

# Data Acquisition with the Transition Radiation Detector of the AMS-02 Experiment

TWEPP-10, Aachen, Sep. 2010

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IEKP  - KIT Campus South



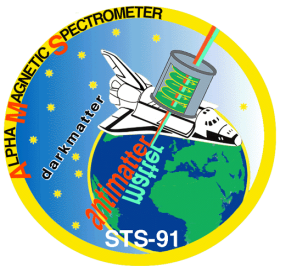
for the AMS-02 TRD Collaboration  
funded by DLR



Massachusetts  
Institute of  
Technology



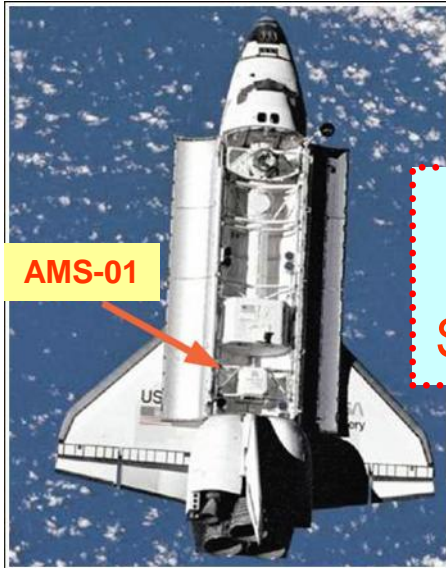
Istituto Nazionale  
di Fisica Nucleare



# The AMS Project: History and Future



1998



10 days precursor flight  
on board the Space  
Shuttle Discovery

Alpha  
Magnetic  
Spectrometer

2010 again ready for launch



10 years on the International Space Station ISS  
with 3000-times higher statistics measurement

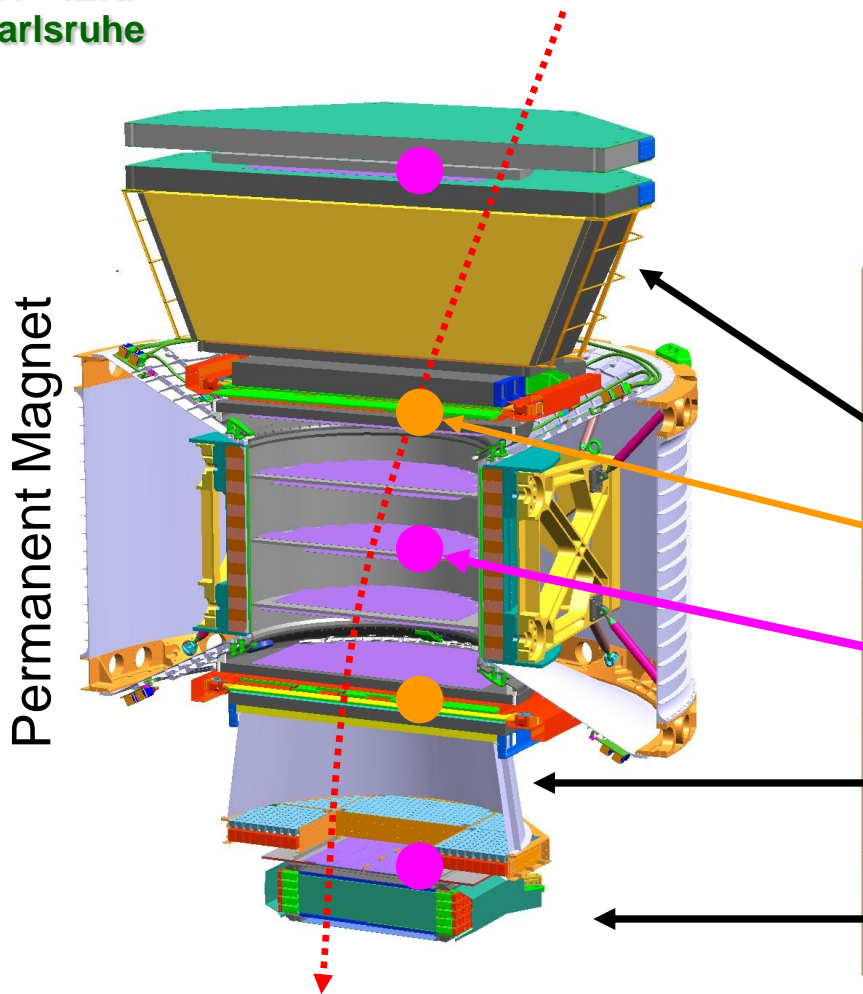
Direct measurement of primary  
cosmic ray spectra

*M. Aguilar et al., Physics Reports,  
vol. 366/6 (Aug.2002), pp.331-404*

Additional new subdetectors for better particle  
identification:

Precise measurement of antimatter, heavy  
nuclei and photon flux

# The AMS-02 Detector



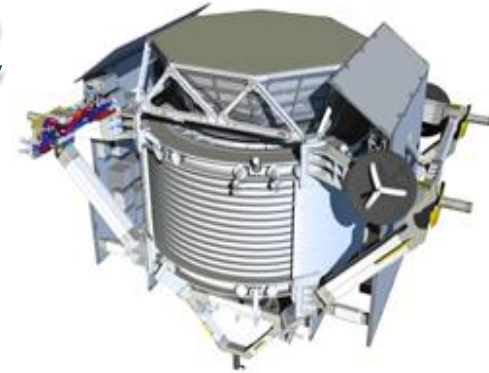
Dimensions: 7 tons and 3x3x3.5 m<sup>3</sup>  
 Acceptance: 0.5 m<sup>2</sup>sr  
 Lifetime: min 10 years (ISS)

