Herd italian meeting
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Pavia group

Study on quenching effect in scintillator for PSD

Quenching and saturation in scintillators

It is known since many years that when the ionization rate in scintillator is much higher than a m.i.p. the yield of scintillation light is not proportional to the energy loss.

$dE/dx = K z^2 (1/beta^2) \ln(\ldots)$

The m.i.p. loss is present when z=1 and beta~1.
Much higher ionization density is achieved for low beta (e.g. low momentum proton) or high z (ions).

Birks law in scintillators

The light yield at the first order is proportional to the energy loss

$dL/dx = a\, dE/dx$

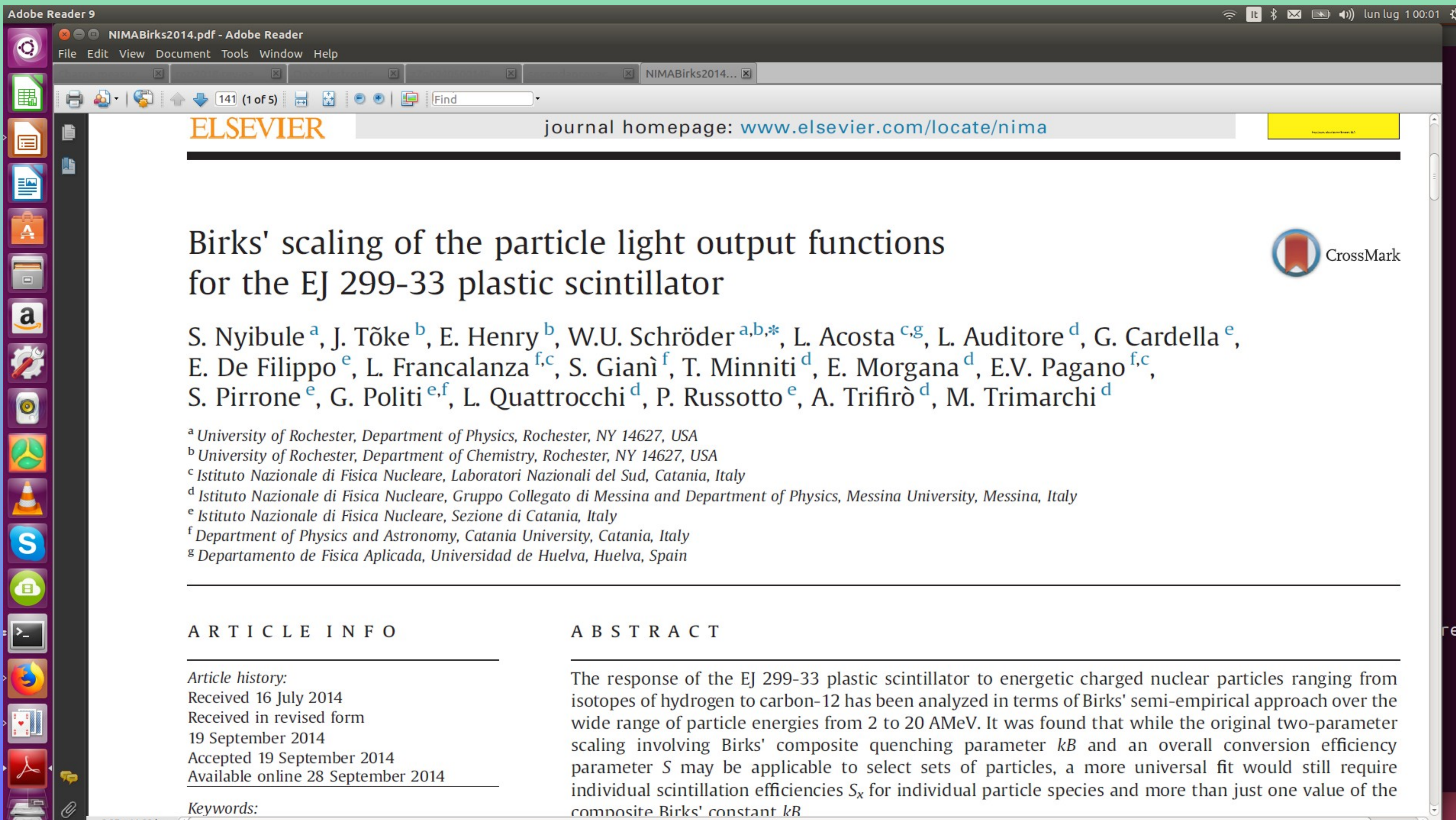
The quenching in light production is described with an approximate formula known as Birks law:

$dL/dx = a\, dE/dx \,/(1 + k_B dE/dx)$

For large dE/dx the leneariry is lost, eventualy dL/dx saturates.

Low beta (low momentum)

Experimental data have been collected in nuclear physics accelerators (LNS) at low beta, few MeV/nucleon.



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Birks' scaling of the particle light output functions for the EJ 299-33 plastic scintillator

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The response of the EJ 299-33 plastic scintillator to energetic charged nuclear particles ranging from isotopes of hydrogen to carbon-12 has been analyzed in terms of Birks' semi-empirical approach over the wide range of particle energies from 2 to 20 AMeV. It was found that while the original two-parameter scaling involving Birks' composite quenching parameter *kB* and an overall conversion efficiency parameter *S* may be applicable to select sets of particles, a more universal fit would still require individual scintillation efficiencies S_x for individual particle species and more than just one value of the composite Birks' constant *kB*.

Measurement of k_B at low momentum

Some values measured at low momentum for EJ 299 are

$k_B \sim 0.5$ mg/MeV/cm^2.

For a m.i.p. the dE/dx ~ 2x10^{-3} MeV/mg/cm^2 .

When beta$^{-2} \sim 10^3 \rightarrow$ beta$^{-1} \sim 30$ (a few MeV for light ions).

The light yeld is suppressed by a factor of 2.

Quenching for ions

The other source of high ionization are ions (z>>1) even at high energy (beta~1).

According to Birks' law the quenching is the same when

$z^2 \sim beta^{-2}$.

Not obvious to be verified!

Energy loss mechanisms for slow (beta <<1) particles

are different from high energy ions (beta~1 high z):

- delta-rays production
- Landau fluctuations.

