MIDAS simulation

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Summary

- Shower simulation
  - Gaisser-Hillas generation
  - Geometry generation and time
  - Profile sampling
  - Flux calculation
- Detection simulation
  - Horn relative gain calculation
  - ADC count simulation
  - Triggers

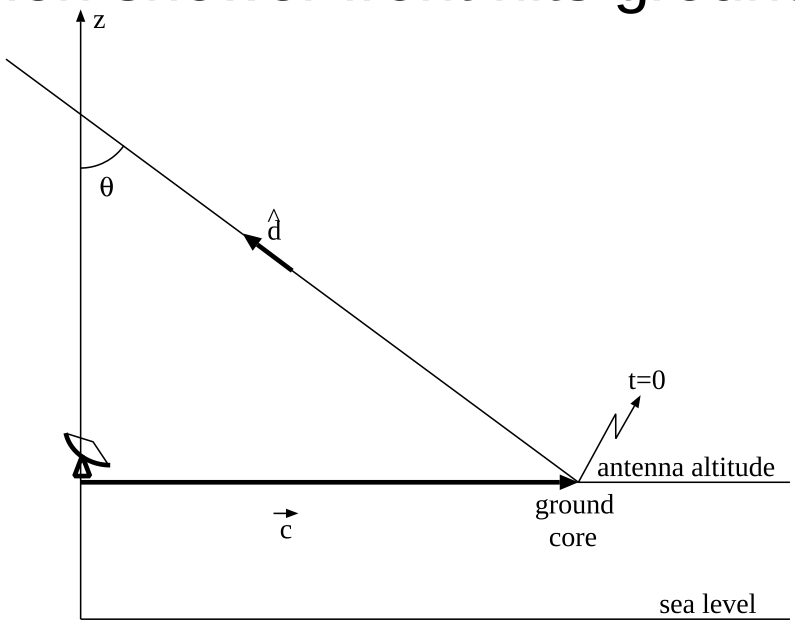
GH generation

- Based on GAP 2005-87
- GH parameters X_0, $\log N_{max}$, X_{max} and λ have approximate gaussian distributions. (first interaction depth X_1 exponenential).
- Mean and σ obtained from CORSIKA fits for every parameter (used linear interpolation in energy).
- GH described in slant depth (describes any θ)
  - Used a factor $f = \cos\theta$ to transform to vertical depth, and X_1 to dislocated the GH.

$$N(X) = N_{max}\left(\frac{\frac{X}{f}-X_1-X_0}{X_{max}-X_0}\right)^{\left(\frac{X_{max}-X_0}{\lambda}\right)}\exp\left(\frac{X_{max}-\frac{X}{f}-X_1}{\lambda}\right)$$

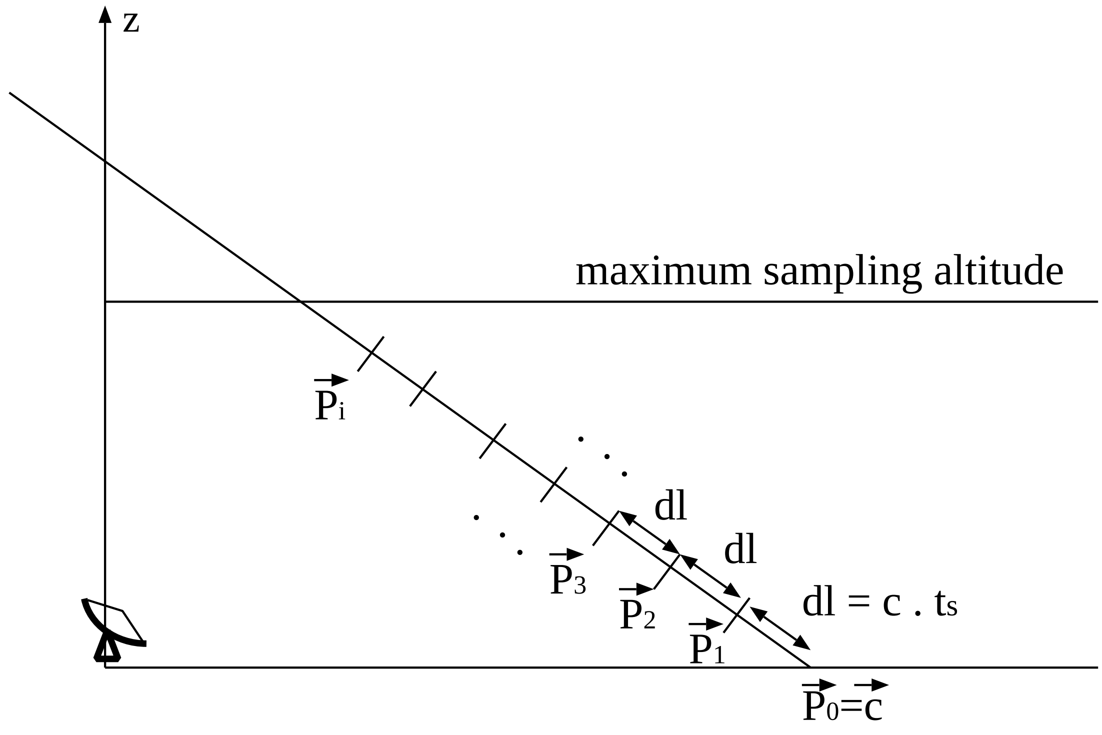
Shower Geometry and time origin

- Antenna system of coordinates (cartesian and spherical).
  - Origin on antenna.
  - Antenna FOV facing positive y, z is vertical.
- Ground core position $\vec{c}$ equally distributed in area.
- Isotropic shower direction $\hat{d}$.
- Time $t = 0$ when shower front hits ground.



Profile Sampling

- Profile sampling time $t_s \rightarrow$ sampling legth $dl = c \cdot t_s$
- Setable maximum sampling altitude A_{max} (saves time and disk space)
  - $N_s = \frac{A_{max} - A_{ant}}{dl \cdot c_z}$



Emission Points $\vec{P}_i$, N_i and ratio ρ_{r_i}

- Calculated from dl and $\vec{d}$
  - $P_{xi} = c_x + i \cdot dl \cdot d_x$
  - $P_{yi} = c_y + i \cdot dl \cdot d_y$
  - $P_{zi} = i \cdot dl \cdot d_z$
- Altitude of emission point i: $A_i = P_{zi} + A_{ant}$ is transformed to vertical depth X_i using Linsley parametrization.
- Number of particles N_i at emission point using GH.
  - $N_i = N(X_i)$
- Density ratio $\rho_{r_i} = \rho_i / \rho_0$ at emission altitude A_i is calculated using atmosphere77 parametrization.

