FAST Framework status

FAST analysis, simulation, data status 30.07.2026

Contents

Technical (~3 min)

- New FAST Framework
- FAST Event Browser

Simulation discussion (~12 min)

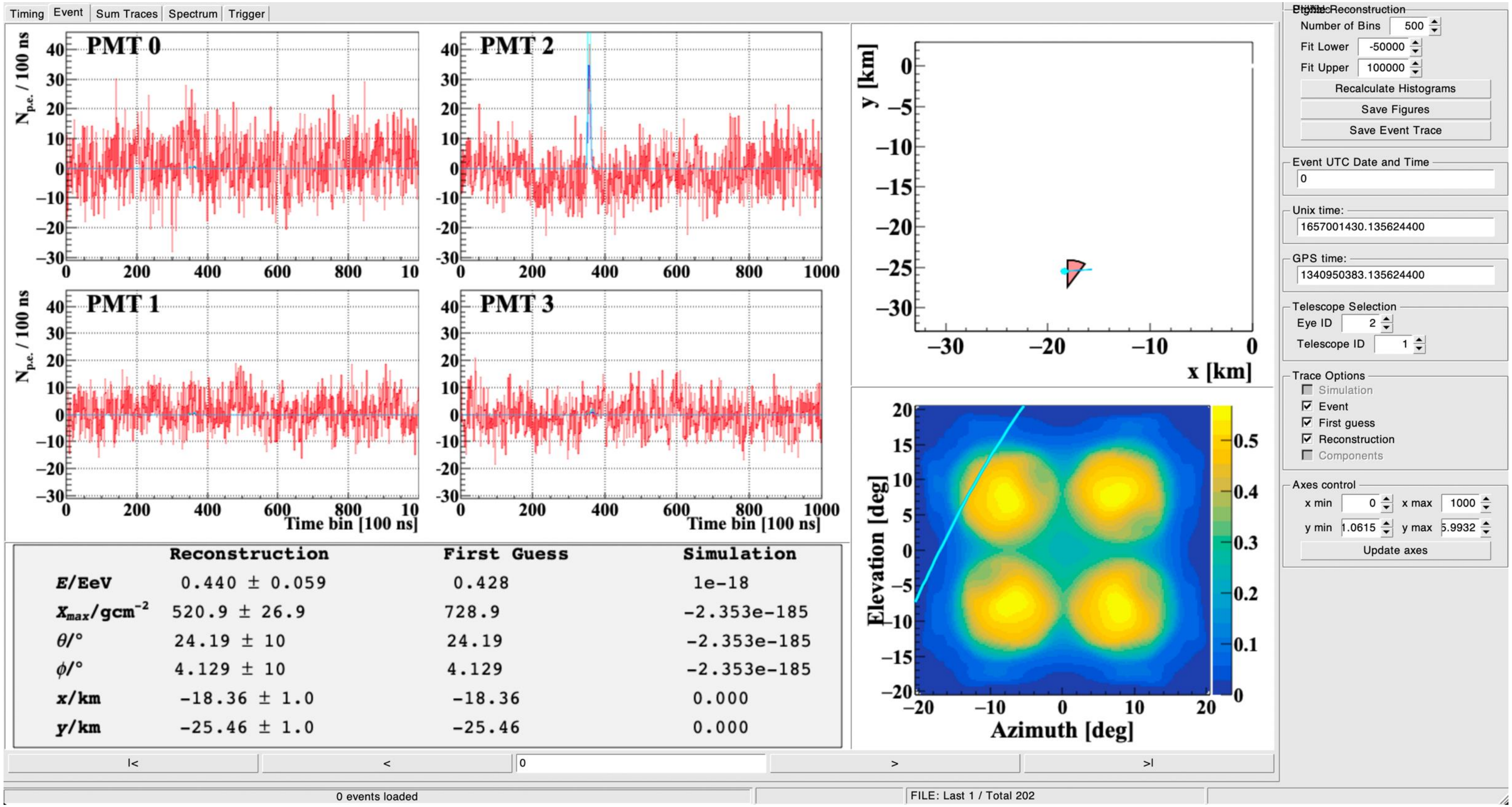
- Simulation flow
- Reality VS simulation implementation
  - How accurately do we know each part? What do we need to improve?

