MARIE – The Martian Radiation Environment Experiment

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martian radiation environment experiment
marie
mars '01 program

Before we open a second Mars Hotel…

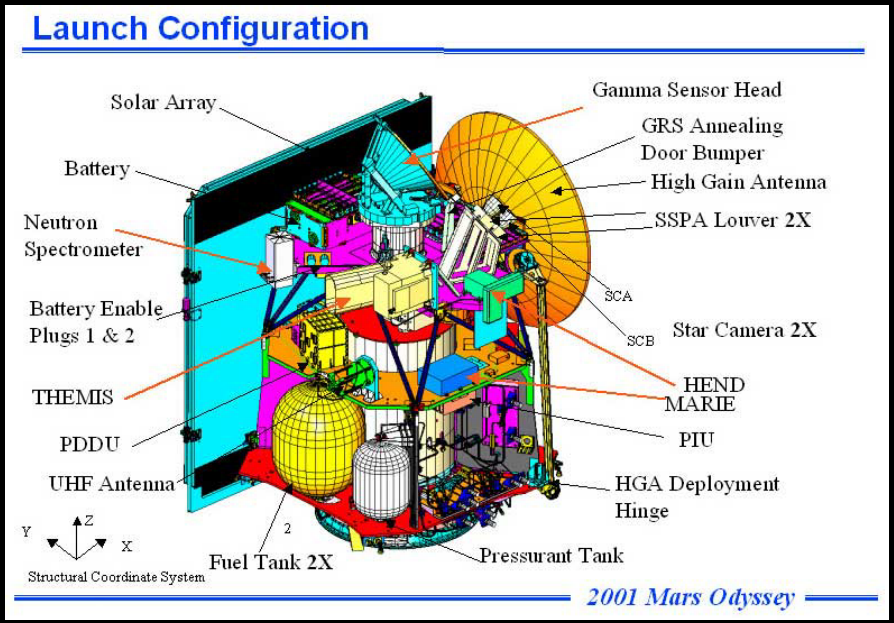
- Measurement of the radiation field on the surface of Mars is a necessary precursor to human exploration.
- Lander component of Odyssey was scrapped but possible opening for ’07.
- Orbital data + transport model is a good first step. MARIE is returning the first detailed orbital data.

History

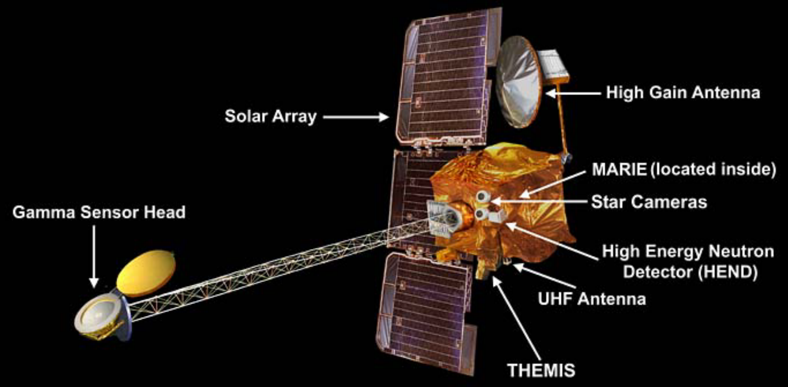
- Launched in April 2001 on Mars Odyssey, arrived at Mars October, orbit stabilized in Feb. 2002 after highly successful aerobraking.
- Orbit is circular, polar, 400 km above mean surface.
- Some data obtained during cruise to Mars, but error condition in Aug. 2001 resulted in turn-off until orbit was stabilized.
- Successfully revived in March 2002. Mission life > 3 yrs.

Orientation

- Odyssey has 3 science instruments: GRS, THEMIS, MARIE.
- GRS and THEMIS point at surface.
- MARIE points along the anti-velocity vector (~ at horizon).



2001 Mars Odyssey Orbiter
Science Orbit Configuration - GRS Boom Deployed

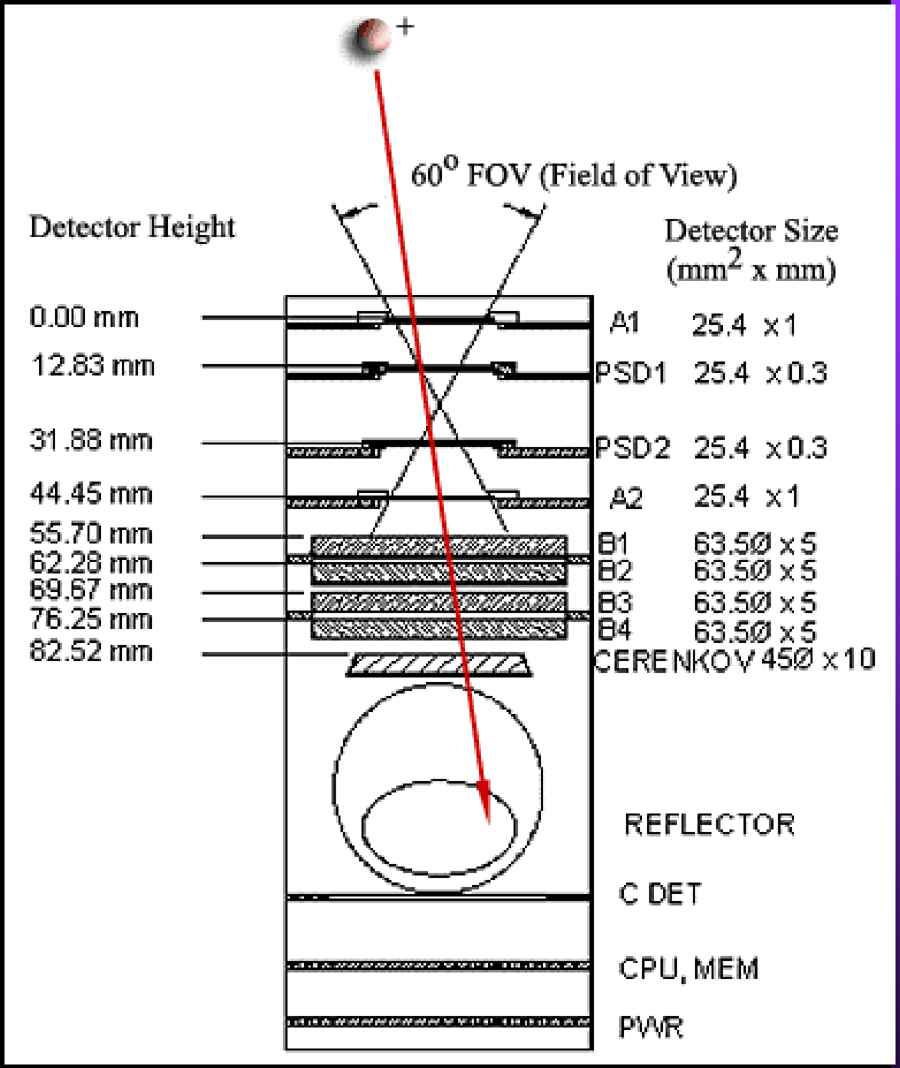


Instrument Package

- Dimensions – 30 cm x 20 cm x 10 cm
- Mass – 3.46 kg
- Power Consumption
  - 3 Watts (survival mode)
  - 7 Watts (science mode)

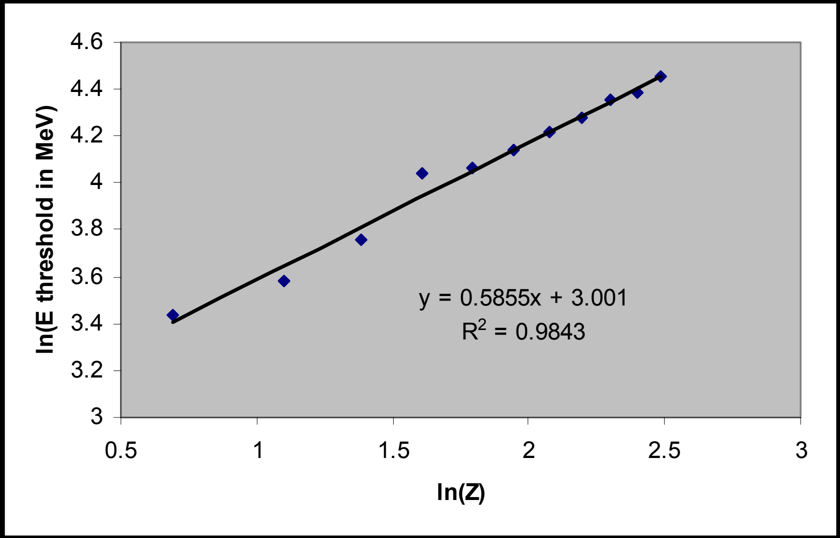
Instrument Details

- A's are 1 mm thickness, B's 5 mm.
- Trigger is A1*A2.
- Due to noise, high trigger rate when thresholds low; raised so highest-energy protons are missed. Minimum LET approx. 0.5 keV/μm.
- A1*A2 geometry factor is ~ 3.2 cm^2 sr.



Trigger Threshold

- Function of incident ion's Z, A, E, θ. For protons, 30 MeV; for ^{20}Ne, 78 MeV/amu; reasonably fit by a power law in Z.
- For backwards going, min. proton energy is 72 MeV at normal incidence, for ^{20}Ne, 420 MeV/amu incident on B4 (much higher before entering Odyssey), with considerable losses due to nuclear interactions.