Flux calculation

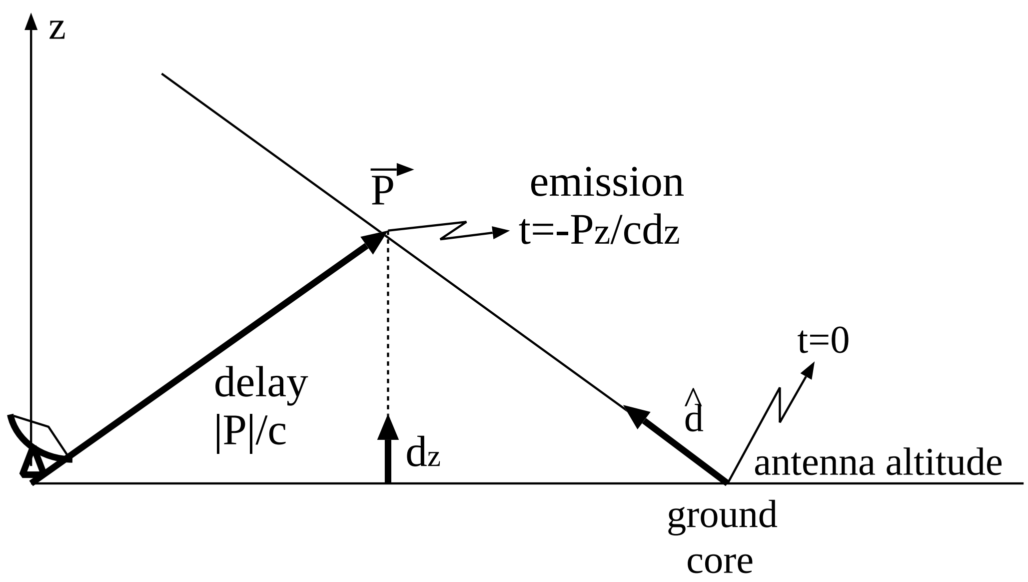
$$F_i = F_{ref} \cdot \rho_{r_i} \cdot \Gamma \cdot \left(\frac{D_{ref}}{|\vec{P}_i|} \right)^2 \cdot \left(\frac{N_i}{N_{ref}} \right)^S$$

- $S = 1$ or 2: Linear or quadratic scaling (Gorham)
- $F_{ref} = 4 \cdot 10^{-16} W/m^2 Hz$: Reference flux (Gorham)
- $\Gamma = L_0/L_\tau = 4.62$: Correction due to chamber size (Gorham)
- $D_{ref} = 0.5m$: Distance from antenna (Gorham)
- N_{ref}: N_{max} of the average GH for an $E_{ref} = 3.36 \cdot 10^{17} eV$ shower (Gorham)

Time

- Emission time: $-\frac{P_z}{c \cdot d_z}$
- Reception delay: $\frac{|\vec{P}_i|}{c}$