New FAST Framework

- Based on “minimal” version of AugerOffline-4.0.1-icrc2023-prod1Source
  - Only necessary code to run FAST simulations / reconstructions
- Uses C++17 standard, compatible with newest versions of GCC and external libraries (Boost etc.)
- Runs natively on Mac and Linux (only Ubuntu >24 tested)
  - Uses CMAKE for build process
- Download and install from here
- Working on additional features (e.g. save info from likelihood fit)

Still need to layout PMTs
correctly for Auger VS TA setups

FAST Event Browser



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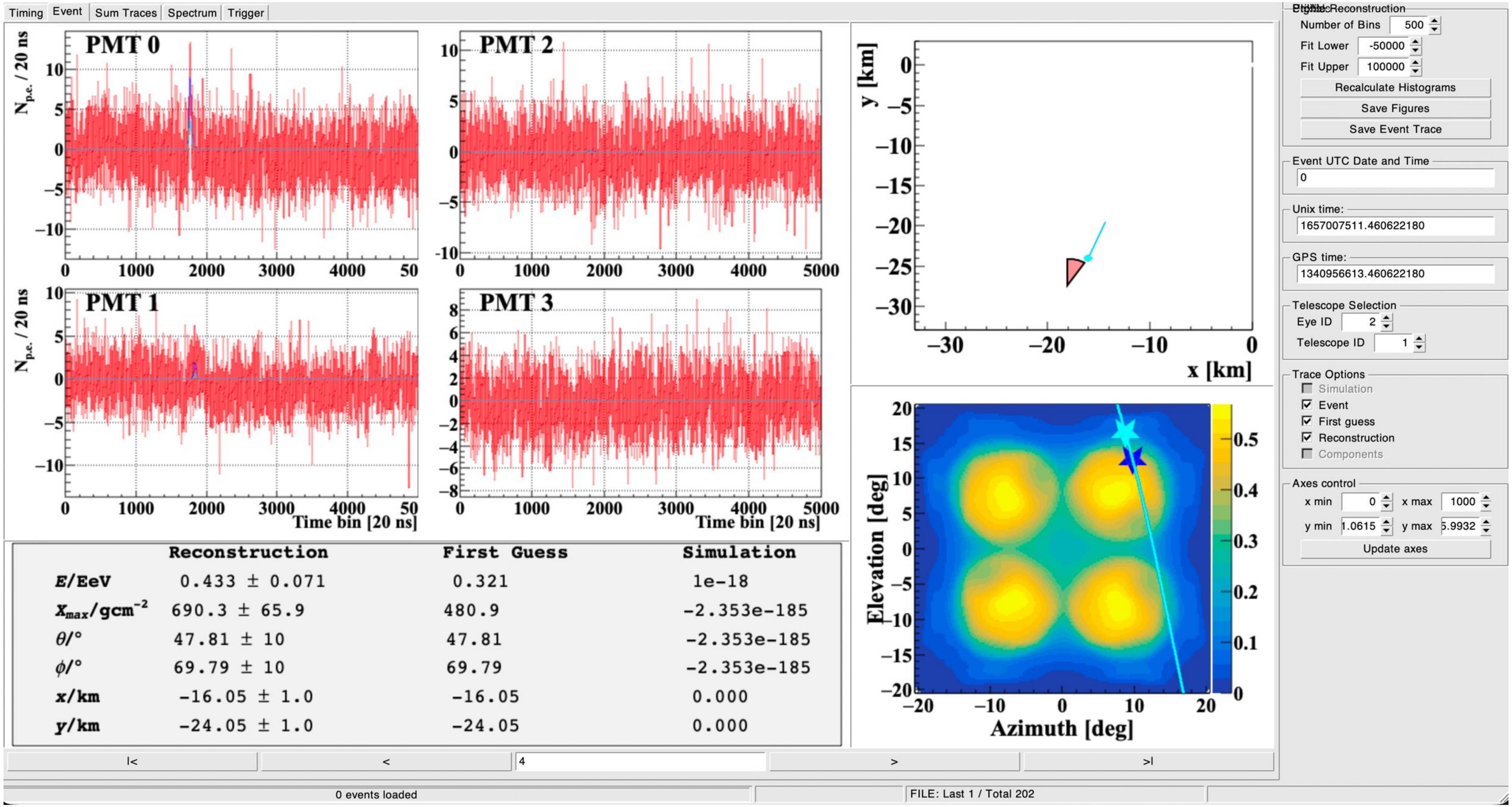
FAST Event Browser



FAST Simulation

- Current simulation uses **four** modules
  - **FASTProfileSimulator**
    - Defines a Gaisser Hillas profile of the # particles as a function of depth
  - **FASTEventGenerator**
    - Specifies core location of the event
  - **FASTSimulator**
    - Calculates light arriving at telescope aperture from shower axis
    - Applies FAST telescope response to estimate number of photo-electrons
  - **FASTEventFileExporter**
    - Applies noise to the final trace