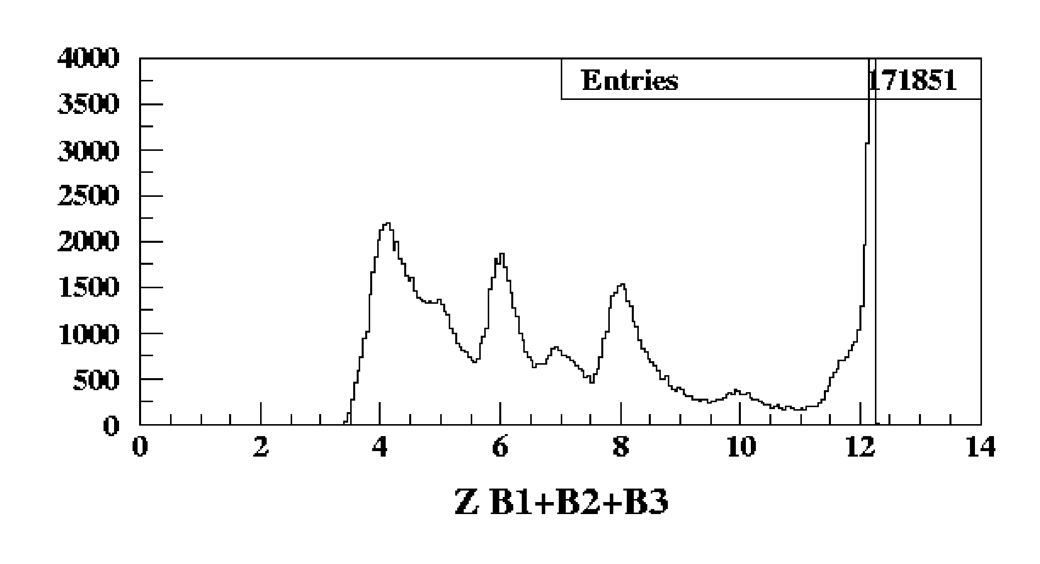


Threshold energy in MeV/nucleon vs. Z for 30º incidence using most abundant naturally-occurring A.

A Day in the Life

- Data storage sufficient for about 500 files; each file has about 1200 events.
- GCR trigger rate ~ 2000/hour or 2 files/hour, SPE rate can go much higher.
- Odyssey has daily session with DSN, MARIE data downloaded (causes 1-2 hour gaps).
- To avoid wrap-around, freeze data acq. when < 500 files written. After all are downloaded, go through erase/re-start sequence (long gaps).

Detection of GCR heavy ions



Data from March-July 2002.

- B detectors provide good resolution. Here, scale ΔE to Z assuming ions have T ~ 0.5 GeV/nucleon.
- Gains are too high to see above charge 11; 20% of the event sample above charge 3 is in the overflow bin.
- No variation in amplifier gains possible, only knob is bias voltage; for B3/B4, set to 150 V after solar conjunction.
- Now see up to Z = 14 (LET ~ 60 keV/μm).

Options for Extrapolation to Higher-Z

- Crude: assume everything above Z=14 is Fe.
- Less crude: use ACE/CRIS data, normalize in Z = 4 to 14 region.
- Model-dependent: use HZETRN.
- Should be able to bracket true values of average LET and Q for purposes of dose calculations. (For March, found <Q> = 3.4.)

Dosimetry

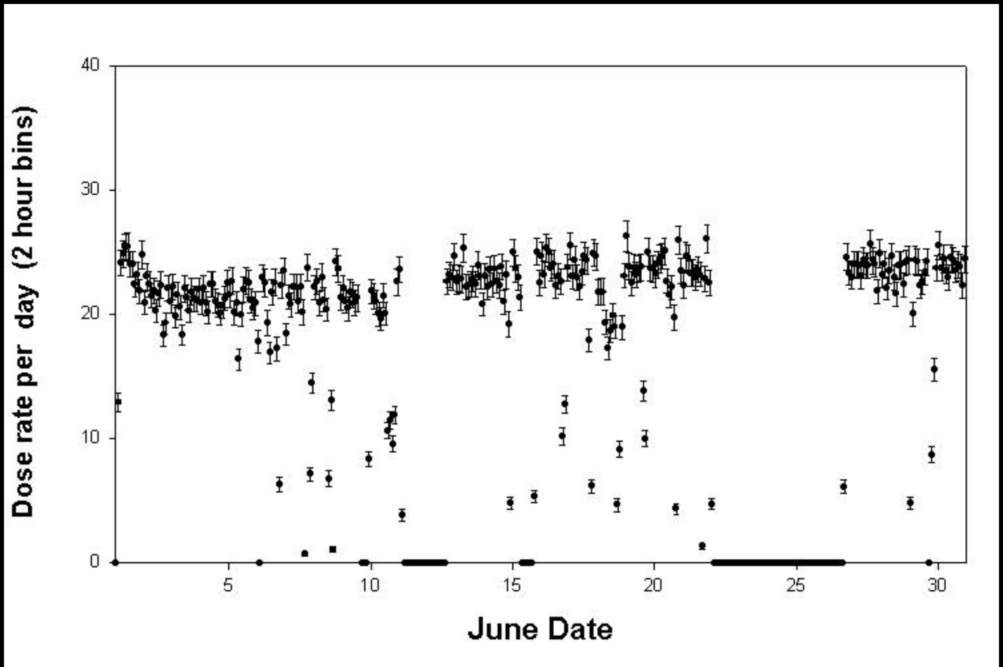
- Problems: No dE/dx measurement for Z > 11 (now 14) due to saturation; high-E protons missed. These effects tend to cancel in <ΔE>.
- Also, some backward-going particles trigger. Need a detailed simulation of the spacecraft (Atwell, Saganti, Andersen). For now, sweep into *f*. After correction for geometry, derive:

$$D(nGy) = \frac{0.129}{0.067(1+f)} \sum_i N_i \Delta E_i = \frac{1.93}{(1+f)} \sum_i N_i \Delta E_i$$

$$\overline{\Delta E} = \sum_i N_i \Delta E_i \Big/ N_{tot} \qquad \text{so}$$

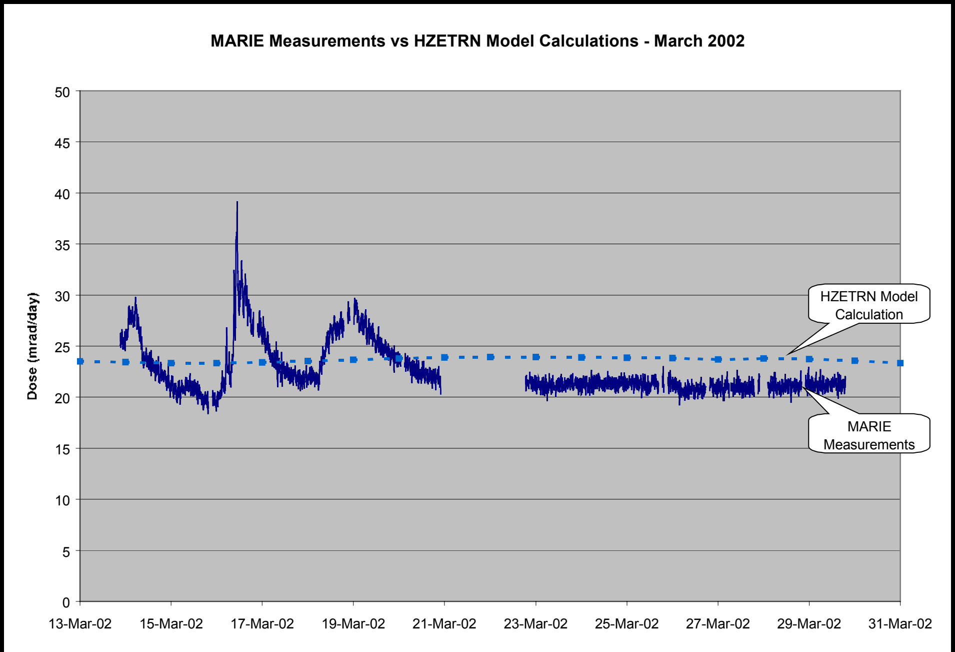
$$D(nGy) = \frac{1.93}{(1+f)} N_{tot} \overline{\Delta E}$$

Dose Rate June 2002



- This uses the first-principles calculation and A1 to get <ΔE>. Assumes $f = 0$.
- Note that <ΔE> is stable even during SPE (fortuitous?).

