SAGENAP presentation Apr 98.

Auger Detector Design

Talk outline:

- What is an air shower?
- What do we need to know to design a detector?
- The available techniques.
- Why Hybrid detection?
- The Auger Design.
- Conclusions

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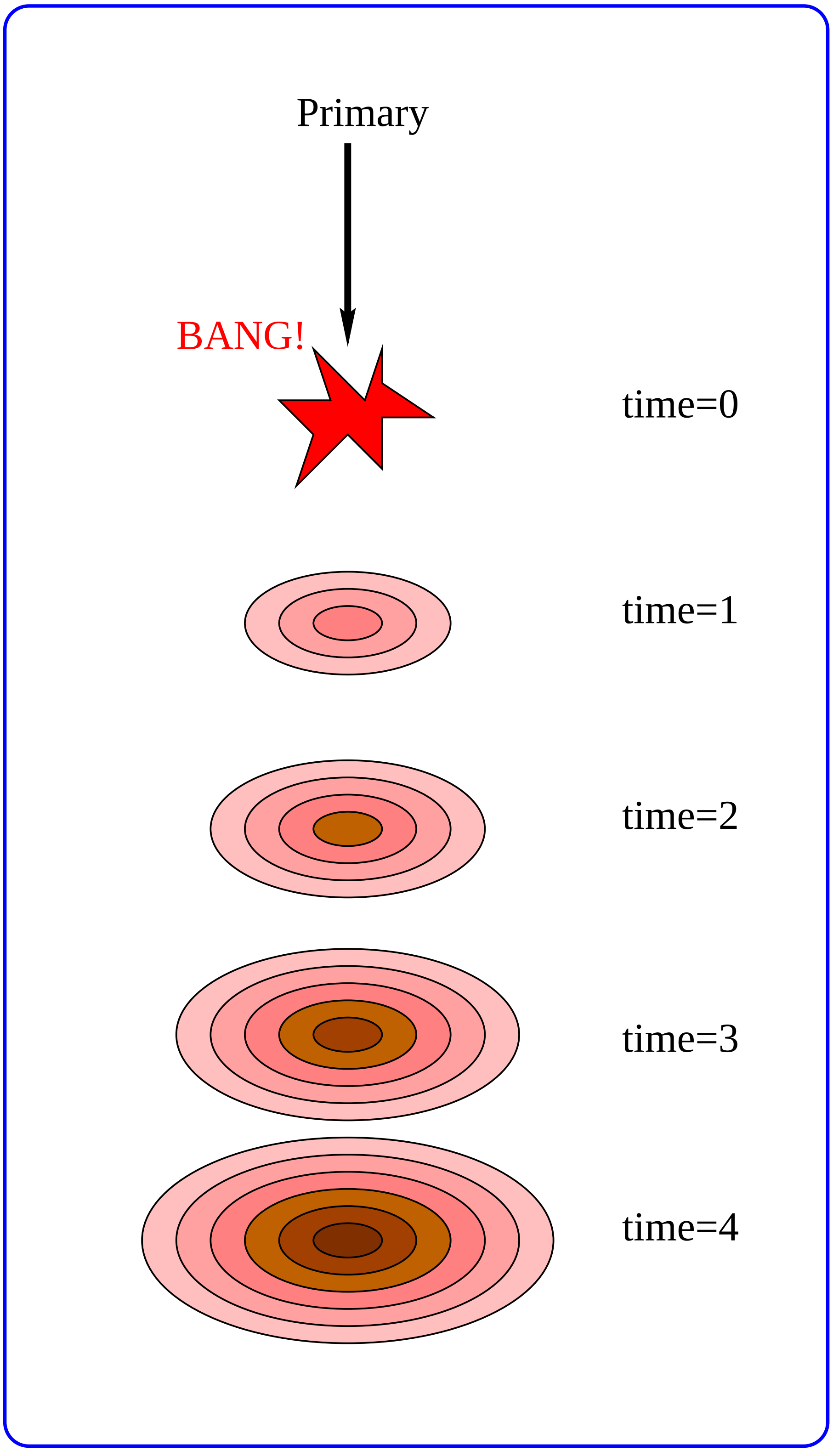
What is an airshower?

