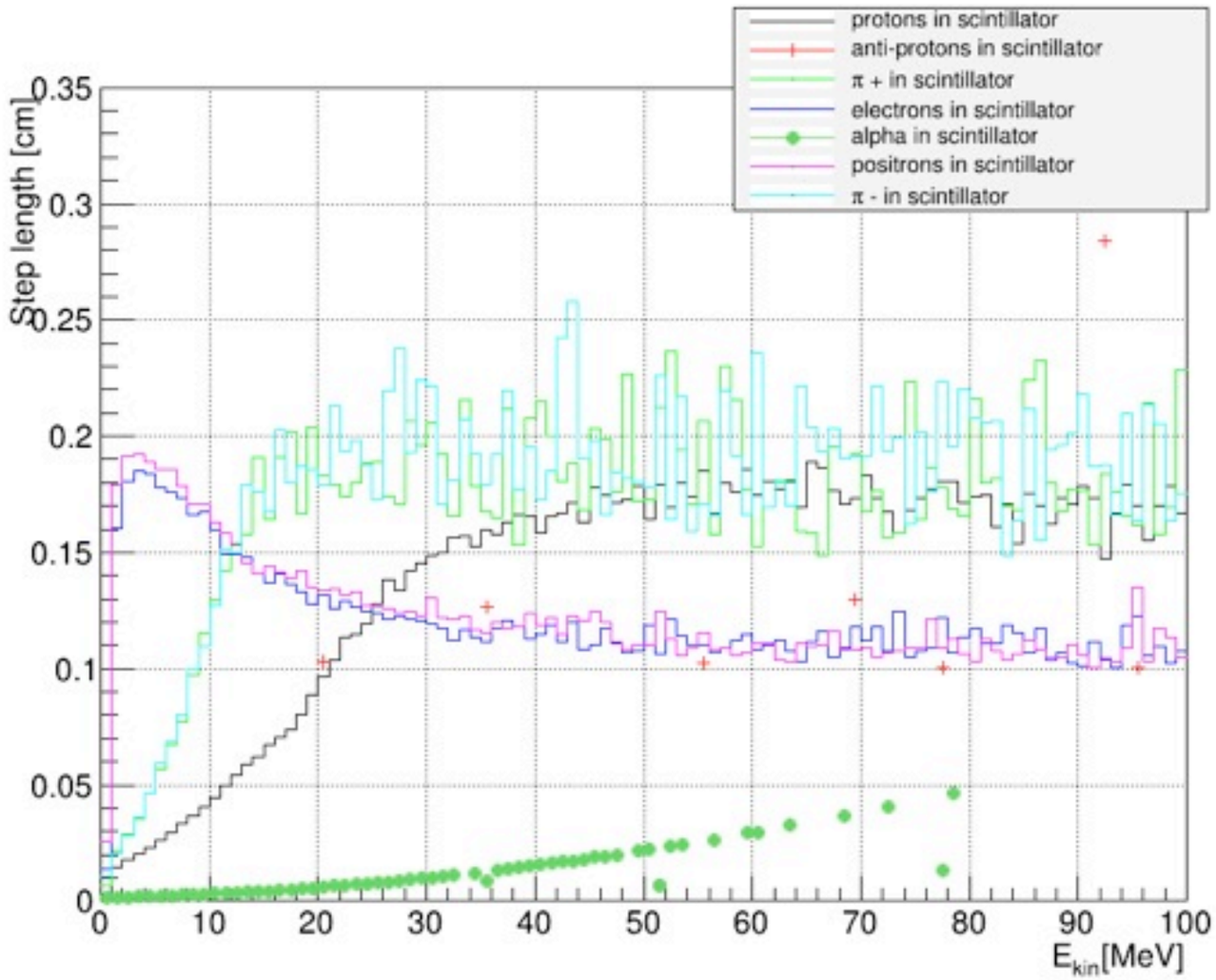
Step length as a function of beta (15 GeV incident pi-)





Step length as a function of kinetic energy (15 GeV incident pi-)





Birks attenuation

- Empirical formula for the light yield per path length as a function of the energy loss per path length for a particle traversing a scintillator.
- Heavily ionizing particles produce less light.

$$\frac{dL}{dr} = \frac{S \cdot dE/dr}{1 + c_1 \cdot dE/dr + c_2 \cdot (dE/dr)^2}$$

$c_1 = 1.29 \times 10^{-2}\, g \cdot cm^{-2} \cdot MeV^{-1}$
$c_2 = 9.59 \times 10^{-6}\, g^2 \cdot cm^{-4} \cdot MeV^{-2}$
$S = 1$

Values used by ATLAS TileCal and CMS HCAL (also default in Geant3)

where:

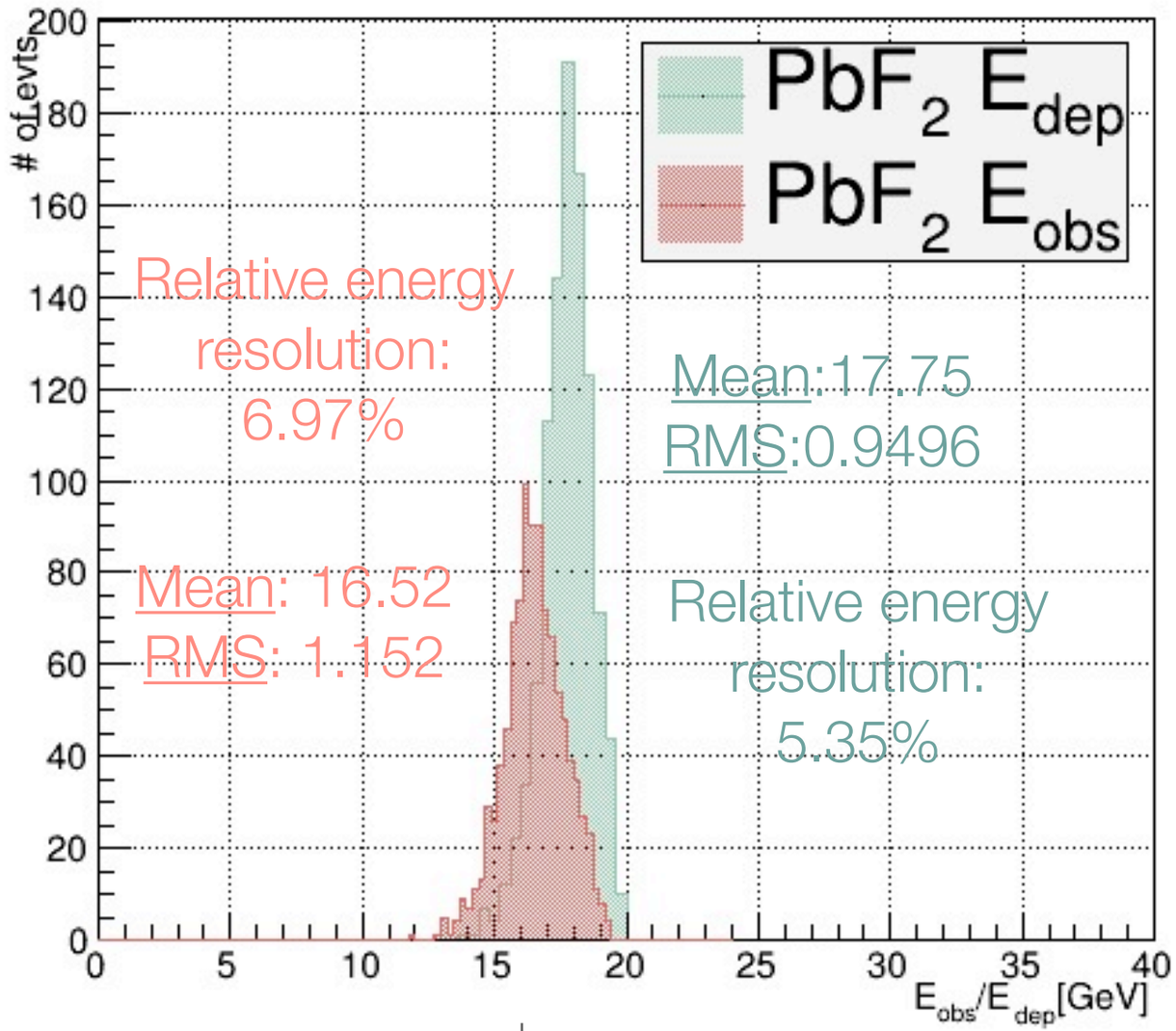
Edep -> energy deposited in the entire calorimeter volume.

Eobs-> observed energy after applying Birks suppression

S -> scintillation efficiency (1)