Data vs. Calculated Dose Rate

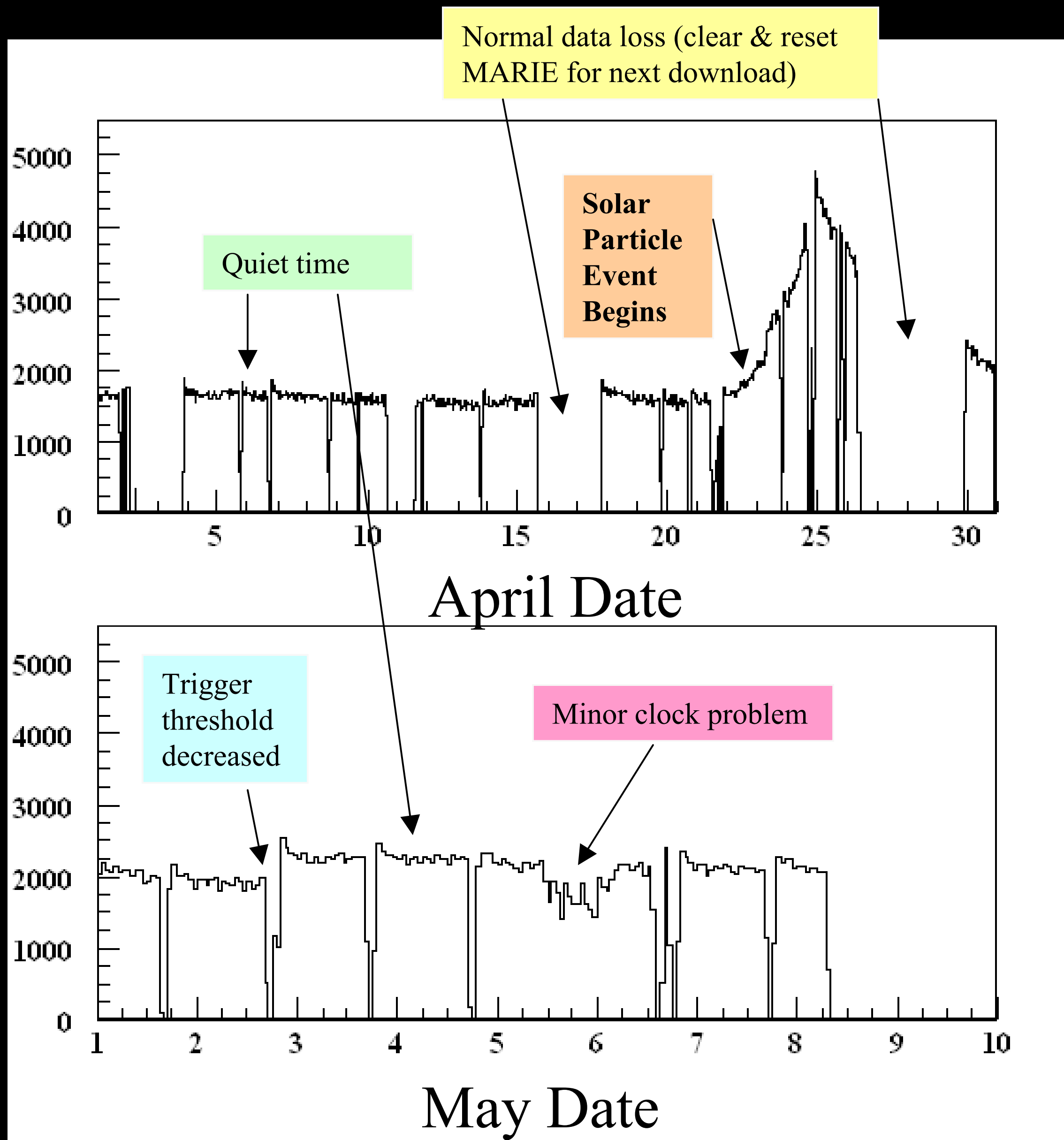


- Can also use A2 count rate to get dose-rate, useful during big SPE like 7/02.
- Note, A1*A2 threshold was high in March, many protons missed (not modeled here). Also, MARIE shielding not modeled.

First Observations of SEP at Mars

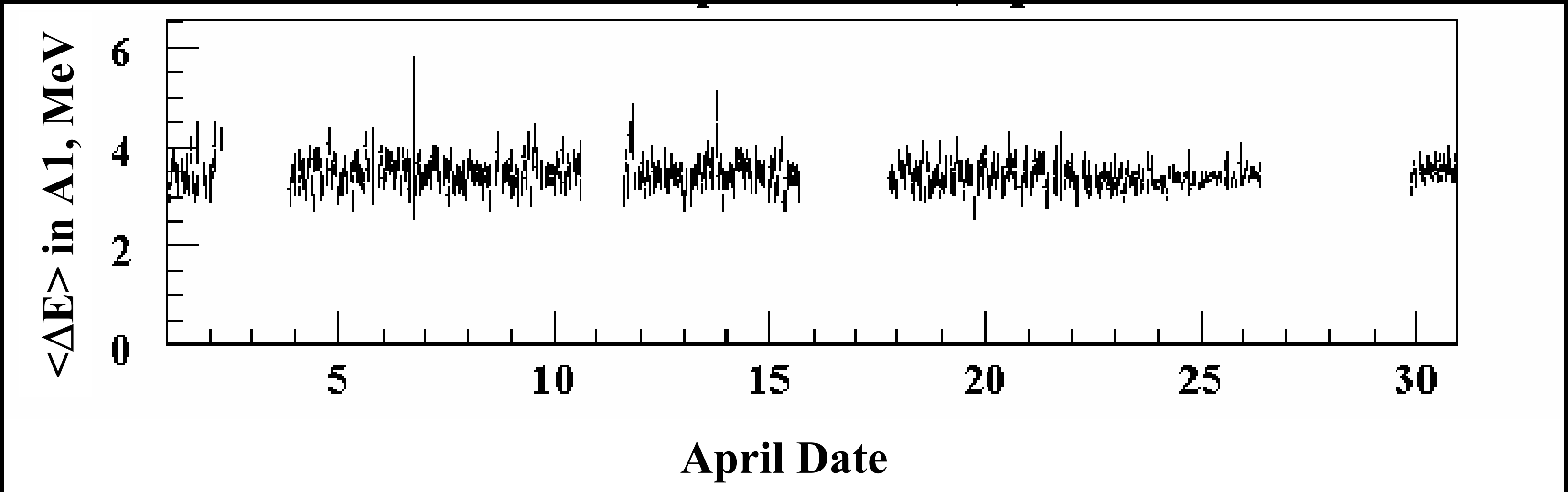
- Several SPE's have occurred since MARIE turned on in March.
- Earth-Sun-Mars angle has varied from about 100° to present ~ 180° so Mars is facing different parts of the sun than Earth is.
- Generally use GOES-8 for comparison (30 MeV proton data available in text).