"Theory"

"Measurement"

- Simulation NEEDS to match reality as closely as possible for accurate reconstruction – <u>must check each step carefully</u>

FAST Simulation

Ideally: Changes in mirrors used, PMTs used etc. need to be accounted for

- Current simulation uses **four** modules
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"Theory"

"Measurement"

- Simulation NEEDS to match reality as closely as possible for accurate reconstruction – <u>must check each step carefully</u>

FAST Profile Simulator

STEP 1: Define primary particle

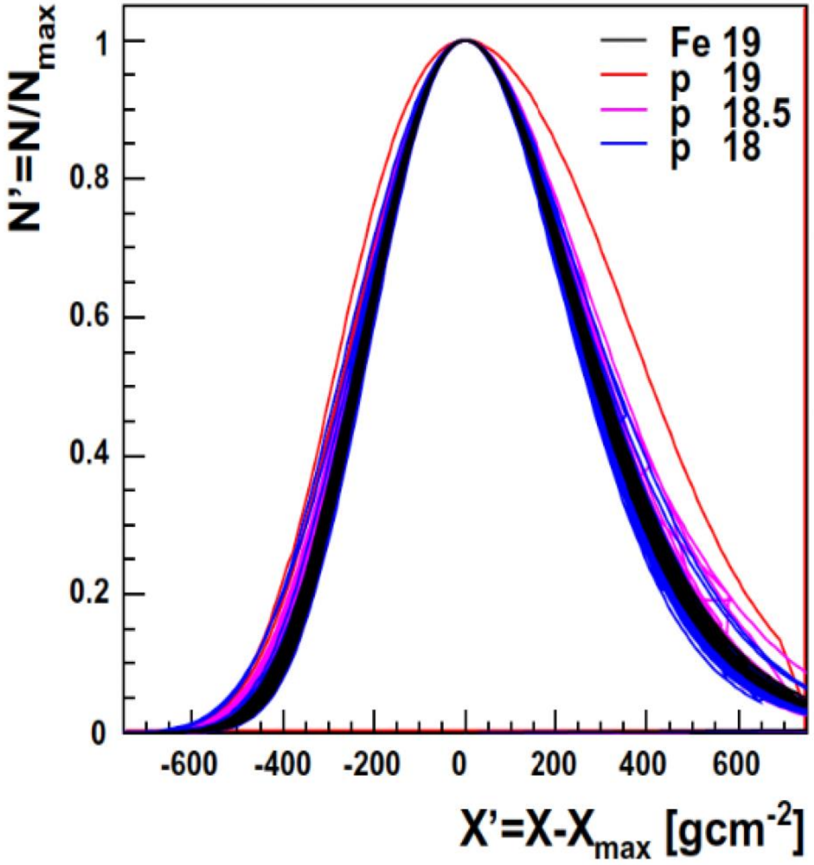
Simulation	Reality
• Default to proton	• Could be any nucleus from proton to iron (possibly heavier)

Validity?
- Low – mass composition changes with energy

Problems?
- Different primaries exhibit slightly different longitudinal profile shapes

  (→include profile shape parameters in fit?)

Importance?
- Low – differences induced small relative to other factors (?)