$$t_i = -\frac{P_z}{c \cdot d_z} + \frac{|\vec{P}_i|}{c}$$

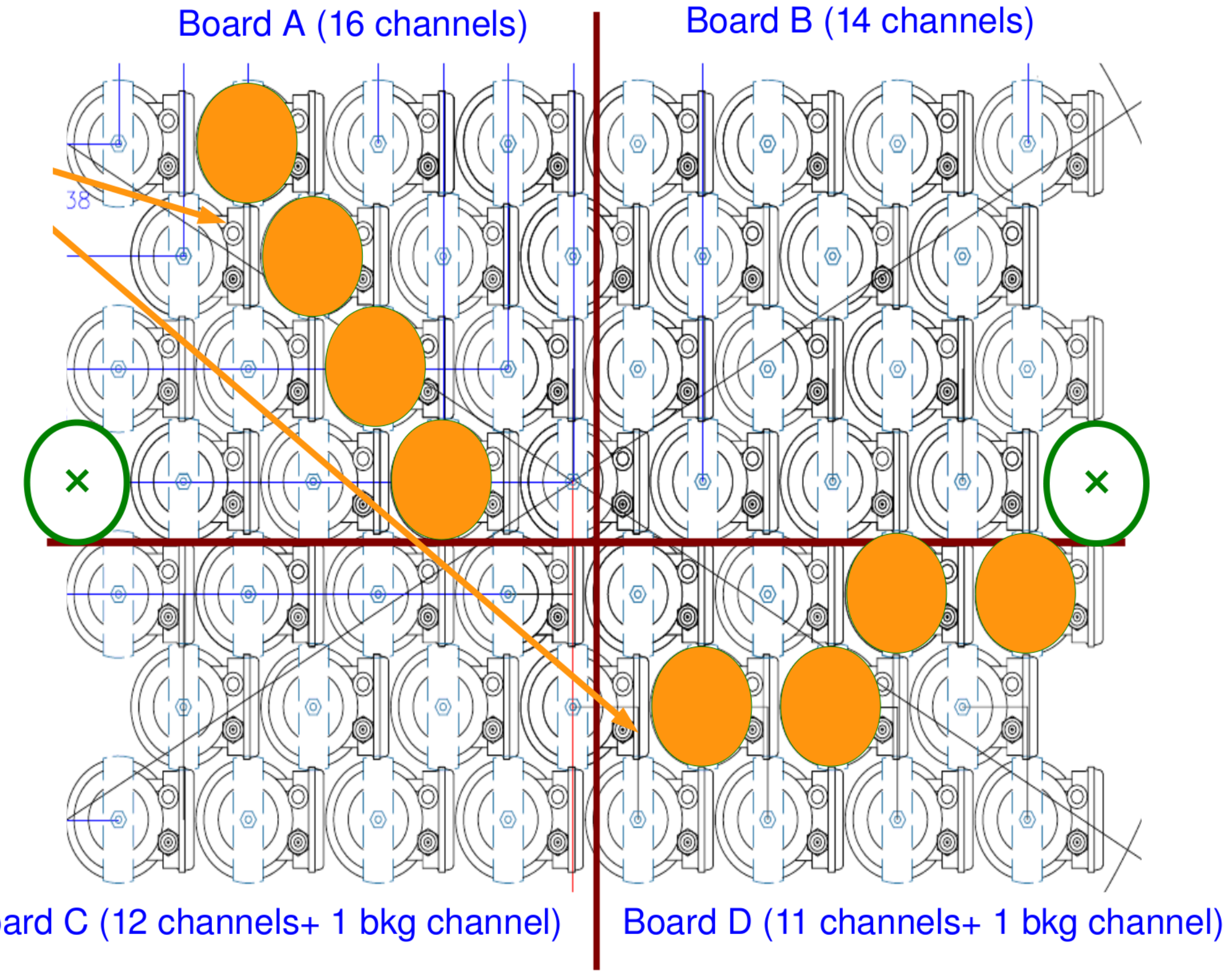


Flux output

- Depends on antenna altitude.
- Depends on emission scaling.
- Does not depend on any other antenna parameters.
- A single flux simulation can be used for multiple antenna settings (e.g. FOV elevations)
- Saves all i emission points for each shower: $(P_R^i, P_\theta^i, P_\varphi^i, P_x^i, P_y^i, P_z^i, t^i, F^i, \chi^i)$
- Saves shower data for each of the j showers: $(E_0^j, \theta^j, \varphi^j, c_x^j, c_y^j, t_0^j, R_p^j, \psi^j, [p/Fe]^j)$

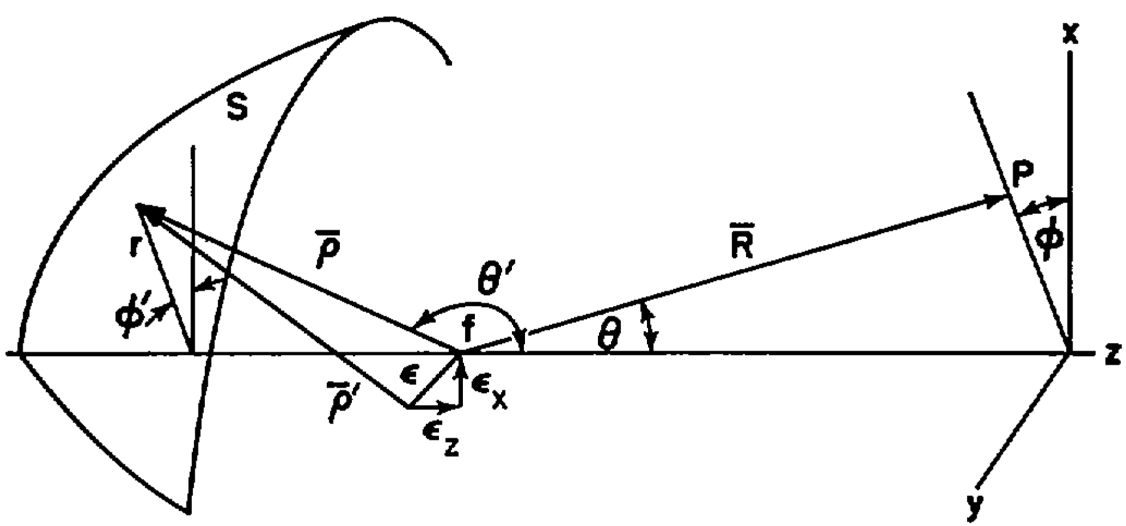
Camera

- Plane camera with 53 horns.
- Horns divided into 4 boards.