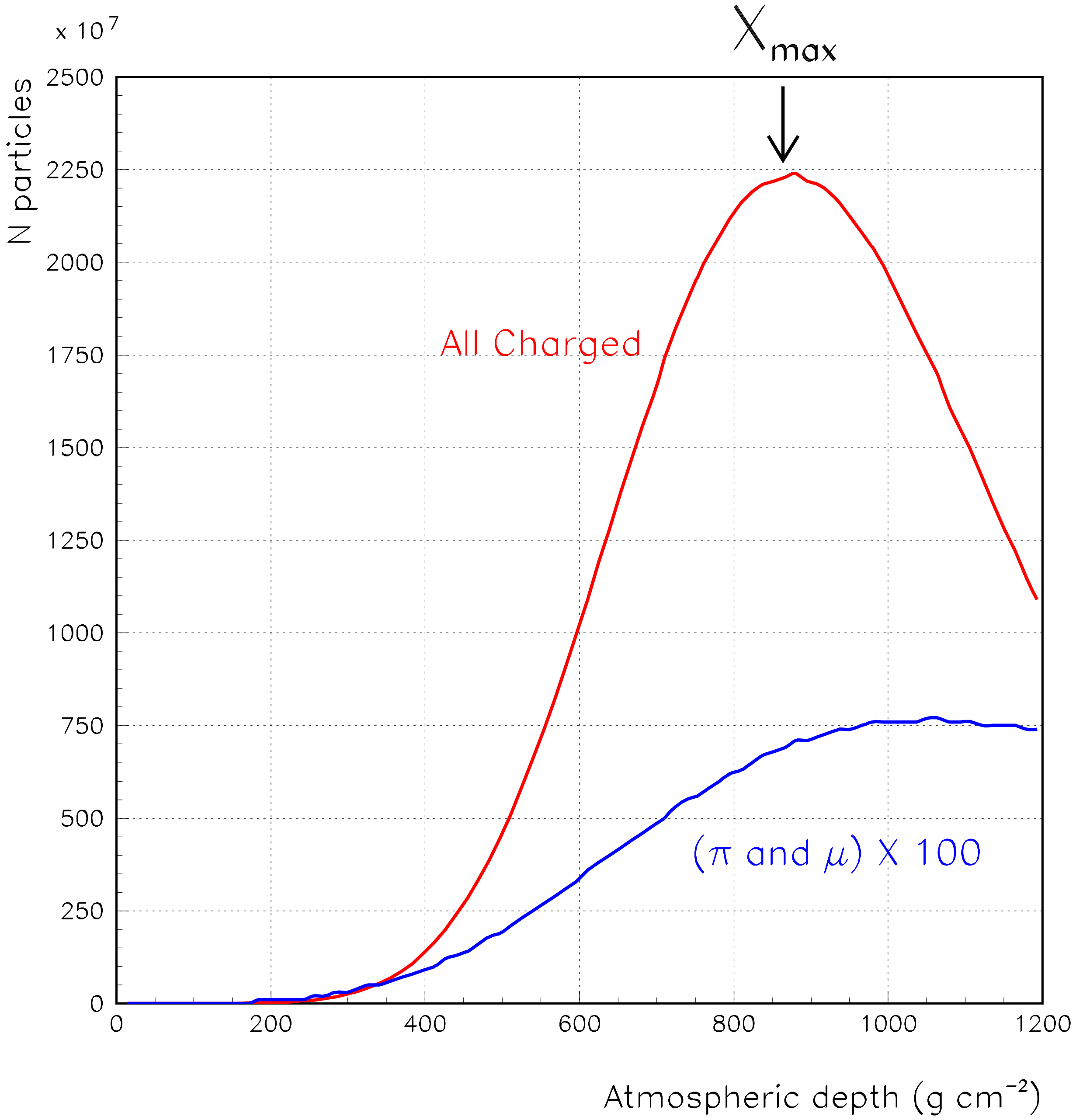


SPEAKER NOTES:

[Objective here is to remind committee members who didn't think about EAS since the last meeting of some basics.]

- Cosmic rays enters the upper atmosphere and interacts...
- Secondary particles interact also...
- Cascade grows...
- Disk of particles sweeps down through atmosphere...
- Shower is 4 dimensional structure (developing in time and space).
- Axially symmetric.

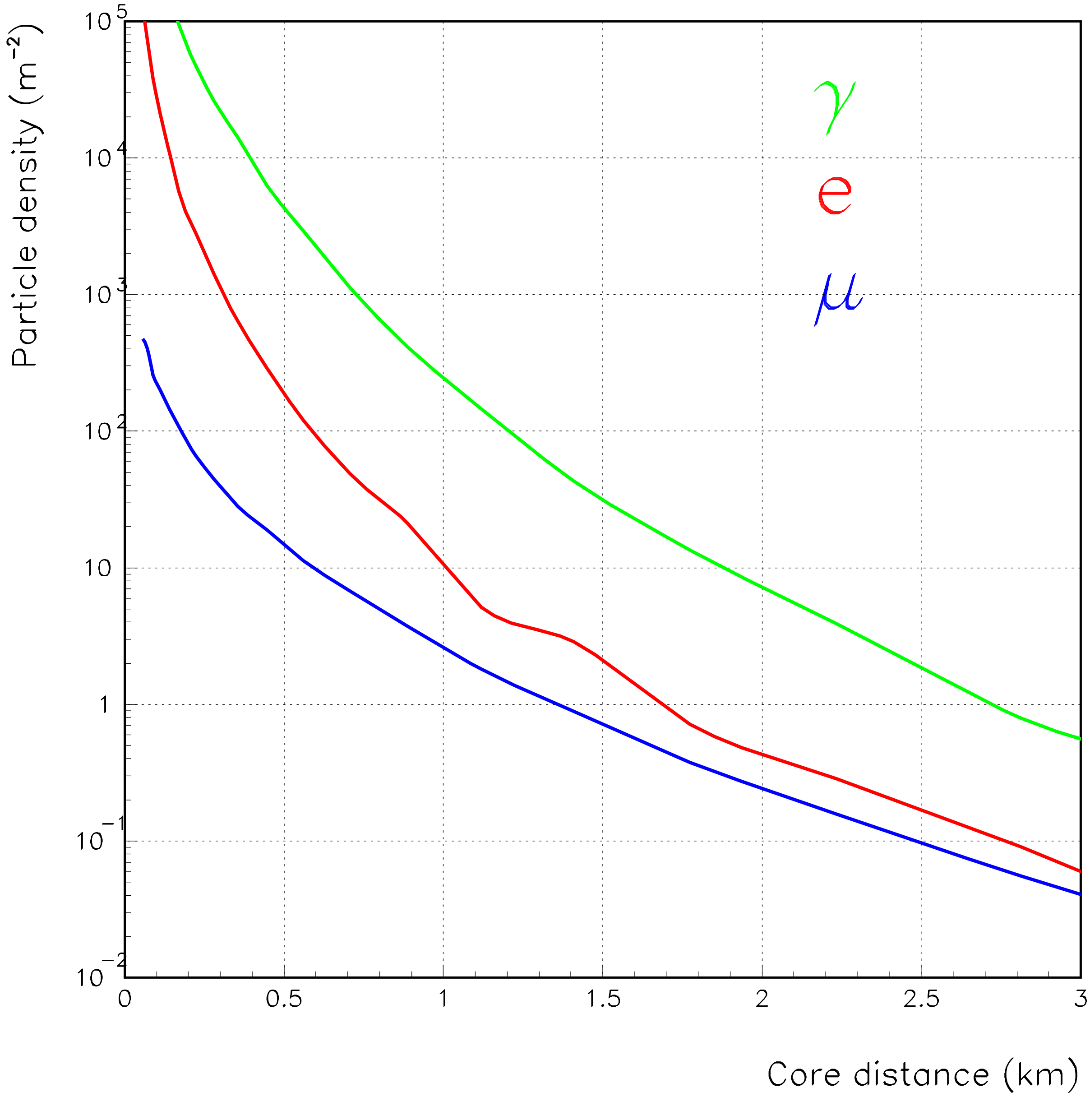
Longitudinal Distribution



SPEAKER NOTES:

- The lateral falloff in particle density moving away from the axis is very steep...
- Hence the bulk of the shower particles are always close to the axis...
- So it is OK to approximate the longitudinal distribution as 1 dimensional.
- (Note X_{max})

Lateral Distribution



SPEAKER NOTES:

- Likewise the lateral extent is normally only observable at one atmospheric depth (the ground)...
- So usually plotted as a 1 dimensional distribution.