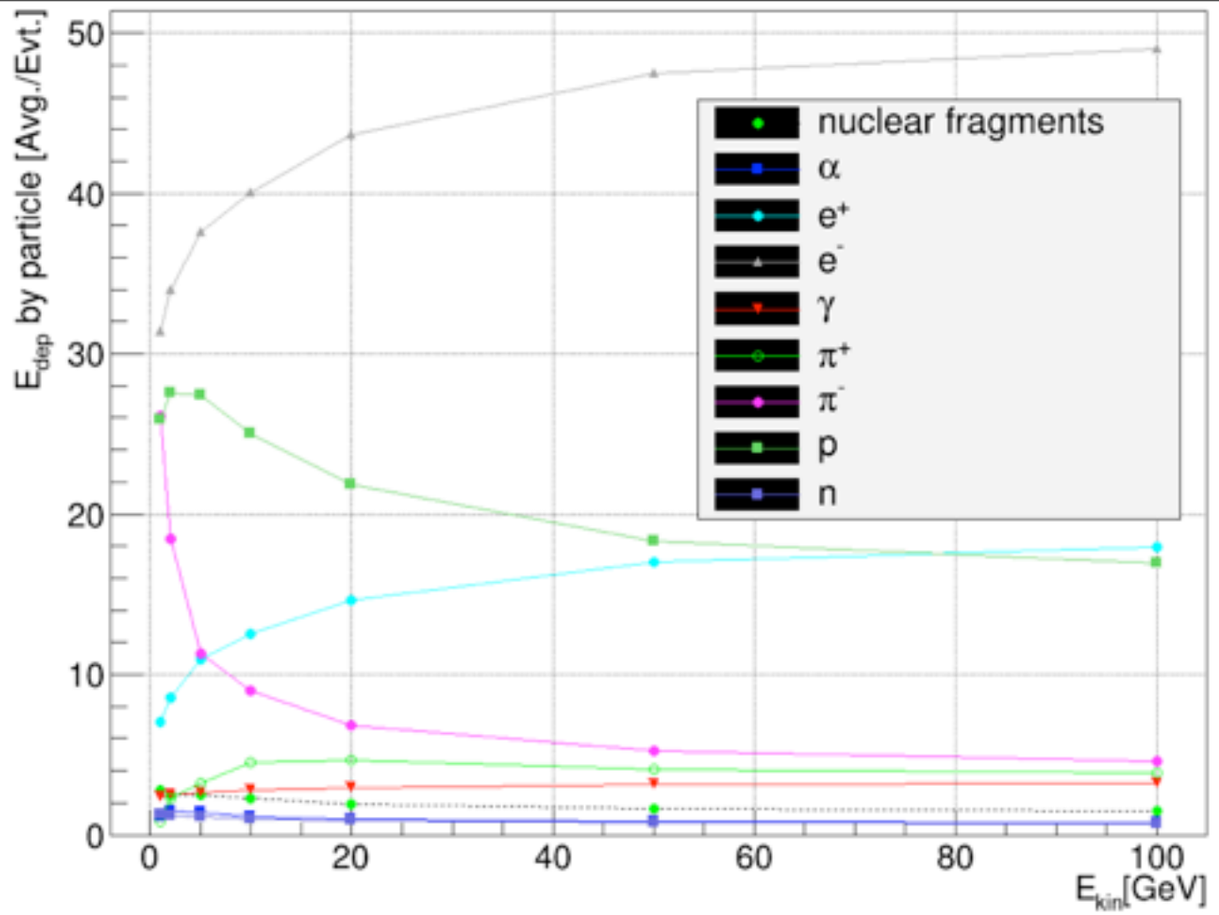
c1, c2 -> Birks constants

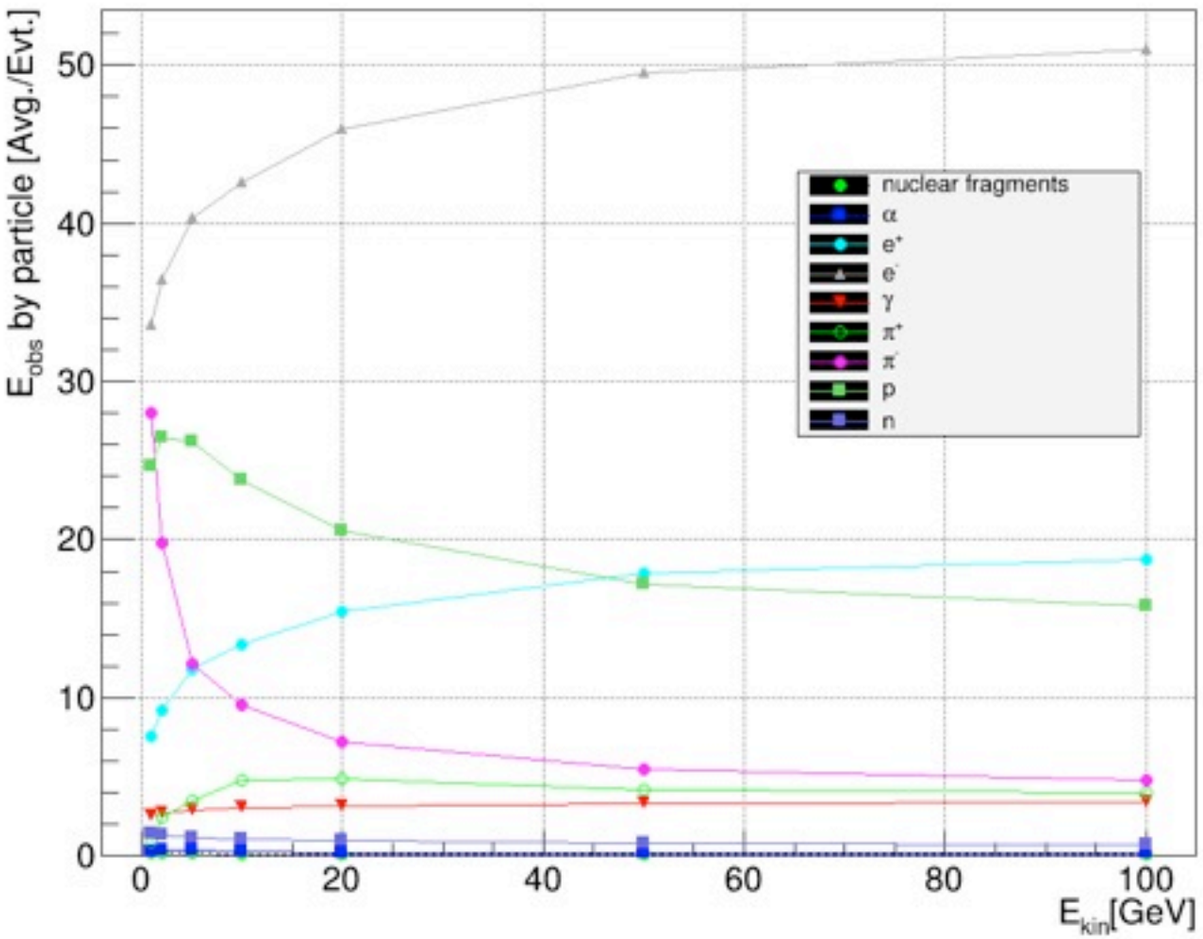
dL/dx -> light output



-> 20 GeV incident pi-
-> 1,000 events
-> FTFP_BERT Physics list
-> PbF2 gdml

Contribution to energy deposition/observed energy by particle (%)