S. Andringa, R. Conceicao, and M. Pimenta (2011)

FAST Profile Simulator

STEP 2: Define molecular atmosphere

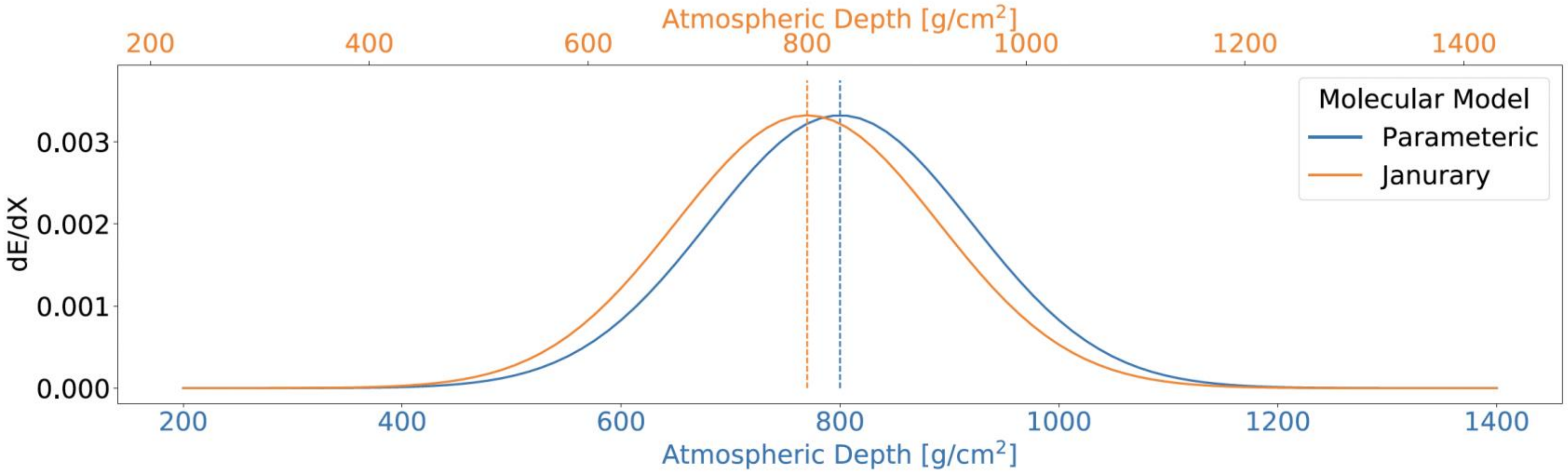
Simulation	Reality
• Can choose between monthly avg. models at Malargüe, US std. atm., or parametric atm.	• Continuously changing (relatively slowly?)

Validity?
- OK? (How much can molecular atm. change nightly?)

Problems?
- Region of development viewed by telescope in sim. may be different to reality

Importance?
- Low – ?

Albury (2020)



FAST Profile Simulator

STEP 3: Create energy deposit profile
3a) Choose parameterization of profile

Simulation	Reality
• Use traditional Gaisser Hillas function $$\frac{\mathrm{d}E}{\mathrm{d}X}(X) = \left(\frac{\mathrm{d}E}{\mathrm{d}X}\right)_{\max} \left(\frac{X - X_0}{X_{\max} - X_0}\right)^{\frac{X_{\max}-X_0}{\lambda}} \exp\left(\frac{X_{\max} - X}{\lambda}\right)$$	• No certain shape

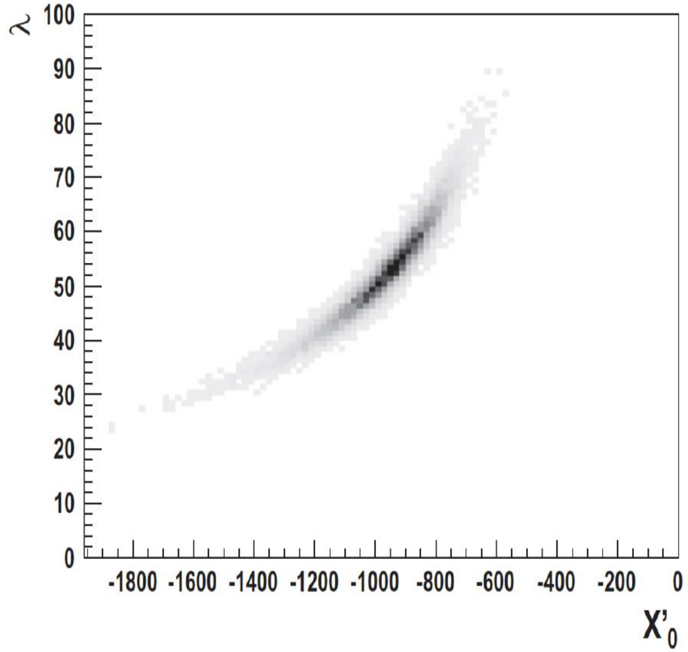
Validity?
- OK? – validated by previous experiments

