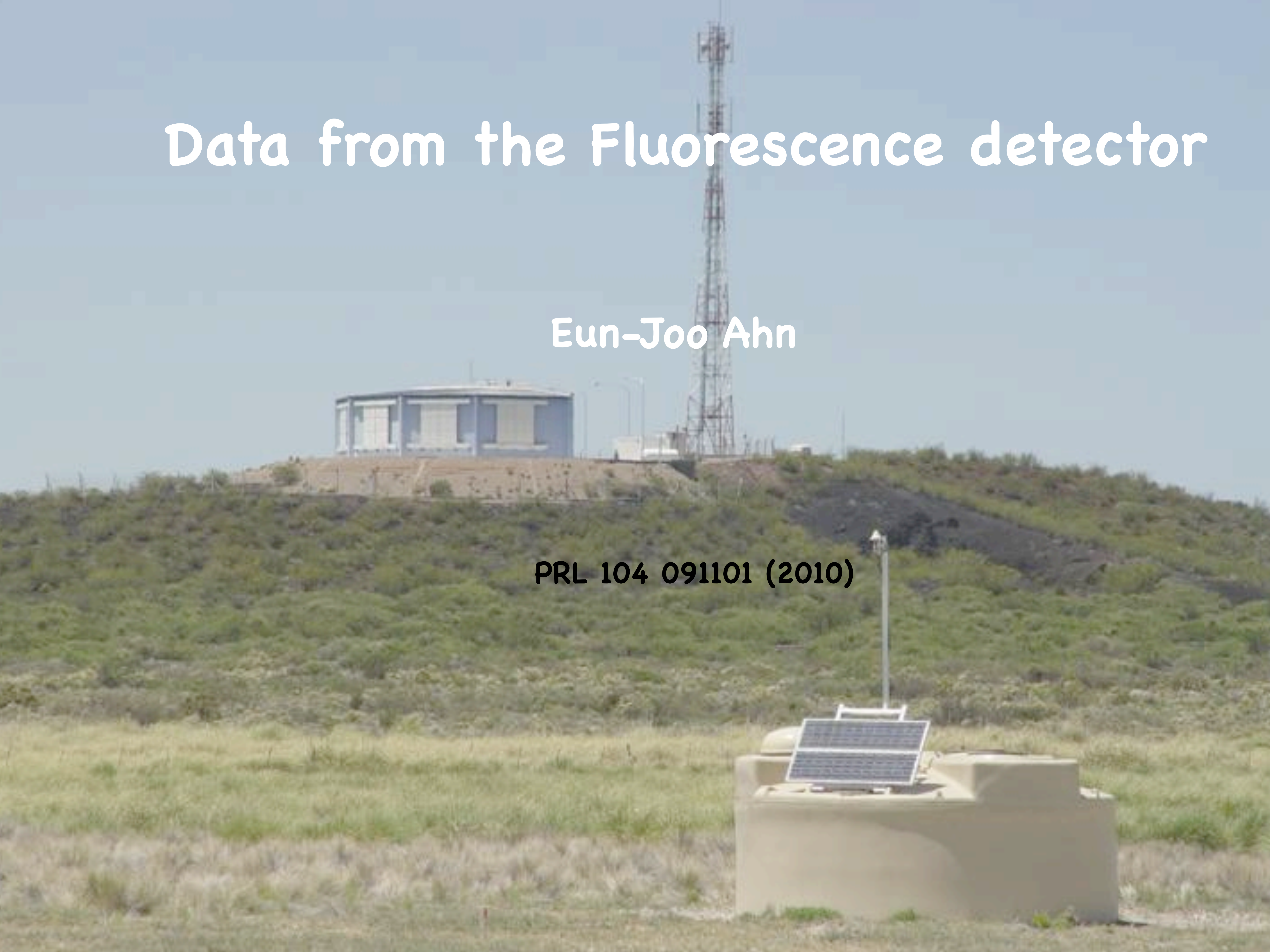
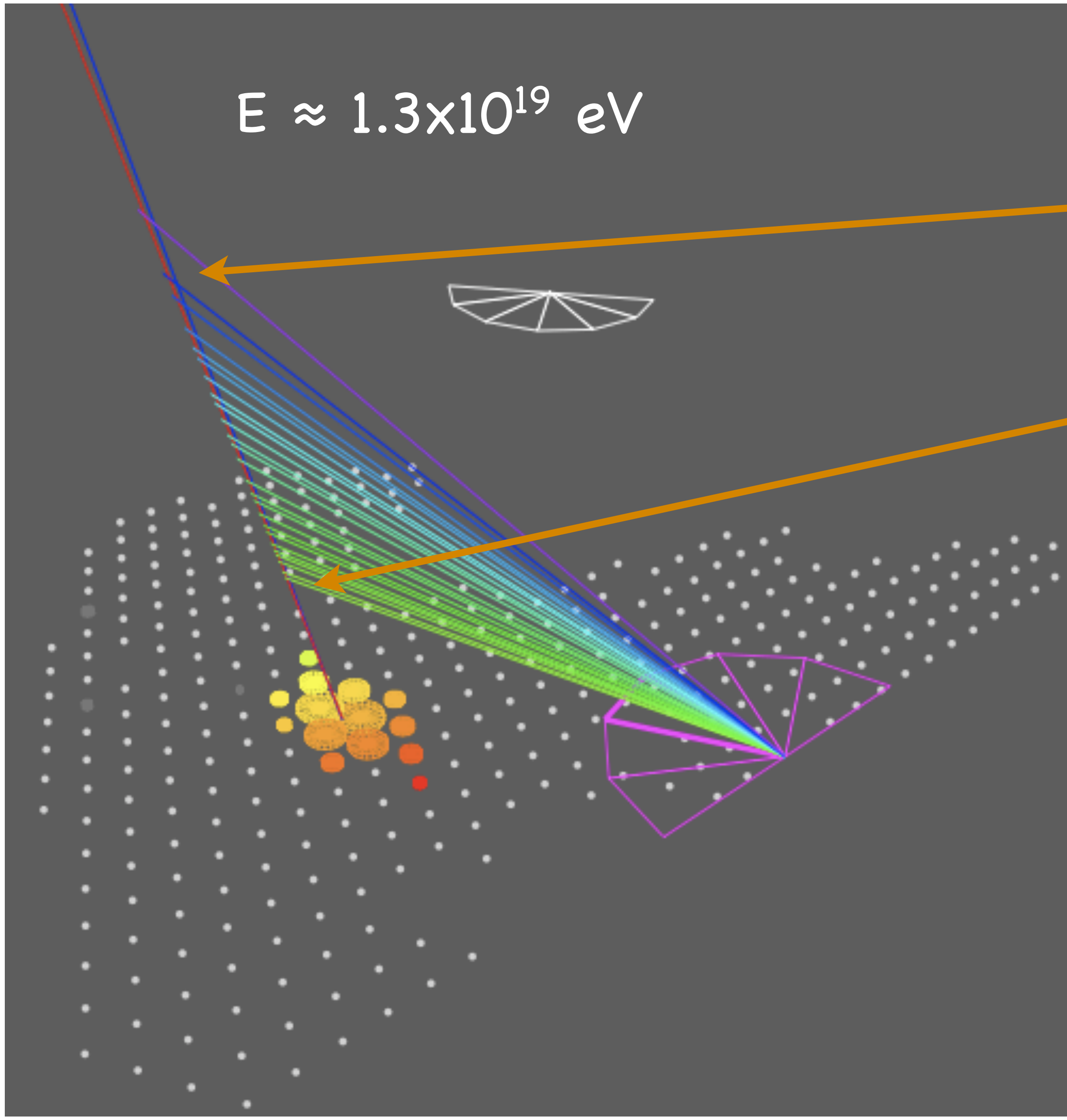