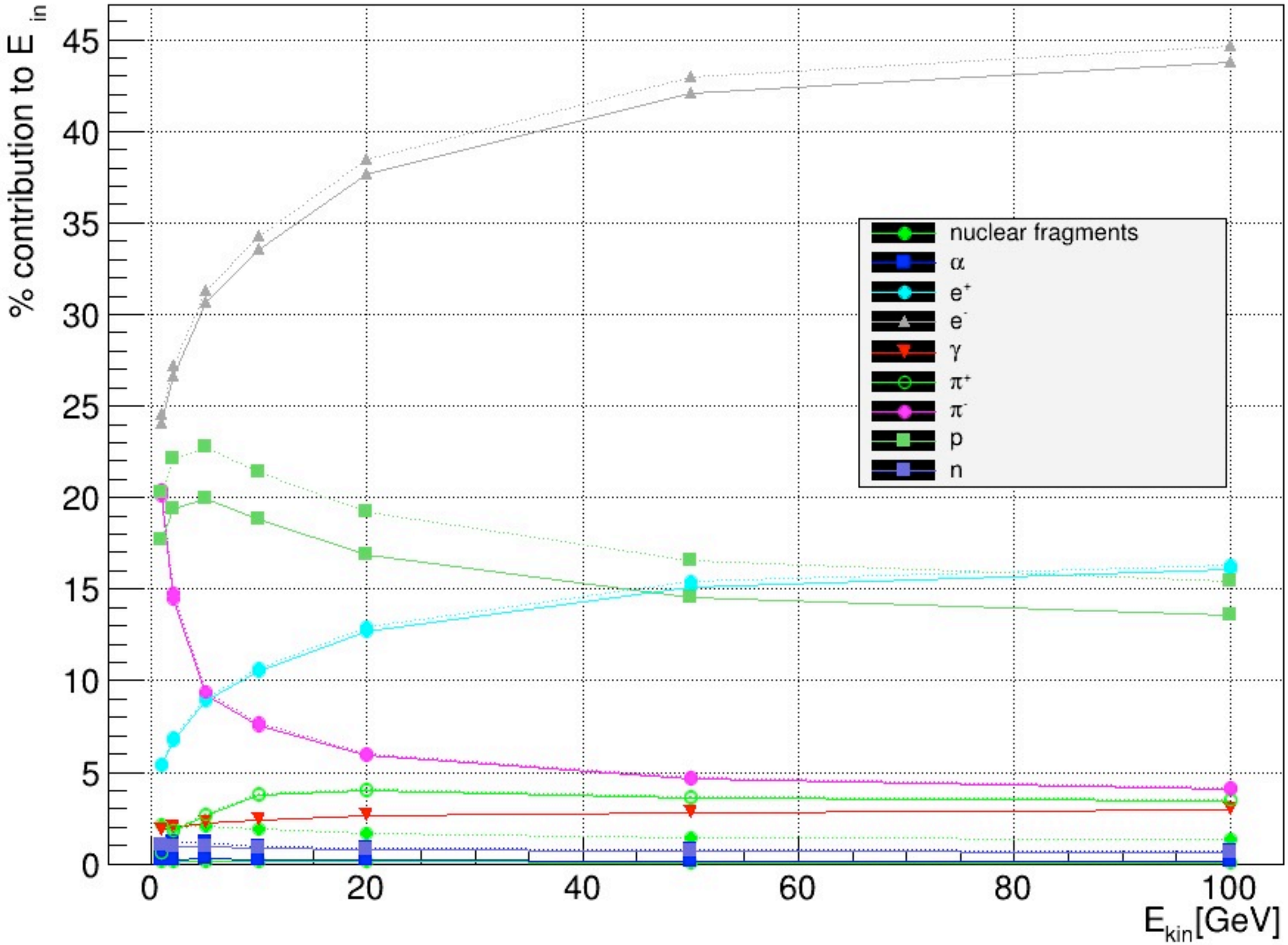


➡ Contribution from protons is suppressed.

➡ Overall, contribution from electrons is increased after considering Birks suppression.

-> Incident pi-
-> 1,000 events
-> FTFP_BERT Physics list
-> PbF2 gdml

Contribution to incoming energy by particle

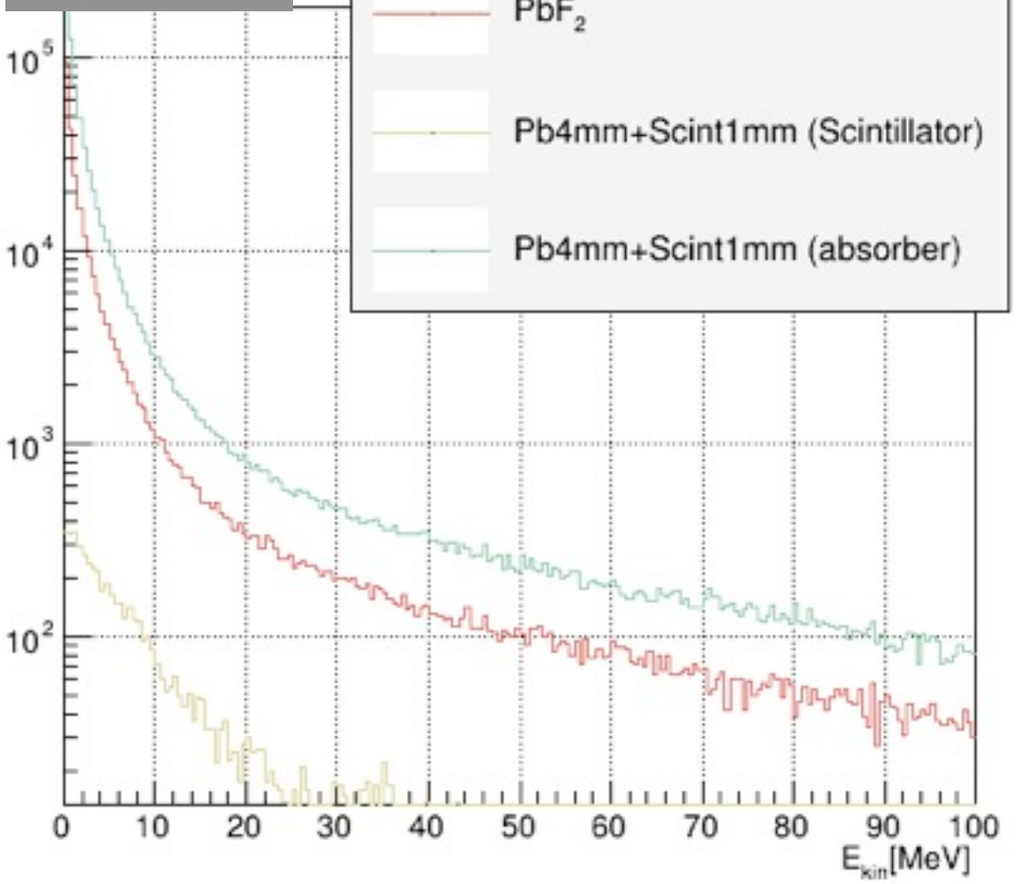


Proton/neutron spectra (5 GeV pi-)