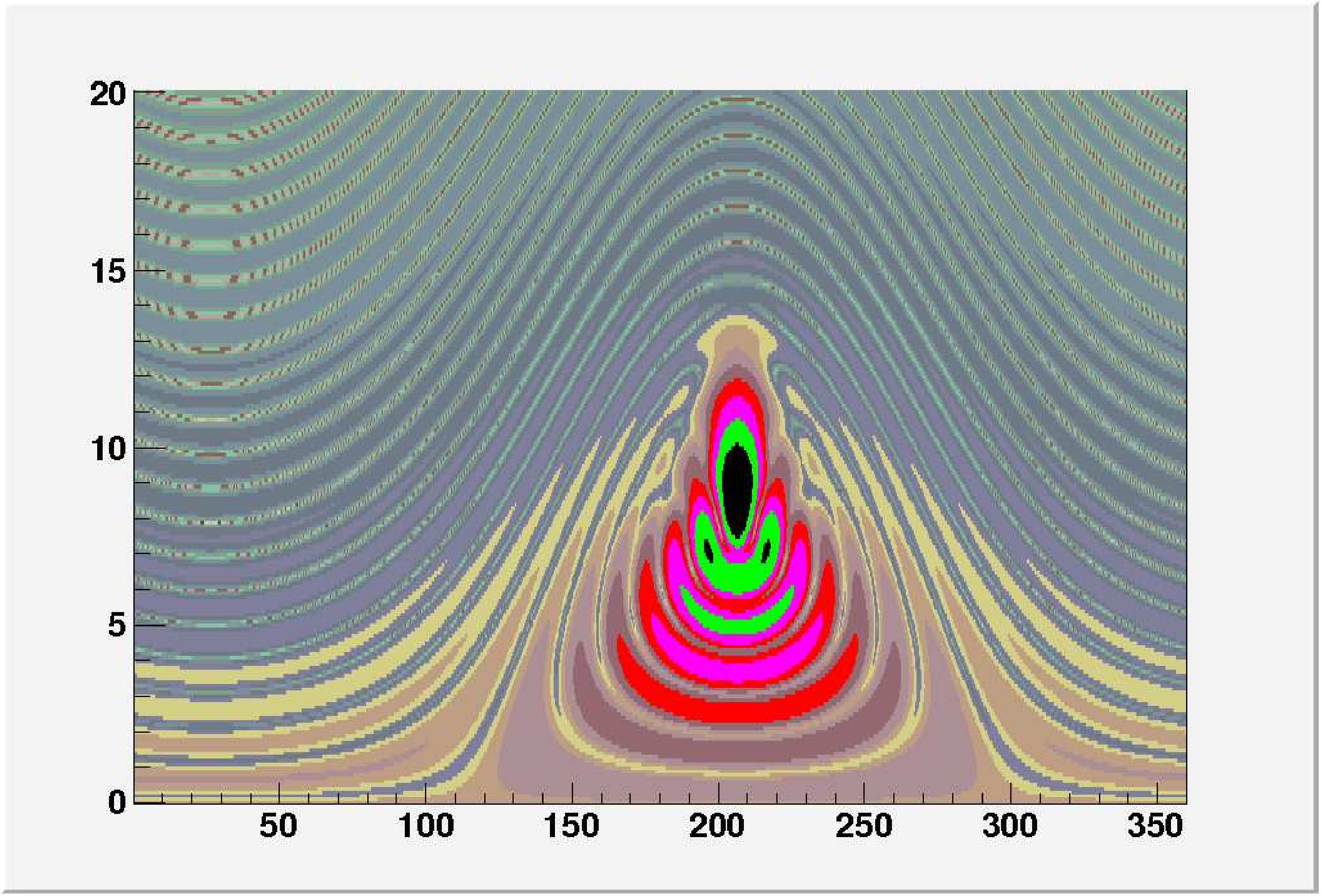


Horn Gain calculation

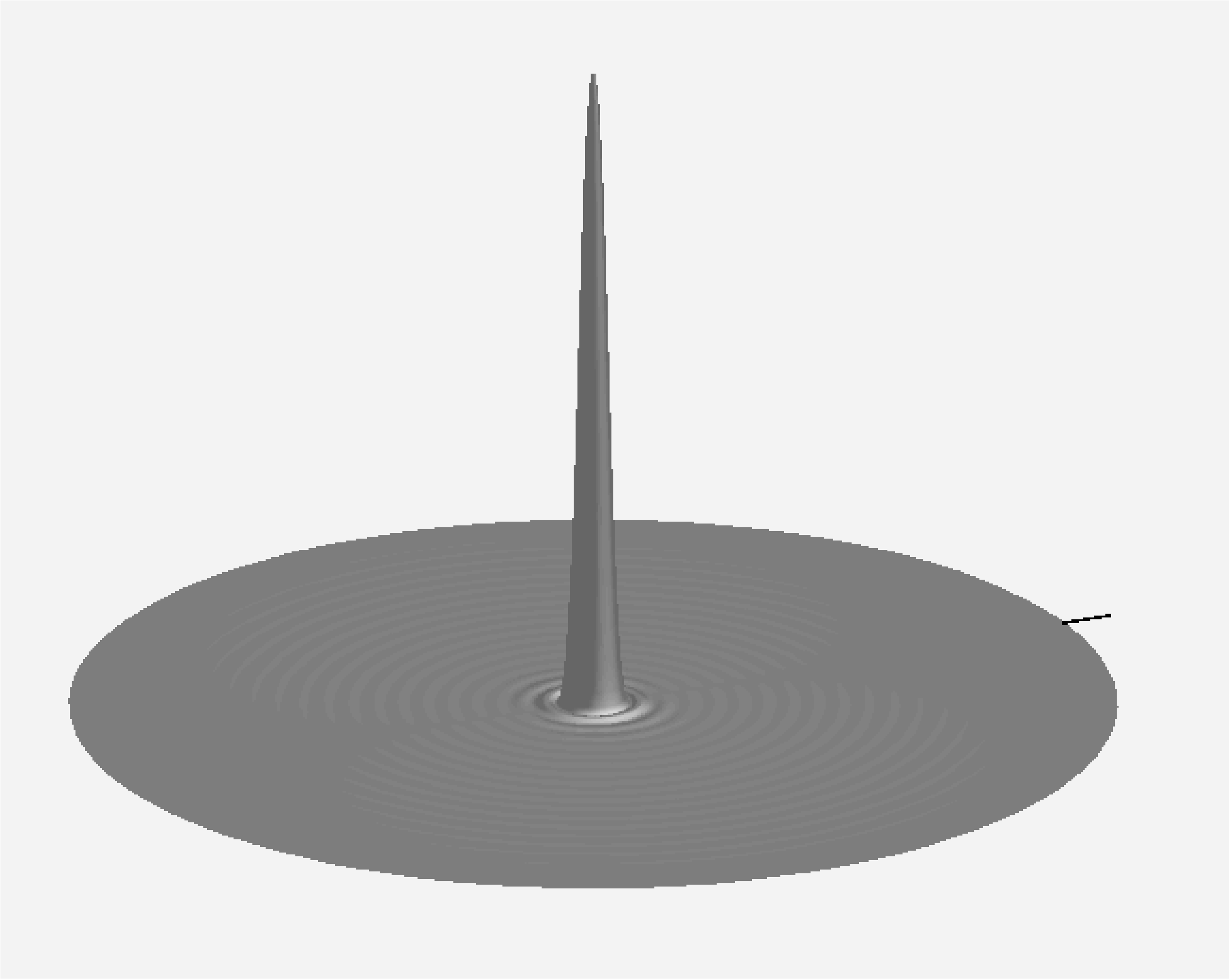
- Ruze, *Parabolic Feed Displacement*, IEEE transactions on antennas and propagation, september 1965.
- Double integral using cerlib's DADMUL.
- Camera shadow not taken into account.
- $\theta \in [0, 20°]$, $\phi \in [0, 360°]$ in steps of $0.1°$



