Study on heavier nuclear CRs

- A challenge for the future -

XSCRC2017 at CERN
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Introduction to myself and my involvement in the Fermi-LAT collaboration

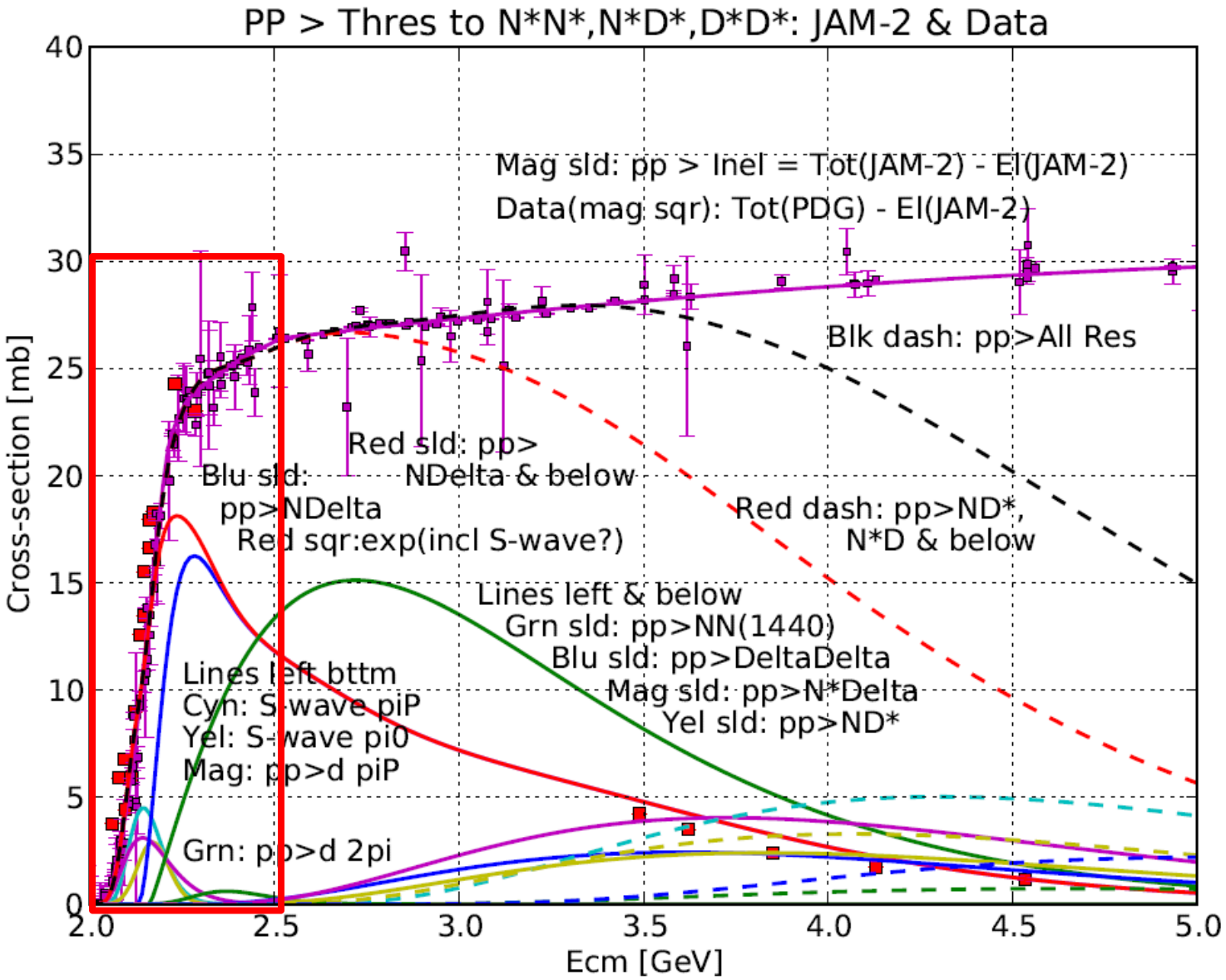
1. Direct measurements (My contribution has been minimum.)
   a. CR electrons + positrons
   b. CR positron/electron
   c. More to come?
2. Indirect measurements of Gal CRs (I have worked on a few SNRs and mol clouds.)
   a. Nuclear CRs at SNRs: Evidence for HE nuclear and/or electron CRs at SNRs
   b. Electron spectra at PSRs and associated PWNe: Accel sites, spectral evolution
   c. Nuclear CRs at molecular clouds: Density of gas measured with nuclear CRs
   d. Use **less-complicated region in the Galaxy** and extract info on CRs
3. Reuse knowledge acquired with analyses on Fermi-LAT for other CR experiments
   a. **Gammas from the Earth limb:** cleaner place to extract nuclear CR spectra
   b. **Can we extract heavy nuclei CR contribution from diffuse Galactic emission?**
4. **Generation of exclusive air-shower events up to 10^15eV**

Let’s start from lower energies

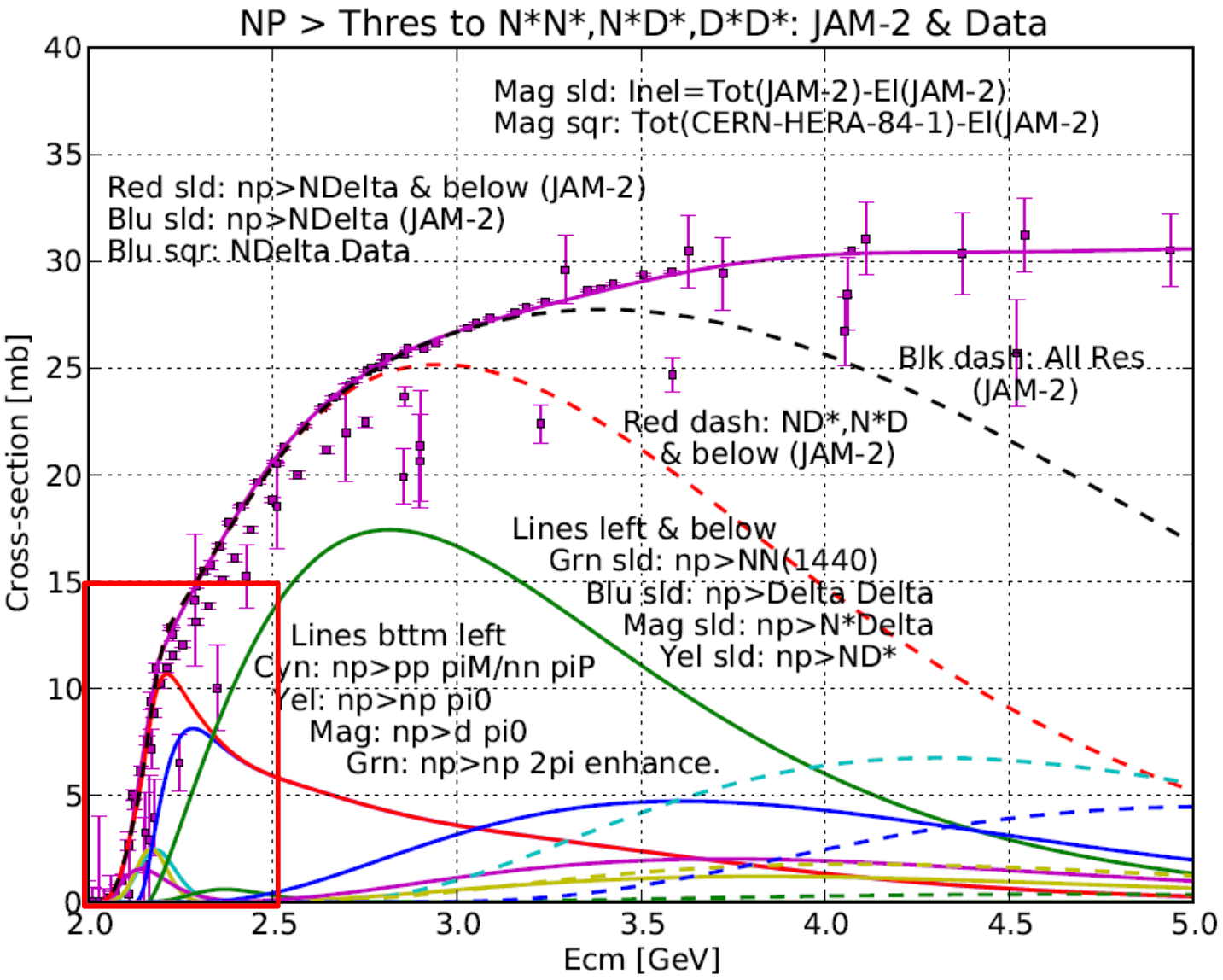
In general:

- Higher fluxes of CRs
- More experimental data available
- Easier to simulate

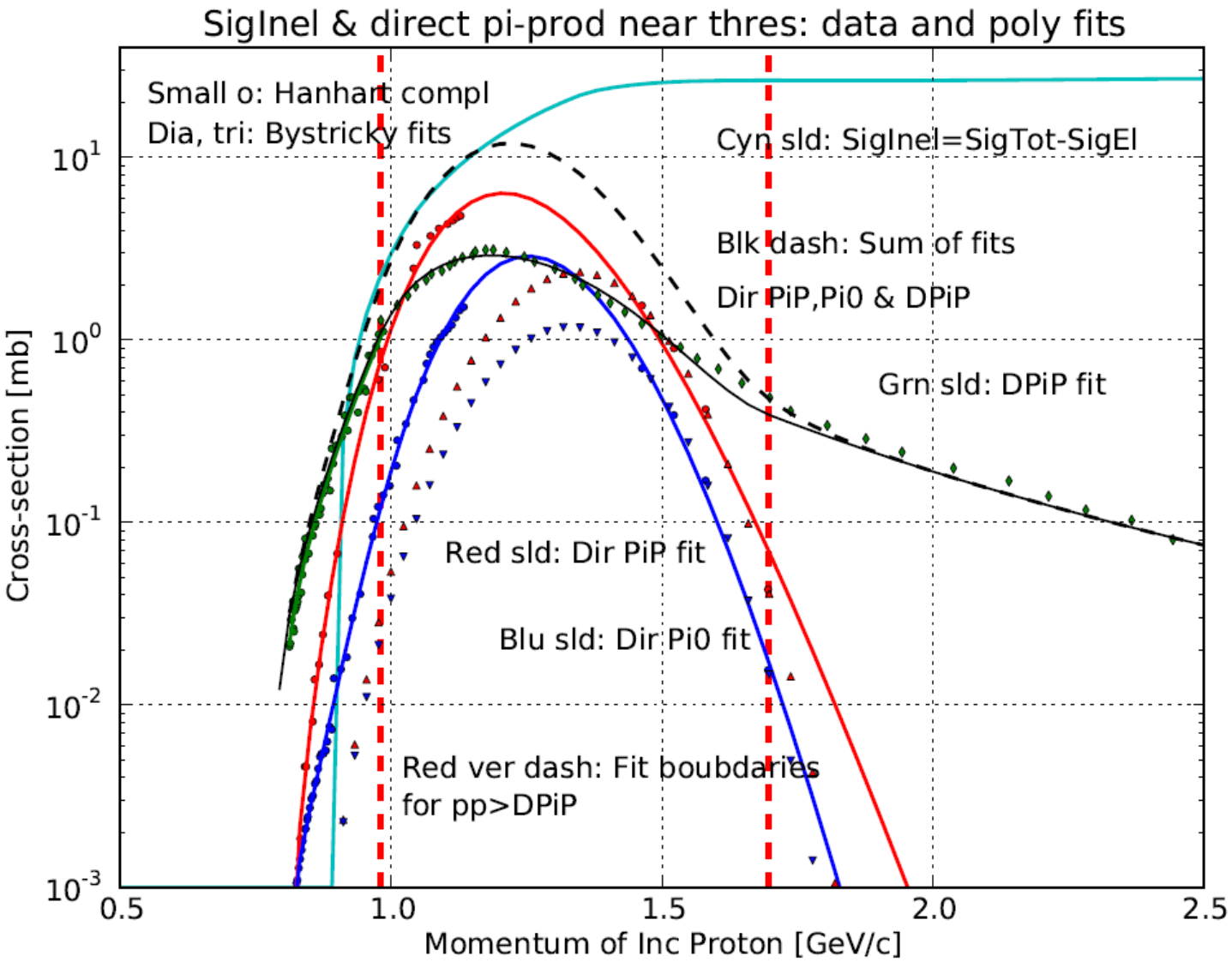
SigInel(pp) below E_{cm}<3-4GeV



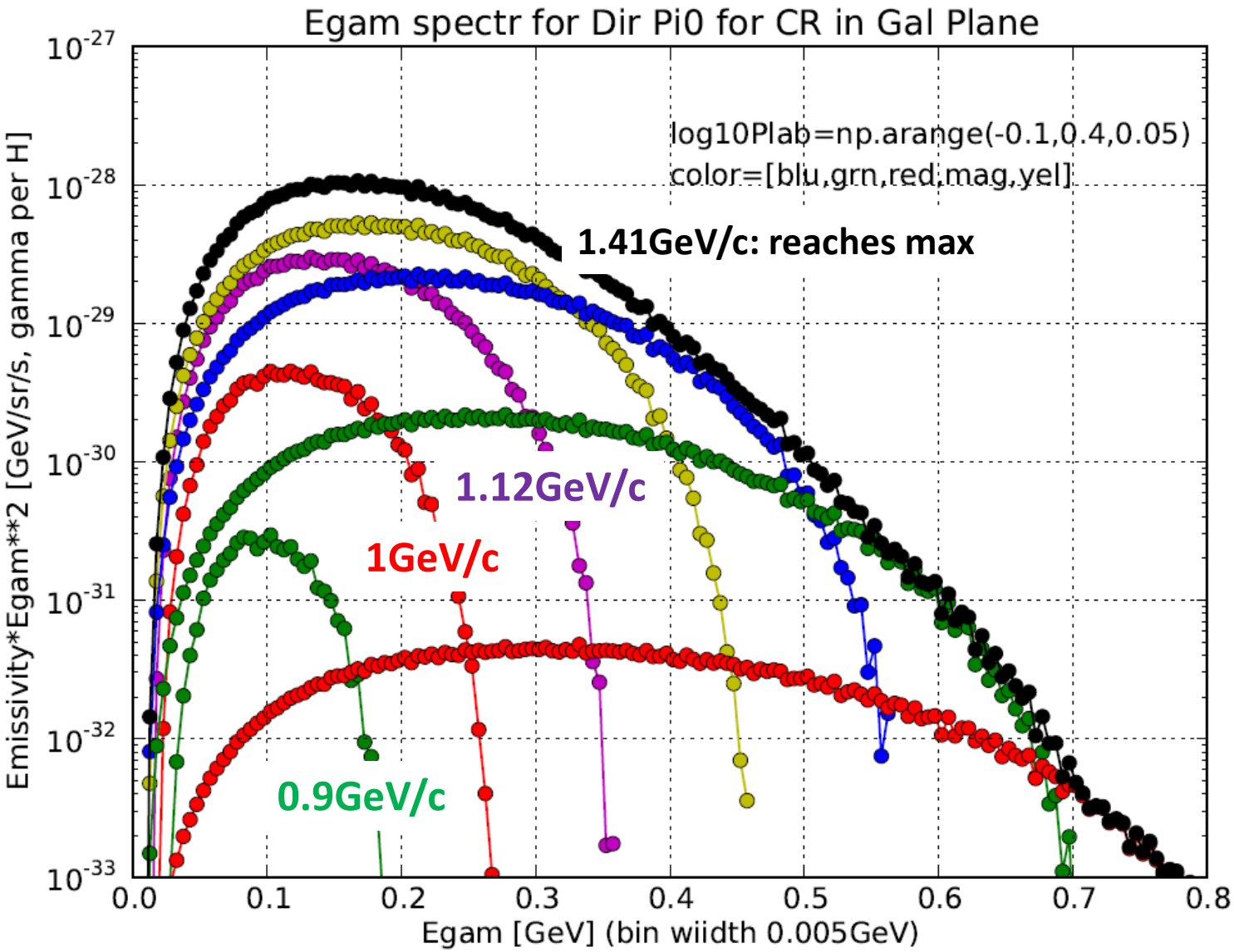
SigInel(np) below E_{cm}<3-4GeV



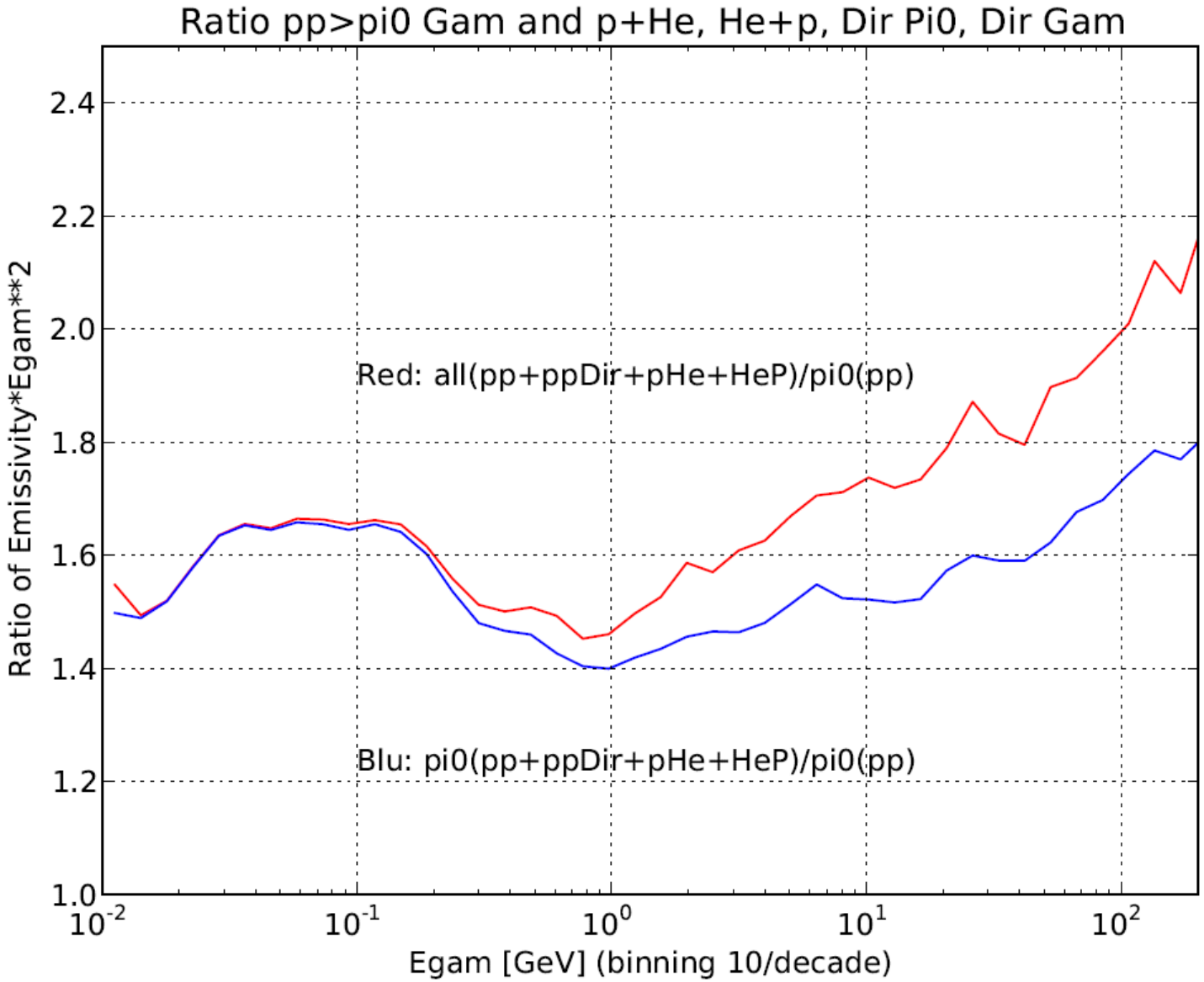
“Discovery” of pp>direct pions near thres



pp>"direct" pions in Gal CRs (PL=-2.75)

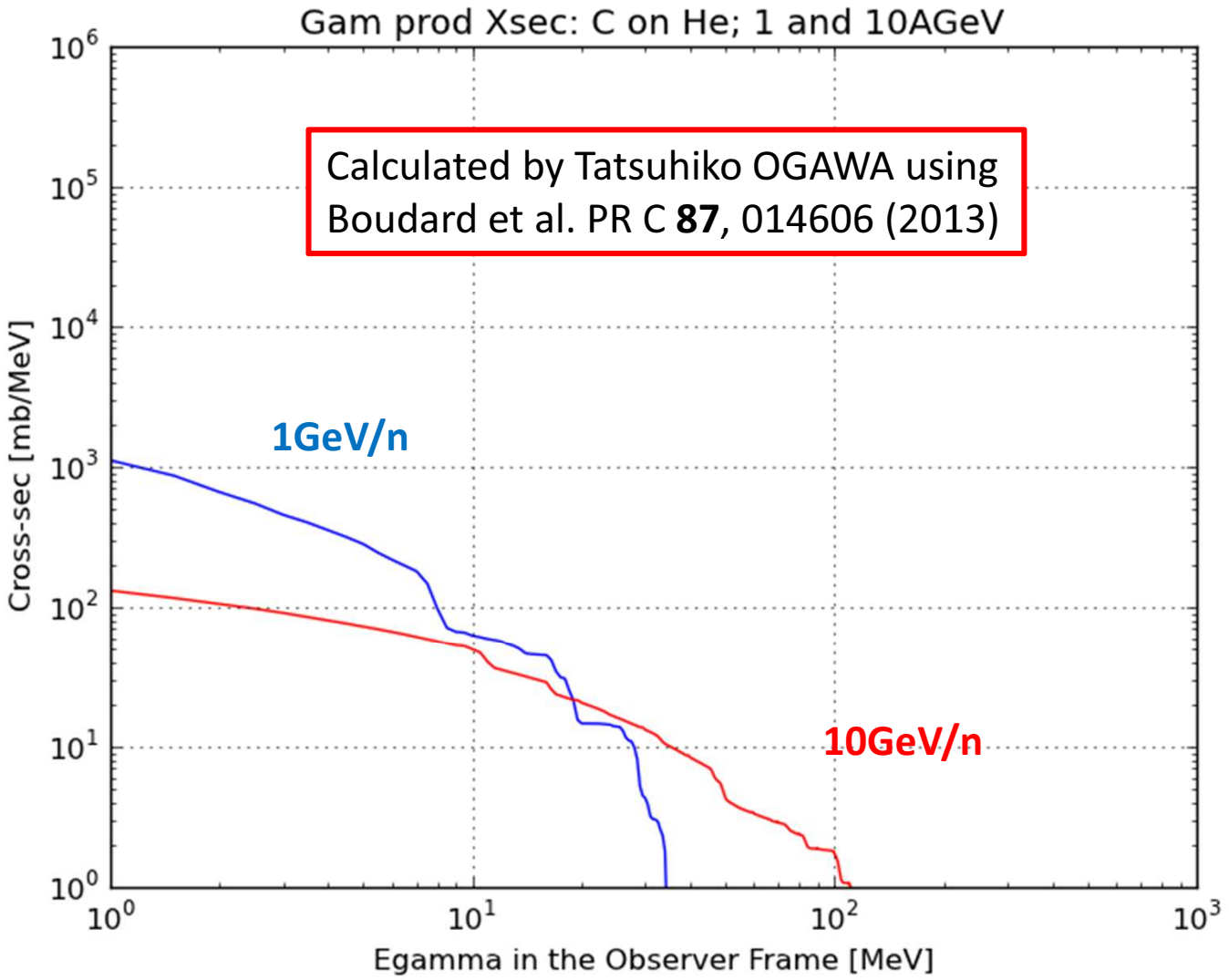


Nuclear enhancement factor: energy depenedent



Then realized: Spallation gammas!

