The ATLAS Particle Detector

- A Toroidal LHC Apparatus
- A general-purpose particle detector at CERN’s Large Hadron Collider
- 44 m long, 22 m diameter, and 7000 tons.

The (New) Small Wheel

- Endcap muon tracking and triggering: 1.3 ≤ |η| ≤ 2.7.
- Upgrade for high-luminosity LHC.
- 750 on-detector boards require 50 kA at 1.2 V-2.5 V
- Use Point-Of-Load conversion.
- Need B-field and radiation tolerant power converters.

Radiation and B-Field

- Magnetic and Radiation Tolerance Requirements
  - Total Ionizing Dose (TID) ≤ 1740 Gy
  - Non-Ionizing Energy Loss (NIEL) ≤ 2.1 × 10^-12 n/cm^2
  - Single Event Effects (SEE) ≤ 4.3 × 10^3 p/cm^2
  - B-field ≤ 14 kG

- NIEL: cumulative damage to semiconductor lattice.
- SEE: transient effects induced by energetic particles.

System Architecture: Two Approaches

Single-Stage System

- Commercial-Off-The-Shelf (COTS) converters.
  - Challenges:
    - Locate COTS device that survives high radiation.
    - ...and can accept V_i = 24 V - 48 V.
  - COTS
    - Radiation-hard FEASTMP (CERN µ-electronics).
    - Challenges:
      - Mechanical: size and cooling.
      - Two on-detector conversions.
      - Intermediate stage: Environment less harsh, but still in radiation, B-field.
    - No existing product suffices.

Two-Stage System

- Rad-hard; CERN product for LHC experiments.
- Single-inductor back.

COTS Testing: Facilities

- TID Testing at BNL SSIF
- NIEL Testing at U. Massachusetts, Lowell ENI
- The Calliope *Co facility
- The TAPIRO reactor
- SEE Testing at CDH Proton Center

FEAST2: A Radiation-Hard DC-DC ASIC

- Cadet Back Converts
- Test Notes
  - LT8612 in 16Co γ, 800 Gy.
    - Output voltage vs. time (ms).
    - Strong contender: excellent TID, NIEL performance.
    - ...too many proton SEE resets (left, σ_E = 650 × 10^-12 cm^2).
    - Hourly at inner radius. Daily at outer rim.
    - With SEE mitigation, viable for use on rim.
    - Rule out for single-stage conversion.

Prototyping the Two-Stage System

- VMM2
  - VMM (BNL): analog front-end ASIC.
  - PMOS preamp: sensitive to noise on input power.
  - Must validate noise performance.

Amalthea: VMM2 + FEAST

- Test board for VMM2 + FEAST.
- Low-profile B-tolerant ferrite.
- U. Michigan + U. Arizona
- Analog pwr direct from FEAST DC-DCC.
- Test noise performance.

Conclusions

- FEAST-only solution preferred for NSW.
  - Low noise, radiation-hard, compact (with COTS ferrite).
  - COTS converters:
    - Radiation performance inadequate for single-stage solution.
    - May be useful in intermediate stage (lower radiation zone).

Goal: evaluate both approaches.