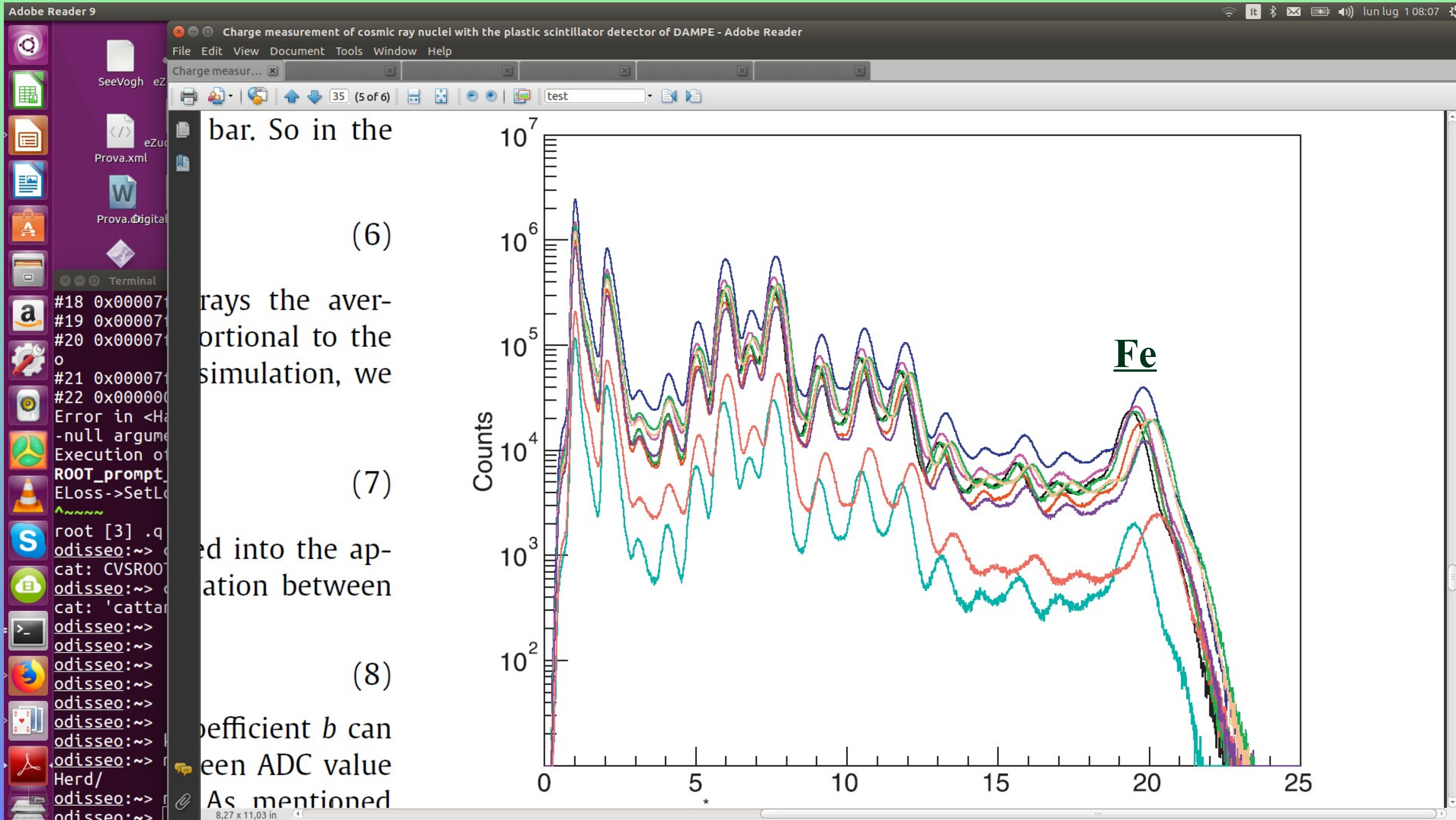
Results for ions

Experimental results of quenching with high energy ions are limited. DAMPE PSD provides important data.

Light collected in the 1 cm thick PSD with the ion flux from cosmic rays with the natural cosmic ray abundance.

Corrections for position dependance and equalizations are applied.