[Maybe should be a log(r) plot?]

What do we Need to Know to Design a Hybrid Detector?

Ground Array:

- Only the gross shape of the lateral distribution needs to be known in advance $\Rightarrow$ Detailed shape will be measured.
- However the size of predicted fluctuations in the ground level signal are important (at large core distance).

Fluorescence Detector:

- Do all models predict the same N_{max} and X_{max} vs E behaviour?

SPEAKER NOTES:

- Remind: a sparse ground array inevitably makes its measurements at large ($\geq$ 1 km) distances from the shower axis.

Shower Simulations

Ingredients:

	MOCCA	Corsika
High E Hadronic	Internal/Sibyll	Sibyll/QGSjet
Low E Hadronic	Internal	GEISHA
Electromagnetic	Internal	EGS4

Corsika Philosophy: Use standard, well tested, HEP code where it is available.

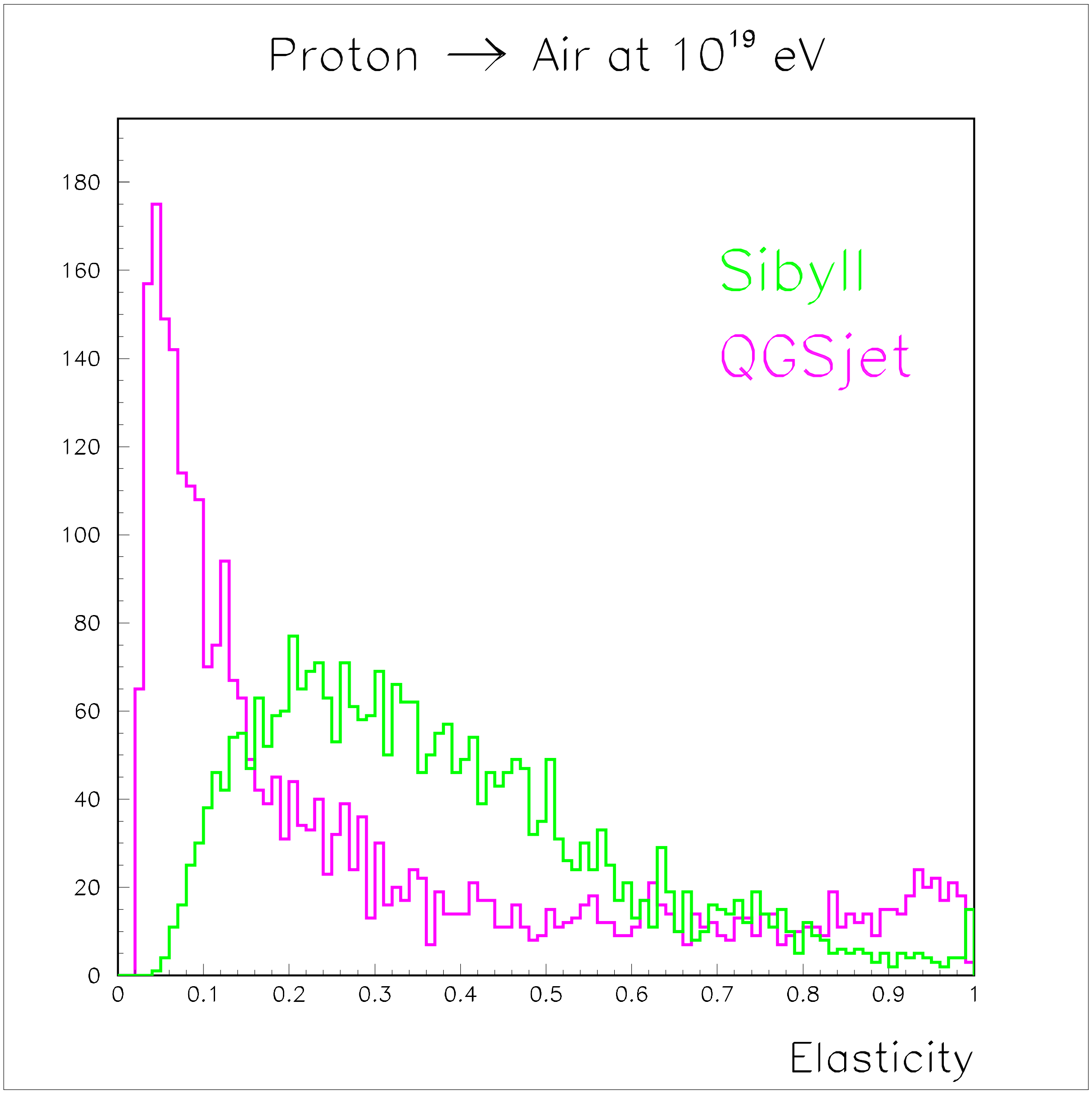
$\Rightarrow$ Keep the uncertainties in the High Energy Hadronic model where they are unavoidable!

SPEAKER NOTES:

- All previous Auger simulations based on MOCCA code.
- Today I will show you some comparisons with another program - Corsika.
- This program is "industrial strength" (German engineering).
- The high energy part of a shower goes straight down the axis. What we see at large core distance is heavily deflected soft stuff - hence accurate low energy models can be important.

The First Interaction

Shower fluctuations mainly come from variations in the depth and elasticity of the first interaction.