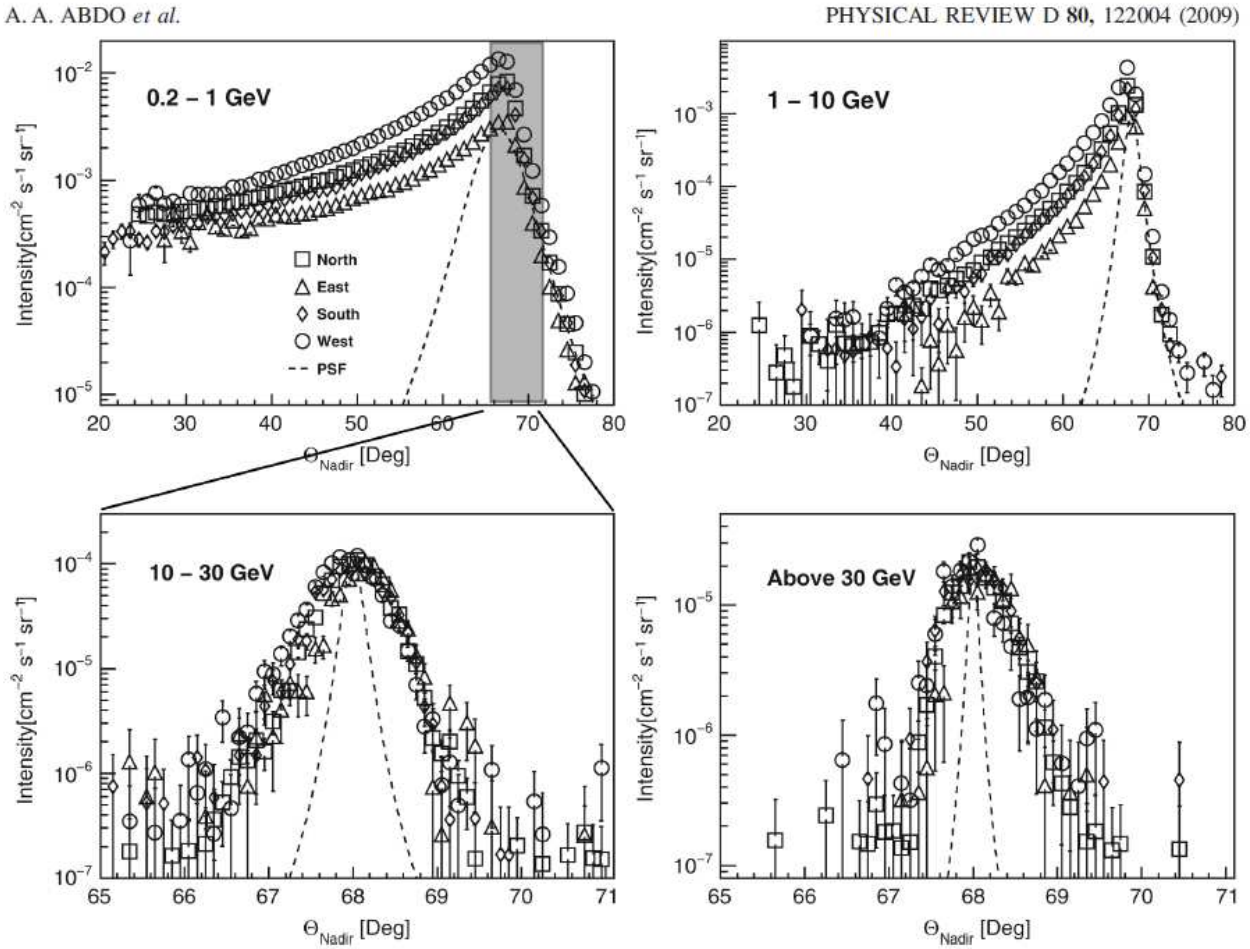
Spallation gammas are non-negligible



But how am I going to test the results?

Attempt 1: Earth-limb gamma rays by Fermi LAT

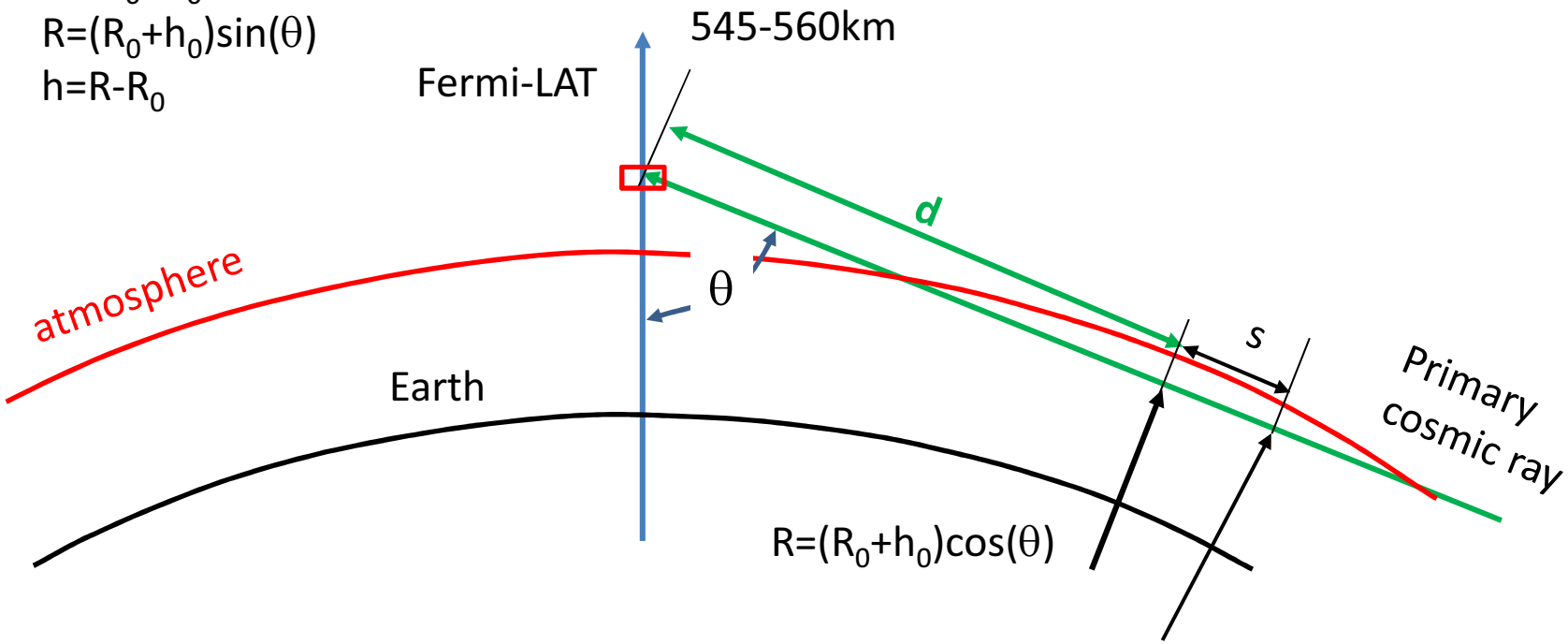
Abdo et al. PR D 80, 122004 (2009)
"Fermi large area telescope observations of the cosmic-ray induced gamma-ray emission of the Earth's atmosphere"
Ackermann et al. PRL 112, 151103 (2014)
"Inferred Cosmic-Ray Spectrum from Fermi Large Area Telescope *γ*-Ray Observations of Earth's Limb"