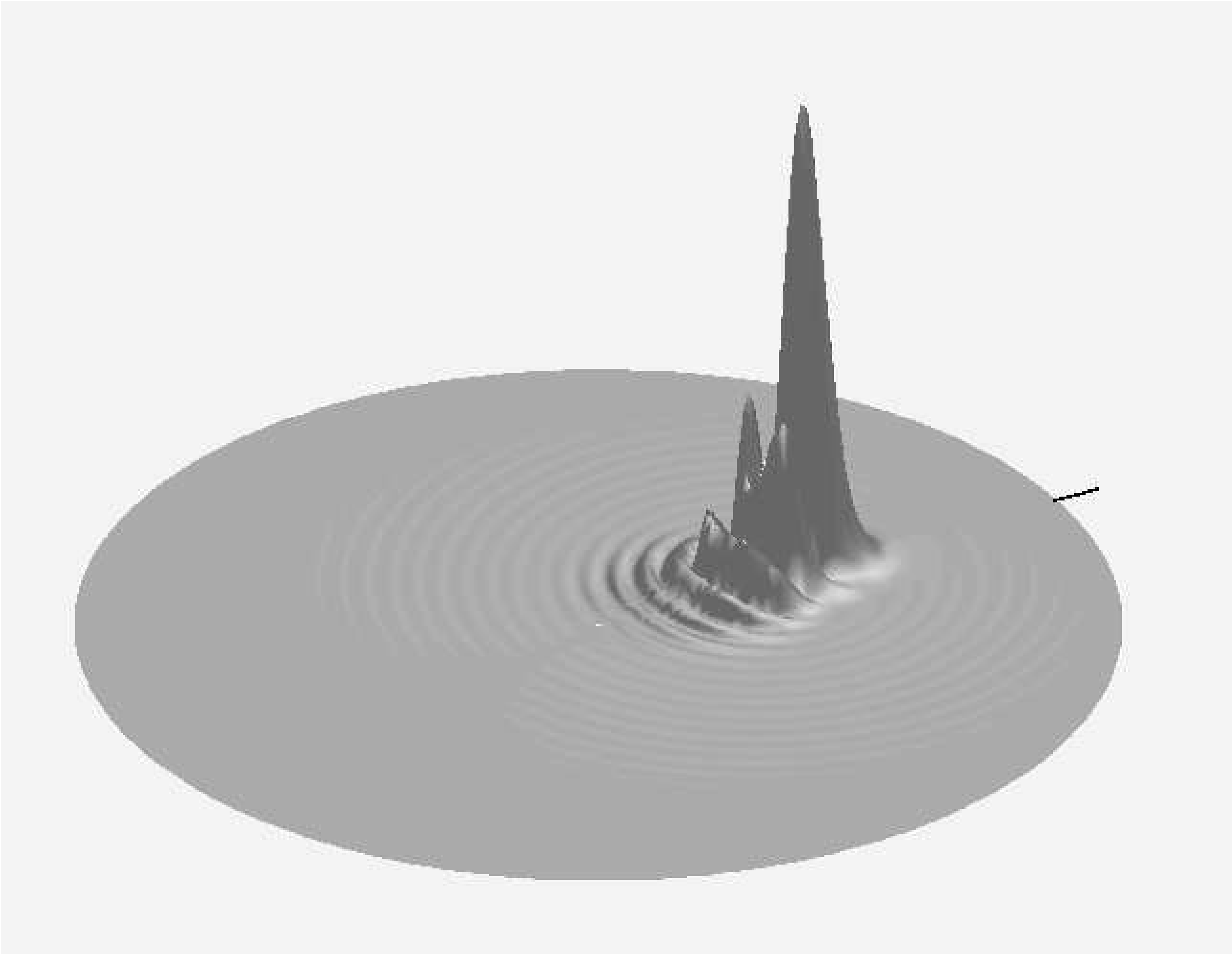
Gain examples



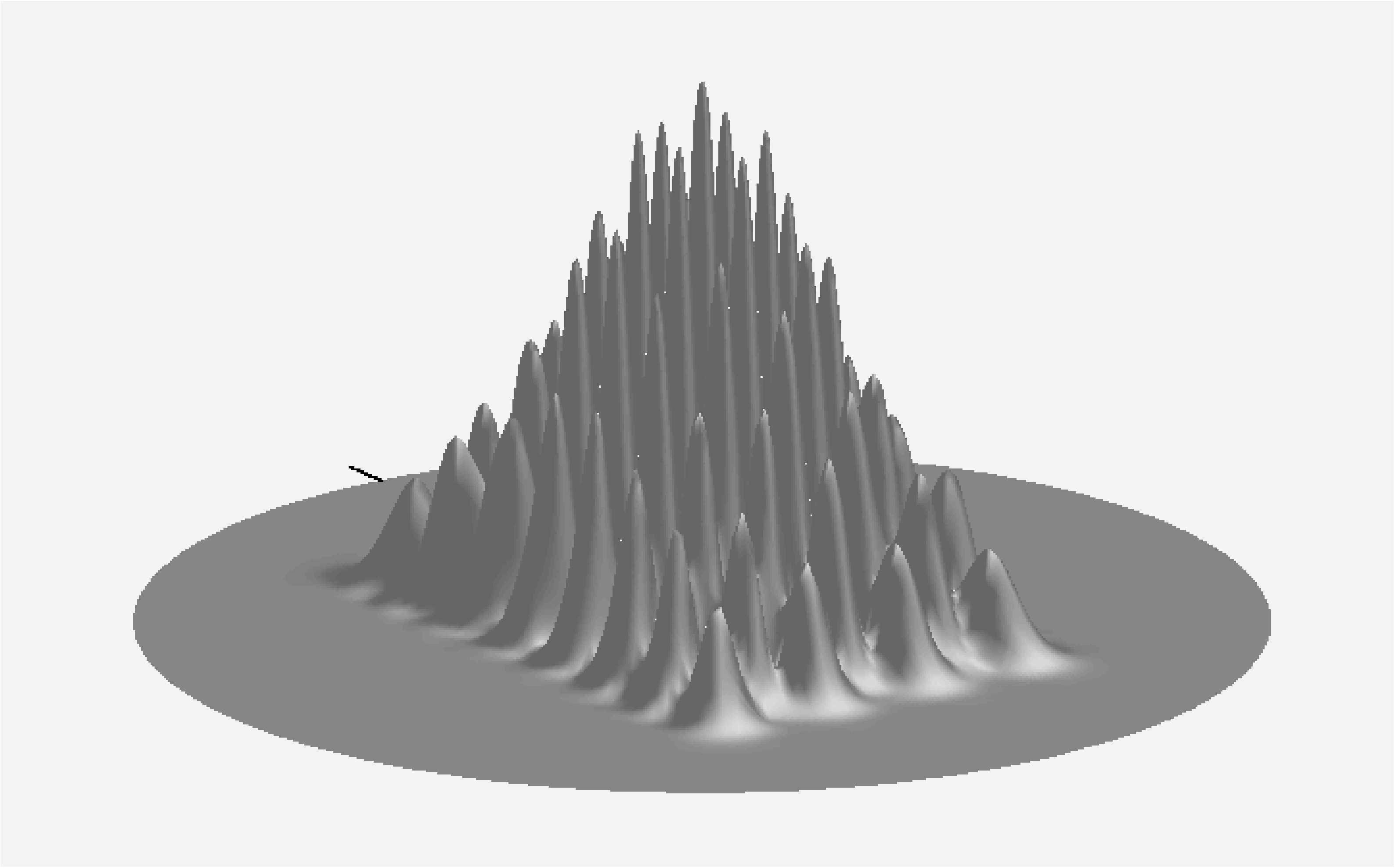
Gain examples - central pixel



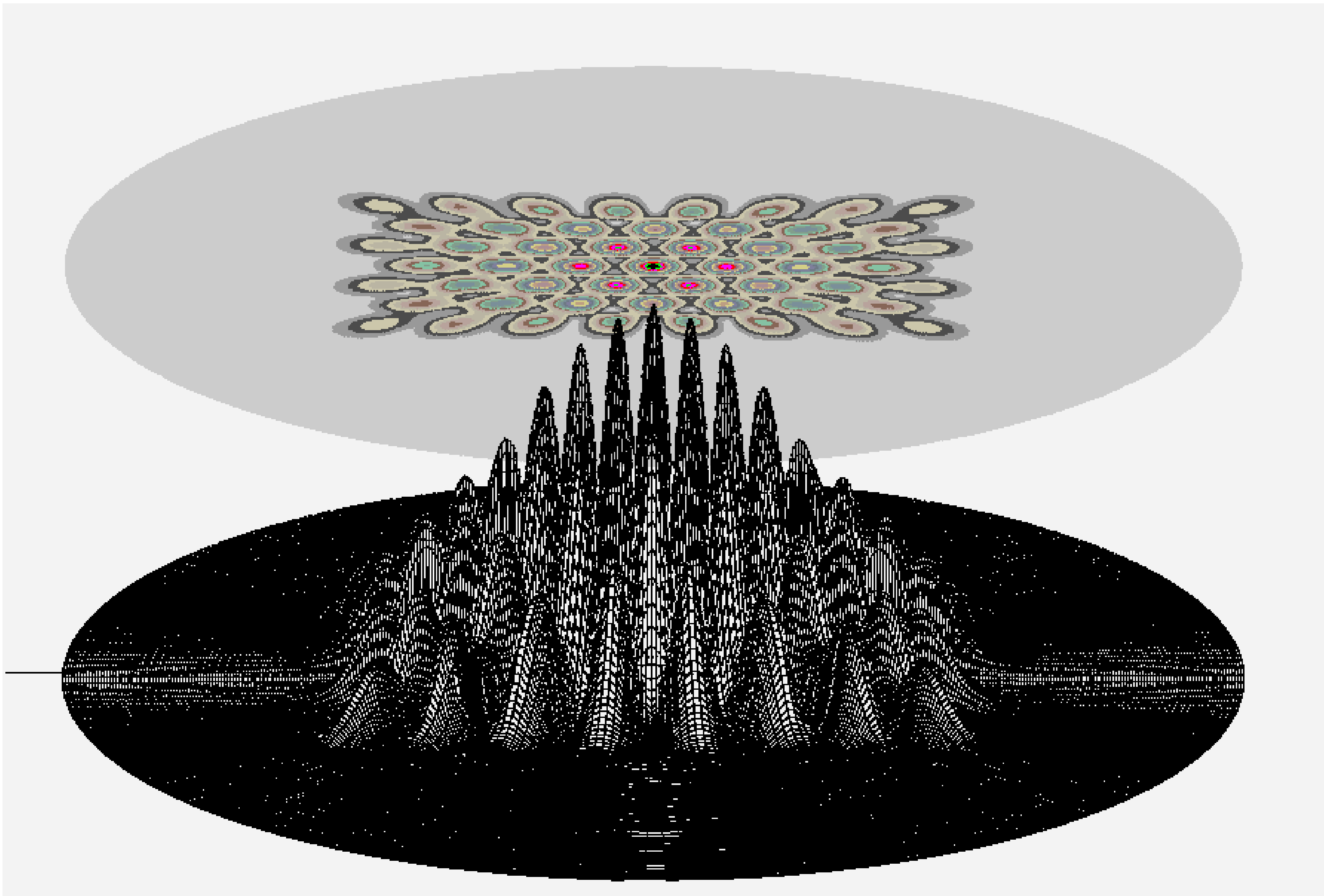
Gain examples - dislocated pixel



Full gain map



Full gain map



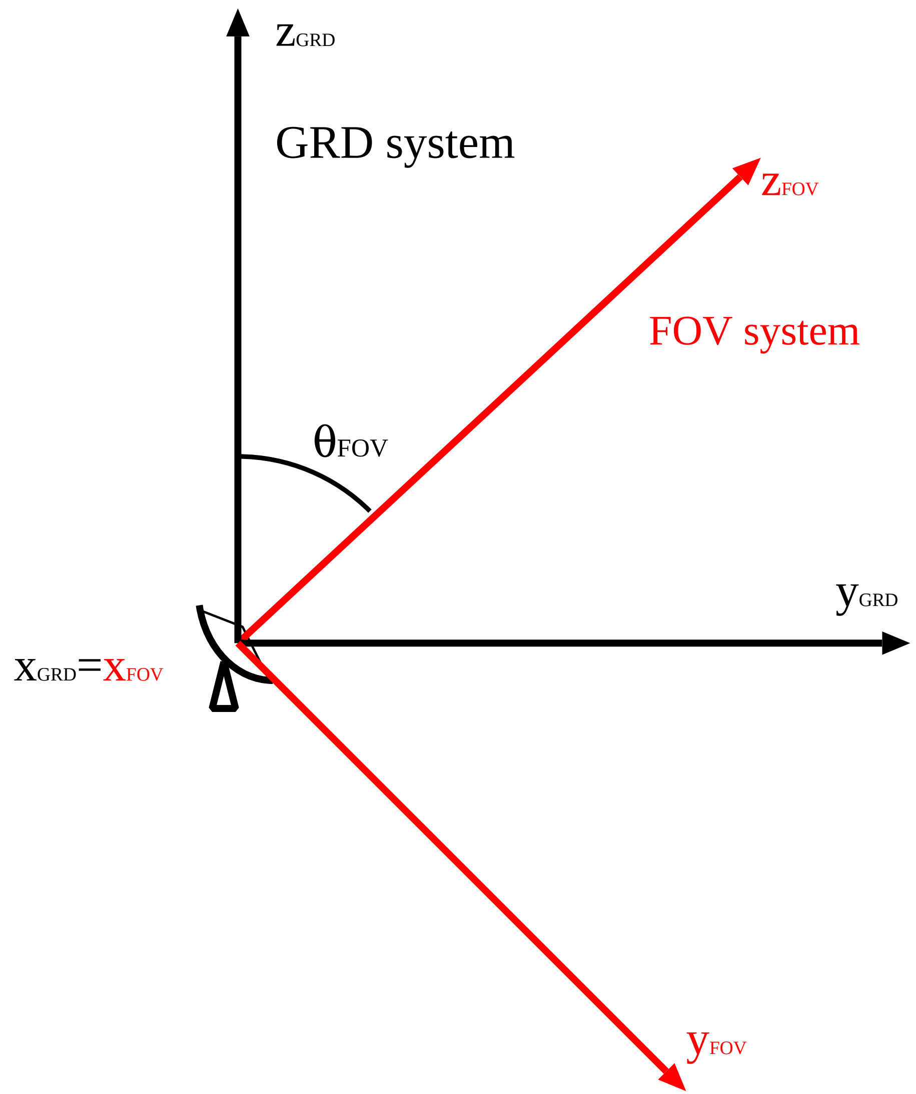
ADC count simulation

- Input:
  - Emission point data (Flux, time, position, etc...)
  - Gain Map (Normalized to 1 at center of central pixel)
  - Shower Data (E_0, core position, etc...)
- Output: Root files
  - simulation format
  - MidasEvent (midas-online)
- Some parameters:
  - FOV elevation
  - Acquisition time t_{acq} (50ns)
  - Calibration parameters (baseline, σ_{ADC}, slope, etc...)
  - Trigger parameters (FLT window, thresholds, etc...)