Sibyll and QGSjet are very different.

SPEAKER NOTES:

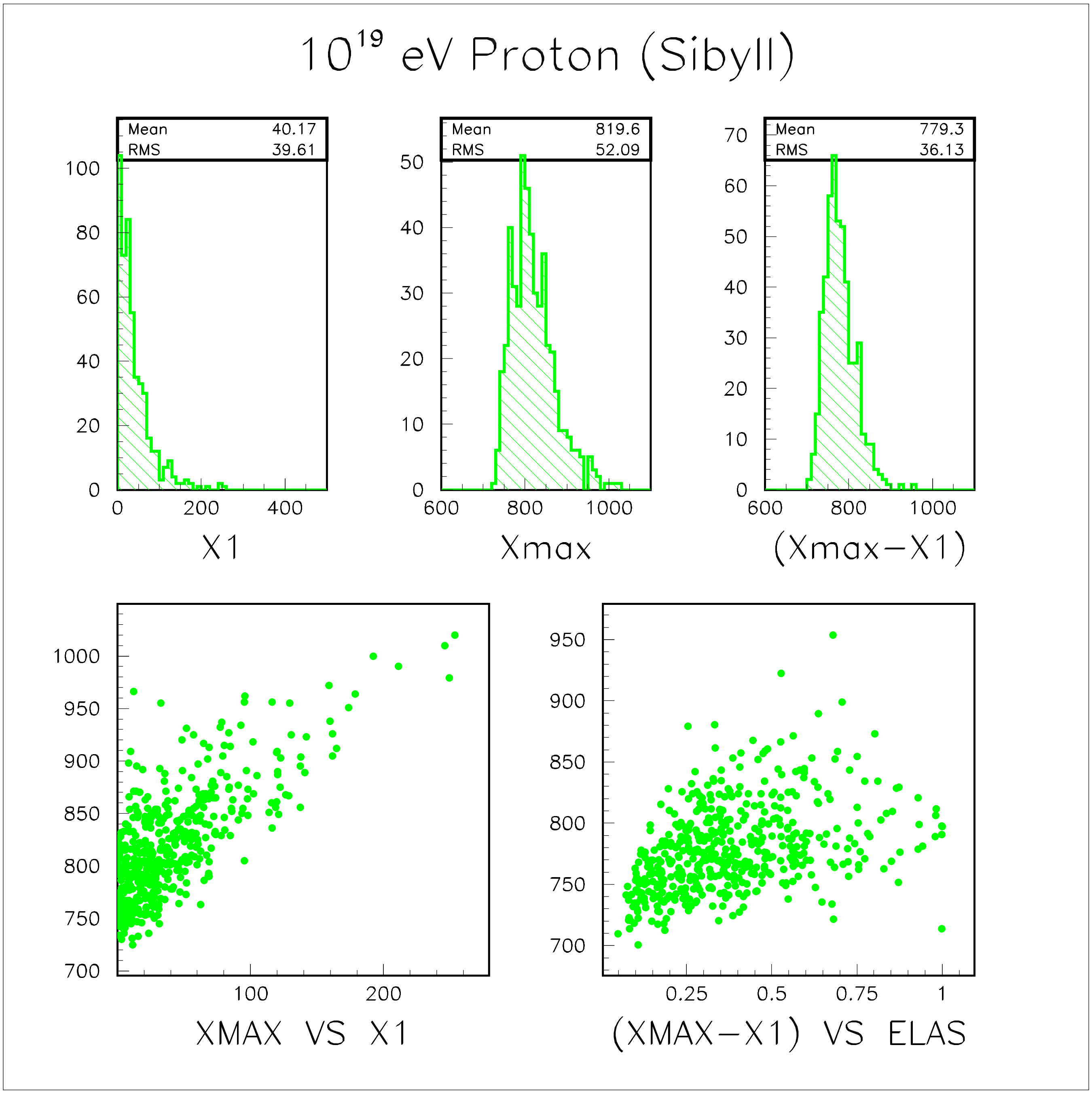
- Energy degradation is very rapid - multiplicity $\gg 100$. After first interaction fluctuations average out.

- (Multiplicity distributions also look different in the way one would expect - Elas. and mult. are anti-correlated. QGSjet has more v. high multiplicities - up to 5000!.)