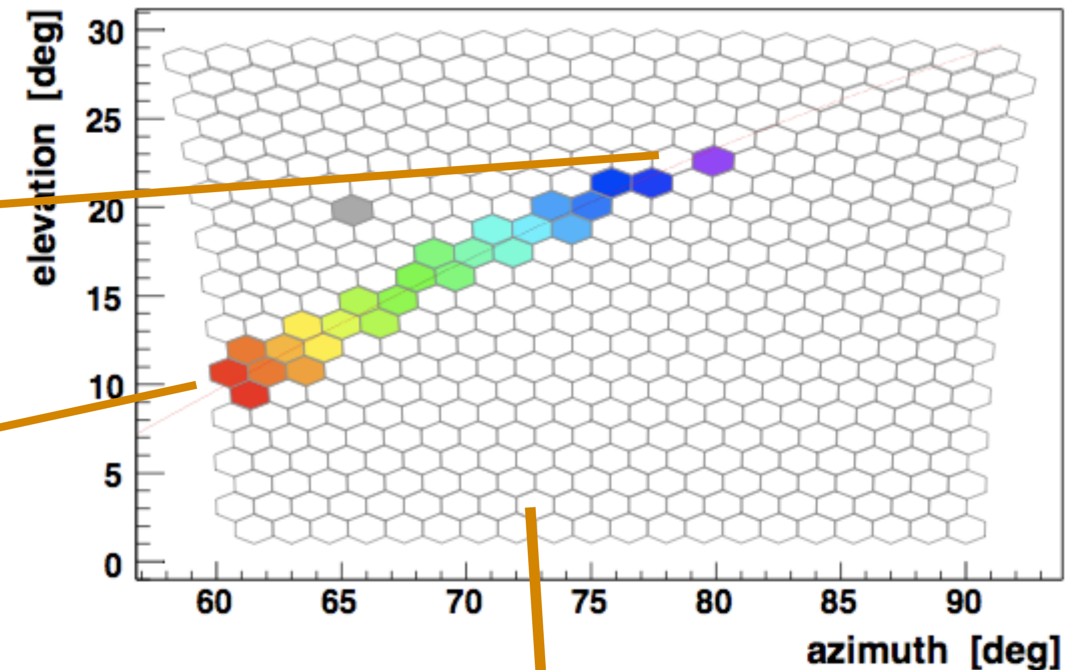
Data from the Fluorescence detector

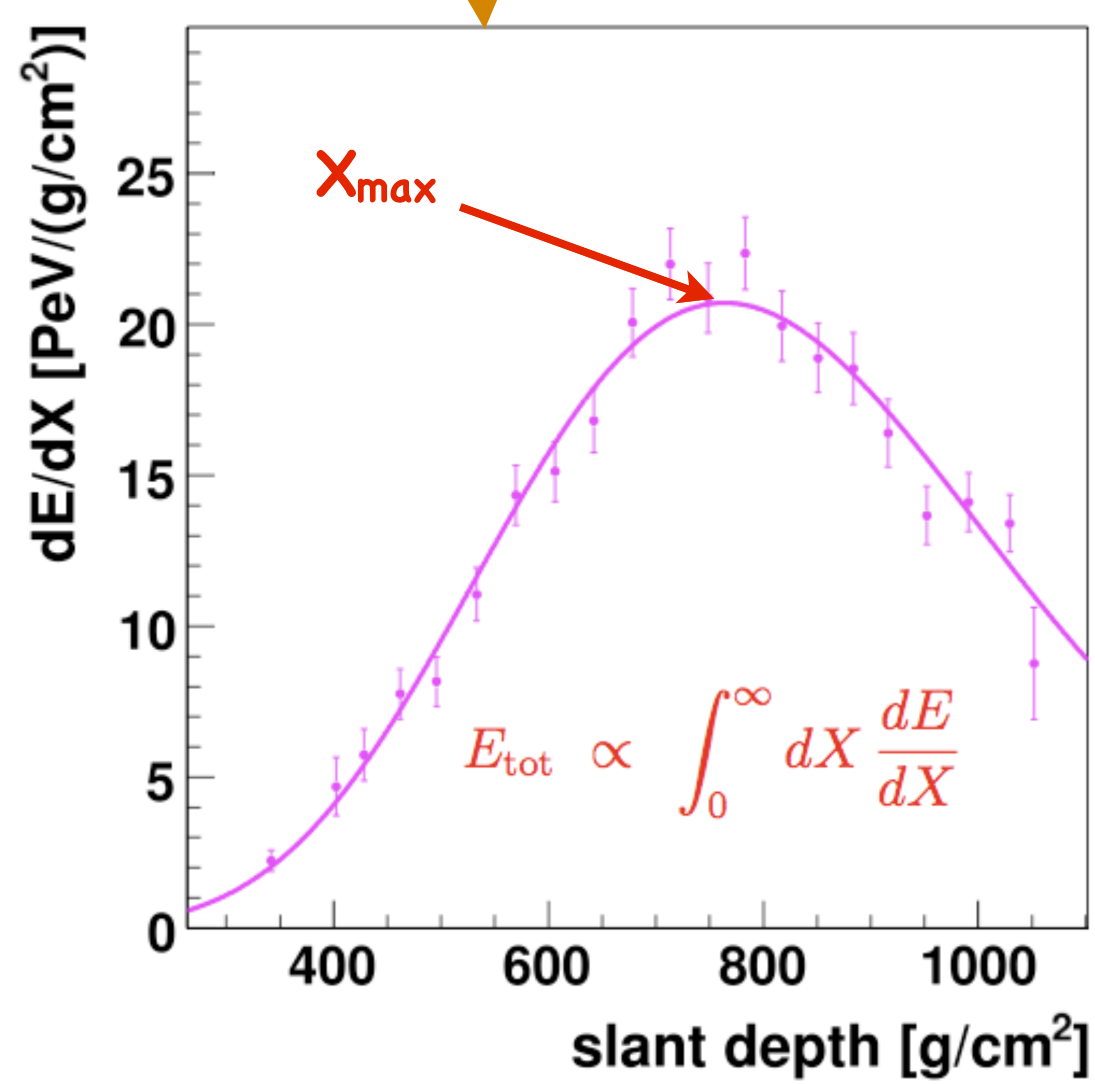
Eun-Joo Ahn

PRL 104 091101 (2010)

