Timing-related observables for UHECR composition studies.[a]

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[a] work done with D. S. Gorbunov and S. V. Troitsky

New experiments are more precise

- Modern EAS ground arrays measure time-resolved signal
  - KASCADE
  - Pierre Auger
  - TA/TALE
  - * Yakutsk (several detectors on, modernization proposals)

- Time-resolved signal provides $\sim$ 100 times more raw data

Timing is important

- For arrival direction reconstruction — from the beginning of times
- For composition studies — in use now
- For primary energy estimation — may be used (e.g. AGASA delayed particles issue)

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...but complicated:

- large amount of data
- small-scale fluctuations are significant
- thinning procedure does not respect shower time-structure

There are many observables

One may imagine a variety of quantities which may be extracted from the time-resolve data. We would discuss three examples:

- Shower front curvature (extracted from shower front $t(r)$)
- Rise time t_r (or shower front thickness), integral signal rise from 10% to 50%.
- Integral signal for the first τ nanoseconds

$$\sigma(\tau) = \int_{t(r)}^{t(r)+\tau} S(t)dt \qquad (1)$$

Public shower library

Livni - the public database of artificial extensive air showers generated without thinning

- The library currently contains 90 showers, with primary energies 10^{17}—10^{18} eV, different zenith angles and interaction models.
- QGSJET, QGSJET II, EPOS, GHEISHA and EGS4 models are used for simulation of library showers
- Shower library is available at `http://livni.inr.ac.ru/` you may register to use it at the workshop or on the website.

Method

- We assume a ground array to consist of $3\ m^2$ area AGASA-like plastic scintillators.
- Full shower simulation allows to calculate the values of observables directly
- For each library shower we calculate a value of the observable at the detector located at $425\ m$ from core averaged over all possible detector positions.