Time references and Coordinate systems

- Time references:
  - Flux calculation time reference
    - t=0 when shower hits ground
  - ADC time reference
    - t=0 when shower enters FOV of antenna
  - MIDAS time reference
    - t=0 25μs before 1st SLT
- Coordinate systems:
  - GRD system: same as Flux simulation
  - FOV system z-axis in the direction of the central pixel
  - Systems related by a rotation around x-axis of θ_{FOV}
  - Gain map described in FOV system
    - independent of θ_{FOV}

Coordinate Systems

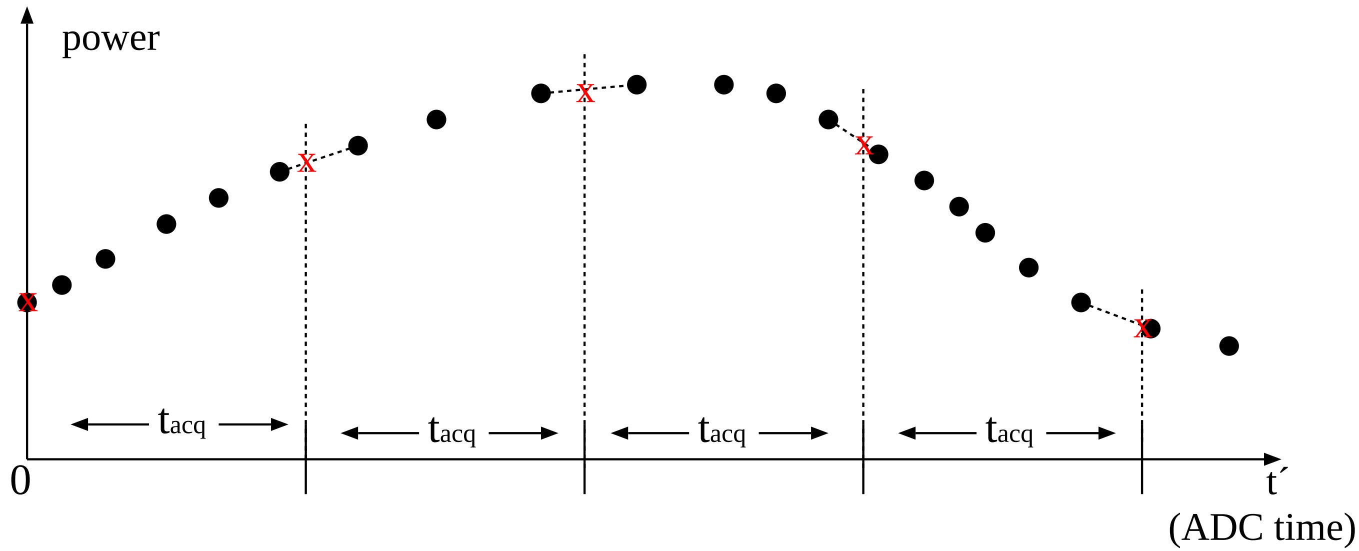


Procedure

- Read emission point in GRD system $(\theta_{GRD}, \varphi_{GRD})$
- Rotate by $\theta_{FOV} \rightarrow$ Emission point in FOV system (θ_F, φ_F)
- If emission point is in FOV $\theta_F < 20^\circ$ loop over all horns
  - Calculate gain $G(\theta_F, \varphi_F)$ for the emission point
    - Gain map interpolation
  - Calculate “power” $P = G \cdot F$
  - Look for overall t_{min} and t_{max}
    - At $t = t_{min}$ shower enters FOV.
    - At $t = t_{max}$ shower leaves FOV or hits ground.
  - Save data (horn#, power P and time t) internally
    - A single emission point can be seen by several horns

ADC time and acquisition

- t_{min} relates Flux time and ADC time: $t_{ADC} = t_{flux} - t_{min}$
- Saved data time is transformed to ADC time.
- Flux is sampled starting at $t_{ADC} = 0$ at equal time intervals t_{acq}.
- Saved data “power” is interpolated (for each horn at the sampling times), obtaining a sampled “power”