Data from the fluorescence detector







- Energy : integrate shower profile
- X_{max} : maximal point in shower profile

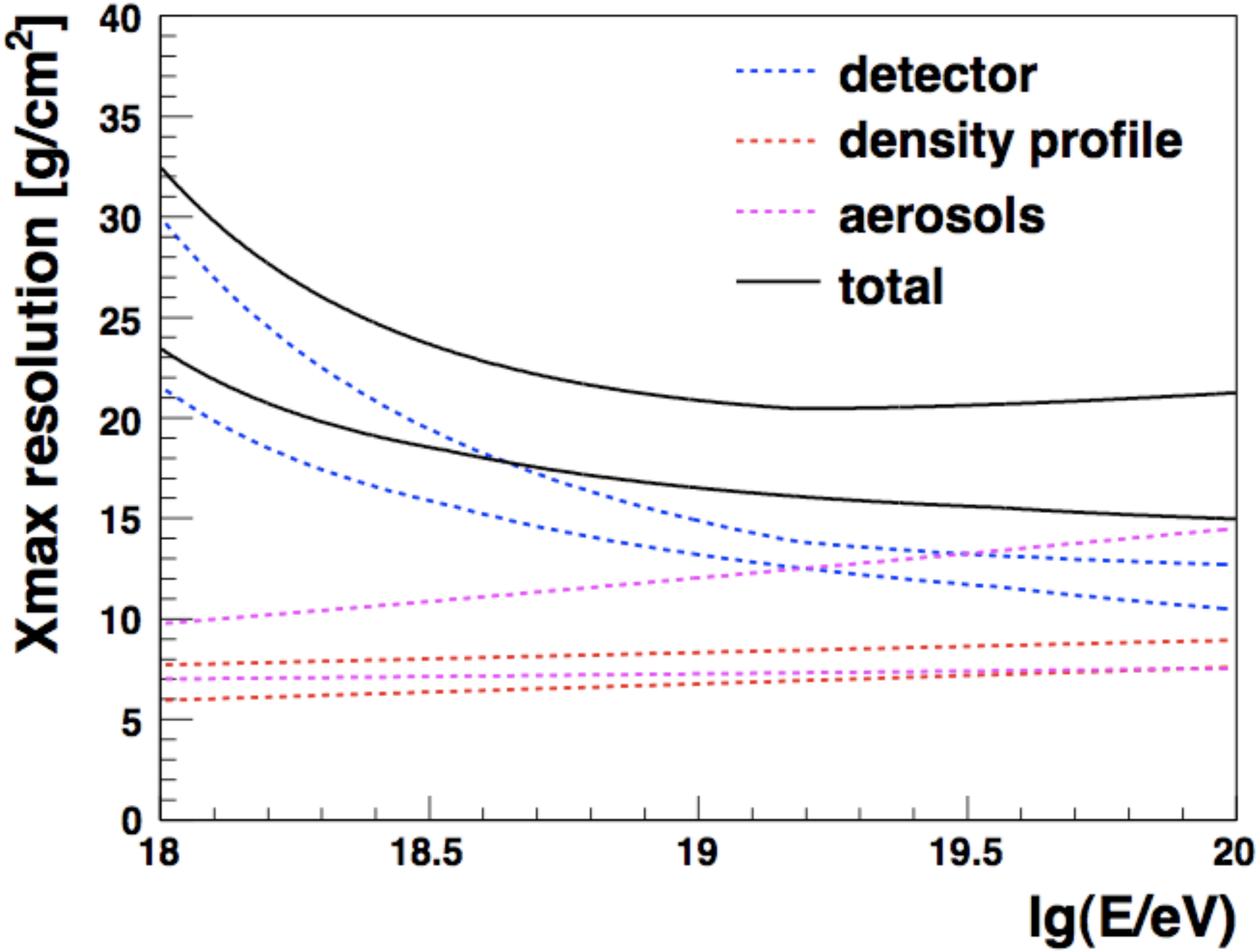
(slant depth: air mass along cosmic ray trajectory)

Data selection

- Hybrid trigger: FD + 1 SD station
- Atmosphere & calibration
  - good camera calibration
  - measured aerosol profile
  - good atmospheric condition
  - cloud fraction < 25%
- Fiducial volume cuts
  - distance to tank, zenith angle (energy dependent) <- minimise bias
  - field of view
- Quality cuts
  - X_{max} observed
  - low expected reconstruction uncertainty
  - reduced χ^2 of profile fit < 2.5

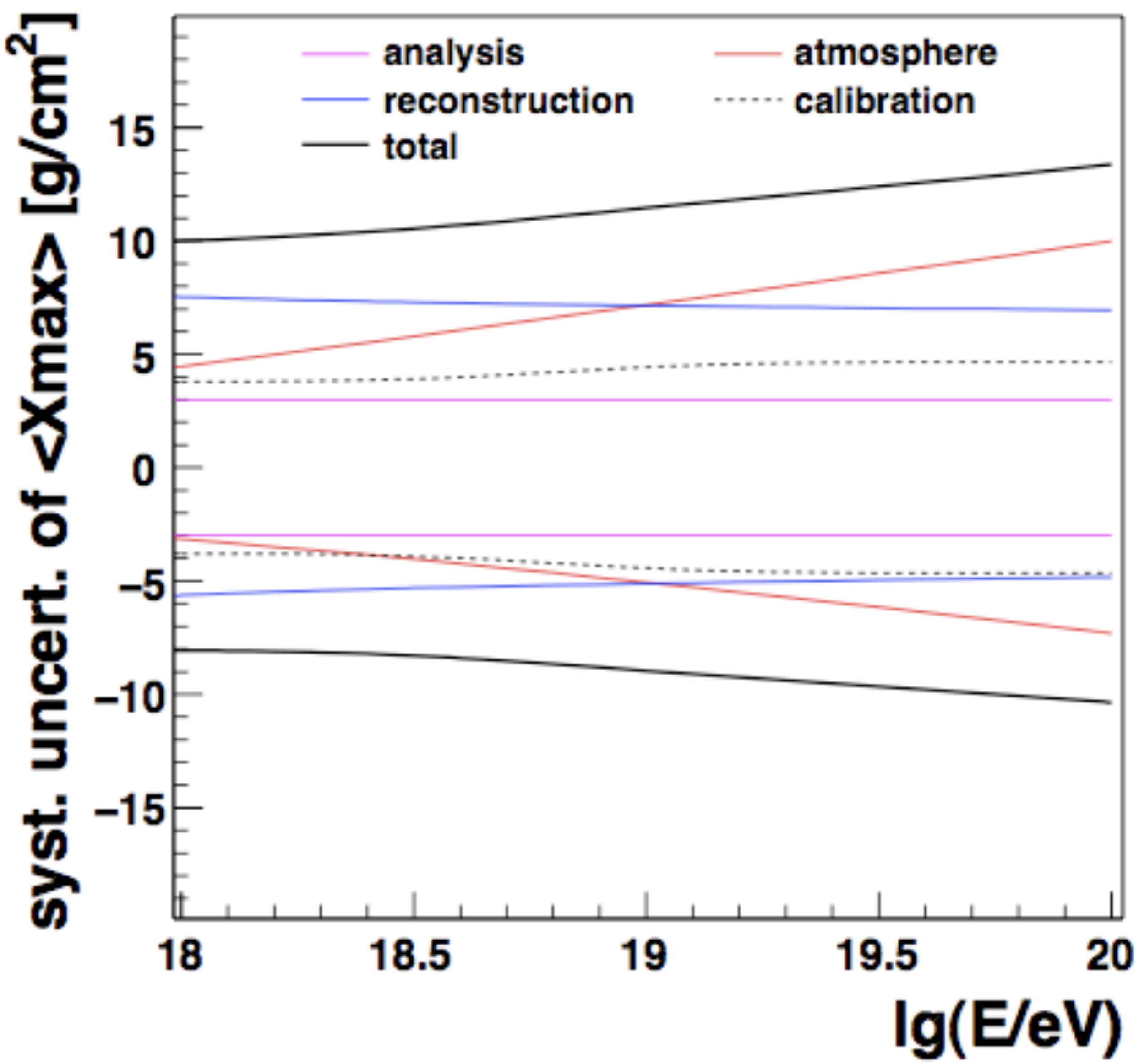
-> Excellent reconstruction, good resolution for accurate studies