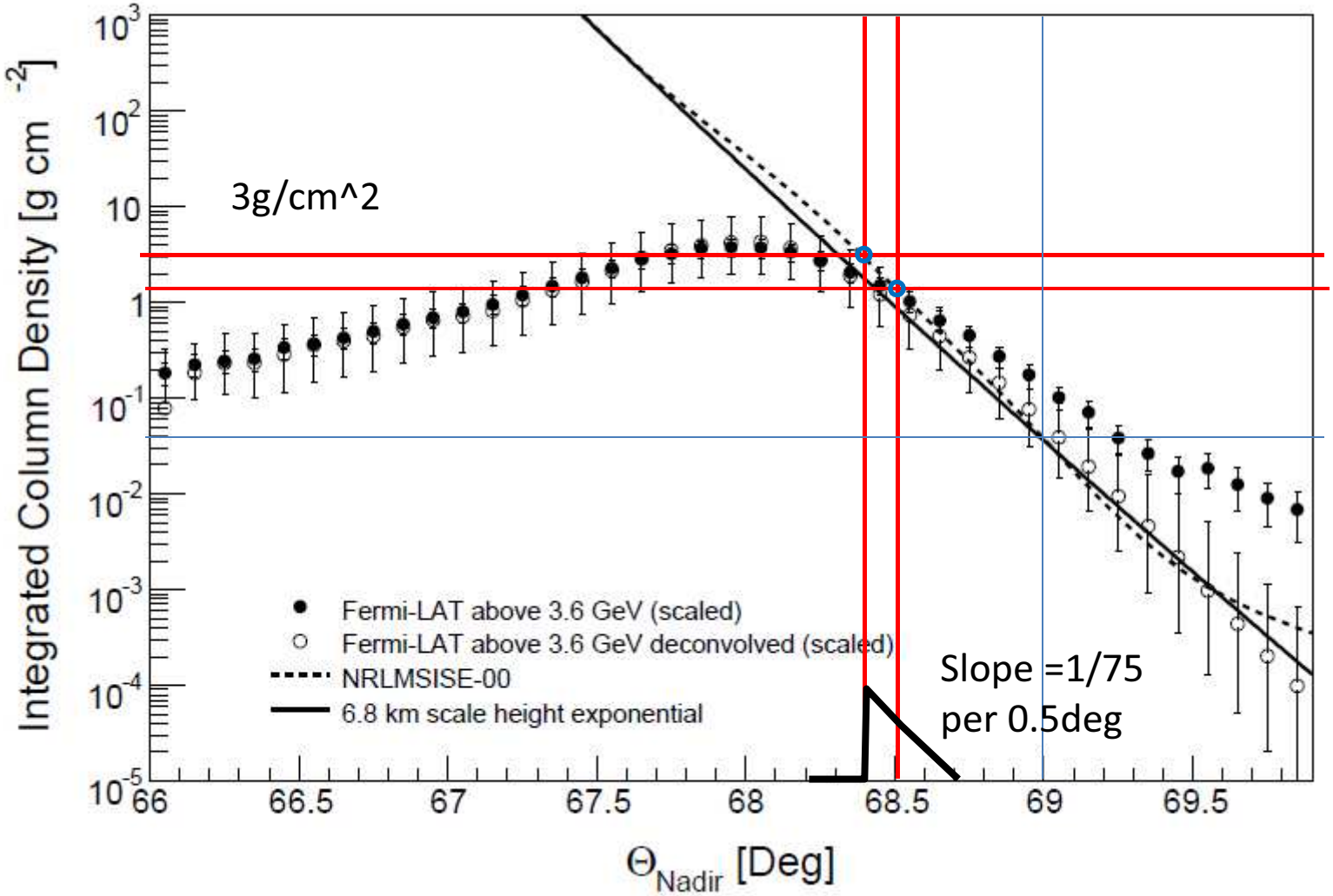
Earth-limb gamma rays

Atm density model: NRLMSISE2000

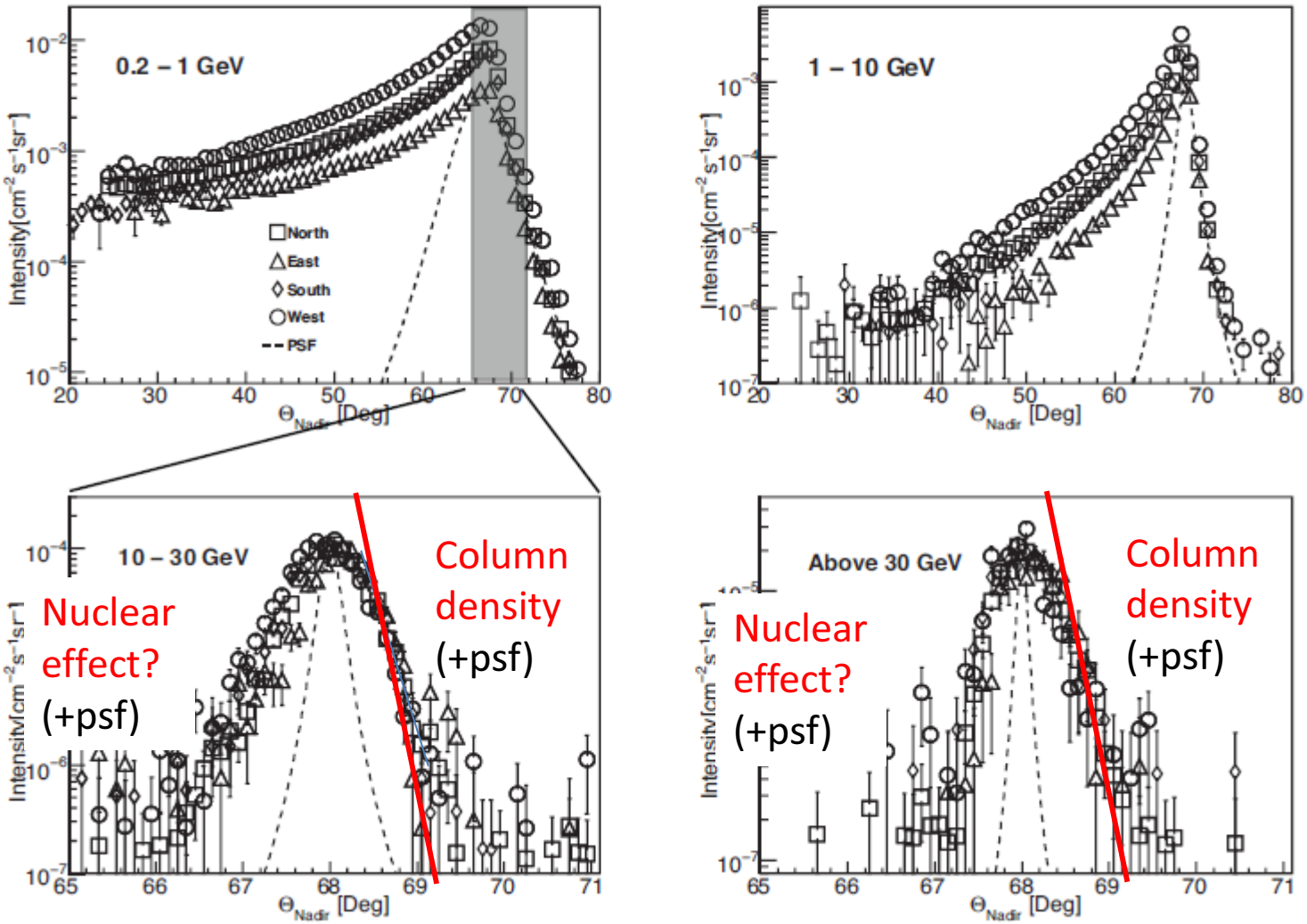
R_0=6371km
h_0=565km
$d=(R_0+h_0)\cos(\theta)$
$R=(R_0+h_0)\sin(\theta)$
$h=R-R_0$



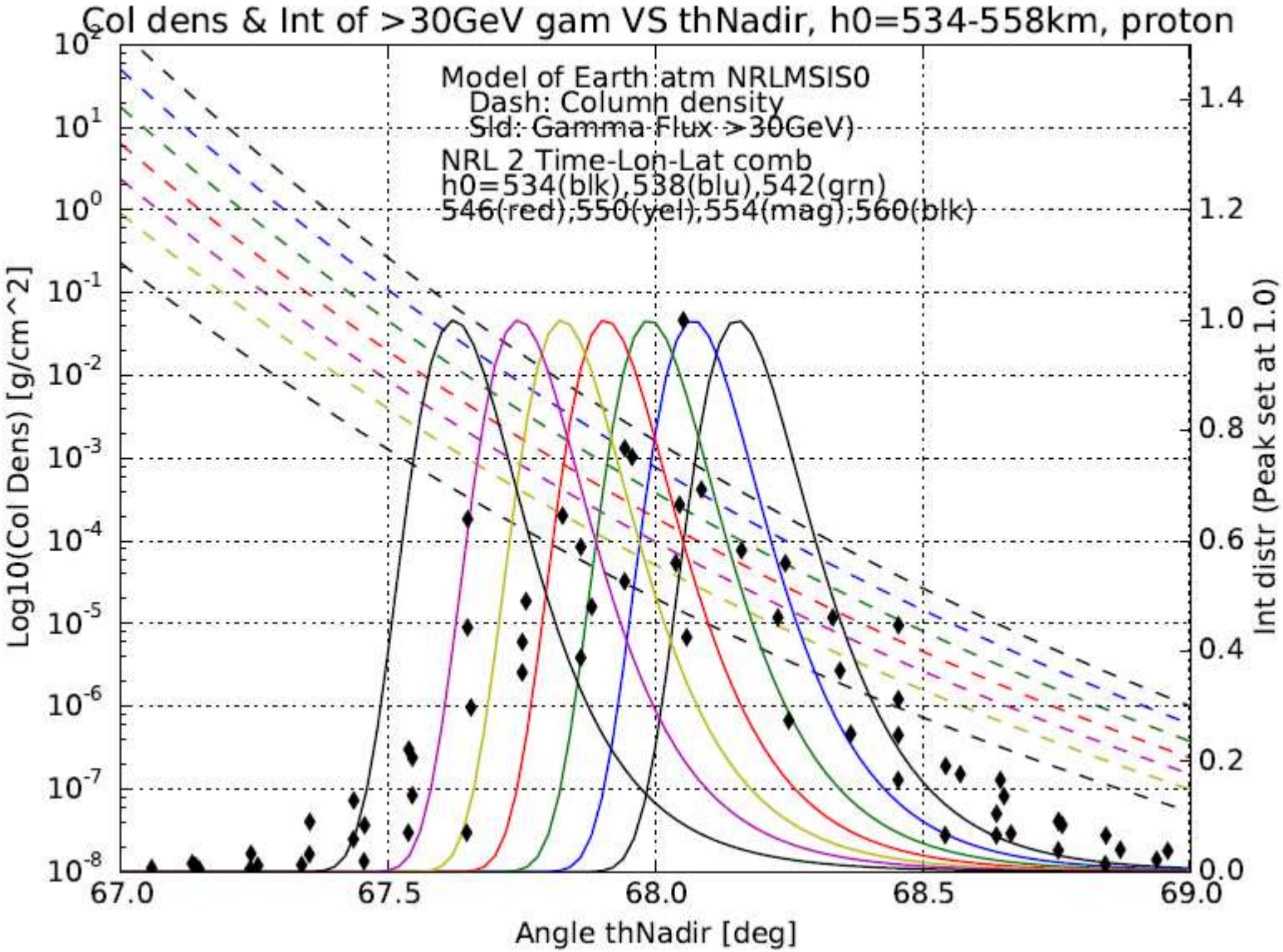
Fermi Earth Limb



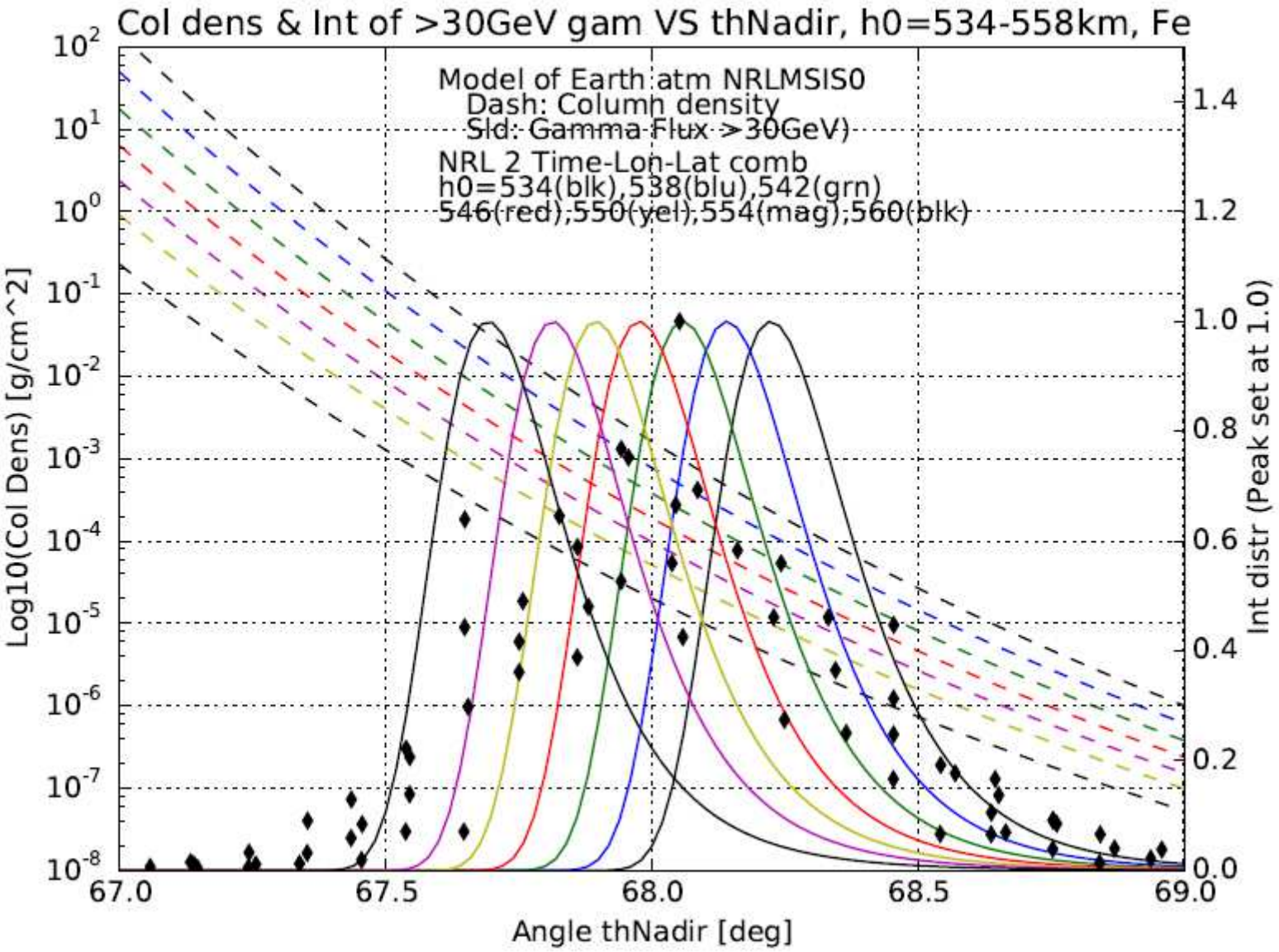
Are we seeing spallation gammas?