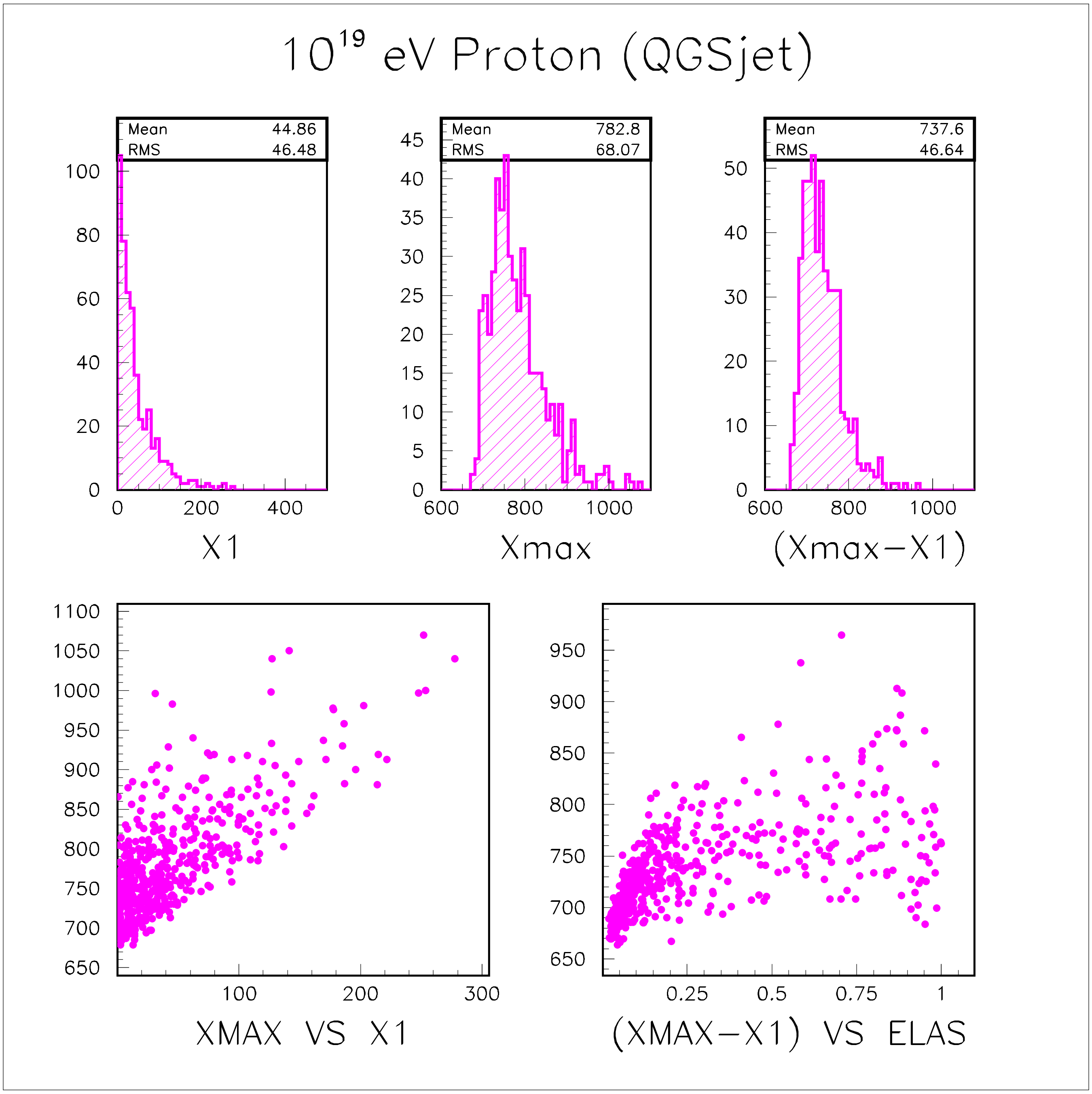
- At very high energy the inelastic cross sections are expected to be rather large. This means that even big errors in estimating them make rather small differences in the mean free path to the first interaction. (eg. 400 $\rightarrow$ 600 mb $\equiv$ 20 g cm^{-2} shift in mean first int. depth. Cf. Fluor det X_{max} resolution of $>$ 10 g cm^{-2}.)

[Backup plot follows: Anything else which should be plotted?]

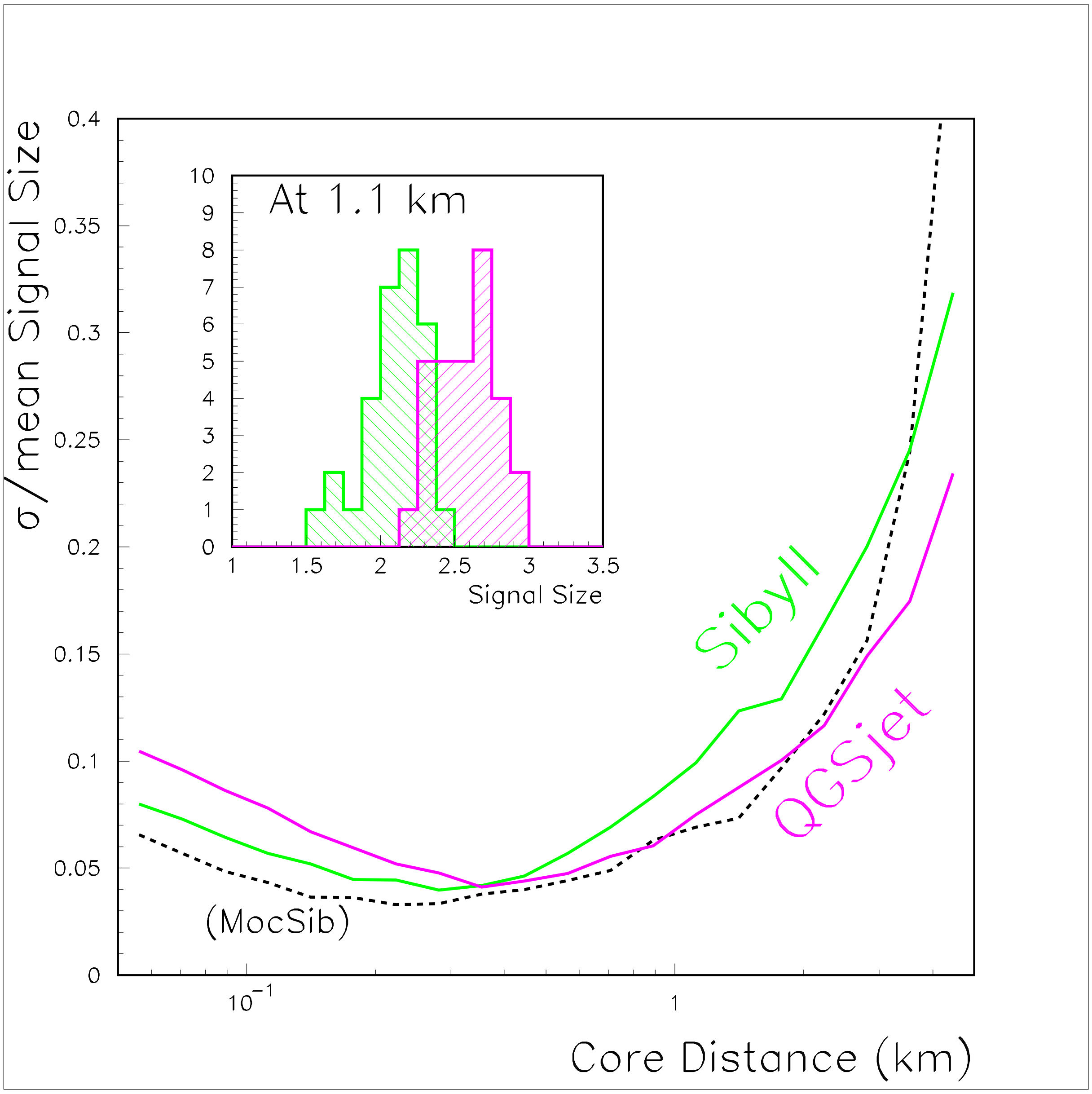
First Interaction and X_{max}



First Interaction and X_{max}



What effect do Different Models have on Ground Level Fluctuations?