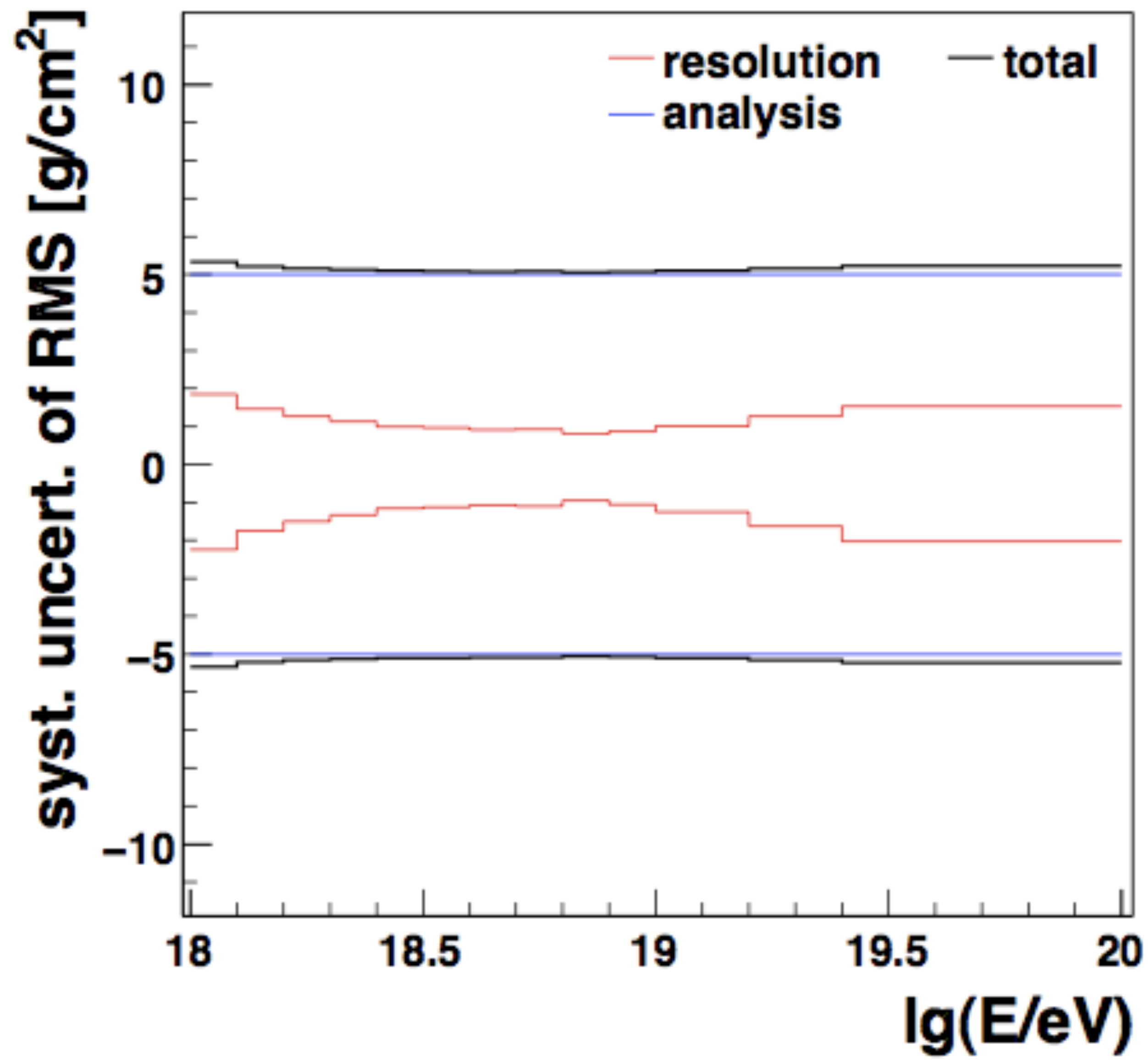
X_{max} resolution



- detector: check with MC
- density profile: seasonal variation of atmosphere & fluorescence yield
- aerosol: cleanliness of atmosphere

Systematic uncertainties



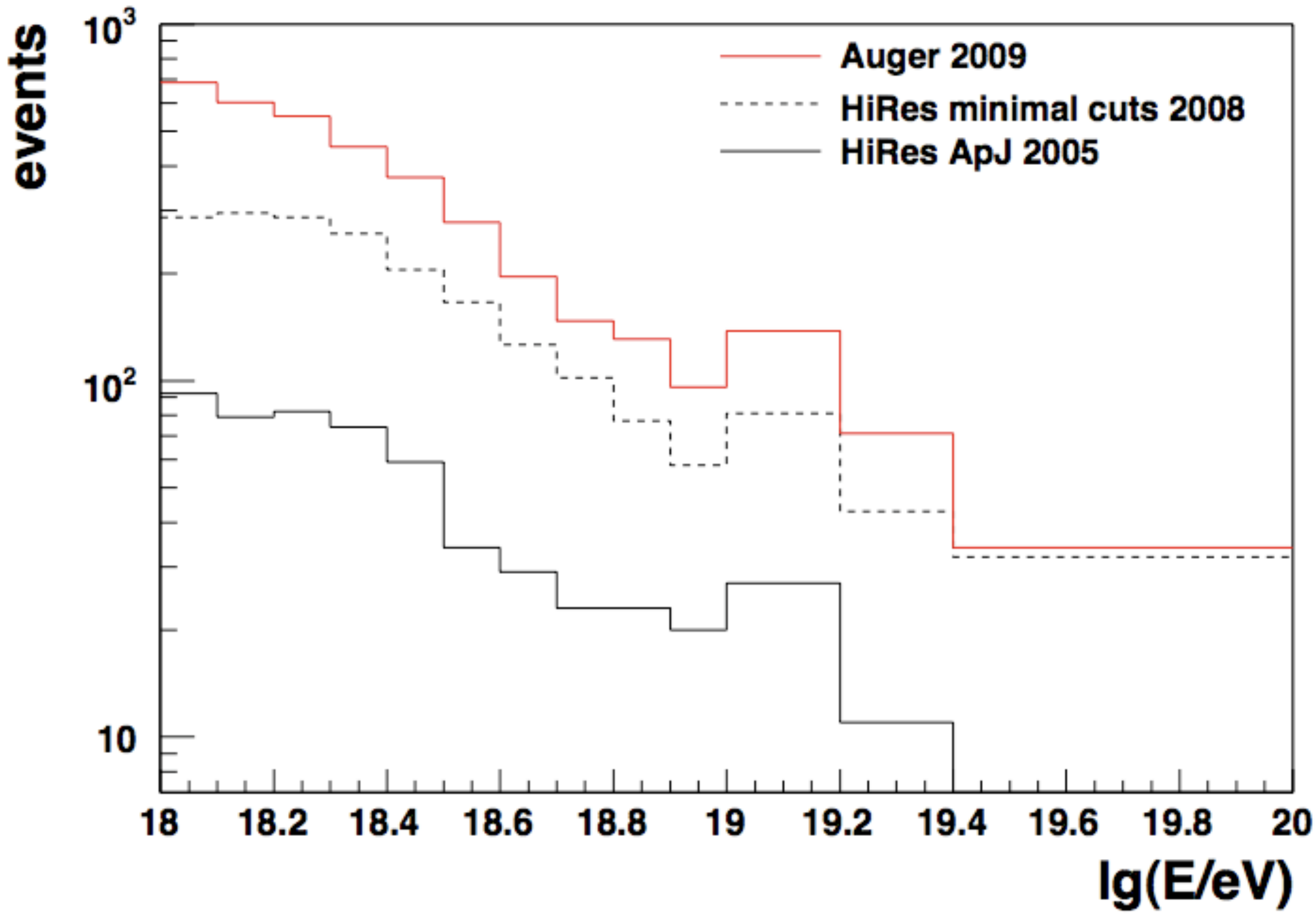


- mean: +10/-8 g/cm^2 (10^{18} eV) ~ +12/-10 g/cm^2 (10^{20} eV)

