The Transition Radiation Detector of the AMS-02 Experiment

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OUTLINE

- The TRD as space experiment: requirements and status
- Operating principle and construction of the TRD
- Performance
- Summary
Positron identification necessary to dark matter search

The primary cosmic radiation is dominated by protons

\[
\frac{\#p^+}{\#p^-} = \mathcal{O} \left(10^4\right)
\]
Requirements for TRD in AMS-02

AMS02 $p^+$ rejection $10^6$ for 90% detection efficiency for $e^+$

Requirements for the rejection power of the subdetectors:

ECAL: $10^3$…$10^4$

TRD: $10^2$…$10^3$

Tracker+ECAL
0.38 m$^2$sr

Tracker +ECAL + TRD
0.06 m$^2$sr
Principle of operation of the TRD

- highly relativistic charged particle generates photons at the boundary between media (\(\varepsilon_{r1} \neq \varepsilon_{r2}\))
- Radiator: fleece
- Good photon (5–30KeV) detection: gas with high atomic number Z

\[
\begin{align*}
\gamma & \geq 1000 \\
N_{Ph} & \propto \alpha_{em} \times N_{tr} \\
E_{Ph} & \sim \gamma(\mathcal{O}(k eV)) \\
\theta_{Ph} & \sim 1/\gamma
\end{align*}
\]
Proton-Positron separation

- 20 layers 22 mm fleece-radiator
- 6 mm straw-tubes Xe/CO2 (80/20)
- Tubewall 72 \( \mu \text{m} \) Kapton-Al sandwich
- Wire 30 \( \mu \text{m} \) W/au tensioned with 100g

- Pressure 1250 mbar
- Gas flow 1 liter/h
- Gain 3000

- Modules 16 tubes
- 8 modules per gas-circuit
Energy deposit

Test beam results
Gas tight Module

Chamber Body

16 straws with lengthwise and crosswise stiffeners

Polycarbonate endpieces
Plasma treated ($O_2$, 0.5 mbar, 20 min)
Glue AW 134 for potting
Copper-Tellurium Crimp Inserts

1.6mm SS Tubing
Double O-Ring
Gas Connector
Gastight Modules Require Gastight Straws

Laboratory Tests:

- 12h Gastightness
  2.8 bar He in Atmosphere
- 60h Gastightness
  1.8 bar CO₂ in Vacuum

Max leakage for 3 years (10^8s)
5x10^-4 mbar/s (safety factor 5)

-pA Leakage Current
-Ar/CO₂ ^{55}Fe Gas Gain Measurement
TRD Gas System

46kg Xe (8100 l @ 1 bar)
4 kg CO₂ (2000 l @ 1 bar)

320 l @ 1 bar in 41 loops
To reach the request positrons/proton rejection factor:

Gas gain controlled better than 5%.

$\Delta T$ controlled at $1^\circ$
Chamber Support in Carbon-Fibre / Honeycomb Octagon

328 Modules in 20 layers
Upper and lower 4 layers parallel to B
Middle 12 layers perpendicular to B

Gain Variation $\Delta G/G$

- Wire: $d=30\mu m$, $M_{\text{TENS}}=100g$
- Tube: $l=2m$, $d=6mm$
- Gas: $\text{Xe/CO}_2$, 80/20
- $U_{\text{wire}}=1460V$
- $G_{\text{gain}}=3000$

Intercalibration

Mechanical precision < 100$\mu m$
Module lengths up to 2$m$
TRD Support Structure made of CFC-Al honeycomb (2.1m x 0.70m, accuracy < 100 µ)
Also shown are two installed chambers: Total 328 = 5248 tubes
AMS TRD GAS SYSTEM
ELECTRONIC CONTROL

**TRD GAS SYSTEM**
- Gas Supply
- Pumps
- MANIFOLD
- Pressure sensor
- Control board
- Slow control

**TRD**
- Command & Monitor Signals
- Power Supply
- Gas Mixture

**Electronic-control**
- Main Computer
Mechanical Structure

Octagon of aluminum honeycomb with carbon fiber walls
- Stable and light
- Dimensions: height 62.3 cm, $\varnothing$ 201.8 cm (above)
- Weight: 207 kg (including external support)
- Thermal stability through multi-layer insulation (MLI)
Structural Verification

FEC sufficient for $f_0 > 50$ Hz

$f_0 = 54.7$ Hz

40 cm Module

$f_0 = 132.3$ Hz

FEC coupled load modal analysis
Parameters from static measurements
Verify with component vibration tests

128.5 Hz
Vibration test up to 6.8 g (90 s)
Gain Gas Measurement
Laboratory

Gas gain precalibration
With Ar/CO2

Test beam
Wire Tensioning and Tension Measurement

Requested wire tensioning measurements 100+/−5 gr

First natural frequency $f_0$
TRD Electronics

- 82 front-end units (FE), 2 crates (+ power supply)
- 5248 channels, double redundant throughout up to the front-end
- a 28V DC connection for each crate
Test Assembly of a Front Electronic
TRD Beamtest beam

![Graph showing single tube energy deposit and 20 GeV X7 Electrons vs 20 GeV X7 Protons.](image)

![Graph showing 20 layer mean tube energy deposit with 20 GeV X7 Protons and 20 GeV X7 Electrons.](image)
TRD Beamtest Proton Rejection for 90% Electron efficiency

Single track preselection with MC 90% efficiency $p^+/e^-$ likelihood separation with

$$\mathcal{L} = \frac{\Pi p_e}{\Pi p_e + \Pi p_p}$$

$p_e, p_p$ from single tube spectra
TRD Testbeam

20 layer prototype tested with $e^-, \mu^-, \pi^+, p^+$

Proton rejection $>10^2$
reached up to 250GeV with 90% electron efficiency
Conclusion

- Required proton rejection of $> 10^2$
  for 250 GeV has been reached

- Quality of the design
  (mechanical, electronic)
  demonstrated through calculations and tests.

- Limits kept for
  - weight, power
  - outgassing, leak tightness