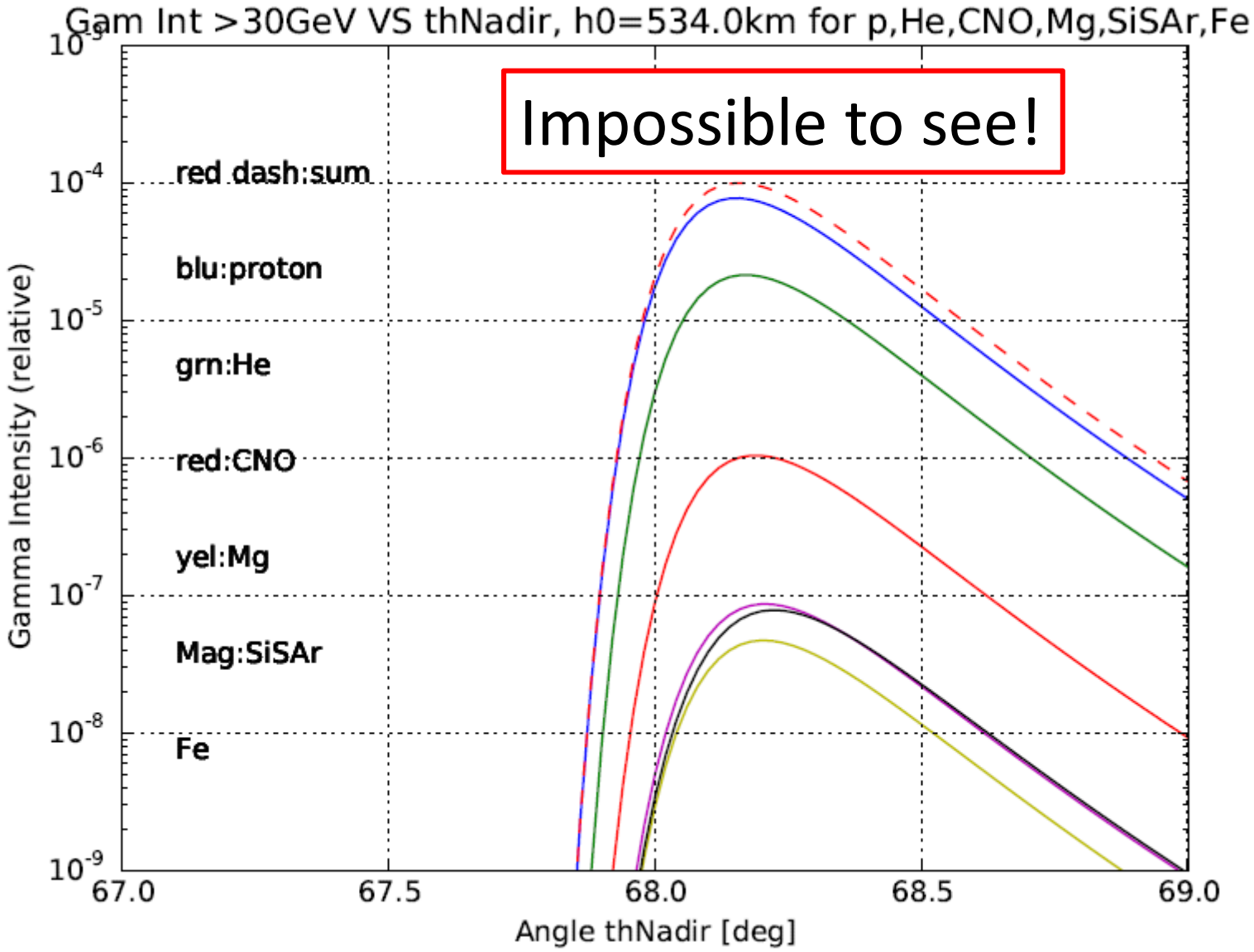
Simulation: Earth limb location for protons



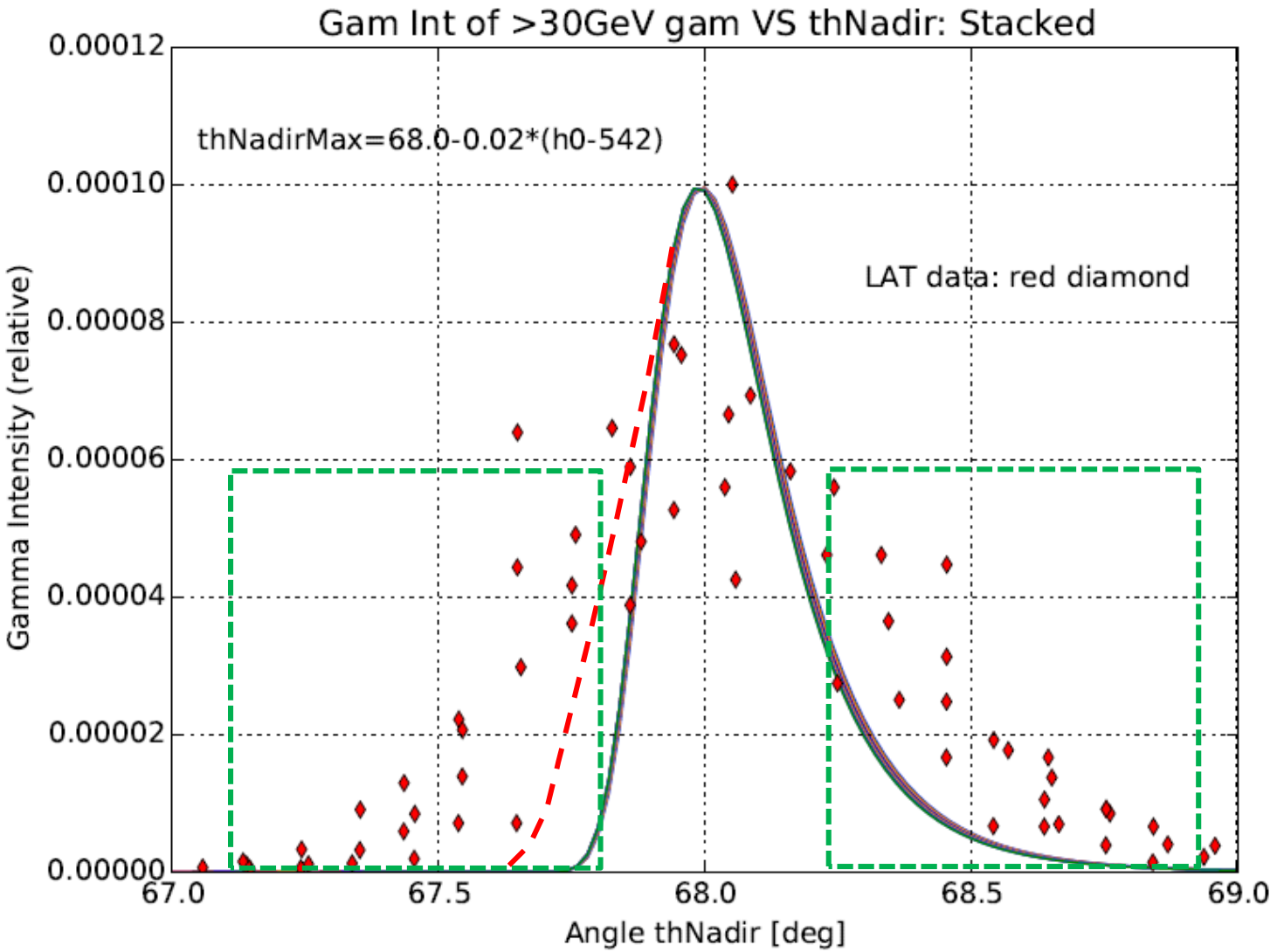
Simulation: Earth limb location for Fe



Earth limb location depends on Sig(inel)