Results for ions

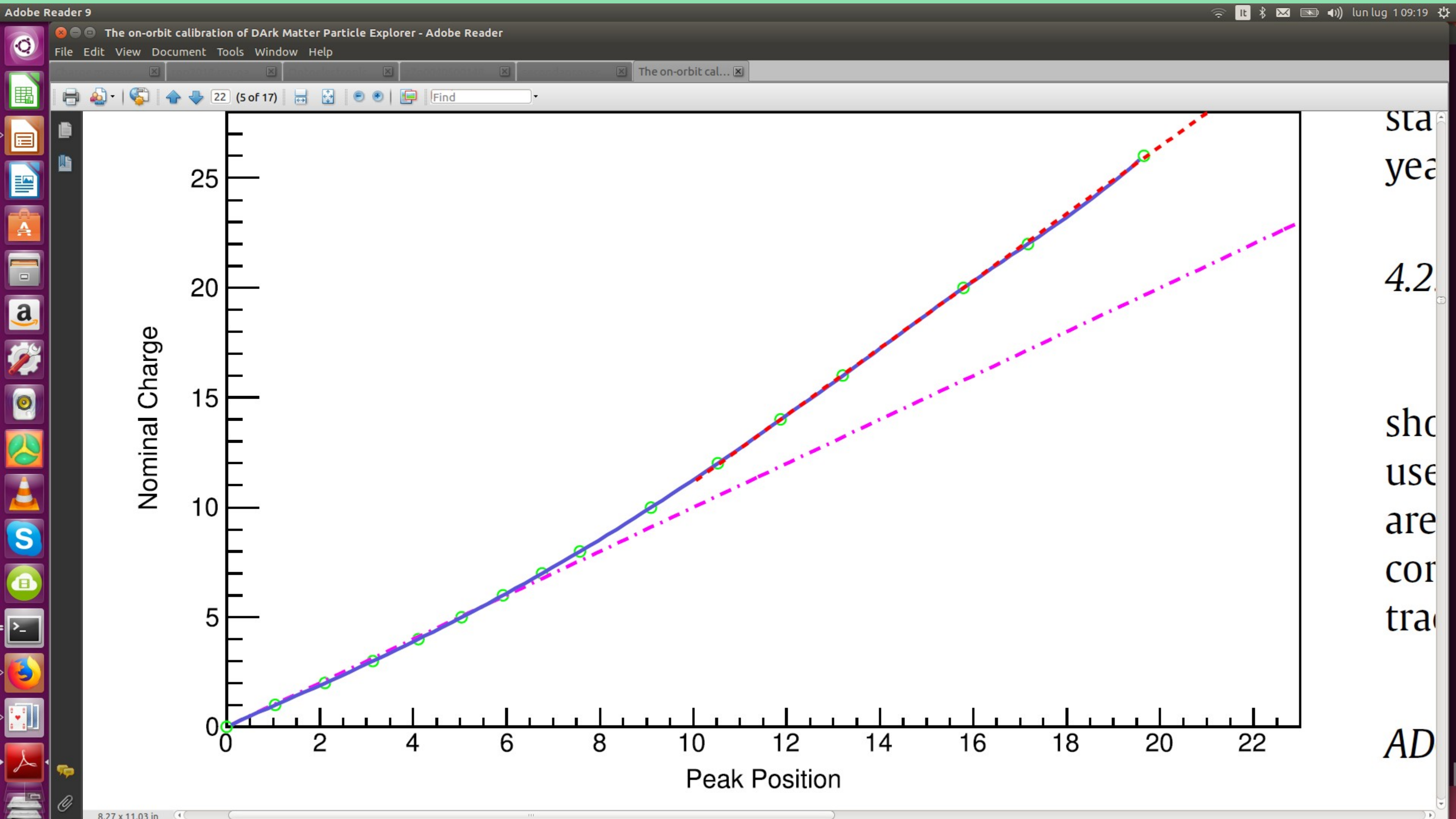


<u>On the abscissa the equivalent ion charge proportional(by definition) the th energy loss</u>

Quenching correction for ions

Birks empirical formula is not adequate.

DAMPE uses a polynomial formula.



Analitical study

For understanding the behaviour of scintillator plate crossed by the flux of cosmic ray ions the analytical calculation of energy loss in 1 cm plate is performed.