MARIE triggers per hour

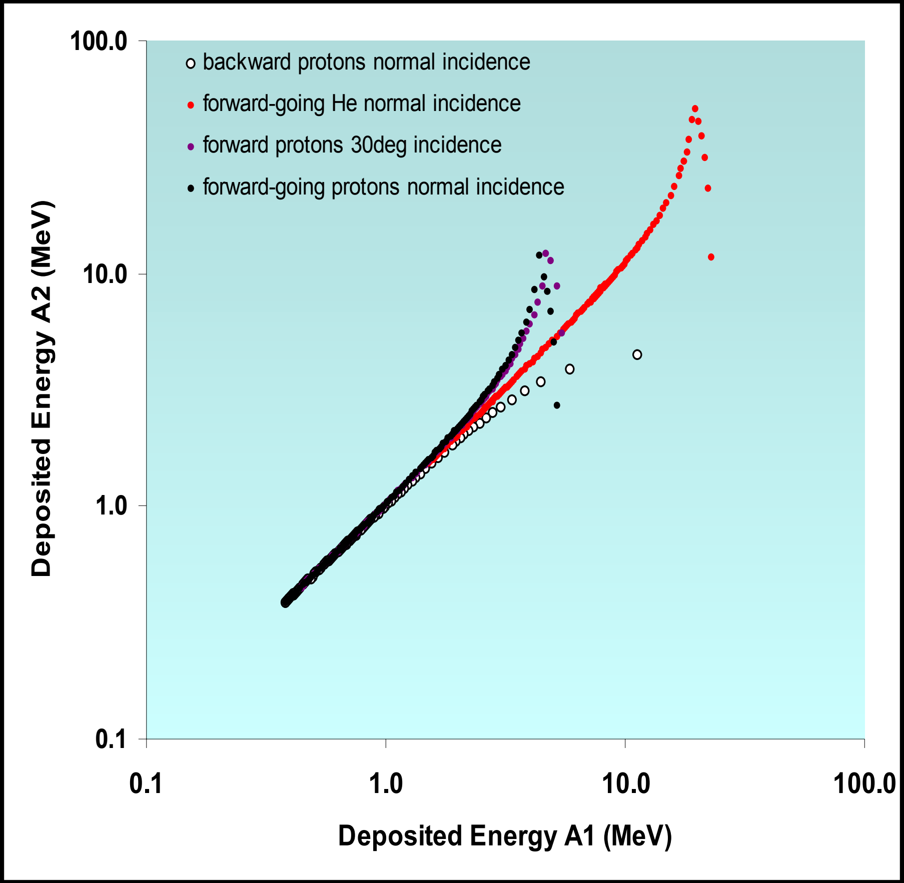


Average A1 ΔE is stable…

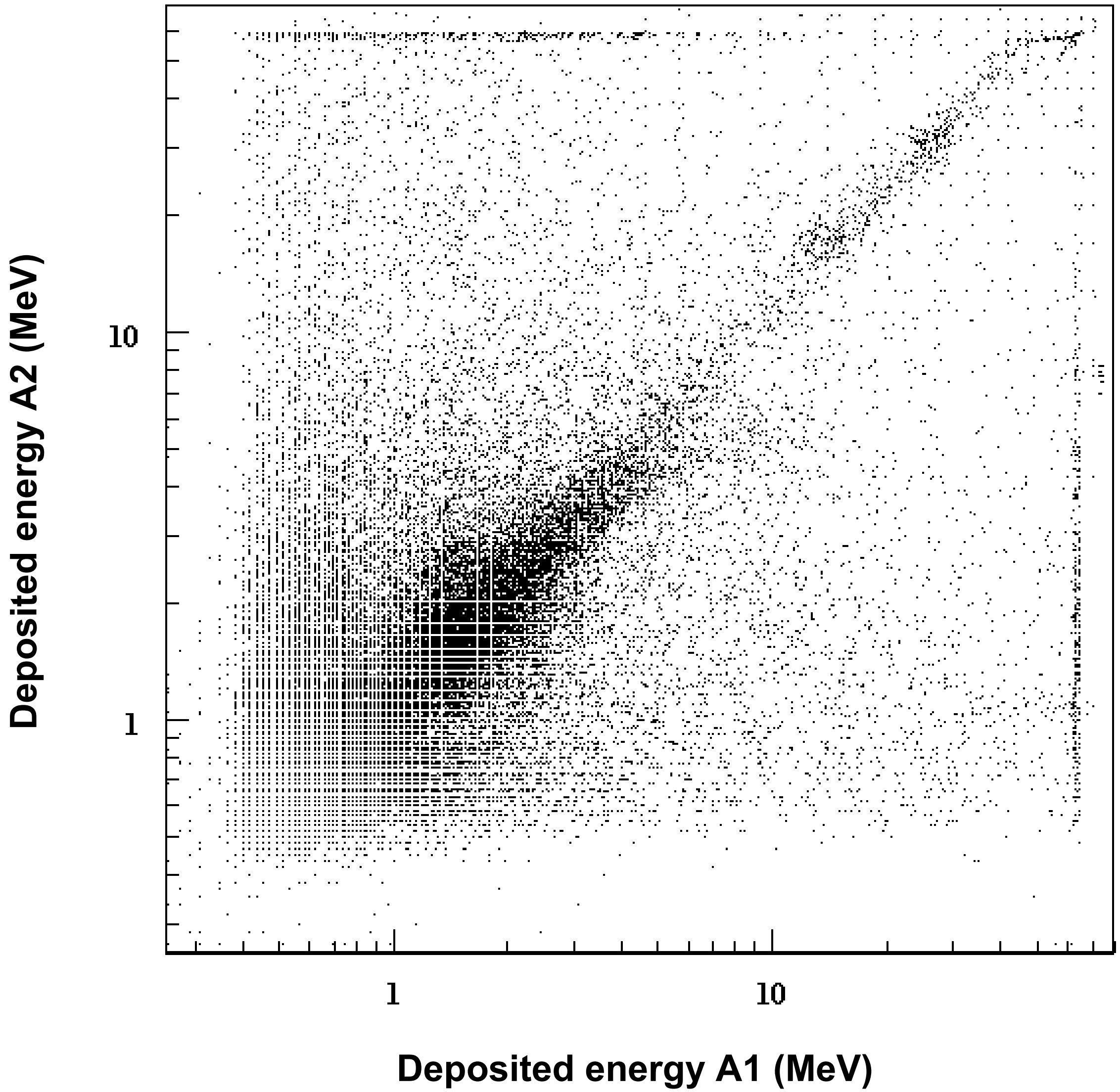
- Value averaged over 1-hour bins shows little variation even when SPE occurs.
- Error bars shrink due to increased rate but central value shows no discernable shift.



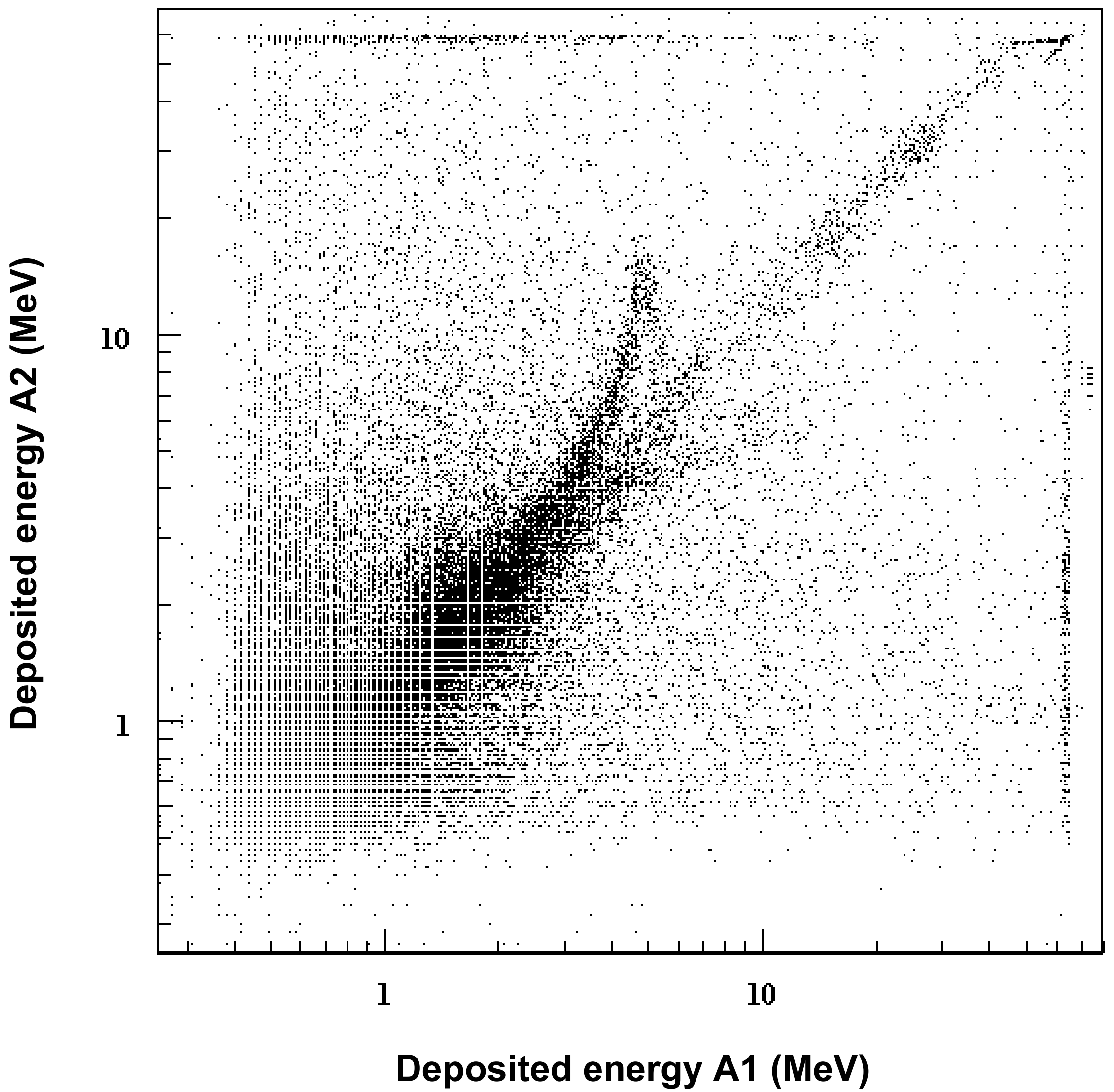
- Scatter plot of ΔE in A2 vs. ΔE in A1, calculated with Bethe-Bloch eqn. and in 1 MeV steps in incident energy.
- Particles stopping in A2 populate the nearly-vertical bands for forward-goers.
- See similar behavior in, e.g., B1 vs. A1, etc.



Prior to start of event.



April 22



April 23

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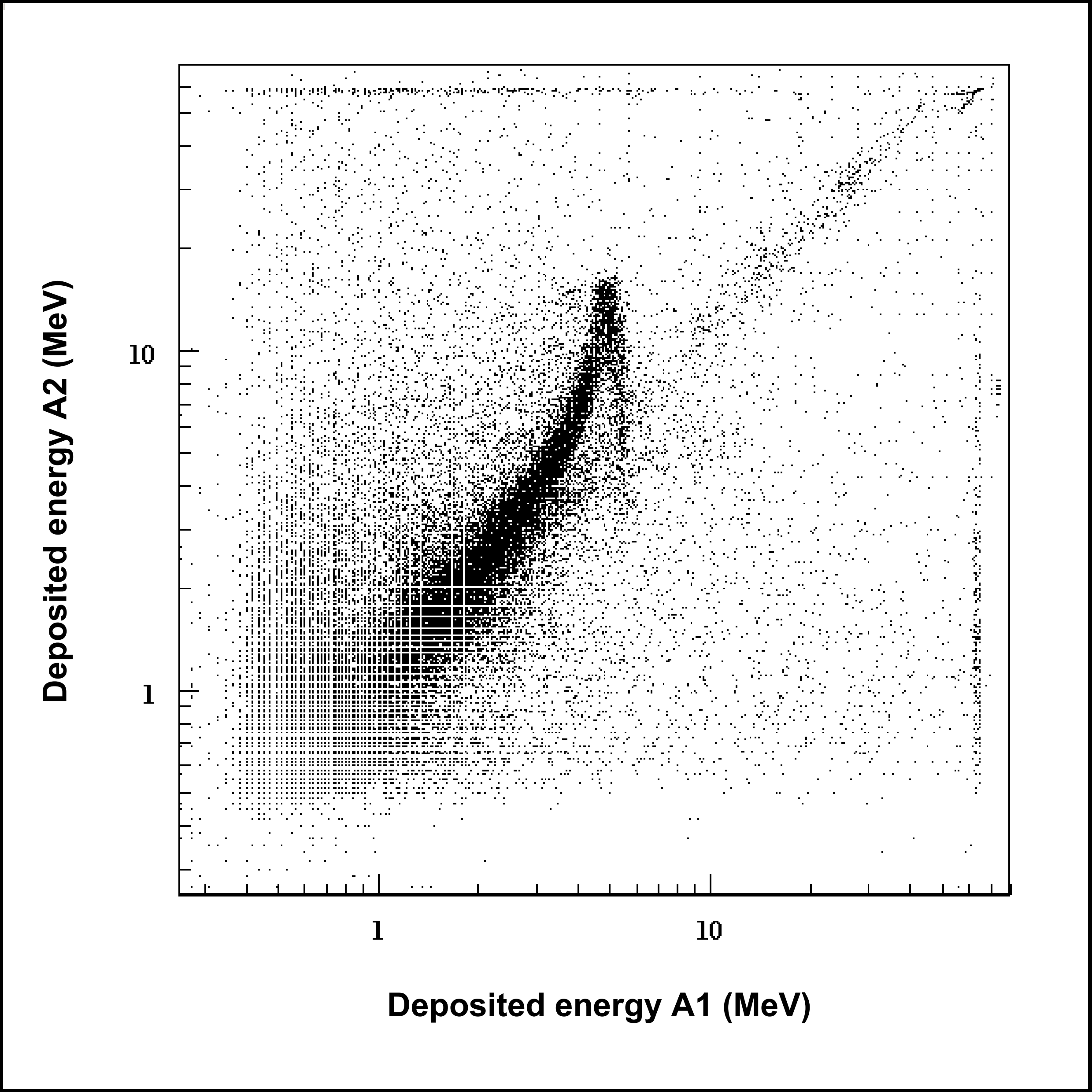