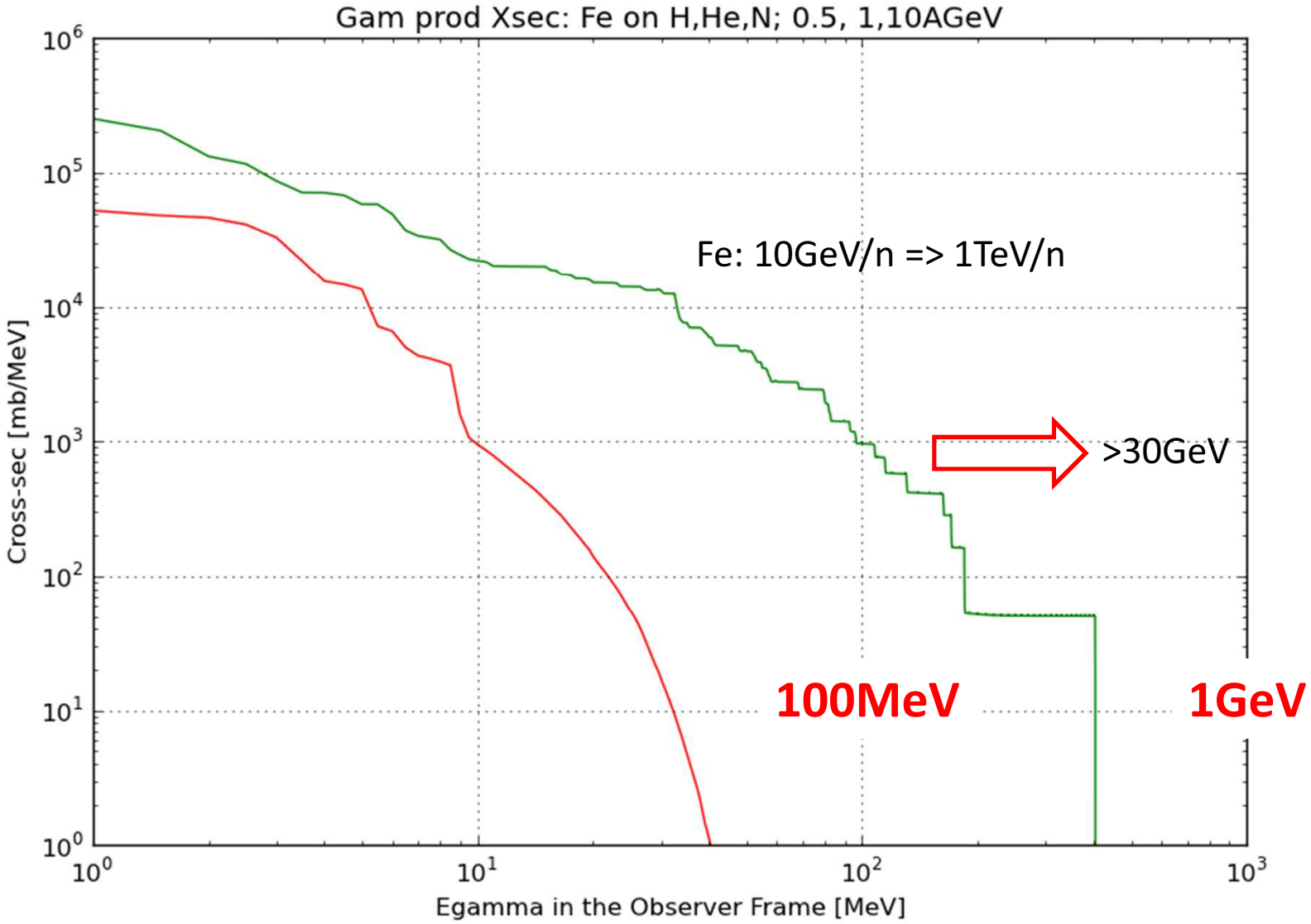


But spallation gammas seem to be there



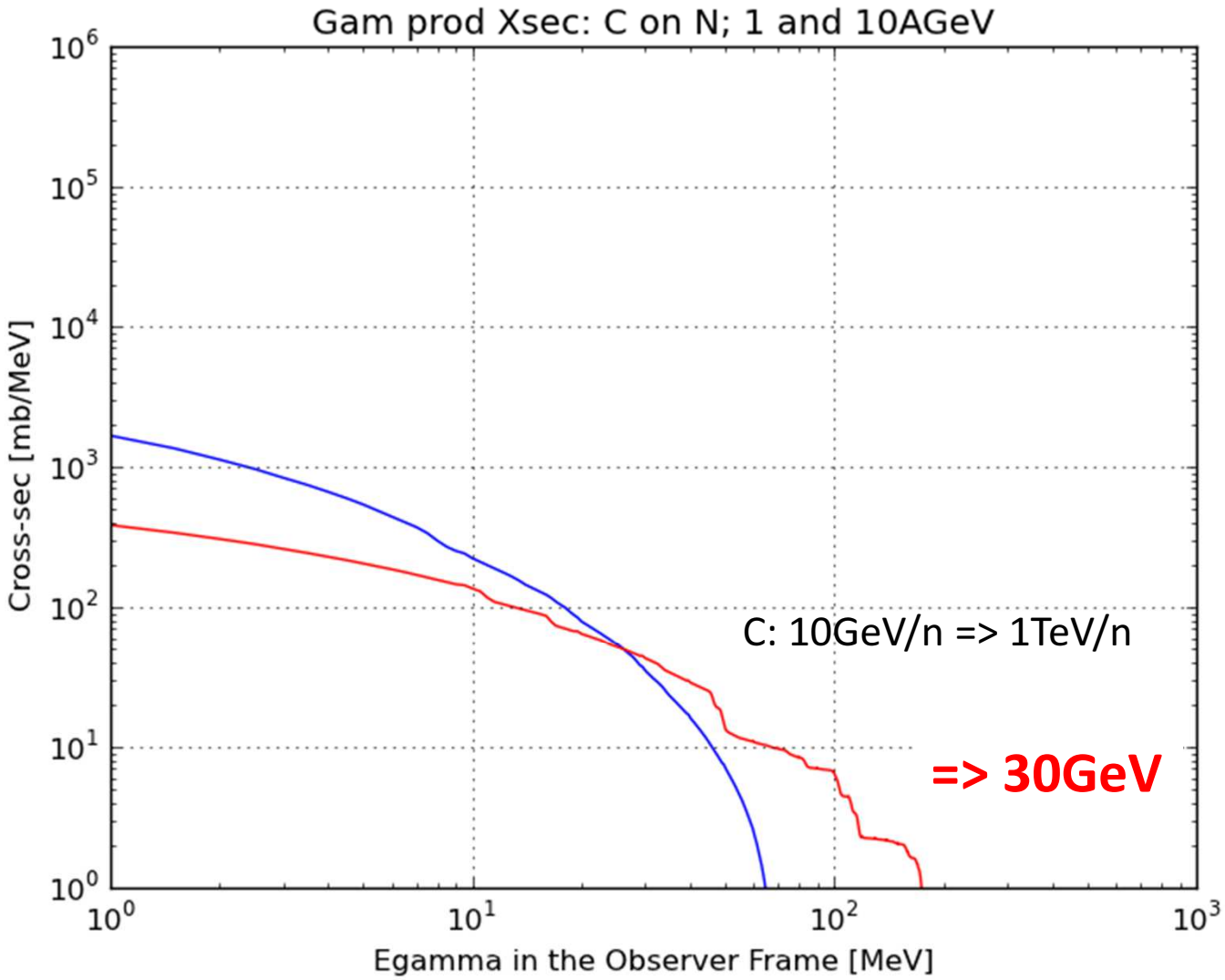
Fe on N: 1GeV/n(red), 10GeV/n(green)

Calculation by T. Ogawa (JAEA)

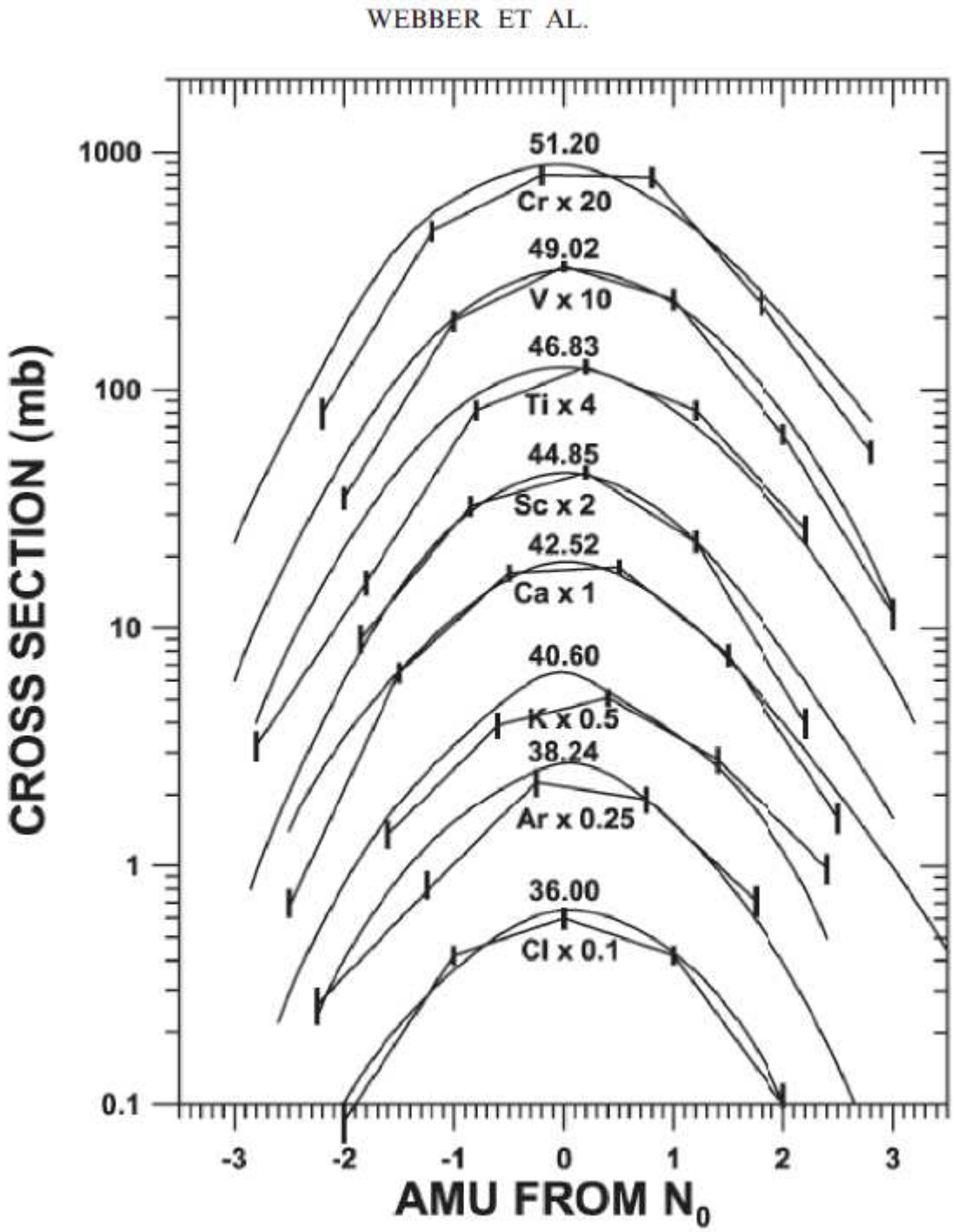


C on N: 1GeV/n(red), 10GeV/n(green)

Calculation by T. Ogawa (JAEA)



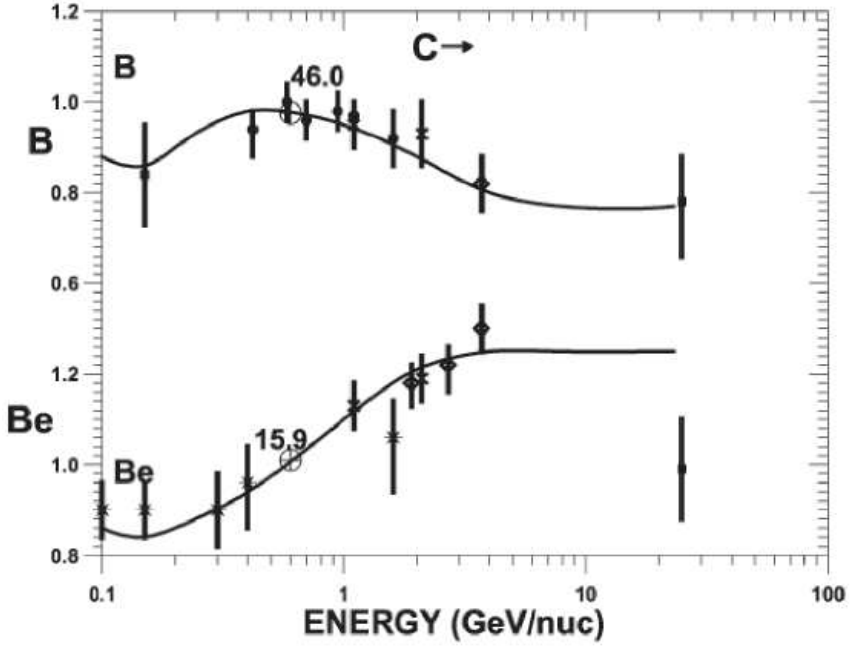
Fragmentation model for Hydrogen target of Webber (2003) - No.1-