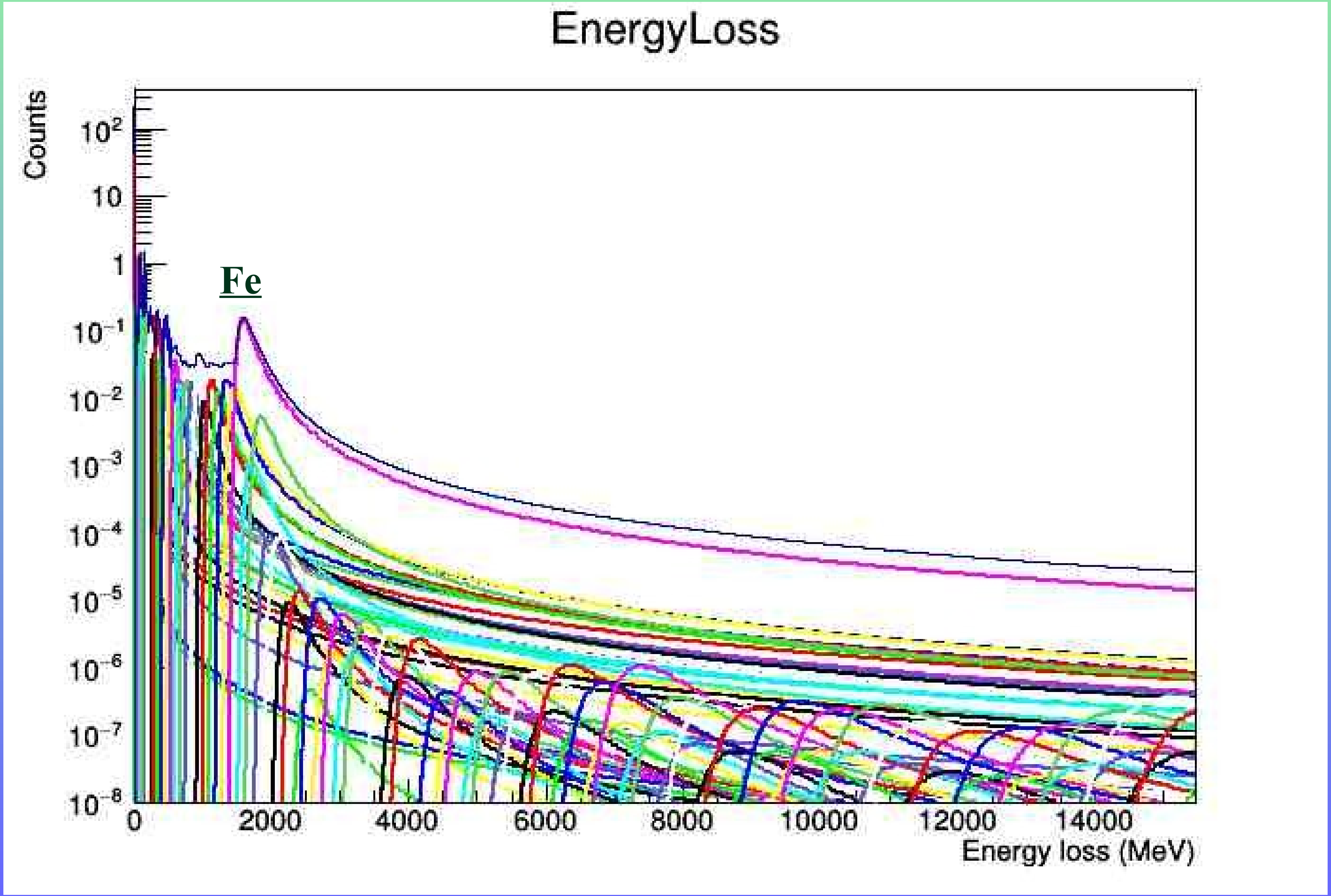
Ion abundance is taken from literature.

Energy loss follows
- Landau
- Gauss
- Vavilov

Goal: what limits charge measurement resolution?

Energy loss in HERD PSD

Energy loss distribution, all chemical species and sum.