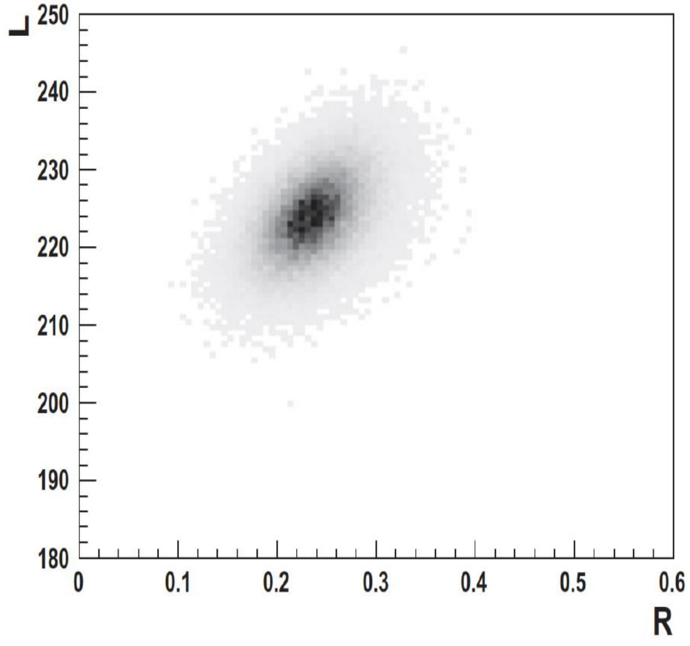
Problems?
- Functional form different from reality
- Degeneracy between shape parameters

(→switch to L and R parameterization?)

Importance?
- Low – medium ?

S. Andringa, R. Conceicao, and M. Pimenta (2011)





FAST Profile Simulator

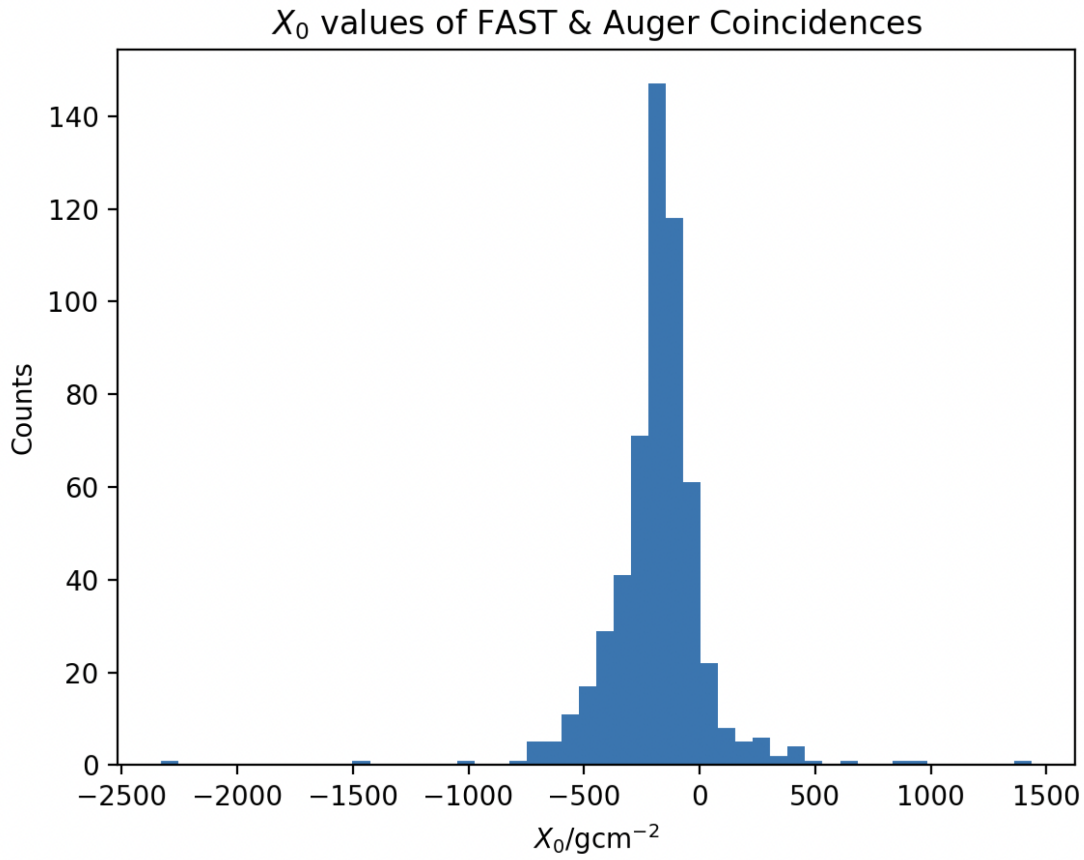
STEP 3: Create energy deposit profile
3b) Set starting depth

Simulation	Reality
• Use value of X_0 if positive, otherwise set to 0.01g/cm^2	• First interaction depth depends on primary

Validity?
- Low – X_0 doesn't strictly represent starting point

Problems?
- Assumed profile offset may be different

Importance?
- Low – medium ?