- RMS: +-5 g/cm^2

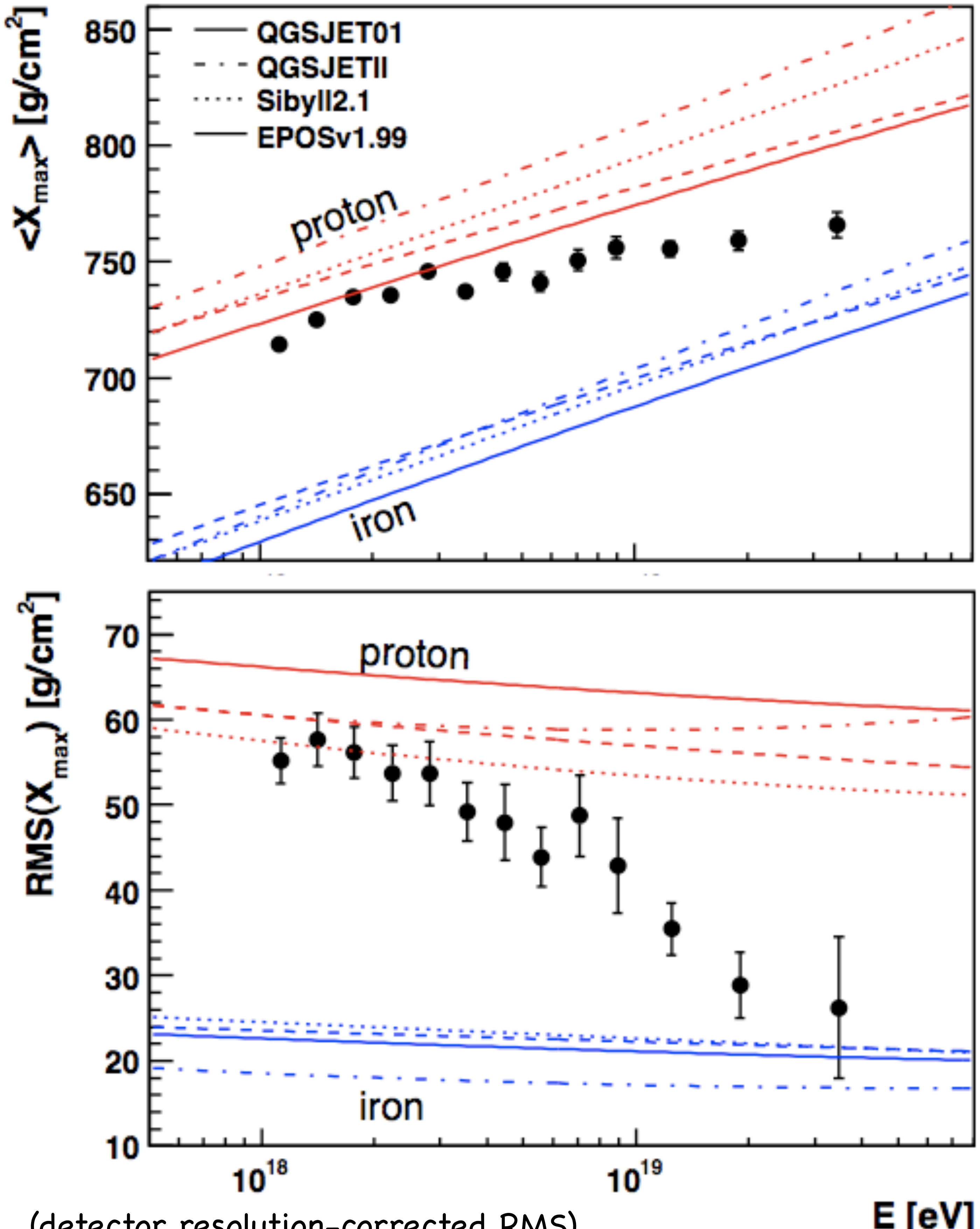
Data collected: 2004.01 - 2009.04

Number of events after selection:



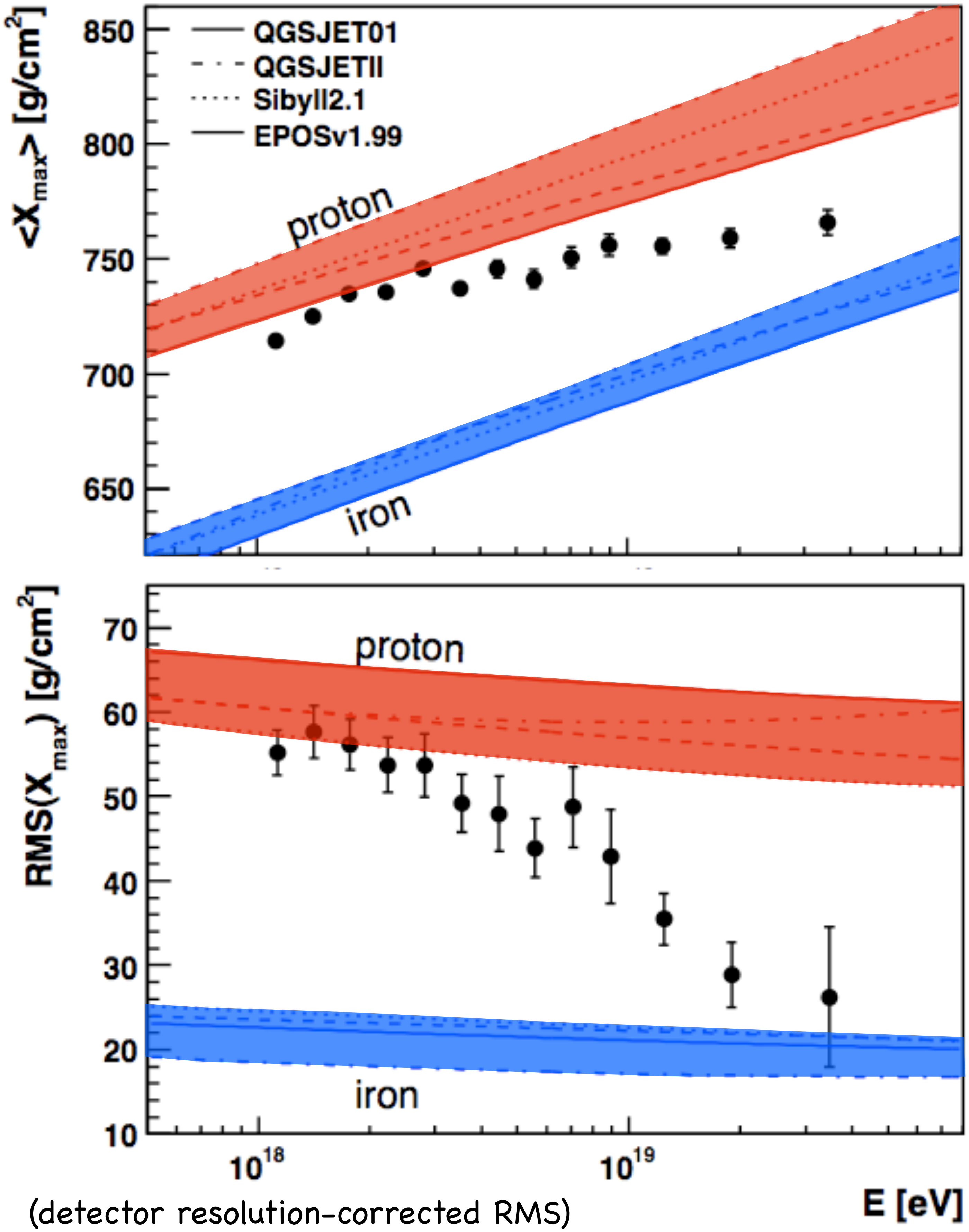
1.35×10^6 -> 3754

X_{max}'s behaviour: mean and fluctuation (RMS)



(detector resolution-corrected RMS)

X_{max}'s behaviour: mean and fluctuation (RMS)



(detector resolution-corrected RMS)

- Mean and RMS not entirely consistent for current models at the HIGHEST ENERGIES - fluctuations smaller than expected from mean.
- Models give different prediction
- Need more data
  (max E bin < 4×10^{19} eV)