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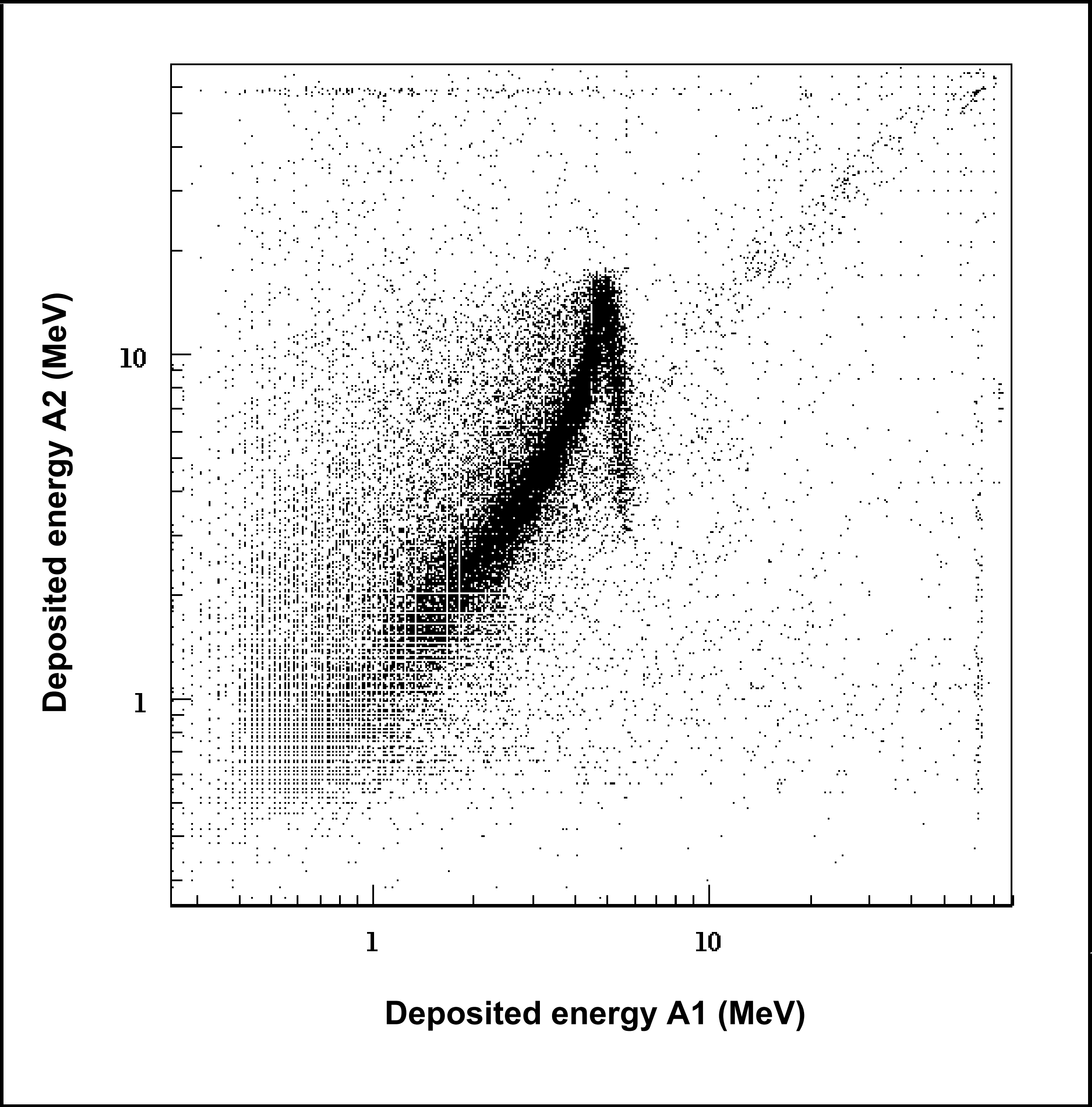

April 25

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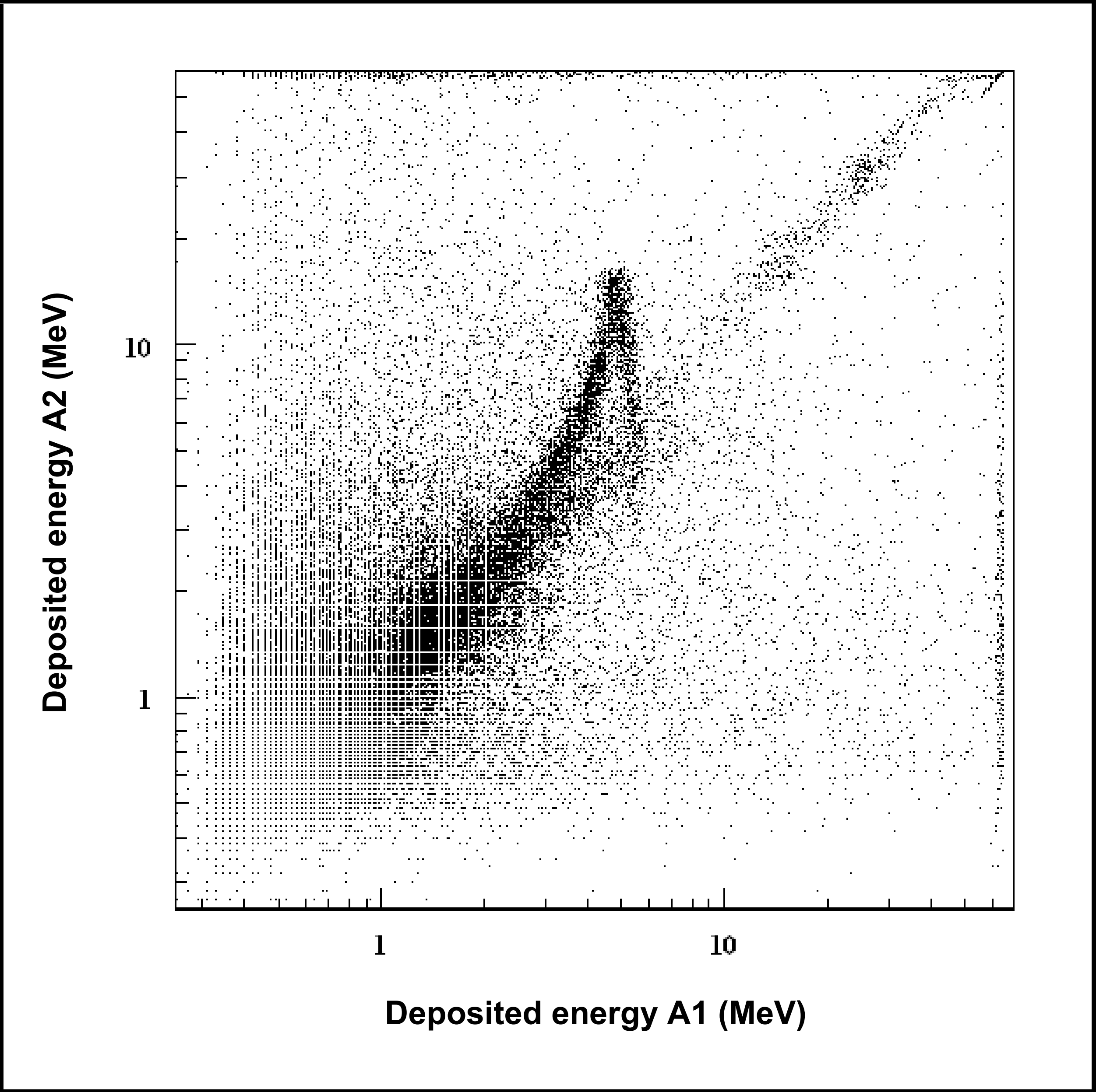