FAST Simulator

STEP 1: Calculate light reaching aperture

Simulation	Reality
• Default to proton	• Could be any nucleus from proton to iron (possibly heavier)

Validity?

Problems?

Importance?

FAST Simulator

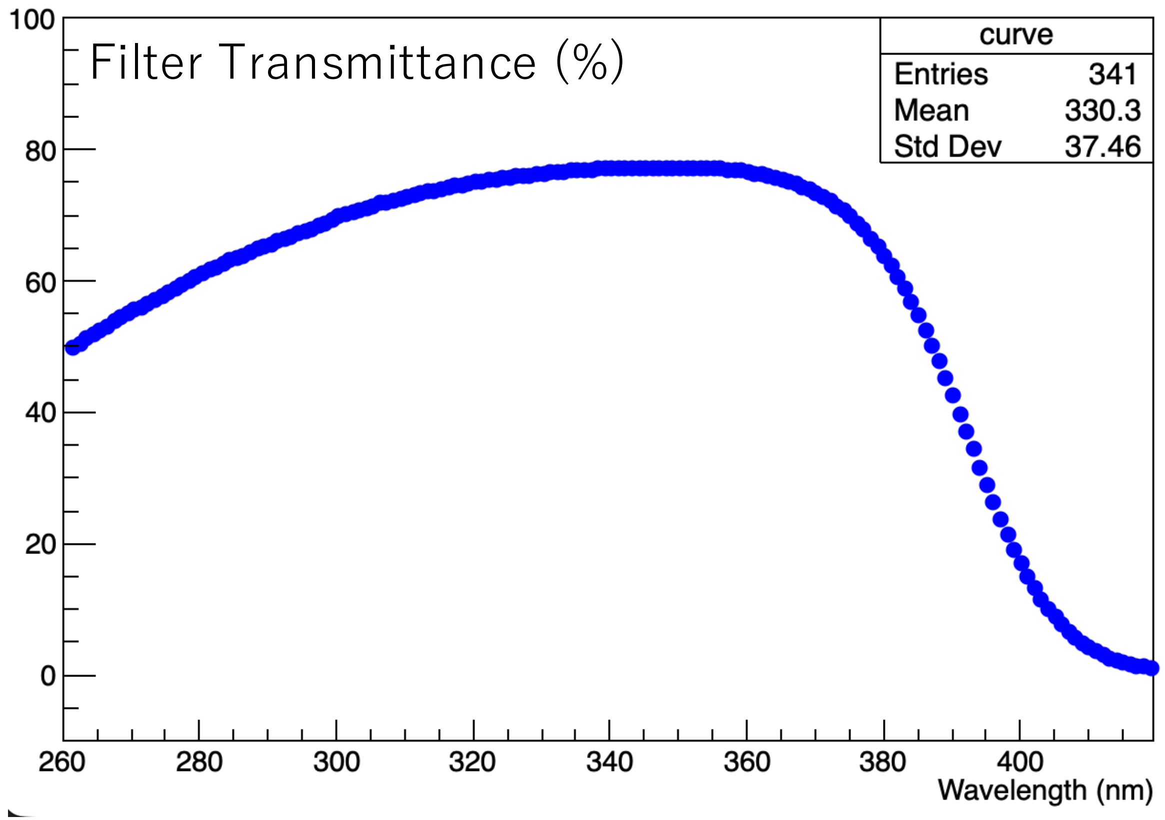
STEP 2: Apply UV filter

Simulation	Reality
• Use the same transmittance curve for each filter • Measured by ? in ?	• Light is attenuated based on wavelength

Validity?
- Good – ?

Problems?
- Filter transmittance can change over time, particularly with build up of dust on filter
  - (10% over 2 years?)

Importance to improve?
- Low – ok for now



FAST Simulator

STEP 3: Apply directional efficiency map

Simulation	Reality
• Use maps • Constructed by Martin/Mira using ray tracing simulations and lab / in-situ measurements	• (Slightly) different for every telescope due to individual PMT differences

Validity?