Aim: composition & particle characteristics (cross sections) at Auger energies

‣ Models give different prediction

❖ Hadronic interaction model required for data interpretation

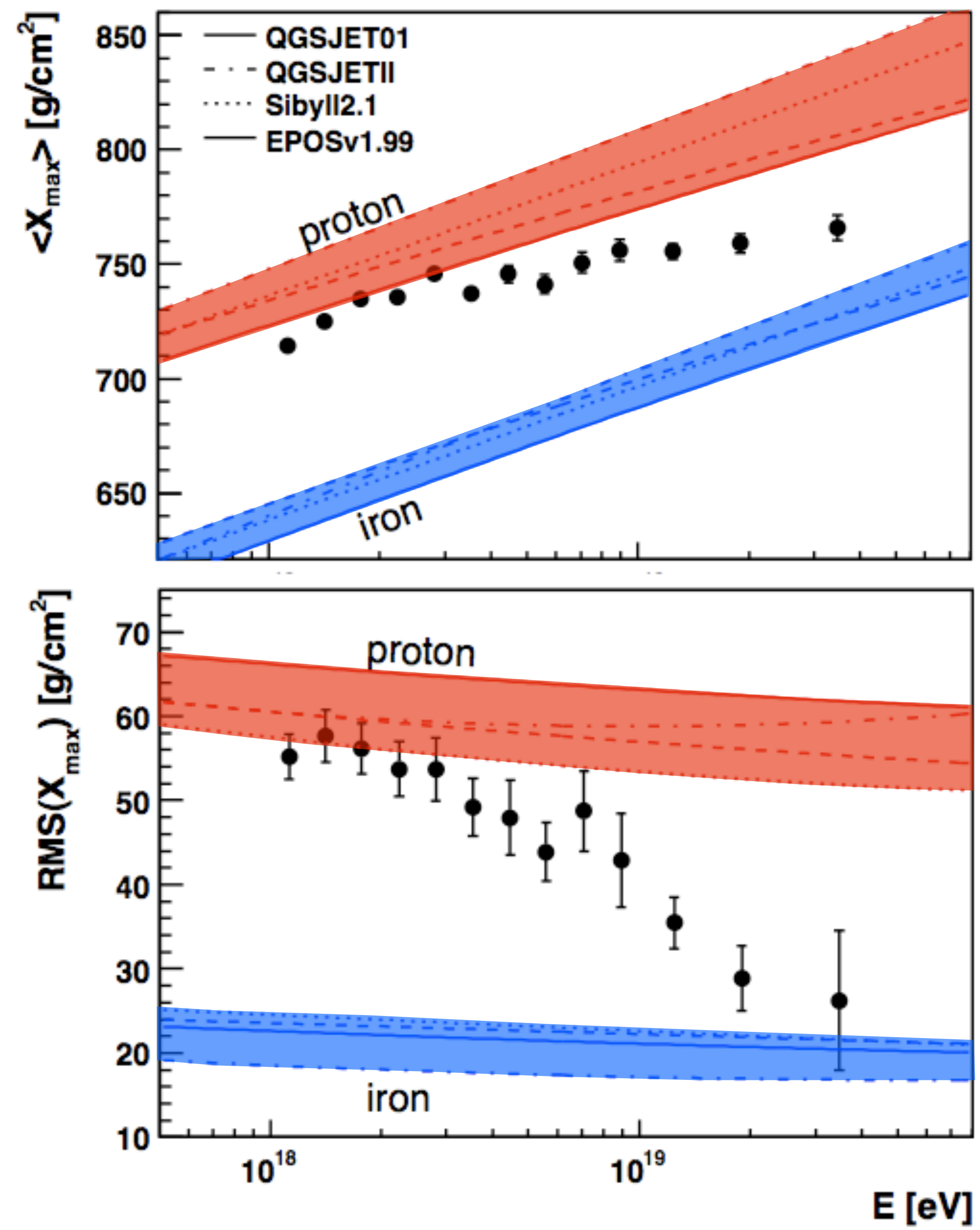
- EPOS, QGSJET, Sibyll ... ← at Fermilab
  ➡ phenomenology-based: dual parton, minijets, pomerons, strings etc.

- “low energy” fixed target and collider data
  ➡ cross section, particle distribution

- extrapolate to higher energies

‣ Tevatron -> LHC : $E_{lab} \approx 10^{15}$ eV -> 10^{17} eV

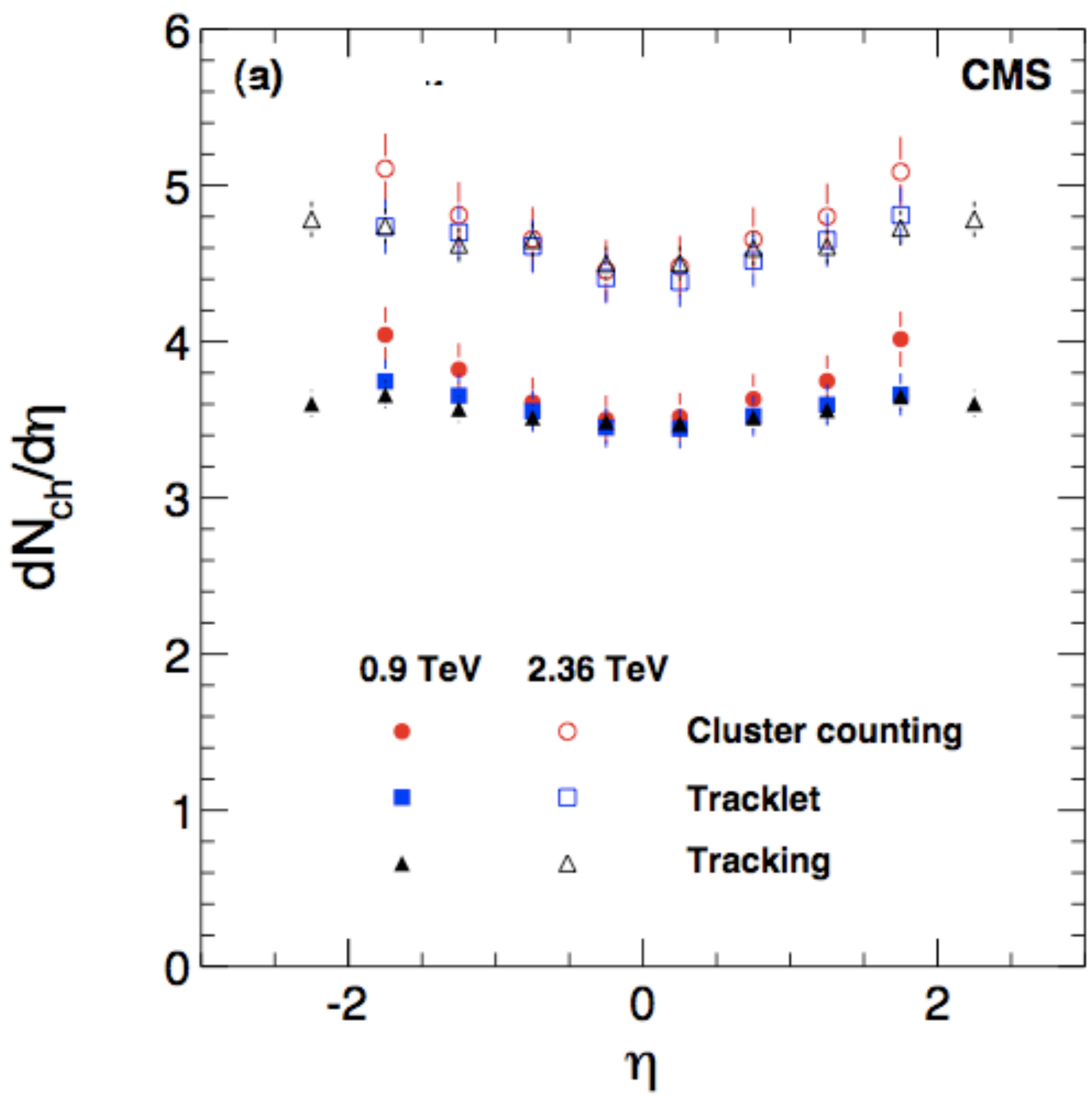
‣ Auger’s HEAT/AMIGA : $E \approx 10^{17}$ eV