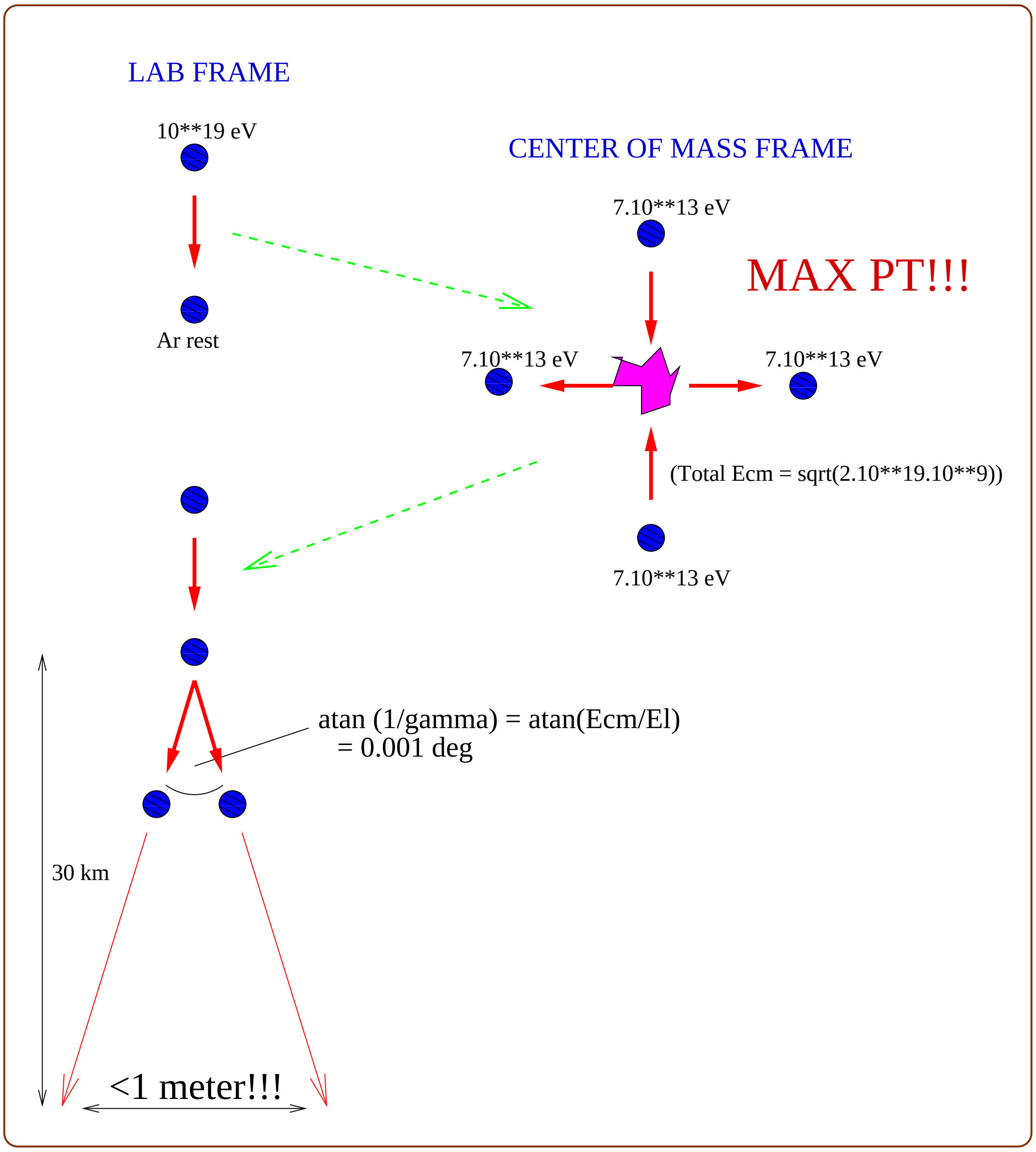
Not much! (For these two at least.)

SPEAKER NOTES:

- Fluctuations in 1 km signal size are $< 10\%$ in all cases.
- What kind of model would be required to change this result? - requires further study - but for sure it would have be very extreme...
- These calculations take ~ 1 day per event to turn first interaction into signal size at > 1 km so please excuse the poor statistics...

Aside: Transverse Momentum

Can high p_t particles from the first interactions disrupt axial symmetry?



Absolutely not!

SPEAKER NOTES:

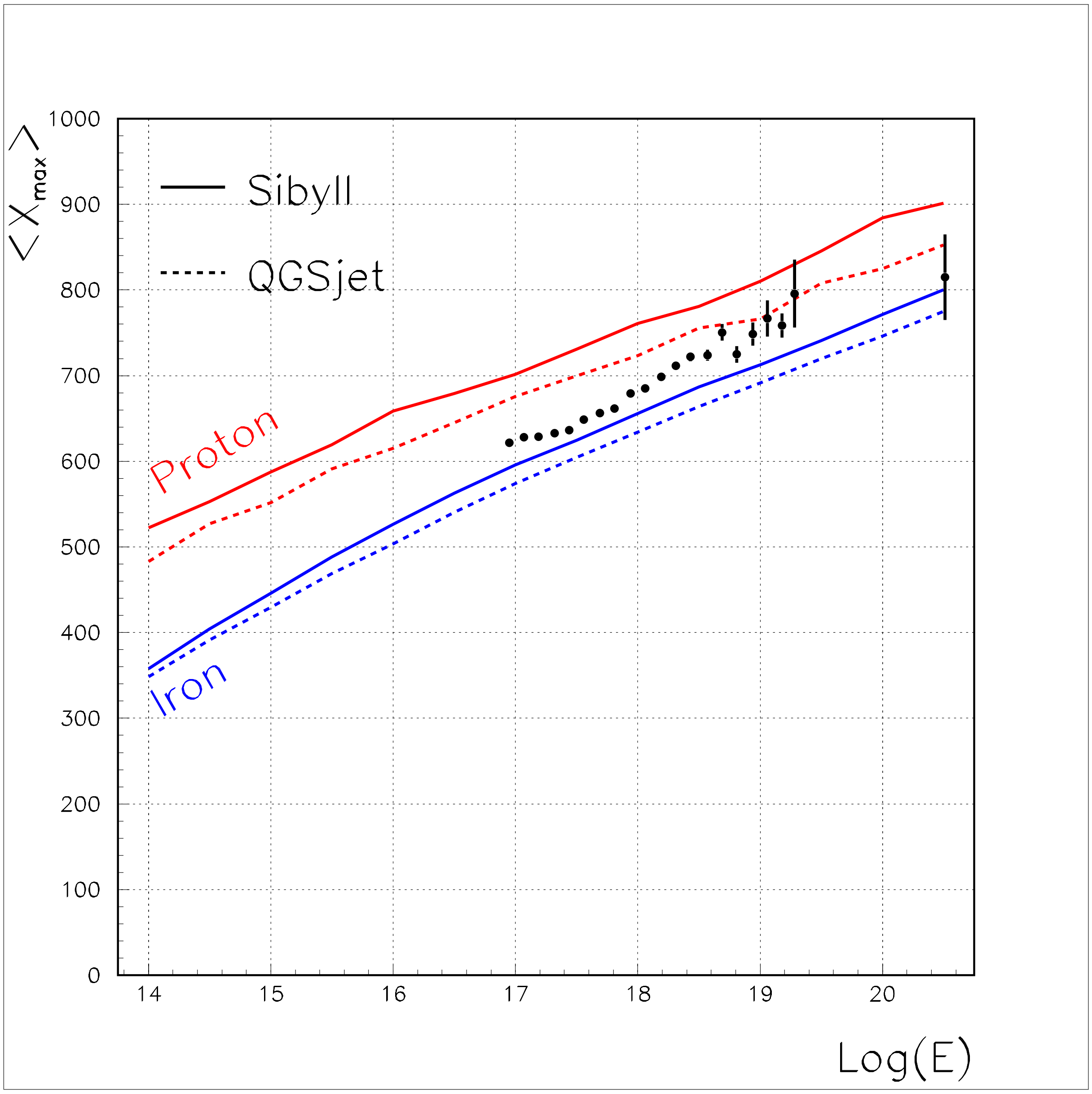
[I have heard mutterings sometimes that people don't believe EAS are axially symmetric. If that were true it would kill ground arrays.]

- Due to the *enormous* Lorentz boost of the Center of Mass frame it is absolutely impossible for the first interactions to give rise to ground level asymmetry.

- Axial symmetry of air showers is an experimental fact. It also follows from first principles. It has *nothing* to do with uncertain high energy hadronic models.