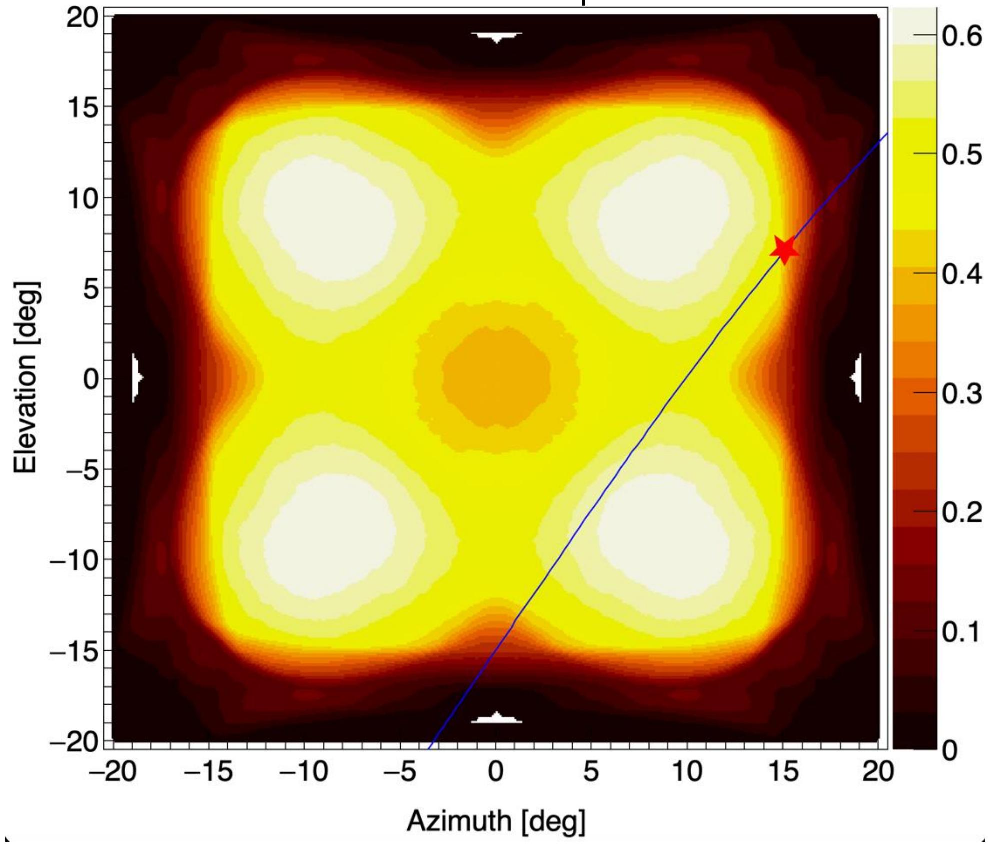
•

Problems?

Importance to improve?

- High?

Ideal map



FAST Simulator

STEP 3: Apply directional efficiency map

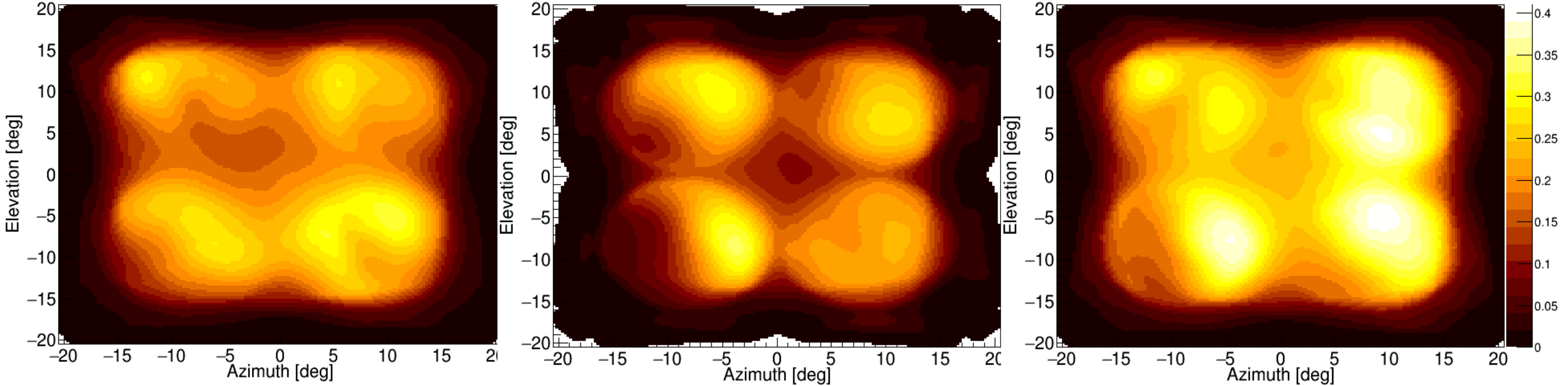
Simulation

- Use maps
  - Constructed by Martin/Mira using ray tracing simulations and lab / in-situ measurements

Reality

- (Slightly) different for every telescope due to individual PMT differences

Examples of directional efficiency maps from TA – very different!
Need to understand how large of an effect assuming same map is



FAST Simulator

STEP 4: Apply quantum efficiency curve

Simulation	Reality
• Use • Measured by ? in ?	