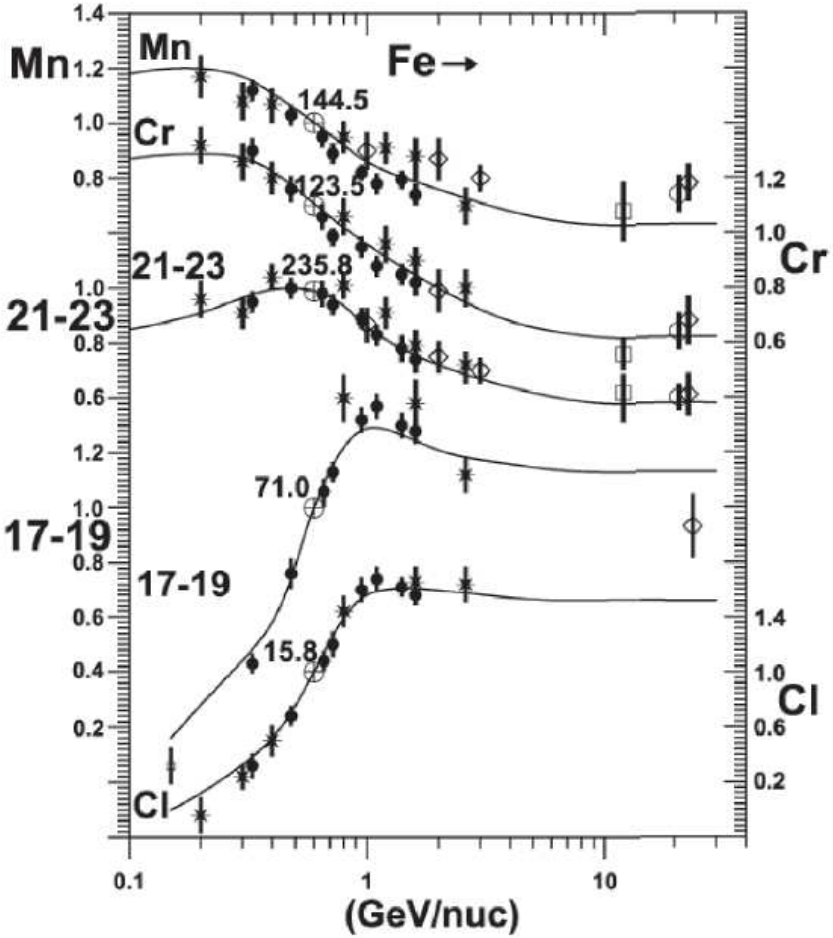


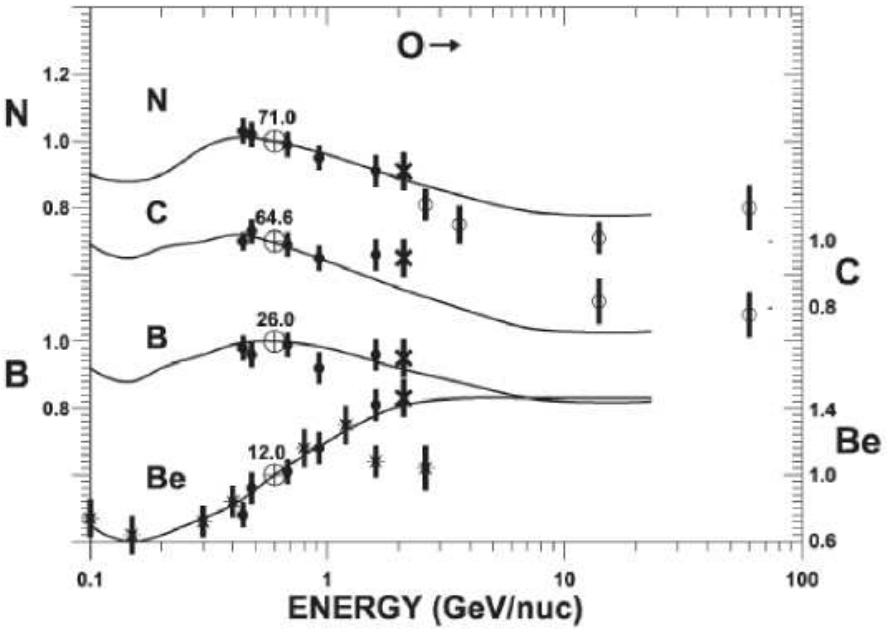
CR composition meas. in air showers

Spallation at the top of atmosphere dictates the energy deposition pattern on the surface

Fragmentation model for Hydrogen target of Webber (2003) - No.2-

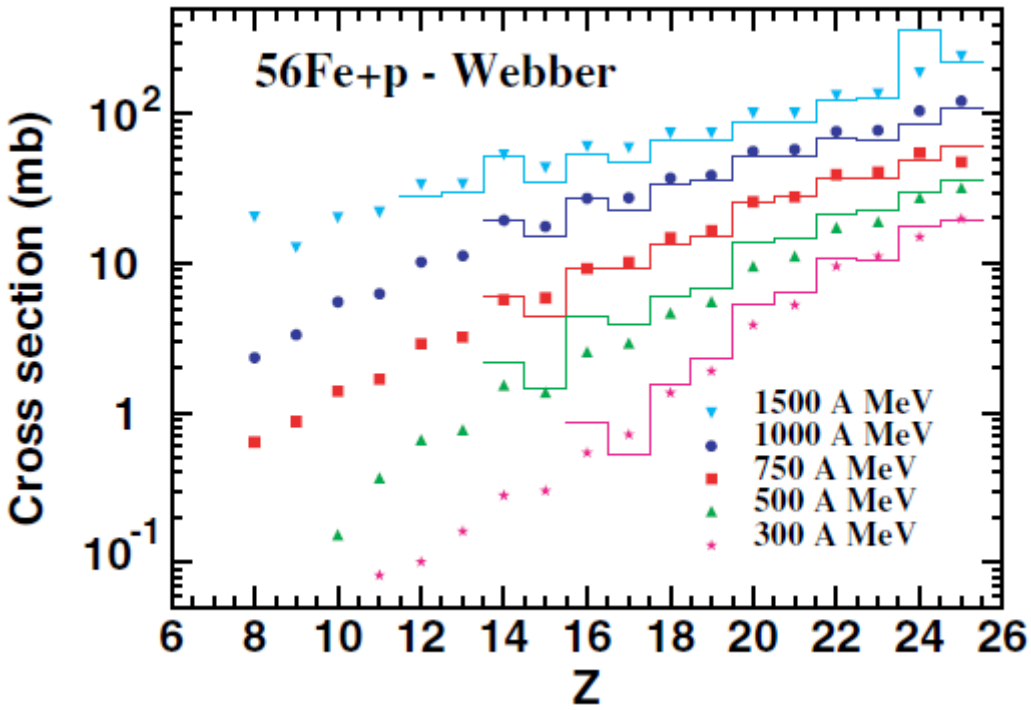






Very extensive experimental study

C. Villagrasa-Canton et al, PRC 75, 044603 (2007)



I could not find comparison with Webber et al (2003)

Very extensive experimental study

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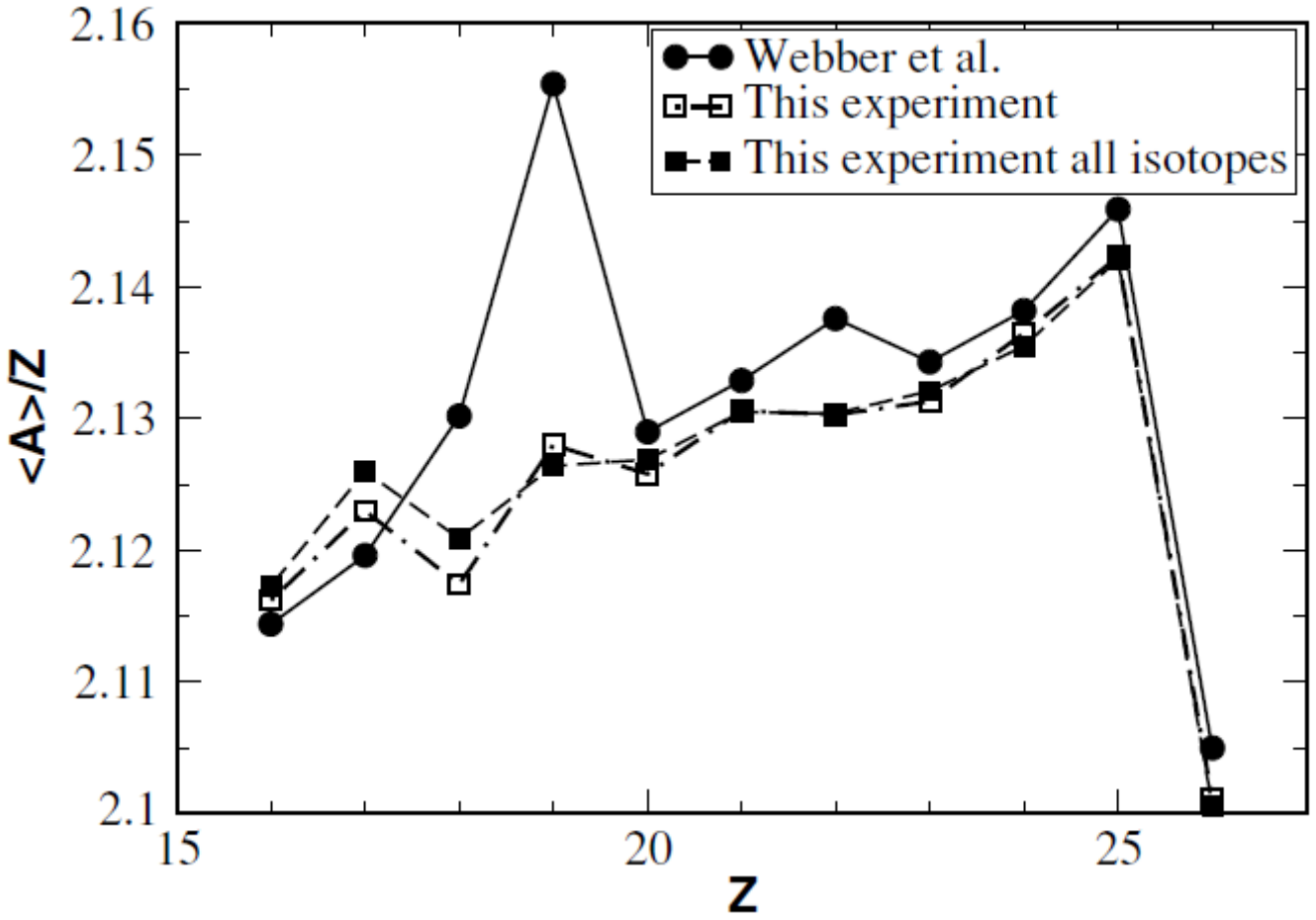

No comparison with Webber et al (2003)