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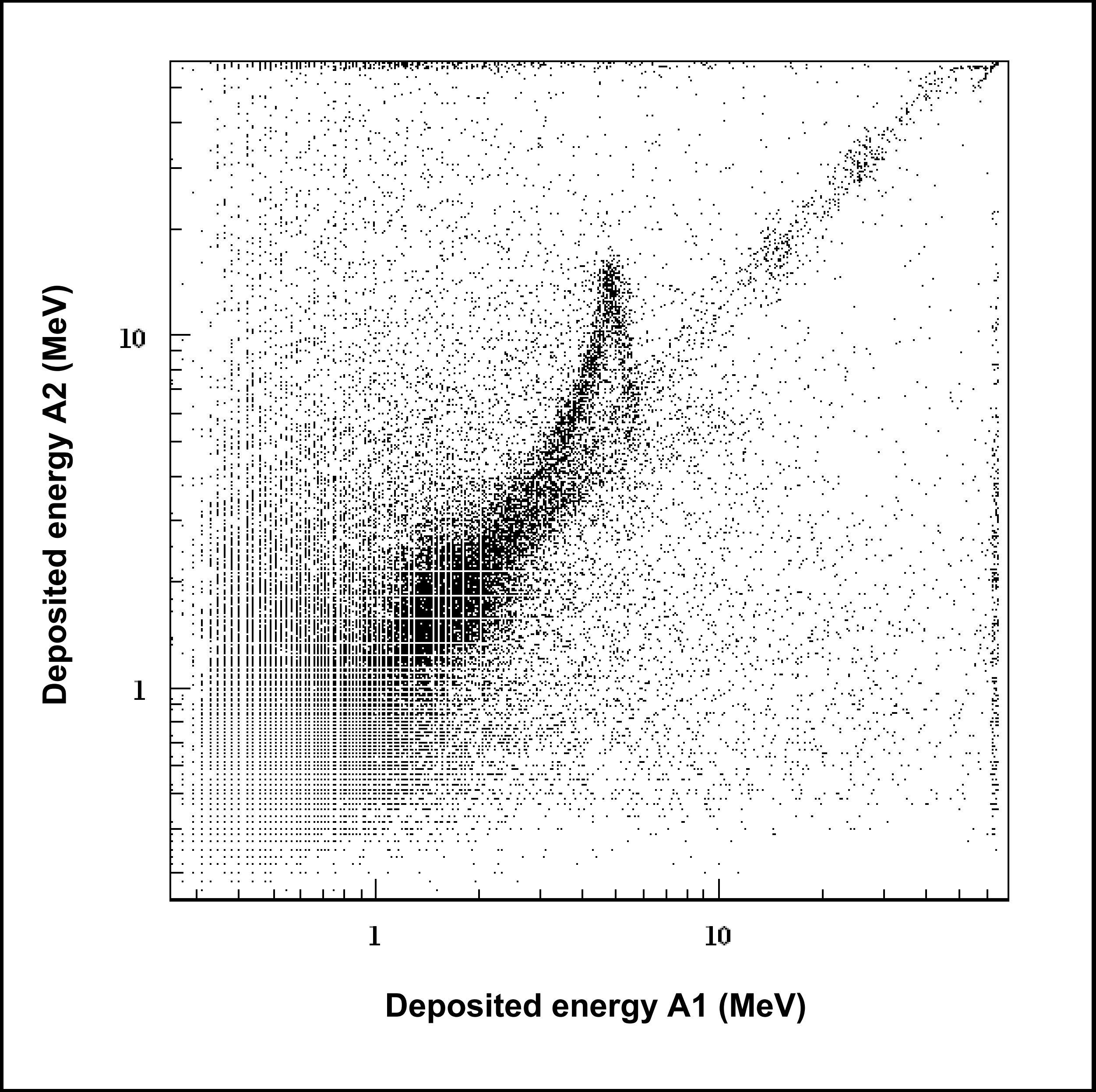
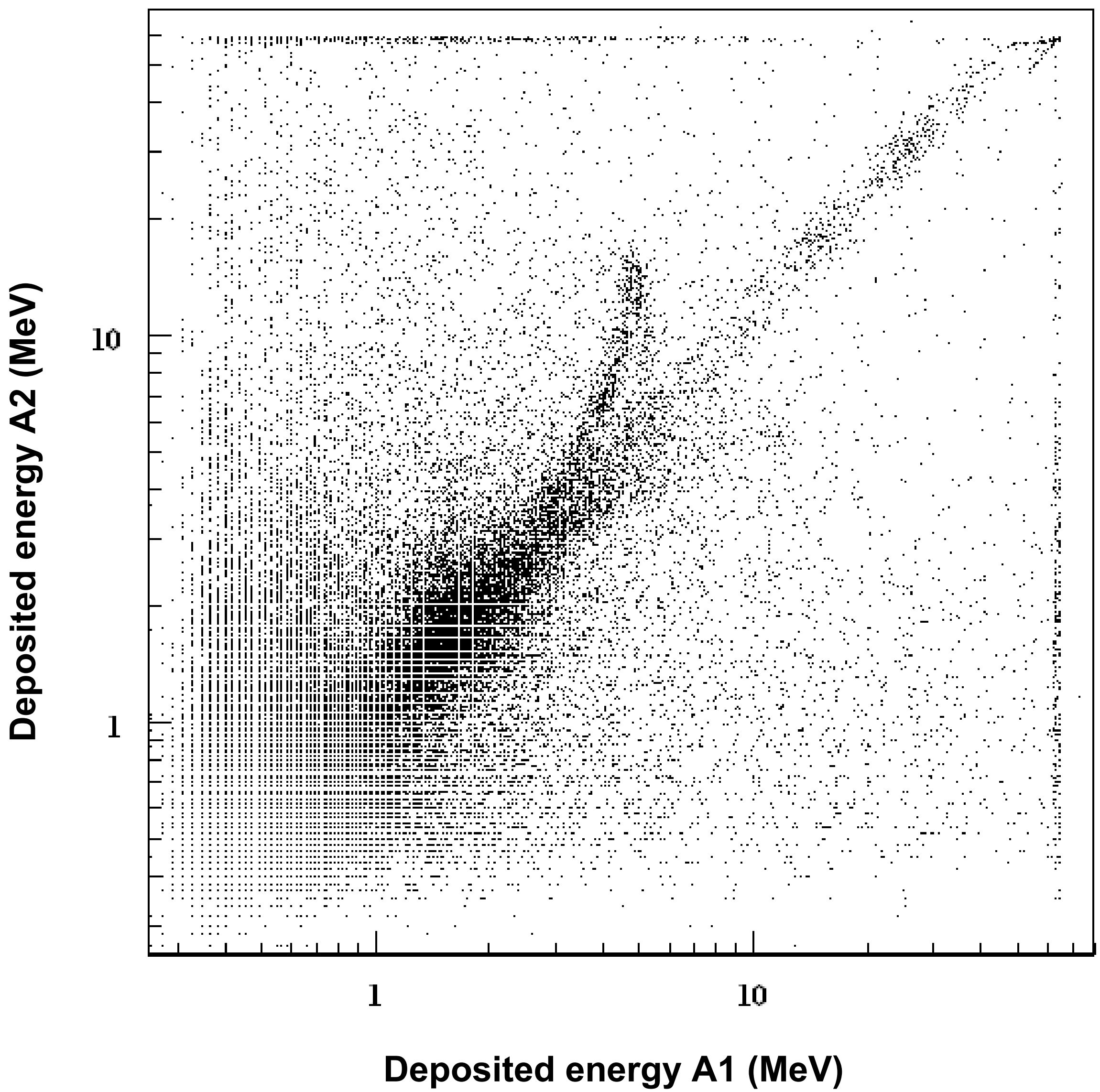
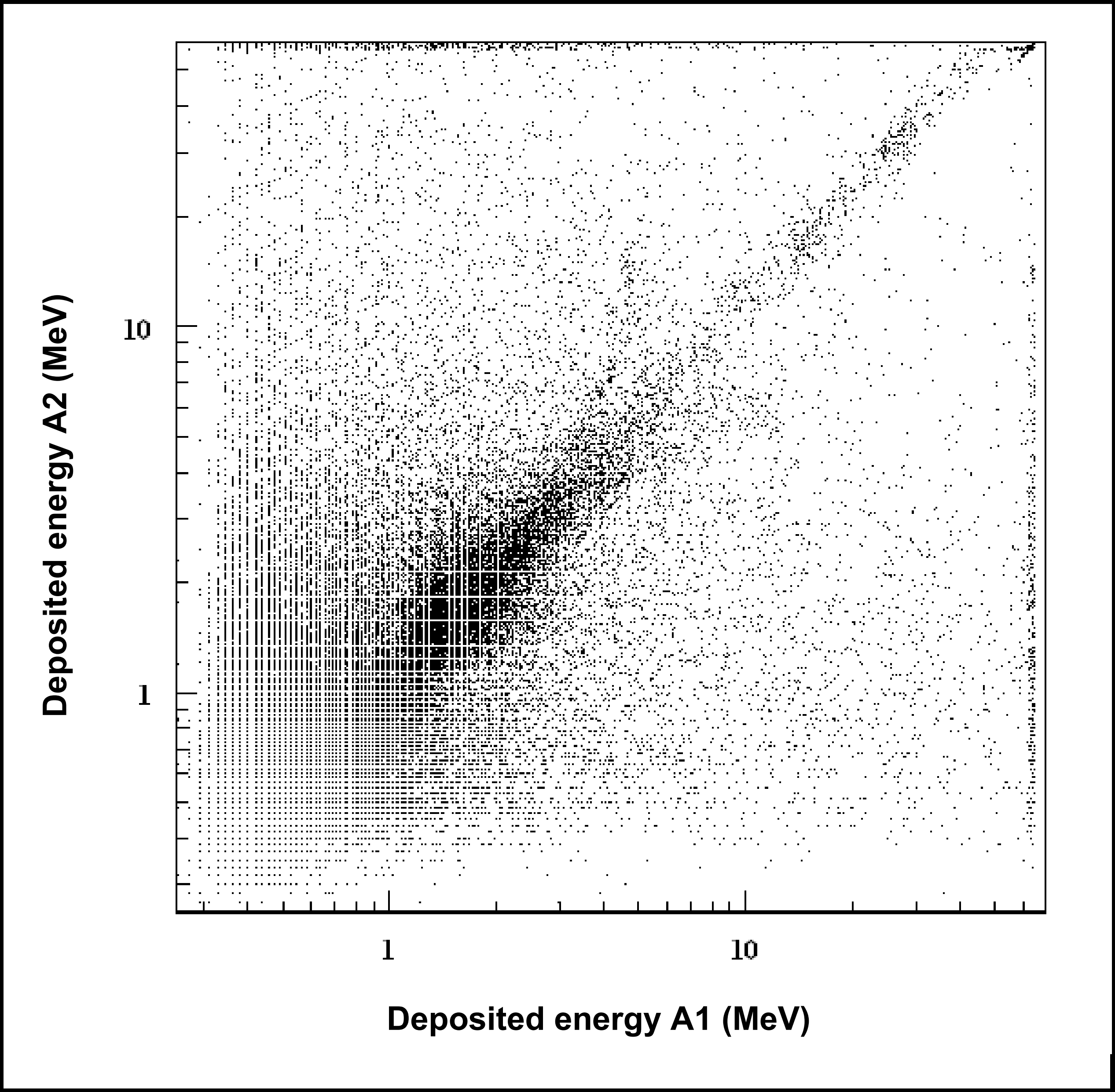