-> gap is decreasing

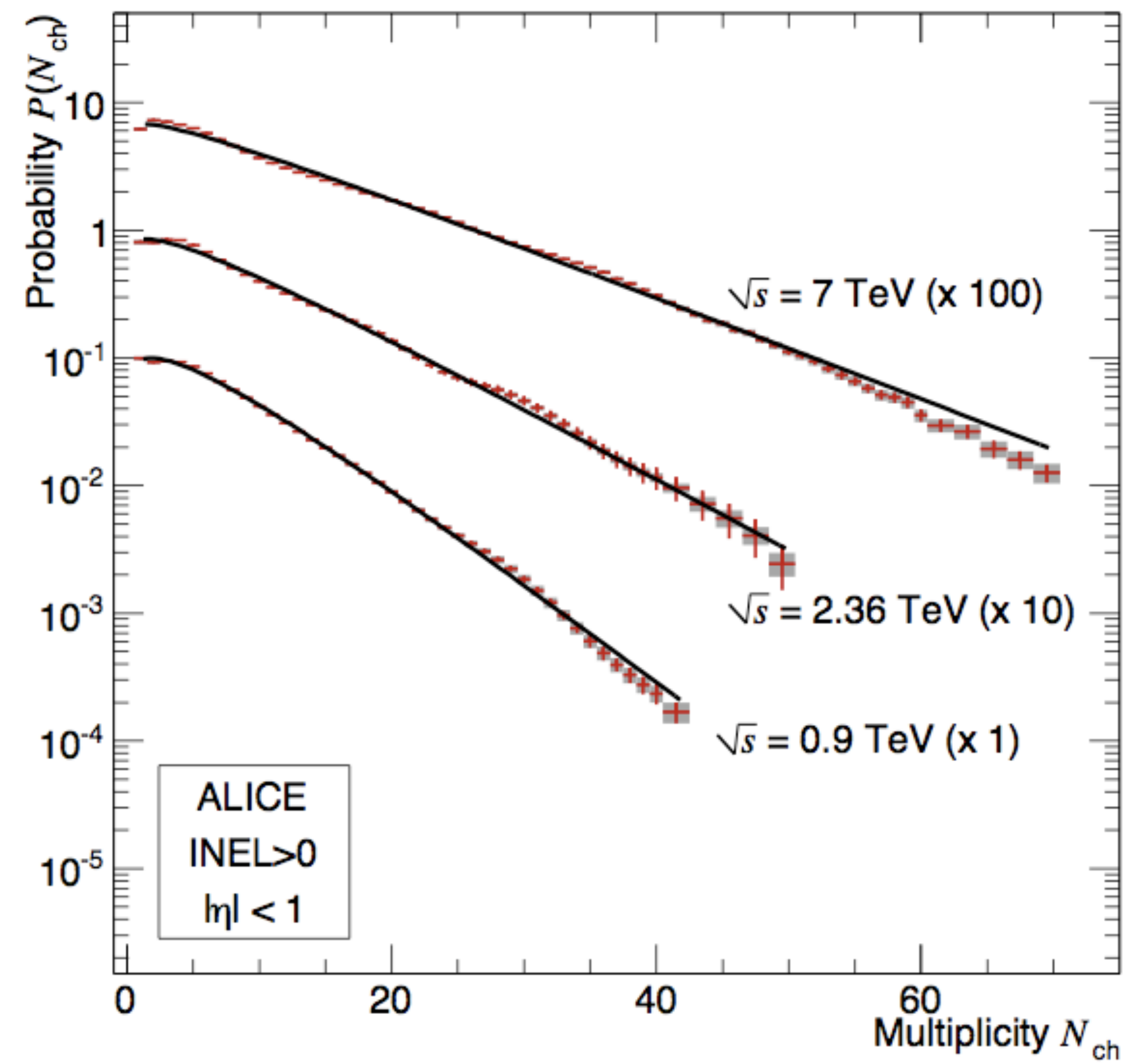
High energy data from LHC

"it's alive!"