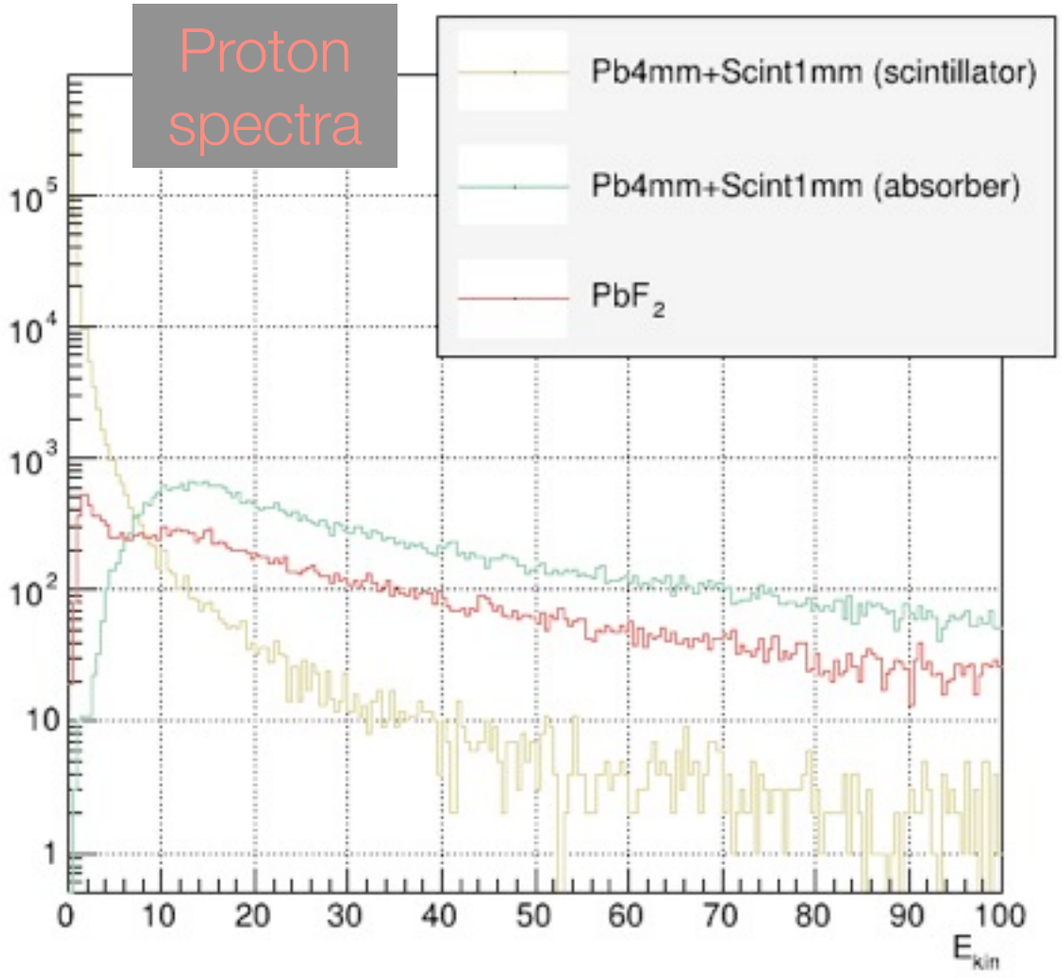
Material	# of neutrons (avg. per evt.)	# of protons (avg. per evt.)
PbF2	279.82	24.339
Pb4mmSc1mm (scintillator)	6.385	545.747
Pb4mmSc1mm (Pb)	781.696	49.849

- ➡ Two components from nuclear spallation processes in PbF2?
- ➡ More neutrons are created in Pb + Scint