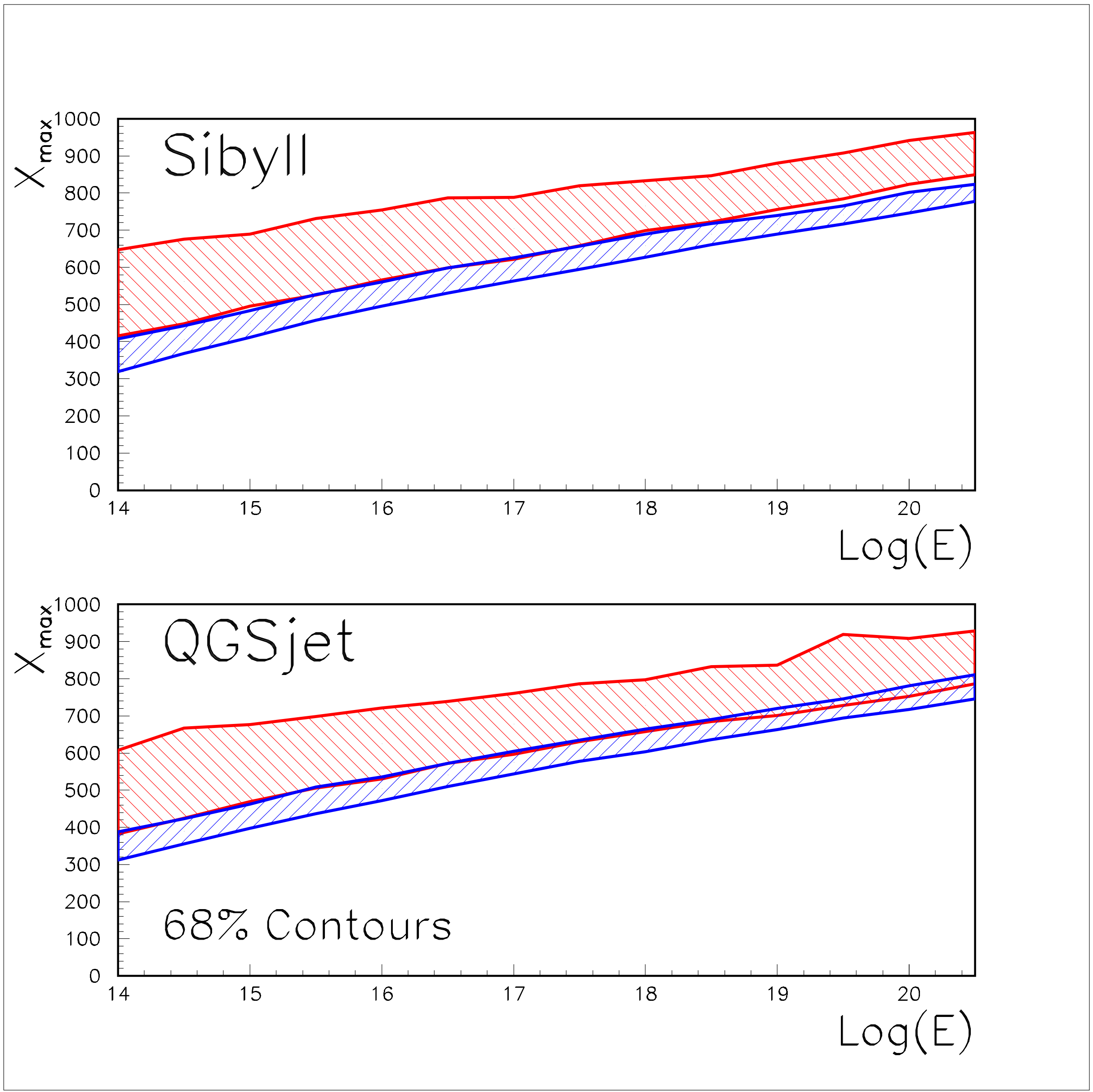
Mean X_{max} vs E

As X_{max} is controlled by the high energy interaction model Composition Sensitivity of *any* air shower detector is model dependent.



X_{max} Fluctuations

QGSjet model makes distributions overlap more.
Reduces composition sensitivity of *any detector*.

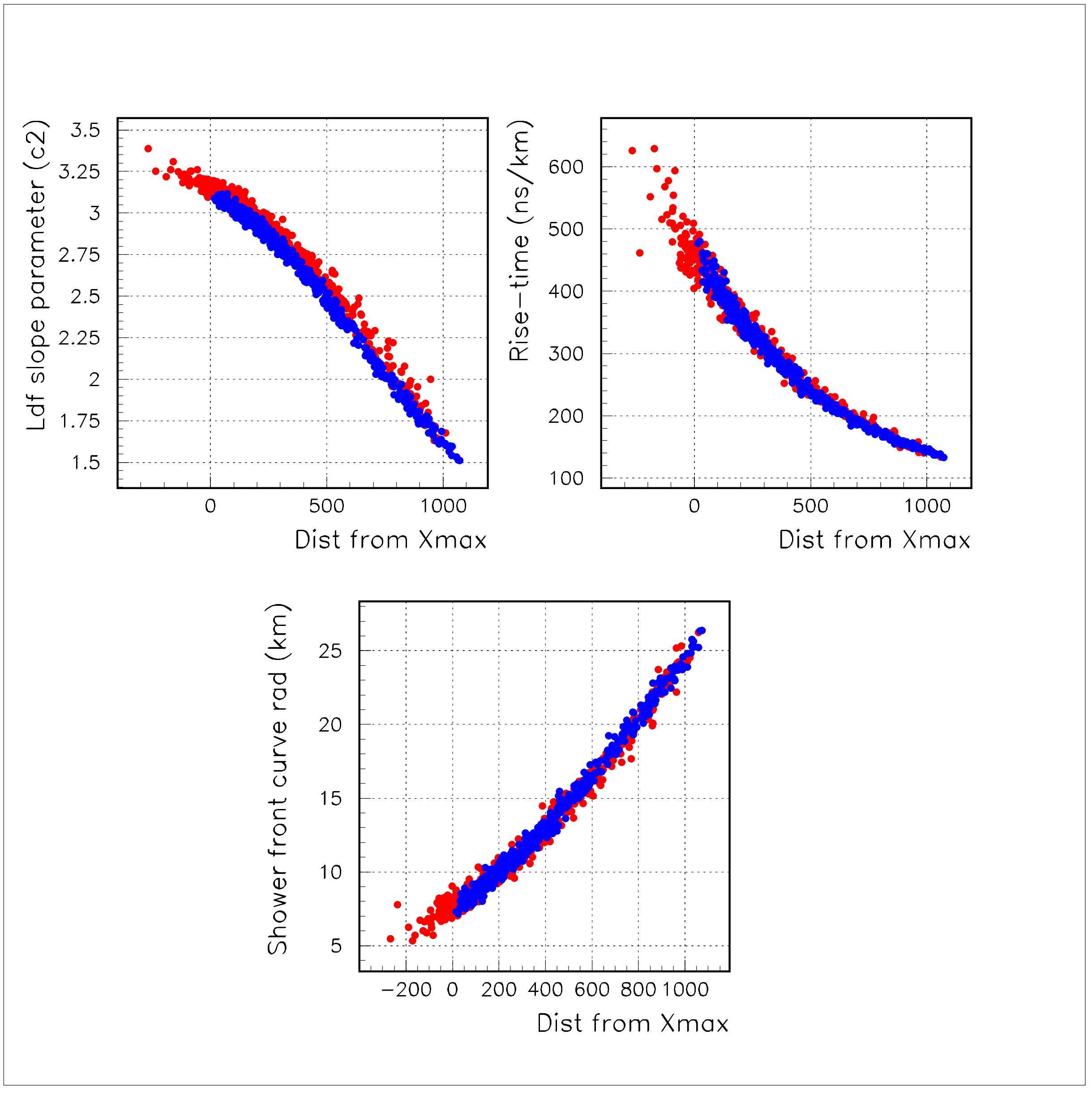


SPEAKER NOTES:

- Emphasize that FE composition result rests on dE/dX_{max} *alone* (Although there is additional circumstantial evidence from claimed correlated change in E spectrum.)

Ground Array Composition Sensitivity

There are a number of ground parameters which correlate closely with X_{max}.



In principle a ground array can measure X_{max} as well as a fluorescence detector.

SPEAKER NOTES:

- It turns out that the ground parameters I have been using for composition sensitivity correlate very closely with the thickness of atmosphere through which the shower has passed since reaching maximum. They are *not* in themselves composition sensitive.

- Since the zenith angle is known, the total atmos. depth at ground level for each event is also known.

- Therefore if the relation between a ground parameter and distance from X_{max} is known then X_{max} is also known.

- Hybrid data will provide these relationships... see later.

- This assumes that a real ground array can measure the ground parameters... again see later.