CMS 2.36 TeV

JHEP 1002:041, 2010 arXiv:1002.0621



ALICE 7 TeV

arXiv:1004.3514

CMS: $|\eta| < 2.4$ -> 10°–170°

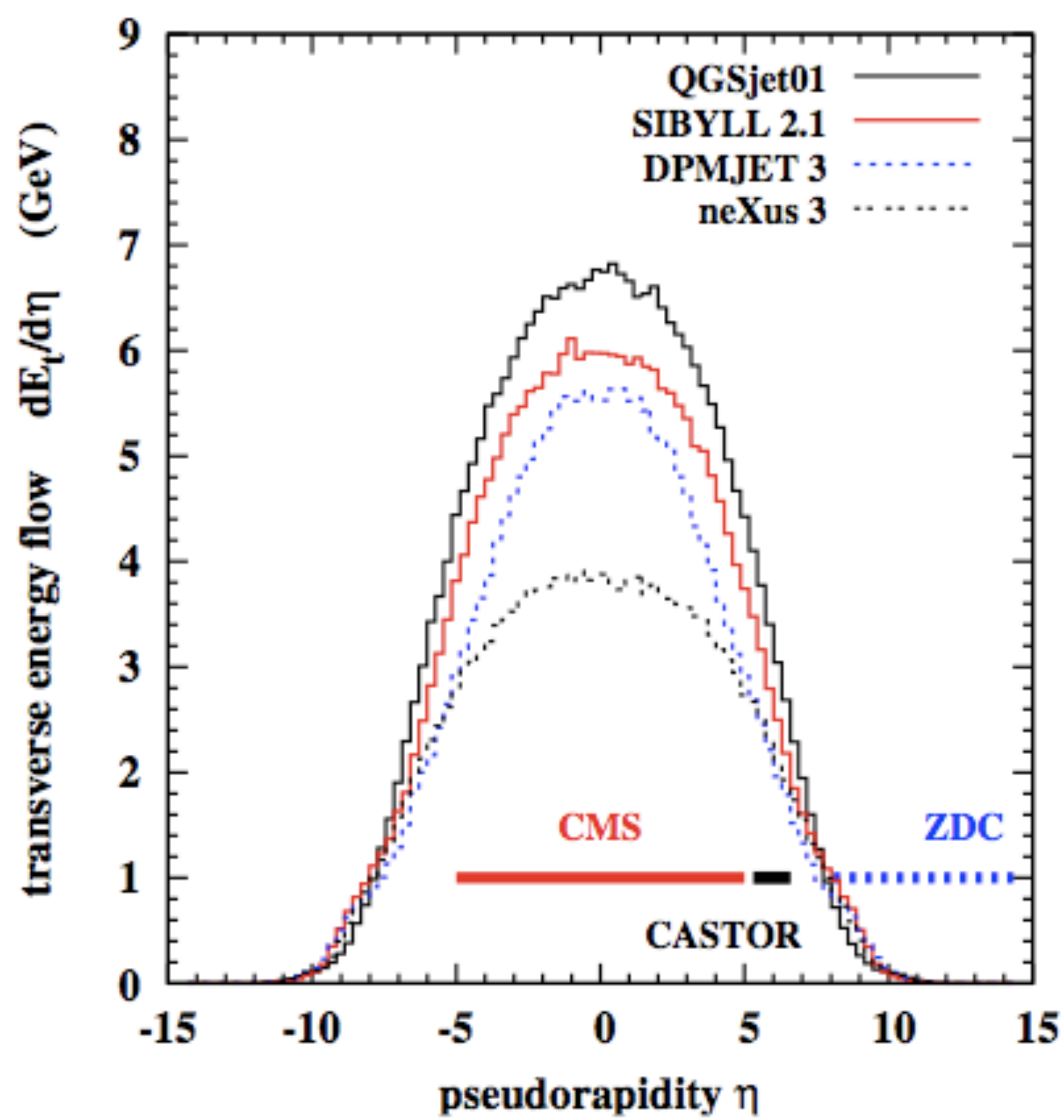
ALICE: $|\eta| < 1$ -> 40°–140°

$\eta = -\ln[\tan(\theta/2)]$

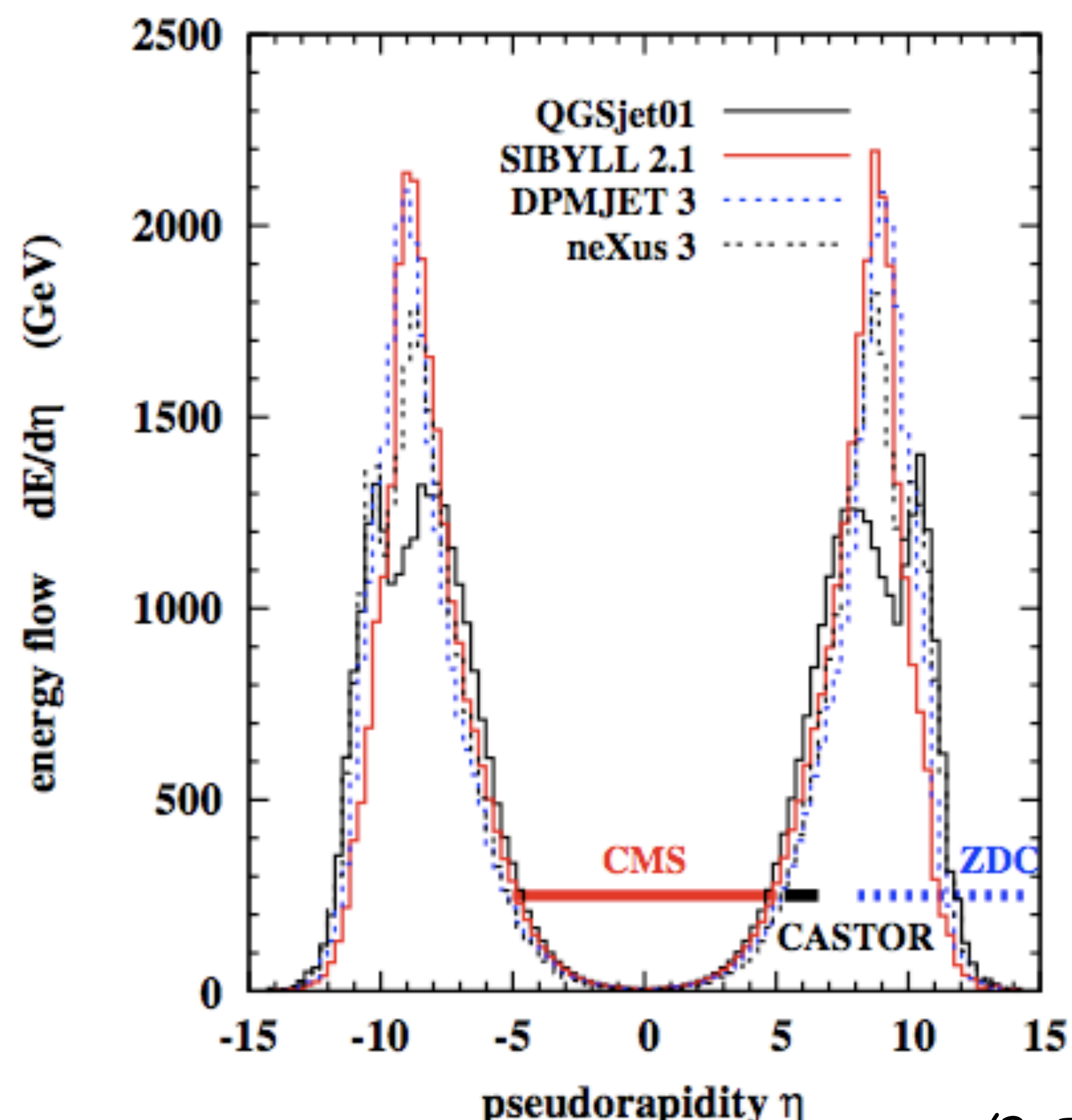
Forward region

- cosmic rays deposit energy mostly in forward region <- crucial
- central region necessary
- LHCf, TOTEM

Transverse energy flow



Total energy flow



(R. Engel)

To understand composition, σ_{p-p} needs to be understood :

- energy-consistent estimation possible at CR energy for the first time
- effort is led by the Fermilab Auger group

possible due to presence of astro & particle physics in the same place

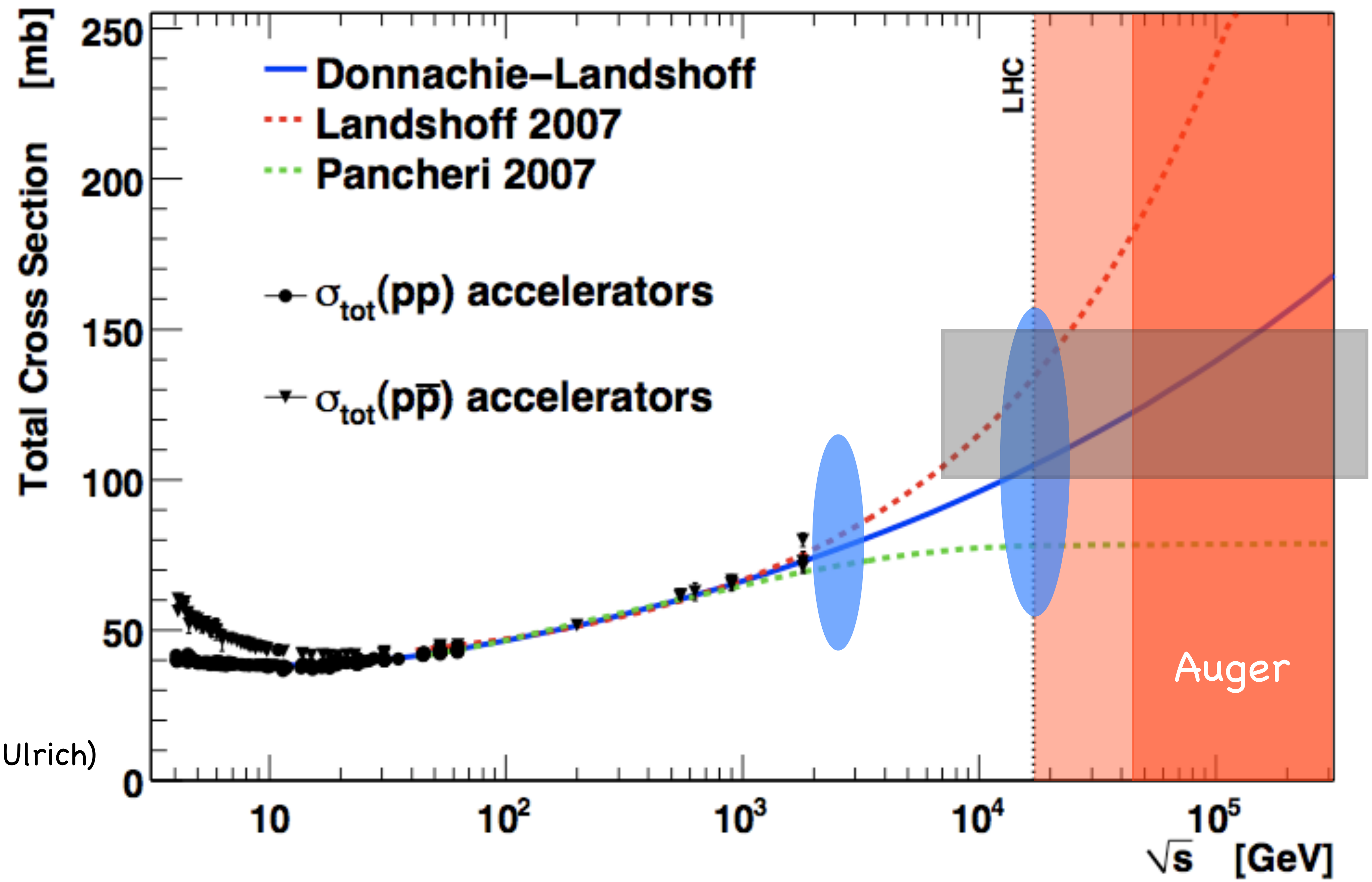
PRE-PRELIMINARY

not approved by the collaboration

- Tevatron -> LHC : $E_{lab} \approx 10^{15}$ eV -> 10^{17} eV
- Auger's HEAT/AMIGA : $E \approx 10^{17}$ eV

-> smaller this gap, the better

Data and prediction of $\sigma_{p\text{-}p}$



125 ± 25 mb?

(R. Ulrich)

★ LHC can tell us which theory is better

★ Auger can tell us which theory is better, **up to a higher energy**

X_{max} of Auger and HiRes