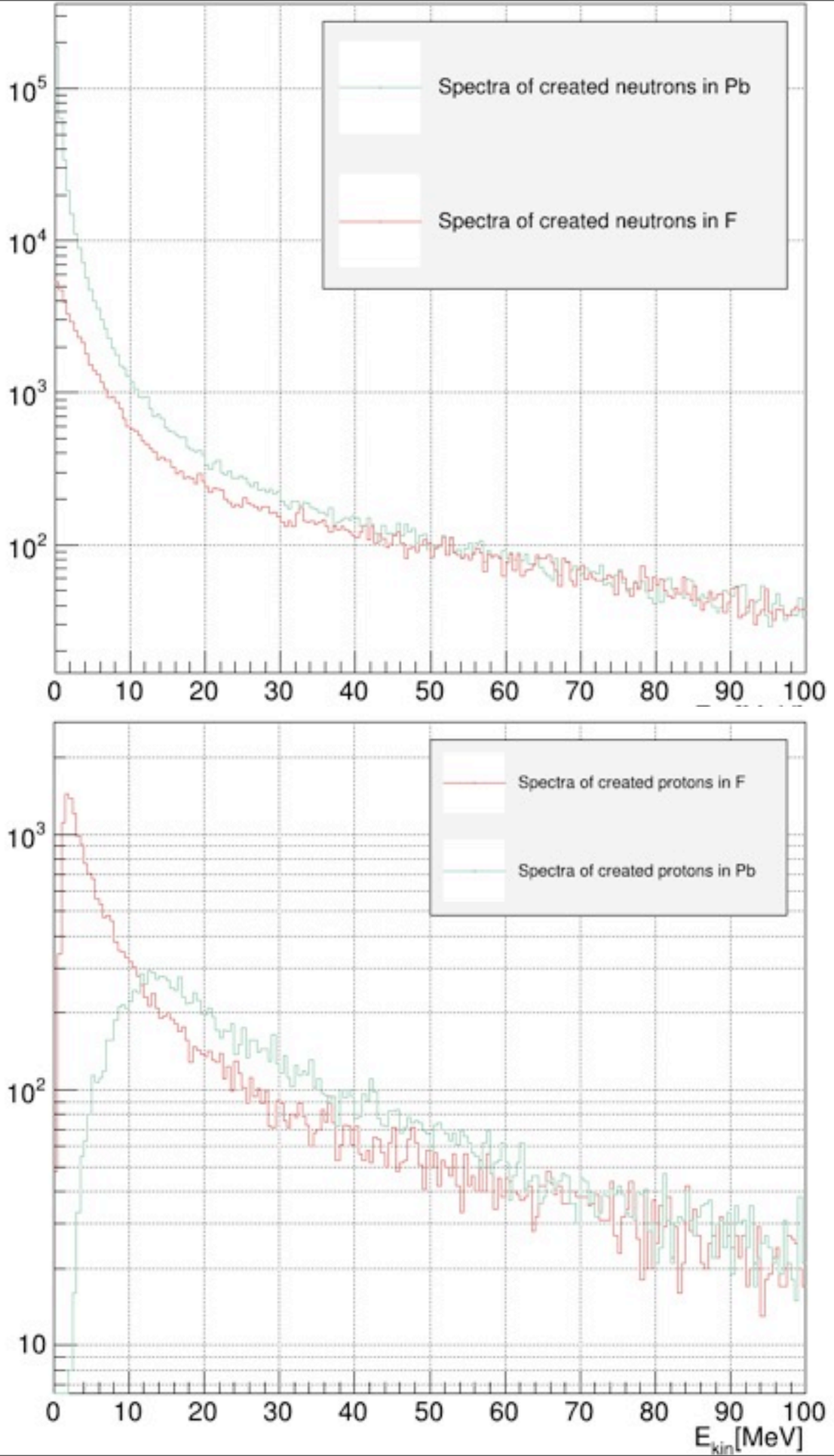
Neutron spectra



Proton spectra

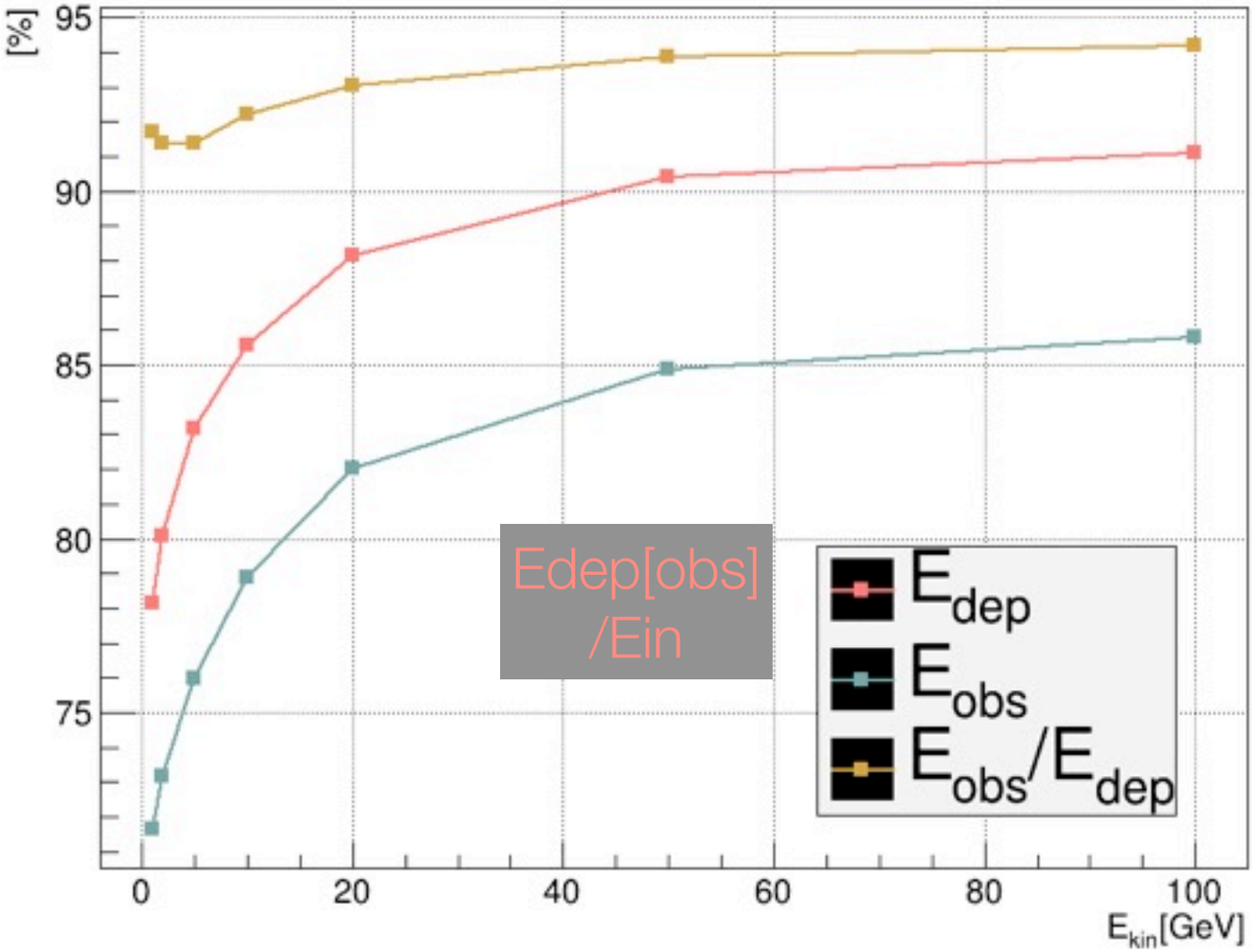