Examples: shower front delay

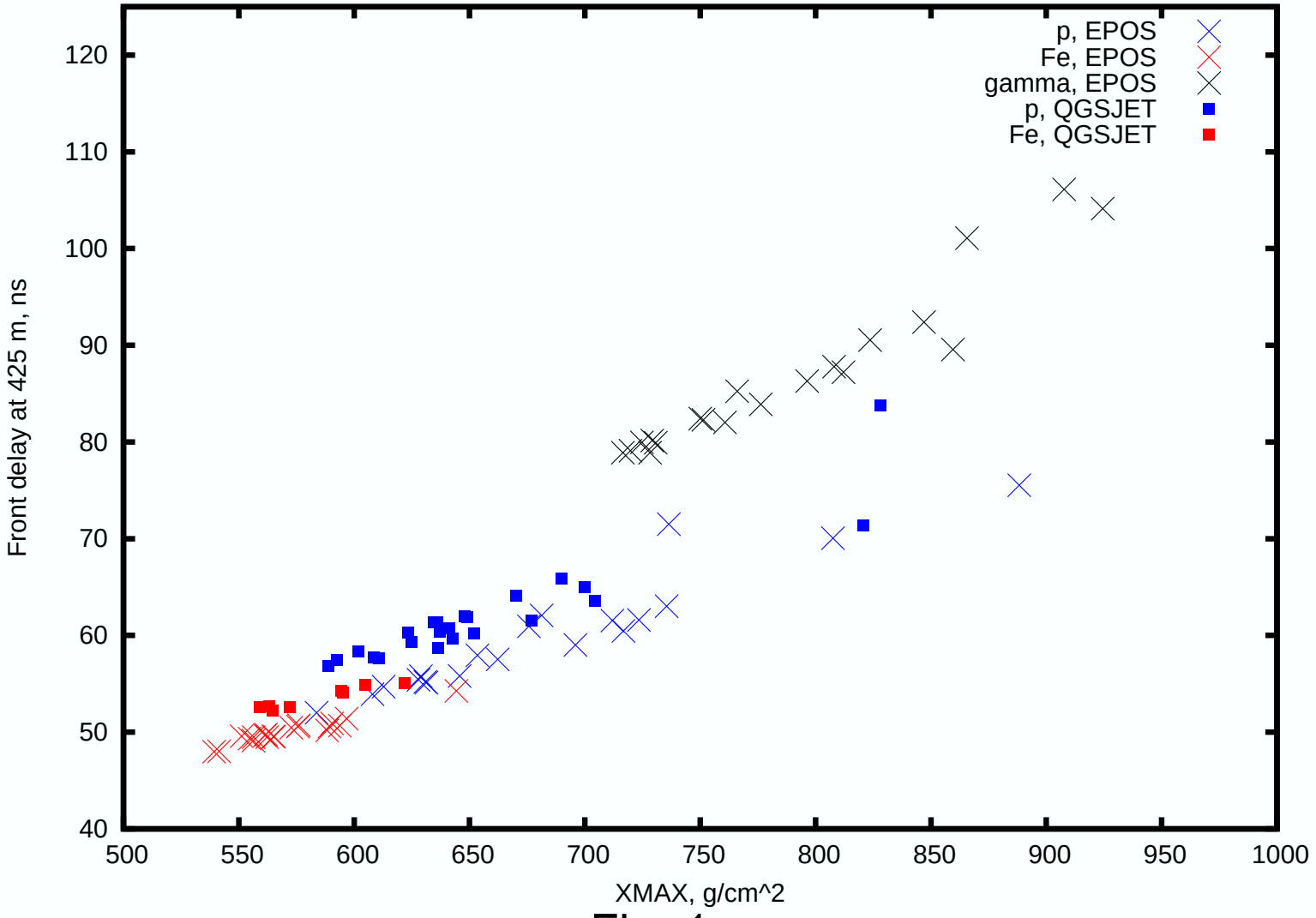

Fig. 1:

Examples: rise time

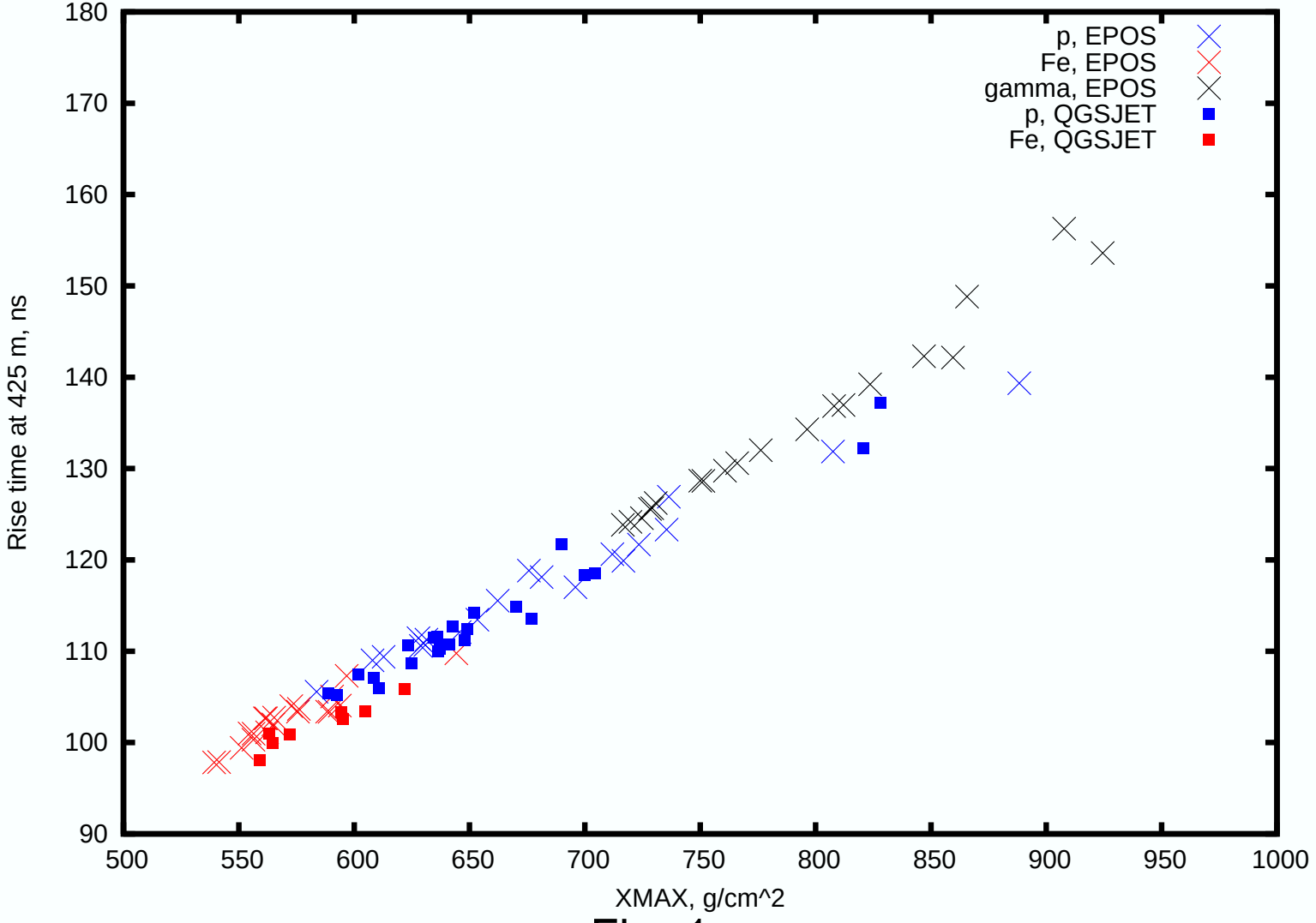

Fig. 1:

Examples: first signal

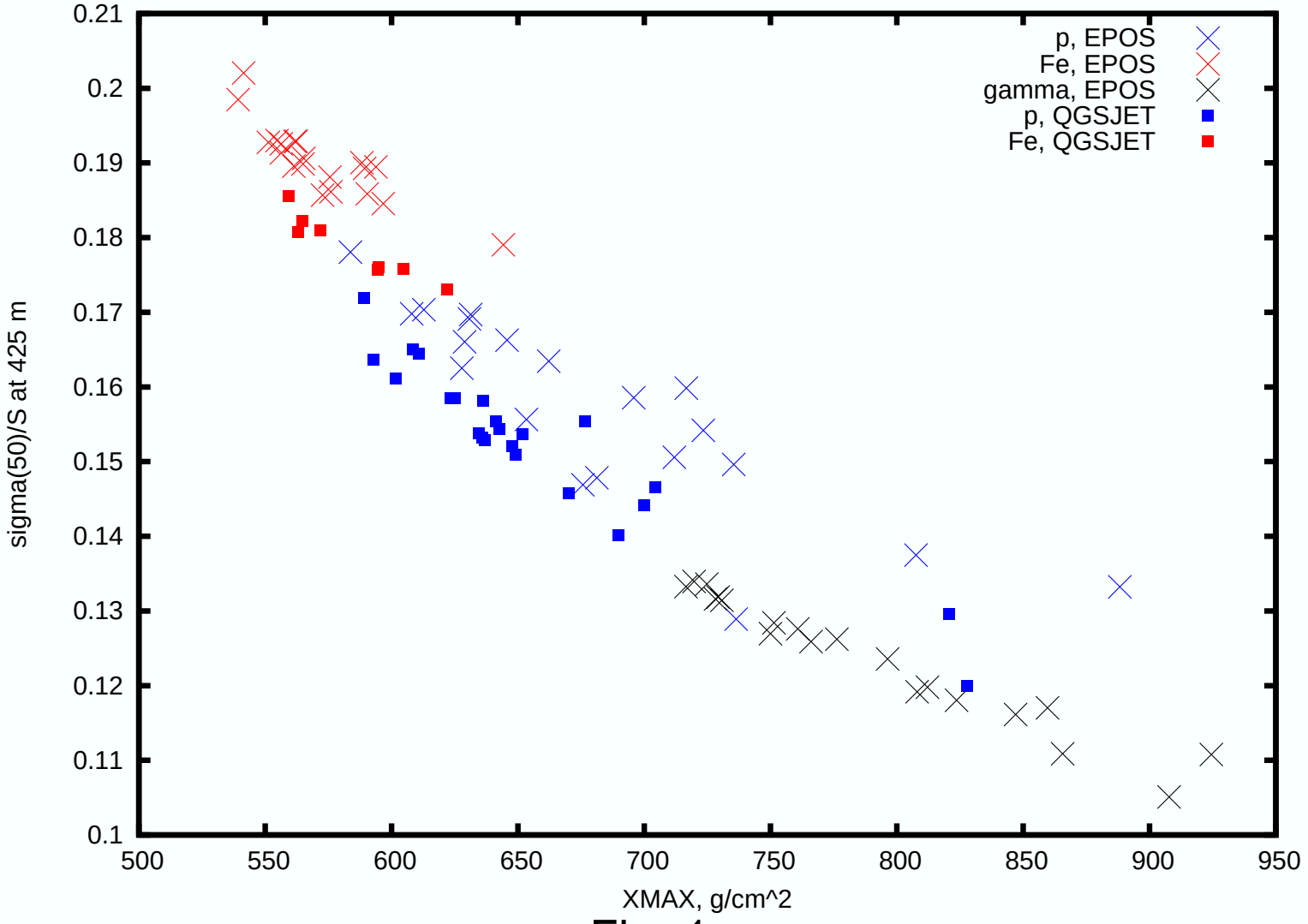

Fig. 1:

Conclusions

- Timing-related observables are important for composition studies of UHECR
- Complete simulations may be performed only for limited energy/statistics
- There is a variety of observables, one should find optimal ones for a particular experiment.