Energy loss in HERD PSD

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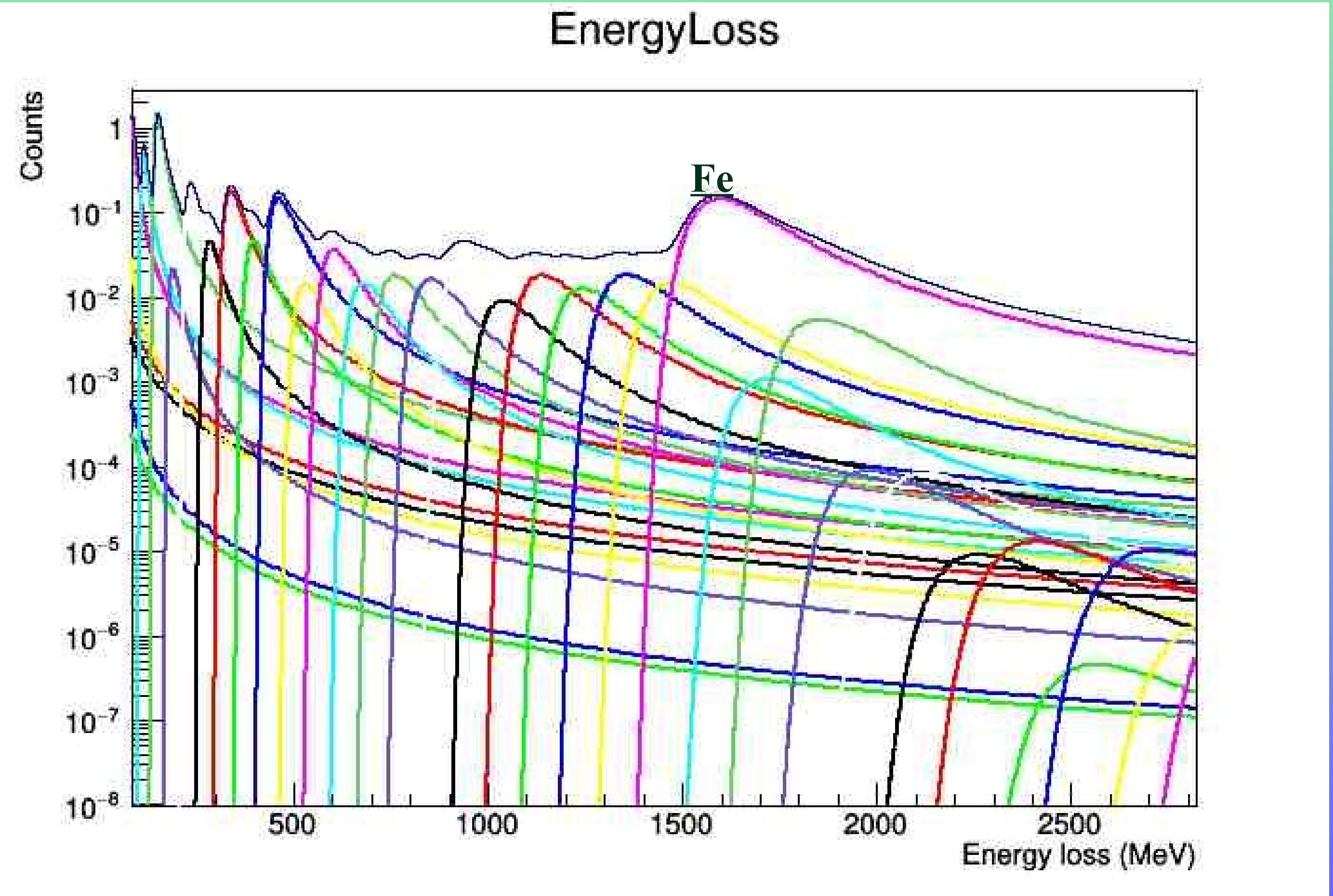
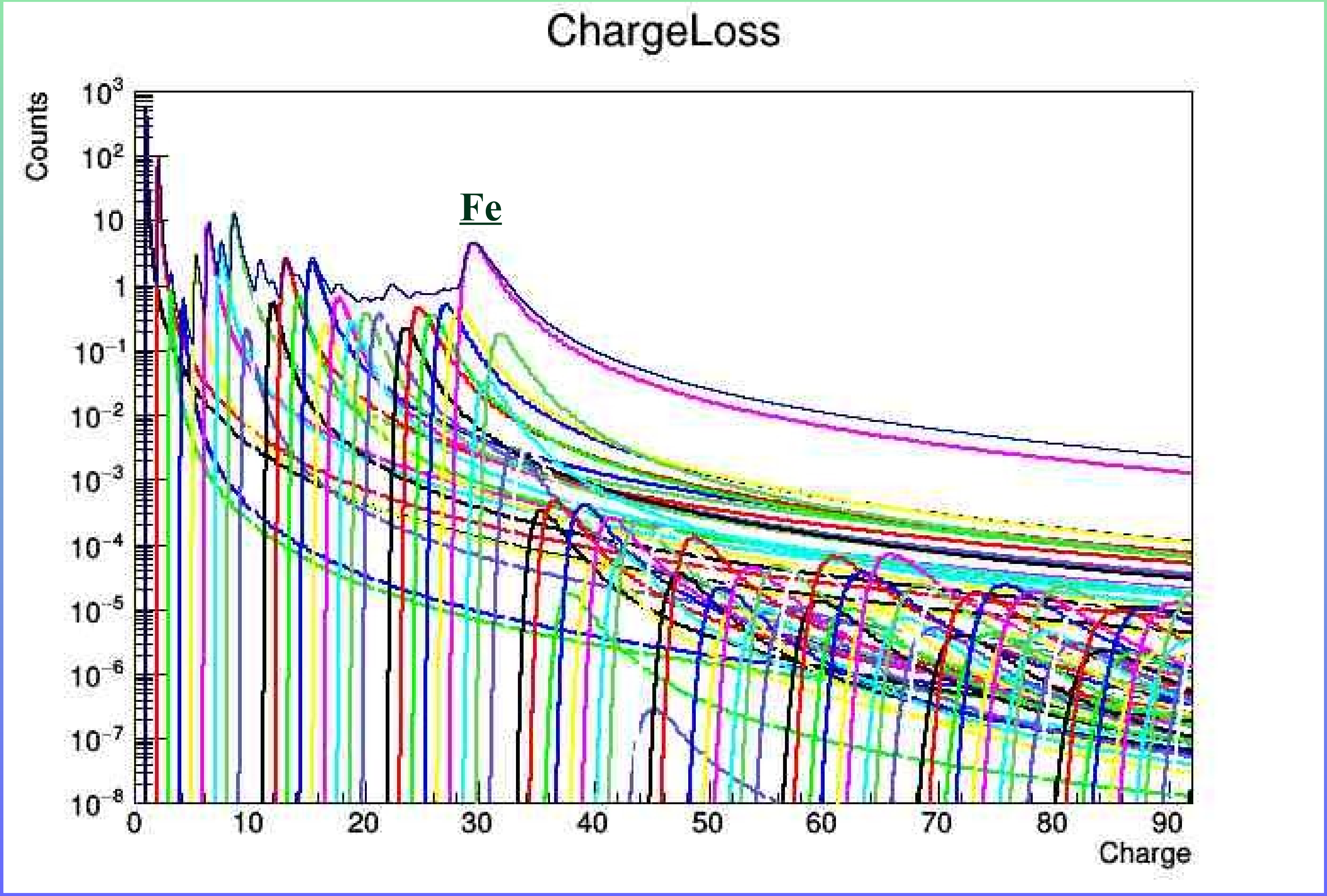