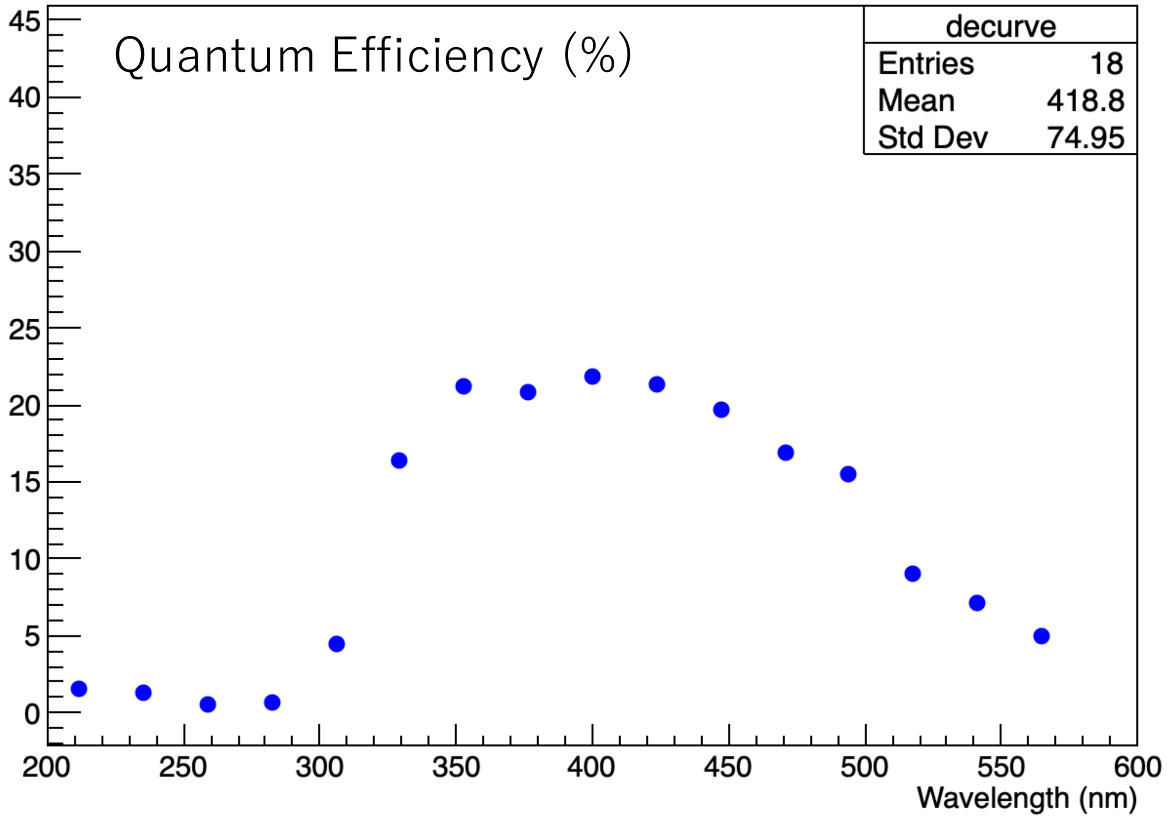
Validity?

- OK –

Problems?

Importance to improve?

- Low – ?



Discussion

- What measurements do we need to redo, or include in the simulation from the new FAST Field telescopes?
- How to include new measurements from Martin?
  - What do we need?

Backup

FAST Profile Simulator

STEP 3: Create energy deposit profile
3c) Calculate max number of particles

Simulation	Reality
• Use formula from Augers "FDSim" • "depth" in below formula = "xMax"	• Can reach upwards of 10^{10} particles, maximum determined by primary energy and

```
double auxXMax = xMax - xZero;

gaisserHillas = (auxXMax*(log(depth/auxXMax) + 1) - depth)/utl::kLambdaGH
+ log(pow(10.0, (log10(energy) - 9.215)));
```

Validity?
- ? (Where does this formula come from?)
  (implemented by M.M. – taken from "FDSim")

Problems?
- Assumed profile offset may be different

Importance?
- Medium?