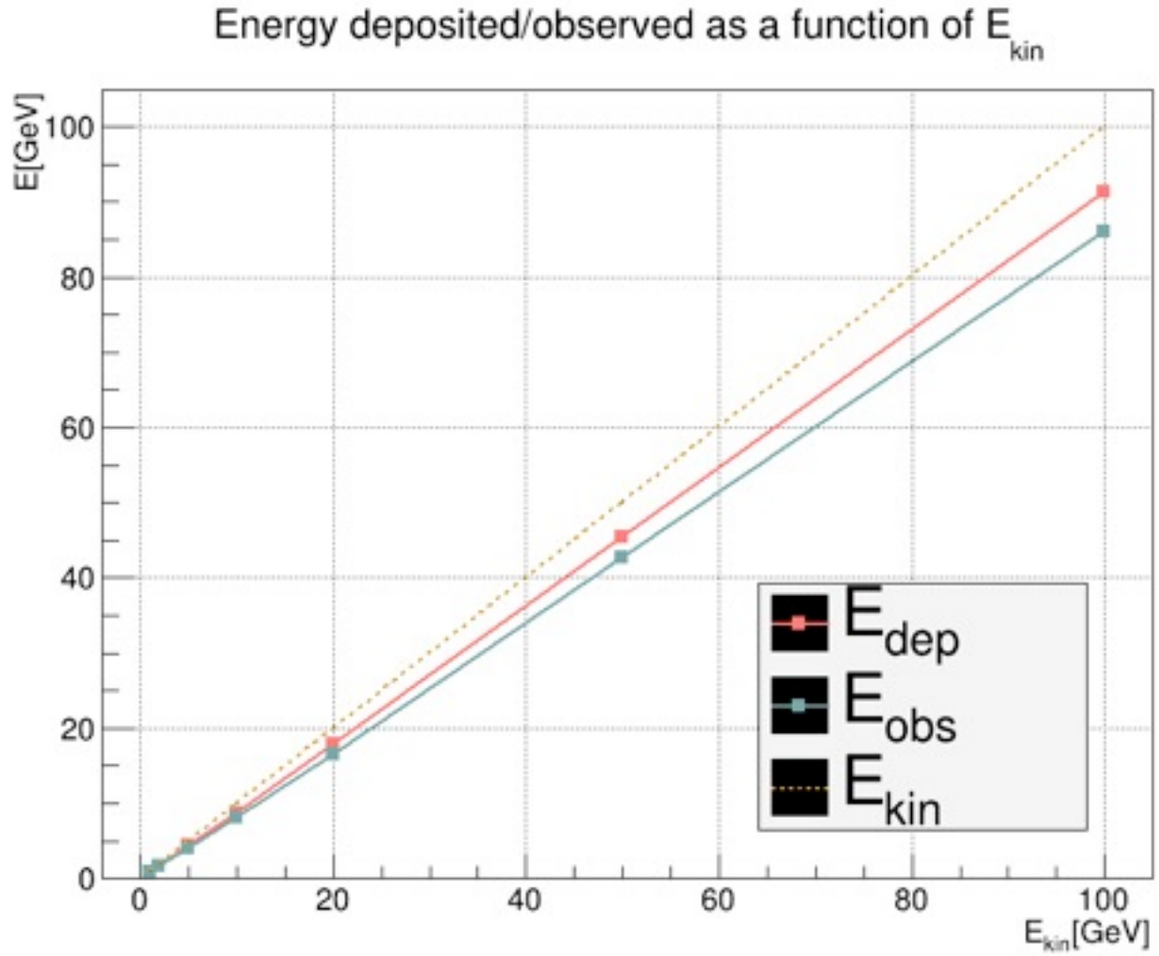
Proton/neutron spectra (5 GeV pi-)