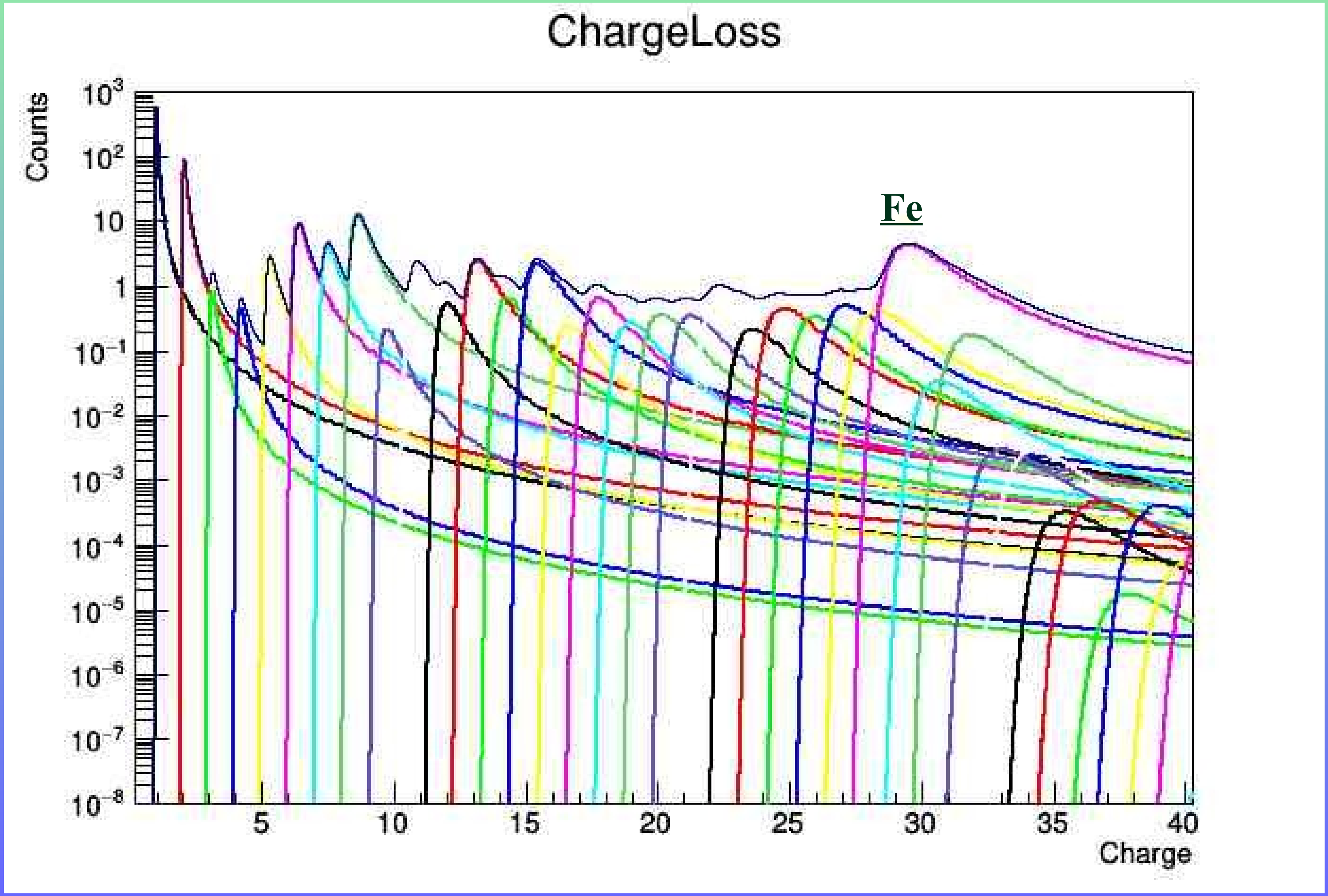
Energy loss in HERD PSD (charge equivalent)

Charge distribution, all chemical species and sum.



Energy loss in HERD PSD (charge equivalent)

Charge distribution, all chemical species and sum.



Conclusions

Efforts to calculate analitically the response of PSD cosmic ray ion flux.

Comparison with DAMPE.

Quenching effect to be included.

Understanding limitation on ion charge measurement.

Testing different geometrical configuration.

Full GEANT4 sinulation to follow.