Very extensive experimental study

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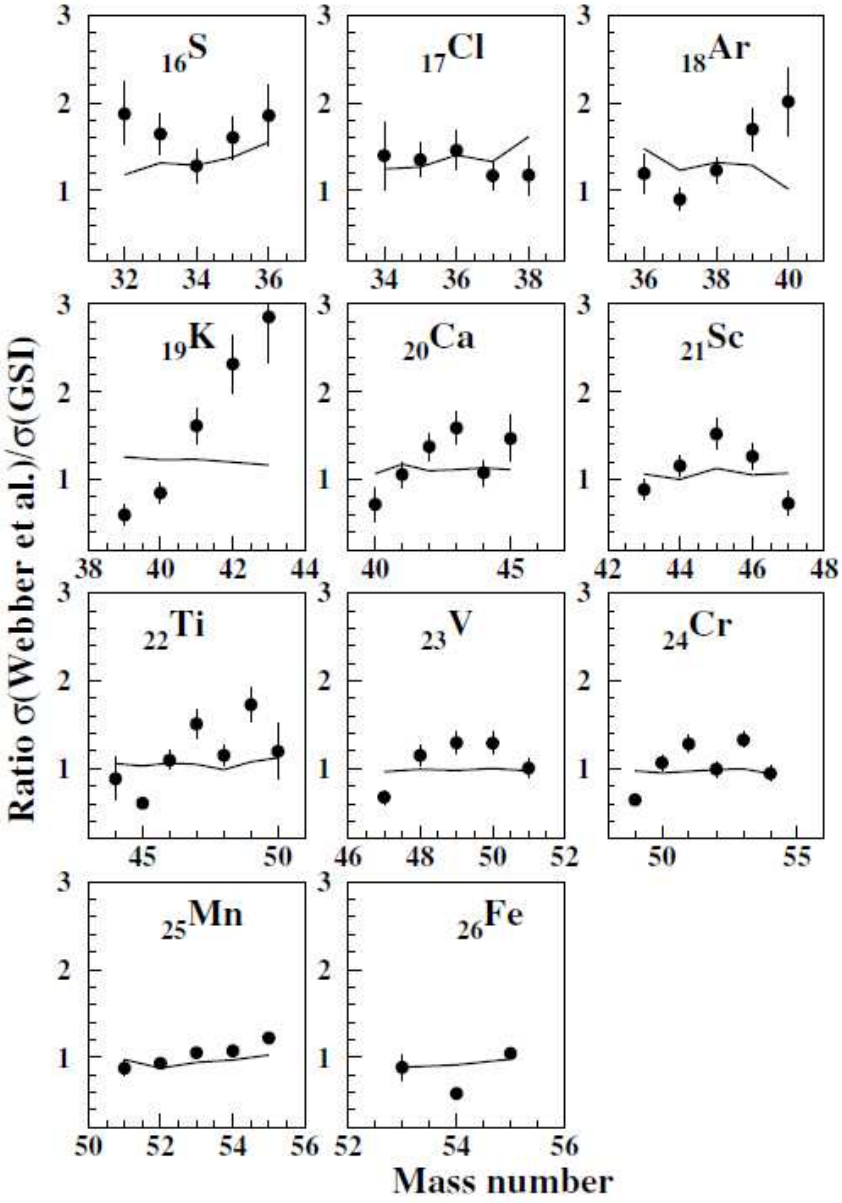
Questions to experts:

1) How do exps compare with Webber (2003)
2) New models?



Very extensive experimental study

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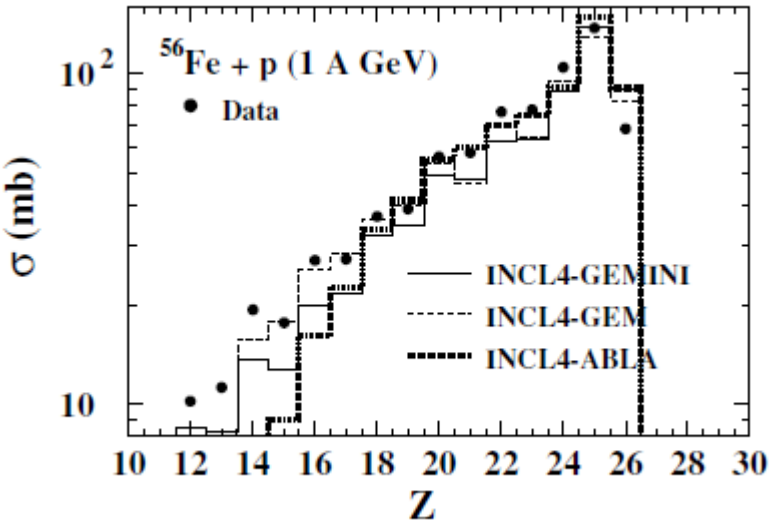
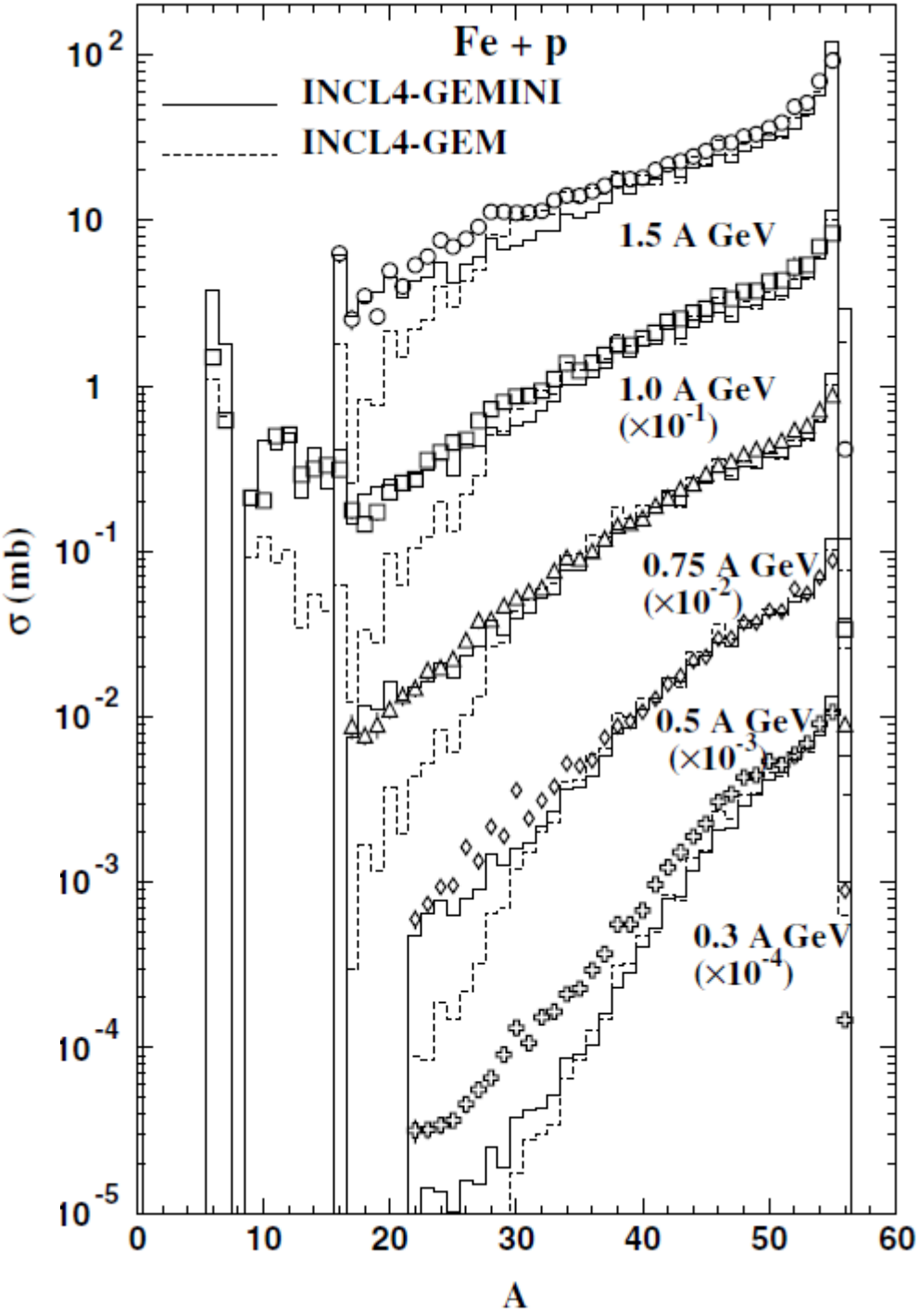
Questions to experts:

1) INCL4-GEMINI is the best choice ?





p_T of fragments: any suggestions

p_T distribution dictates the lateral development and fluctuation of air-shower development.

Can some exp in RHIC measure p_T of fragments?

New simple exp to test fragmentation models?

- Tot Xsec by Cecchini et al (2008) -

$$\sigma_{tot} = \pi r_0^2 \, (A_P^{1/3} + A_T^{1/3} - b_0)^2$$

Can they measure p_T of fragments?

$r_0 = 1.31$ fm, $b_0 = 1.0$, A_P and A_T are the projectile and target mass numbers,

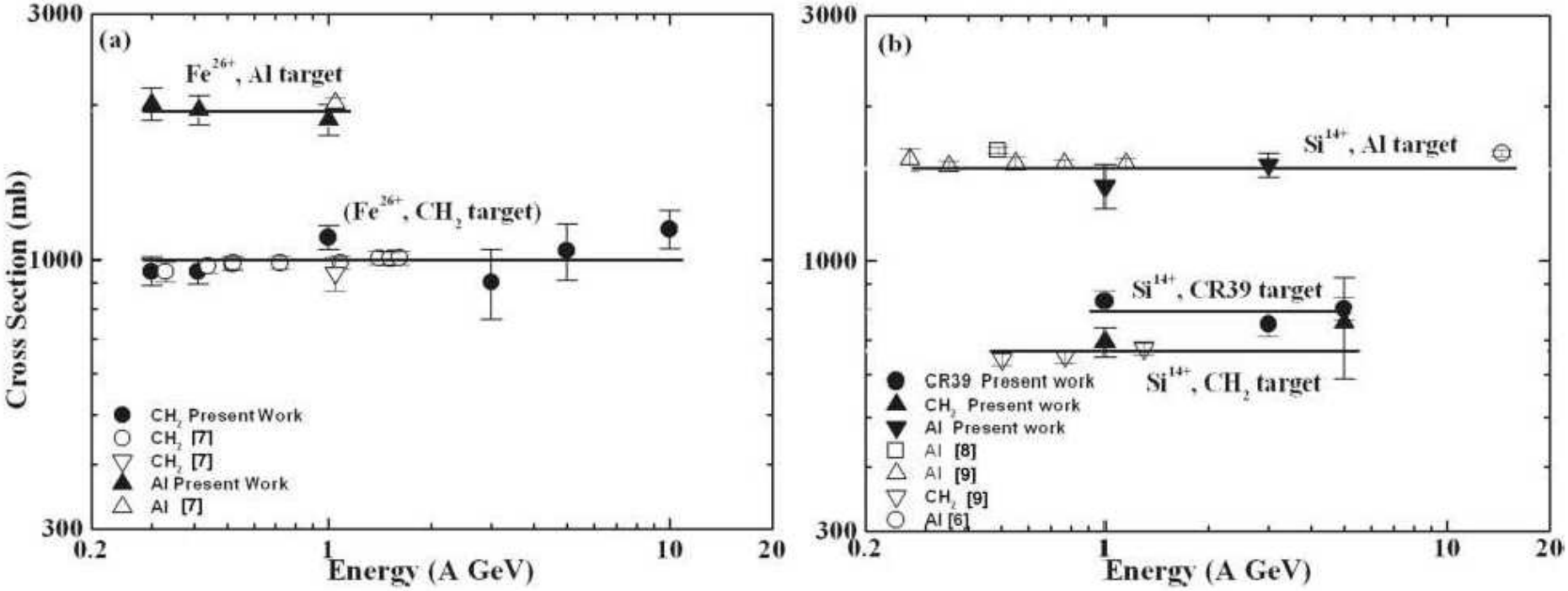


Figure 3: Total fragmentation cross sections for (a) Fe ions of different energies in CH_2 and Al targets and (b) for Si ions in CH_2, CR39 and Al targets. For comparison the measured cross sections from refs. [6, 7, 8, 9] are also shown, together with the predictions from Eq. 2.

We need experiments on
Fe+N/O, C+N/O, O+N/O, Ne+N/O

I found a nice solid target with approx. right mix of N and O

N_2O: Nitrous oxide, known as laughing gas, is **used as a dissociative anaesthetic**.
A colorless, odorless non-flammable gas at room temperature.
Safety code: ICSC 0067 (Avoid direct contact, **Skin:**Frostbite, **Eyes:**Frostbite)
Melting point = −102C Probably stay solid if put on a cold plate submerged in liq N_2
Density of solid N_2O = about 1.0?

Thank you for invitation to this

Nice Conference

and

your attention