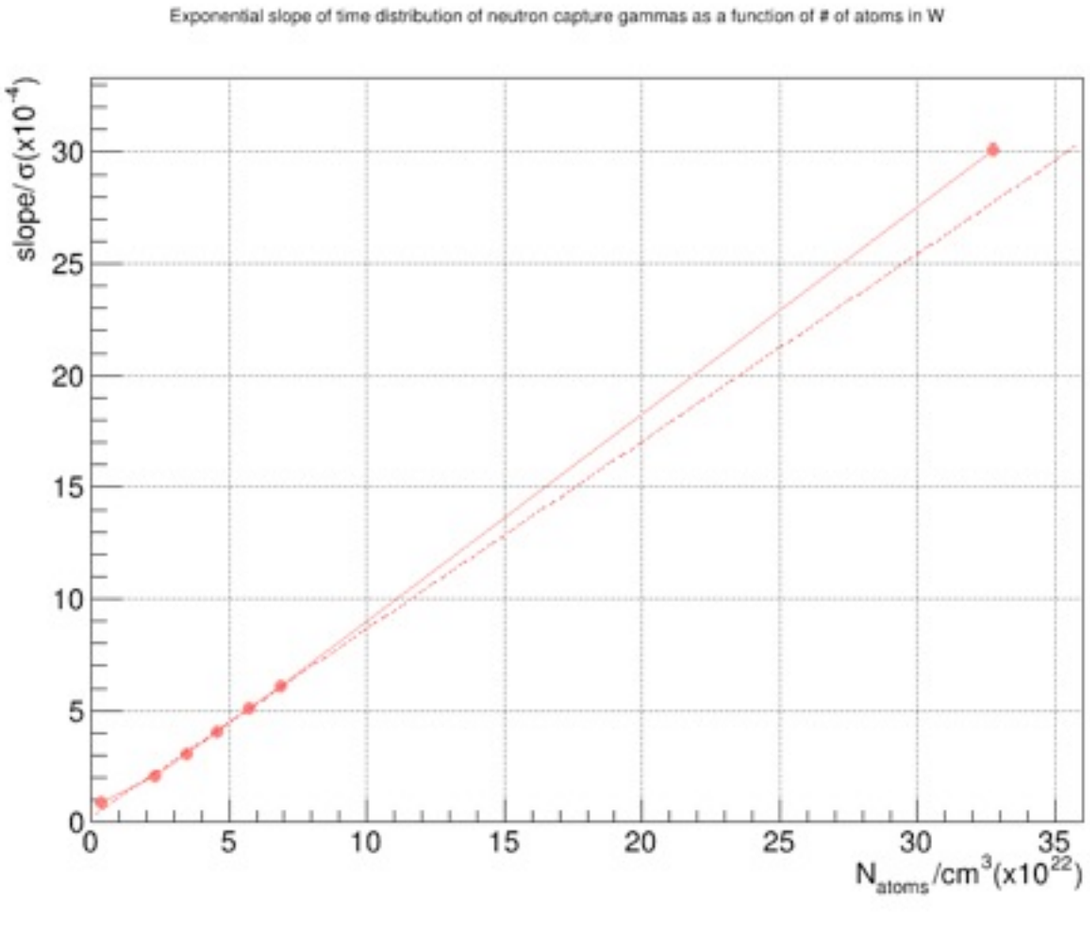


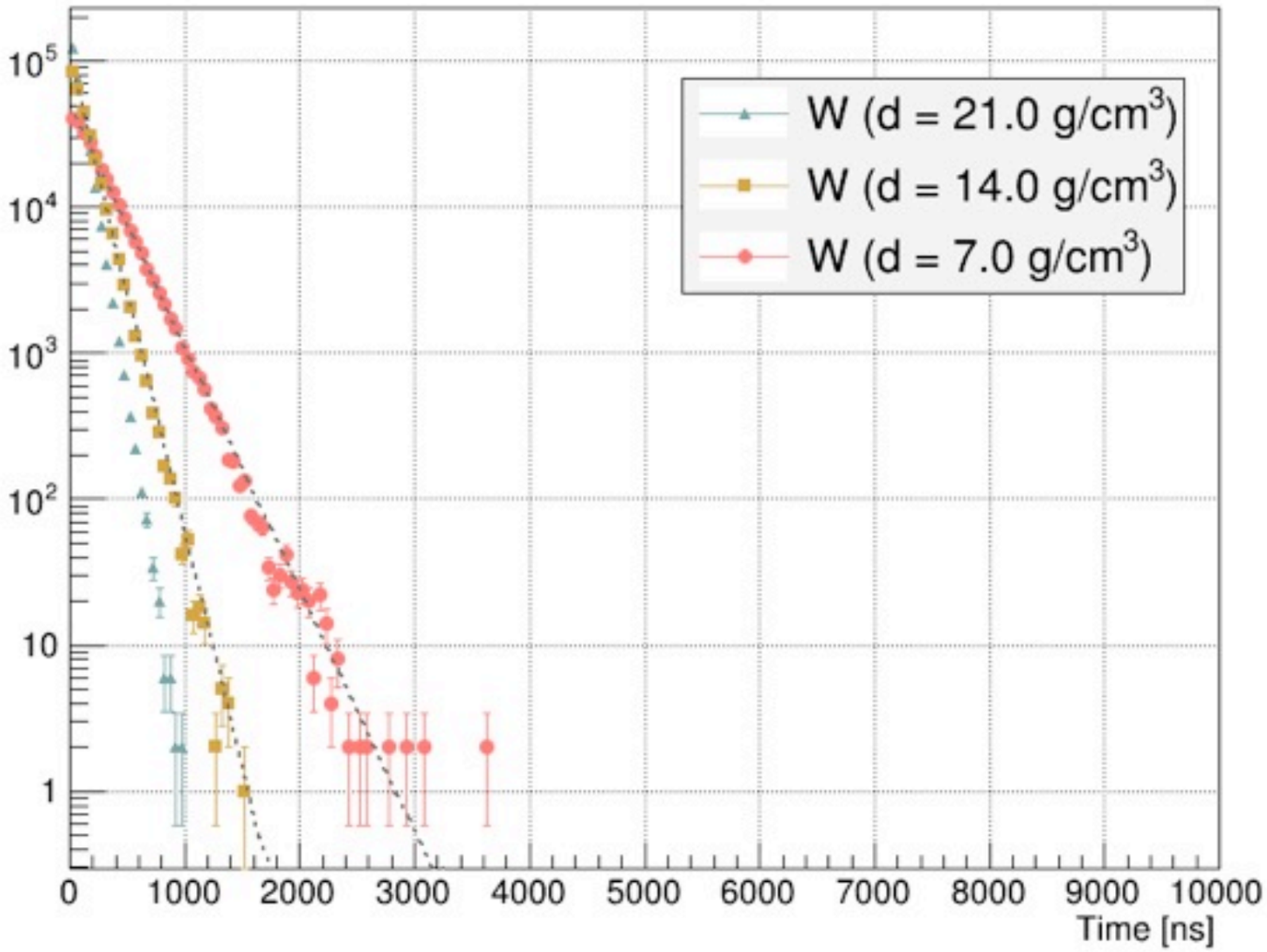
Material	# of neutrons (avg. per evt.)	# of protons (avg. per evt.)
Pb	419.641	21.54
F	69.11	30.426

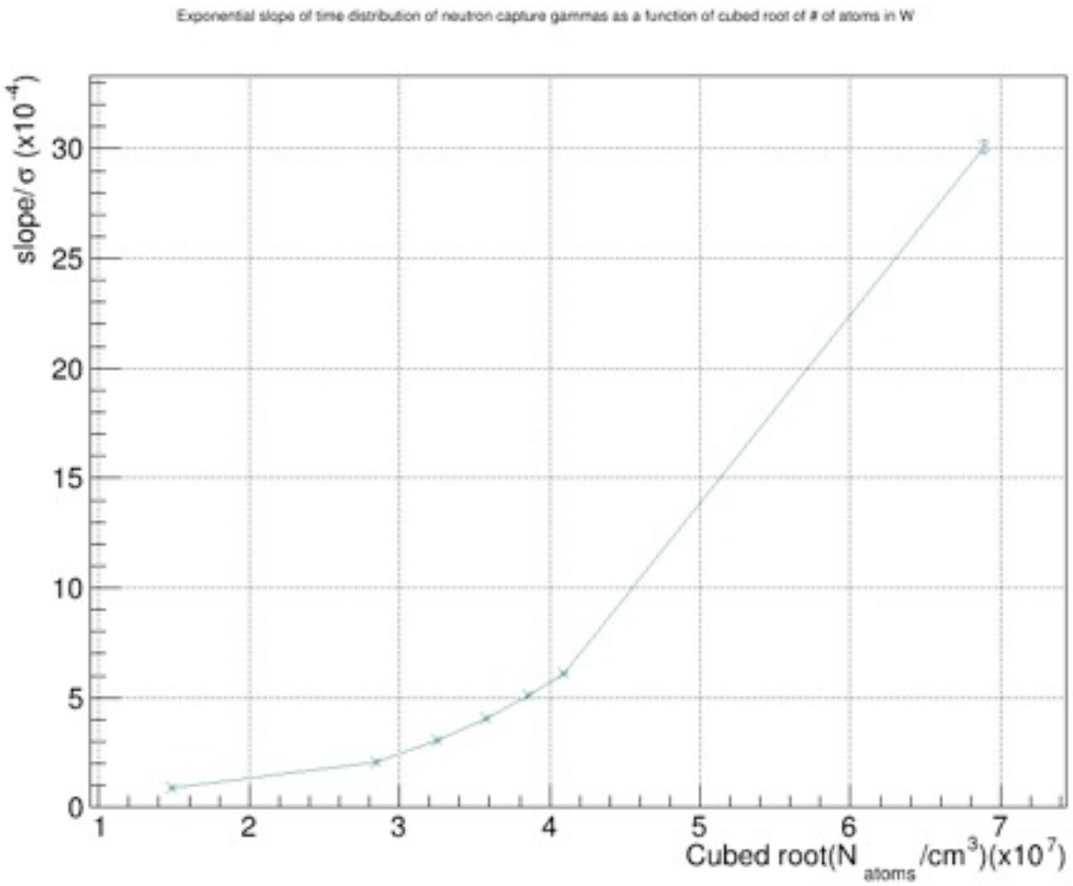
Energy response in PbF2 for incident pi-






Exponential slope of time distribution of neutron capture gammas as a function of # of atoms in W
slope/σ(x10^-4)
N_atoms/cm^3(x10^22)


W (d = 21.0 g/cm^3)
W (d = 14.0 g/cm^3)
W (d = 7.0 g/cm^3)
Time [ns]


Exponential slope of time distribution of neutron capture gammas as a function of cubed root of # of atoms in W
slope/σ (x10^-4)
Cubed root(N_atoms/cm^3)(x10^7)