April 30

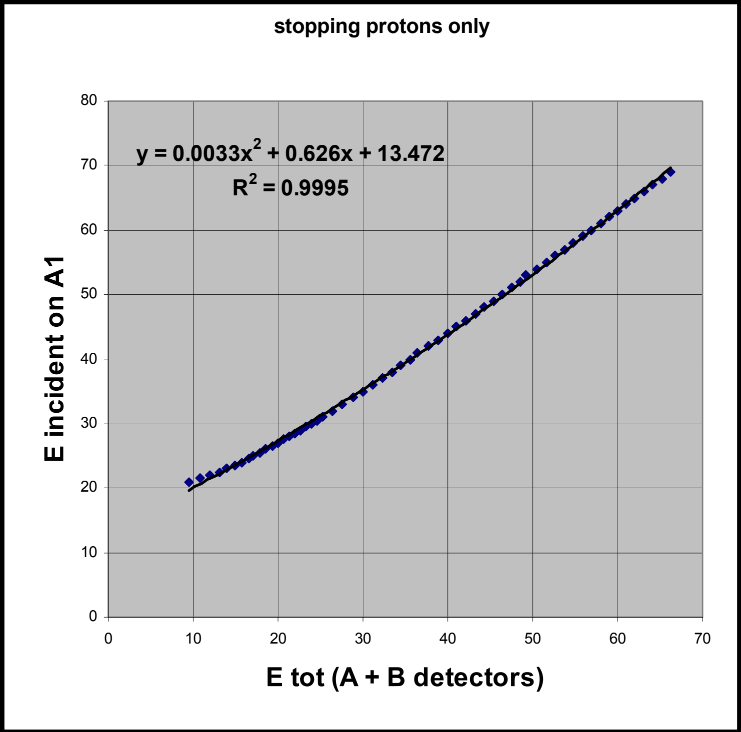


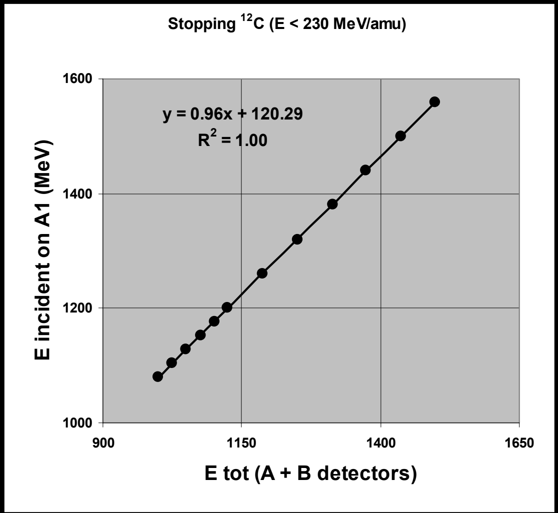
May 2


Deposited energy A2 (MeV)
10
1
1
10
Deposited energy A1 (MeV)

SPE Analysis

- As expected, large increase in # of slow protons seen in all events.
- Protons up to ~ 75 MeV stop in MARIE so relatively easy to get low-E spectrum (2nd-order polynomial fit to go from $\Sigma\Delta E_i$ to E_{inc}).
- Can generate similar curves for other ions, useful for small portion of GCR.
- At higher E, use χ^2 method developed for GCR by K. Lee (U. Houston).



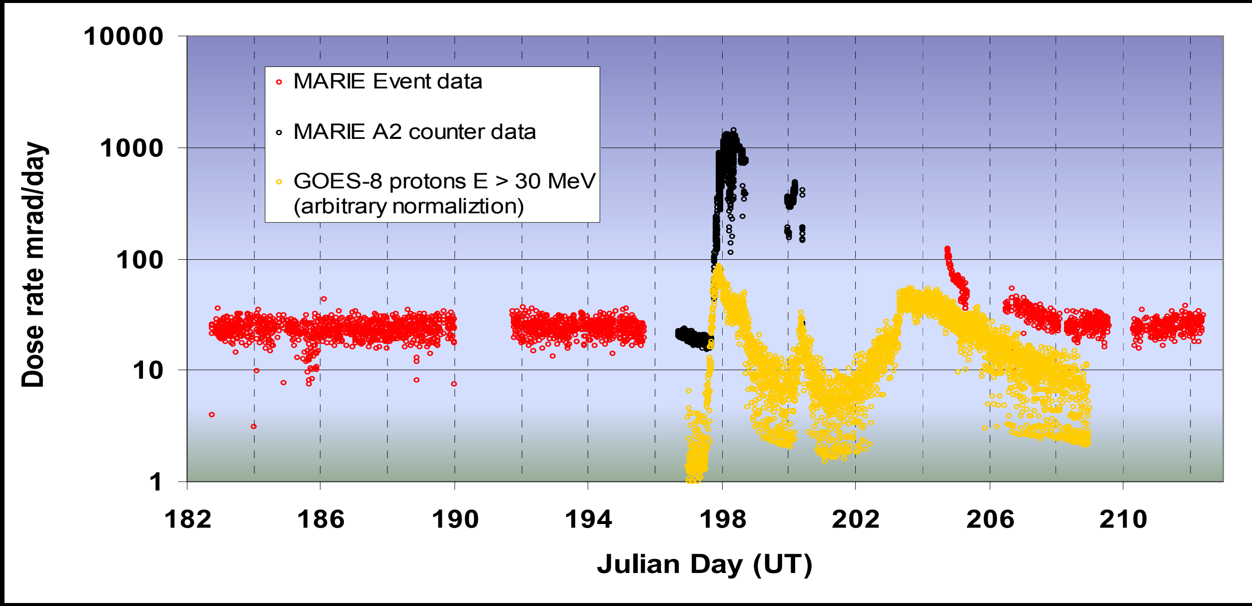


χ^2 Analysis

- Algorithm uses ΔE in as many detectors as possible to determine most likely (Z, A, E, θ) of incident particle.
- Has to be flexible to handle events with a nuclear interaction in the stack or particles exiting/scattering out.
- Probably no E resolution above energy where dE/dx curve flattens (~ 1 GeV/u)
- Code will easily transfer to IV and EV CPDS data analysis.

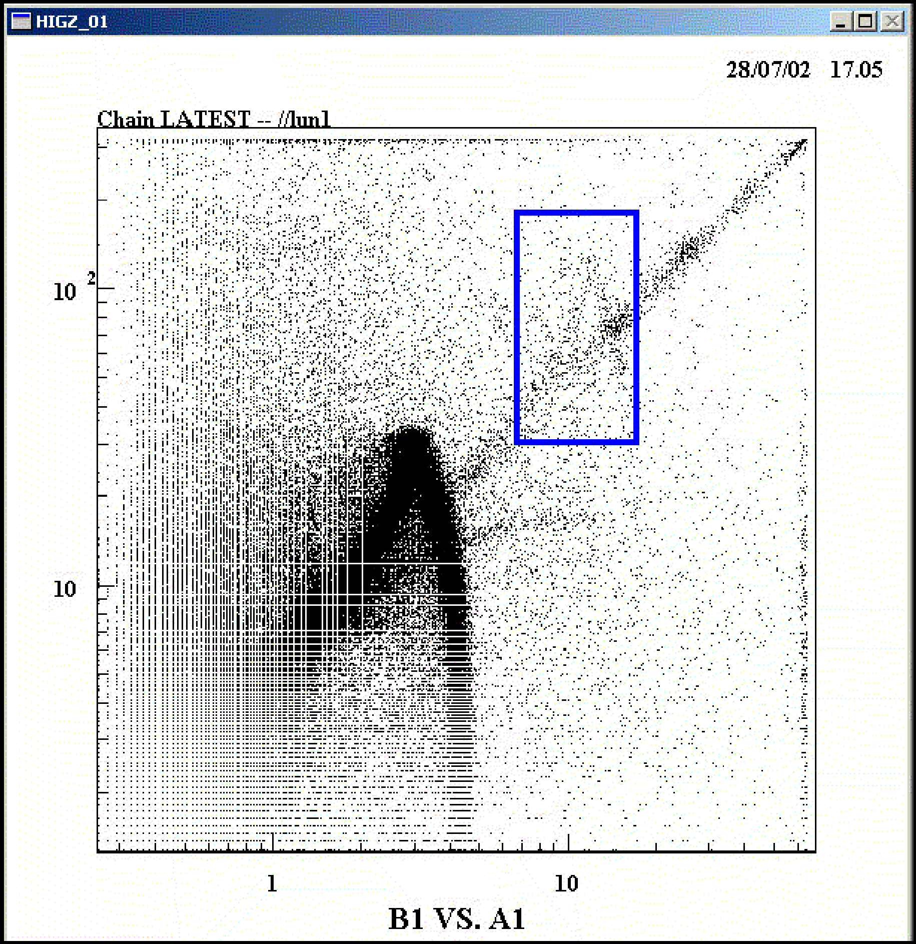
July 2002 SPE compared to GOES-8

- Full-halo CME's on days 198 and 200. MARIE data acq saturated, use A2 hit counter.
- Good correlation between MARIE & GOES-8 is interesting considering nearly 180° Earth-Sun-Mars angle.