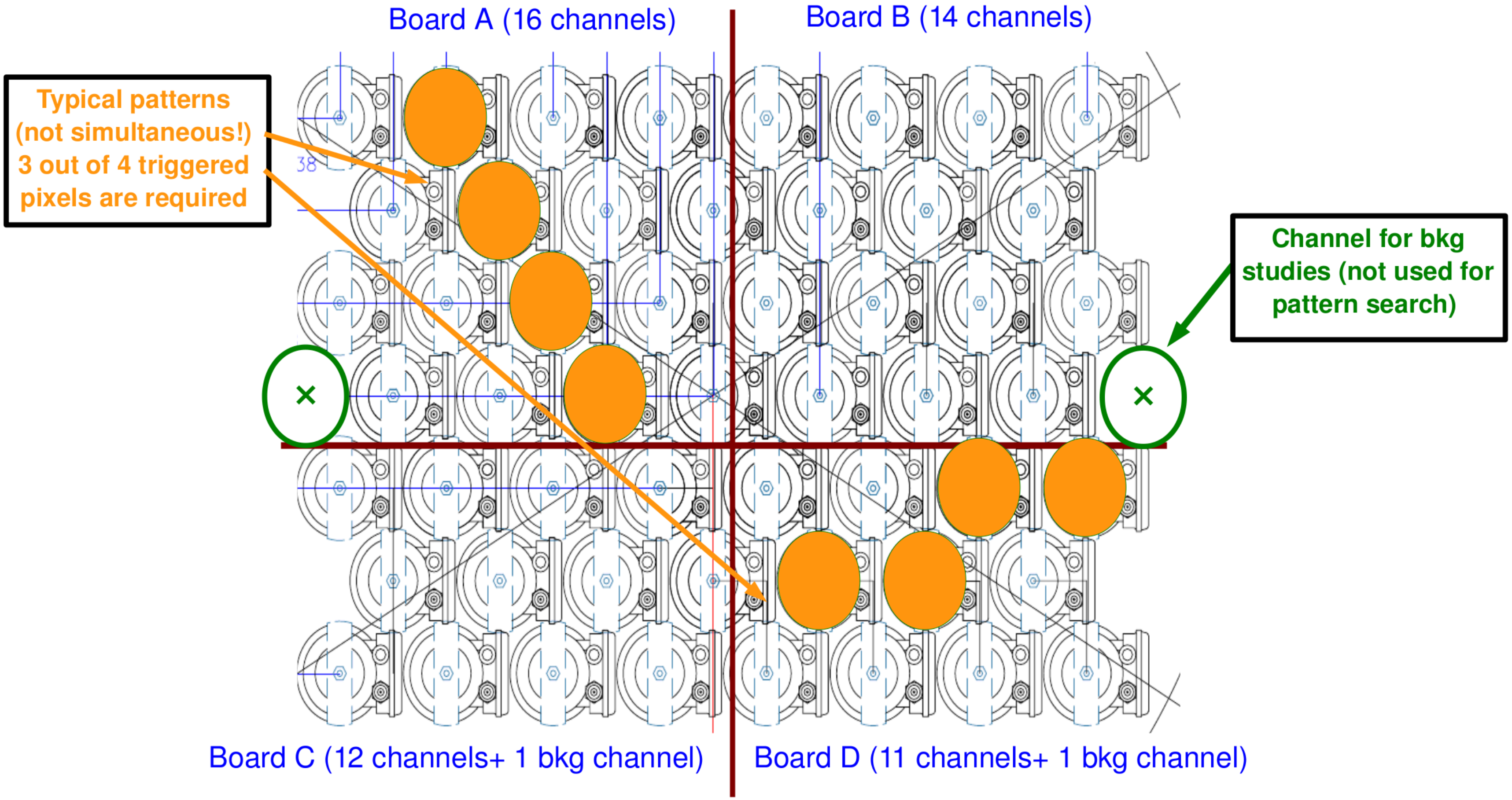
Power to ADC counts

- Interpolated power is transformed to ADC counts using calibration parameters:
  - baseline power in sfu units $P_{base} = 2.32$
  - baseline $ADC_{base} = 11180$
  - slope $S = 0.00584$
  - $dB_{ref} = S \cdot P_{base} + 10 \cdot \log_{10} P_{base}$
  - $\sigma_{ADC} = 71$
- $P_{tot} = P \cdot 10^{-22} + P_{base}$
- $dB = 10 \cdot \log_{10} P_{tot}$
- $N_{ADC}^{nonoise} = \frac{(dB_{ref} - dB)}{S}$
- $N_{ADC} = N_{ADC}^{nonoise} + Noise$ (sampled from a σ_{ADC} gaussian)

FLT

- Running sum of 20 bins ($ADC_{base} - N_{ADC}$)
- Triggers when sum greater than threshold T
- Sets window (FLT window) for SLT search

SLT



Board A (16 channels)
Board B (14 channels)
Typical patterns (not simultaneous!) 3 out of 4 triggered pixels are required
Channel for bkg studies (not used for pattern search)
Board C (12 channels+ 1 bkg channel)
Board D (11 channels+ 1 bkg channel)

SLT and Midas Output

- Analysis separated by boards
- 3-pixel pattern maps are used to look for patterns in a board, if 3 or more pixels inside the board have an open FLT window.
- The 1st SLT sets the origin for the MIDAS time reference
  - $t = 0$ $25\mu s$ before 1st SLT
  - Midas event ends at $t = 25+$PostSLTWindow μs
- When a pattern is found, the pattern code is saved
- MIDAS output
  - Times are transformed to the MIDAS time reference
  - An extra output file is created in the MidasEvent format

Questions?

Results after cuts

Uhecron $50GeV$, $30GeV$ **and** $20GeV$

$E_U\ (EeV)$	$E_p\ (EeV)$	N'_u/N_u	N'_p/N_p	N'_p/N'_T
320	320	0.417	0.022	0.081
352	320	0.402	0.043	0.152
108	100	0.366	0.039	0.143
54	50	0.299	0.016	0.080

$E_U\ (EeV)$	$E_p\ (EeV)$	N'_u/N_u	N'_p/N_p	N'_p/N'_T
352	320	0.400	0.053	0.178
108	100	0.344	0.043	0.159
54	50	0.257	0.015	0.078

$E_U\ (EeV)$	$E_p\ (EeV)$	N'_u/N_u	N'_p/N_p	N'_p/N'_T
352	320	0.390	0.062	0.198
108	100	0.359	0.057	0.188
54	50	0.411	0.071	0.198