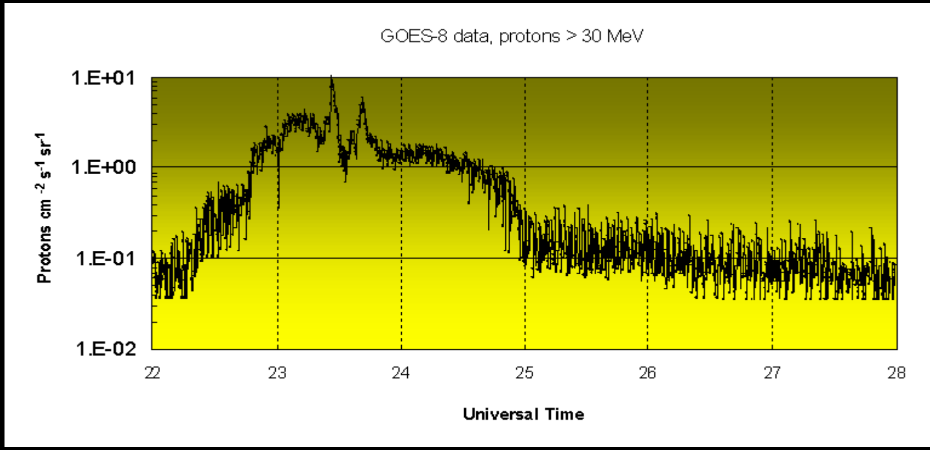


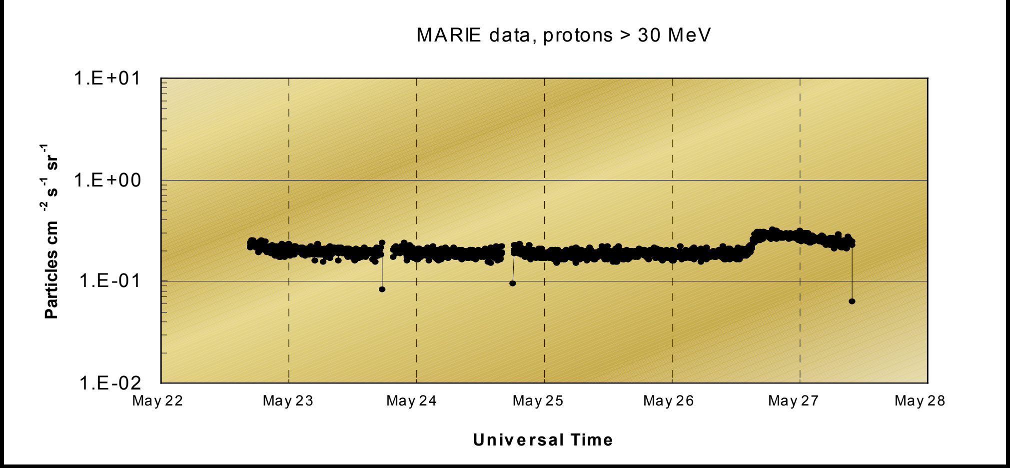
July 2002 SPE

- See stopping He in B1 in this event (also in A2 vs. A1).
- Not seen in earlier events; maybe just statistics, or maybe something different about this event.



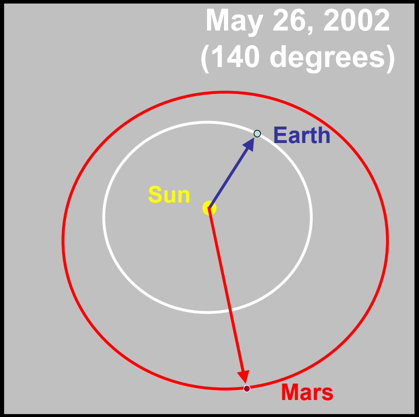
MARIE vs. GOES-8 for other SPE's



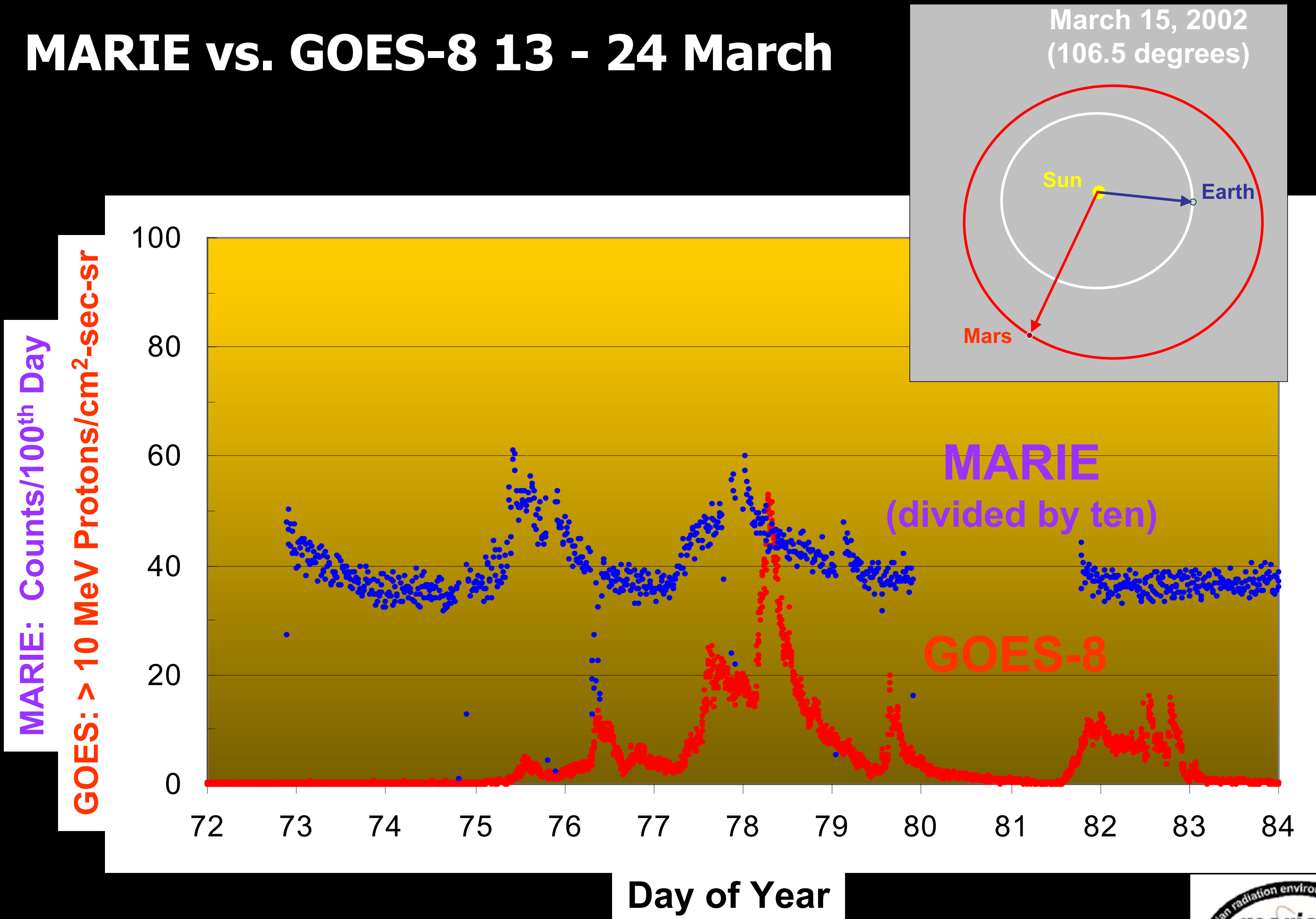


MAY 22-28

Apparently these were not very isotropic SPE's...



MARIE vs. GOES-8 13 - 24 March



Summary

- MARIE is working well and has observed several SPE's as well as GCR up to Z = 14.
- Agreement to ~ 10% between HZETRN and the observed dose rate in Mars orbit during quiet time; details of acceptance still to be determined from modeling. Also, sophisticated particle i.d. algorithm being developed.
- Established contacts with SPE experts (Tylka et al.) for eventual collaboration.
- Data analysis methods and detector model should be transferable to similar ISS units.
- Mission life of at least 3 years, we hope.