0.3 TeV	e <sup>-</sup>	P	He	C	Fe	γ
TRD	↓ ↓ ↓ ↓ ↓					∇ ∇
TOF	∇	∇	∇	∇	∇	∇
Tracker	∪	∪	∪	∪	∪	∪
RICH	○	○	○	○	○	○
Calorimeter	∧	∧	∧	∧	∧	∧

**Concept: Redundant** measurement of particle properties in different subdetectors!



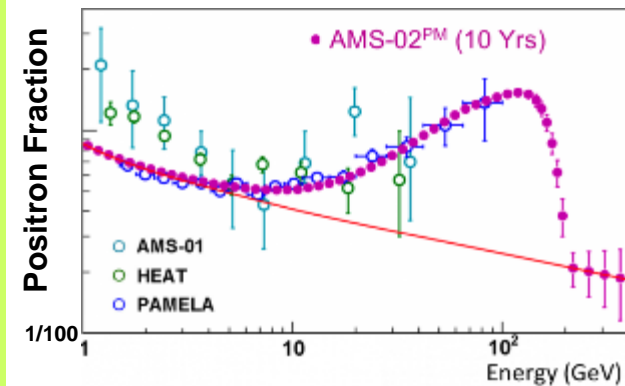
# Physics with AMS-02



AMS-02 = Alpha Magnetic Spectrometer 2  
Project lead: Prof. Samuel C.C. Ting, MIT

- Precision measurement of primary cosmic ray spectra with high statistics (10 years)
- Investigation of the isotopic composition of CR
- Determination of parameters of propagation models by precise  $\text{Be}^9 / \text{Be}^{10}$  or C/B ratio measurement
- Is there annihilation of cold dark matter...
- Gamma ray astronomy (same instrument!)
- Search for heavy antimatter:  $\bar{\text{He}}$
- Signatures of exotic physics? (e.g. strangelets)

Is there positron excess?



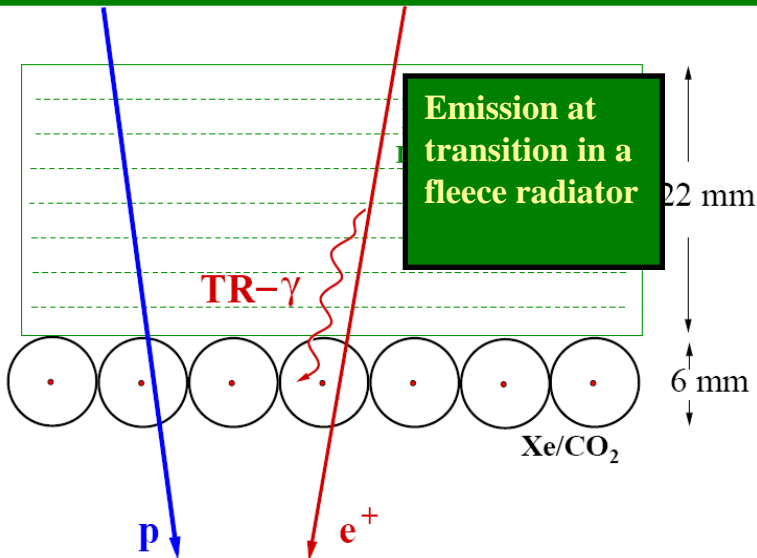
- unfortunately this is not the topic today -



# Operation Principle of the

# Transition Radiation Detector (TRD)

- the challenge: ratio proton/positron  $\sim 1,000,000/100$  in primary cosmic rays

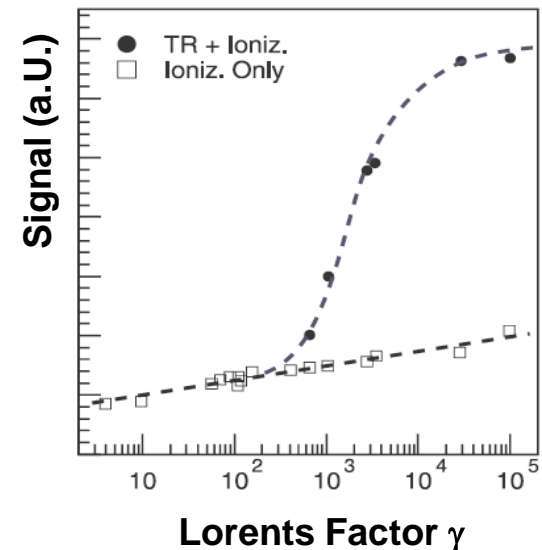


- solution: independent proton rejection by TRD and ECAL  
 **$> 10^6$  in the range 10 to 300 GeV**

$$\Theta_{Ph} \sim 1/\gamma$$

$$W_{Ph} \sim \gamma$$

$$N_{Ph} \approx \alpha_{em} \cdot N_{\ddot{U}}$$

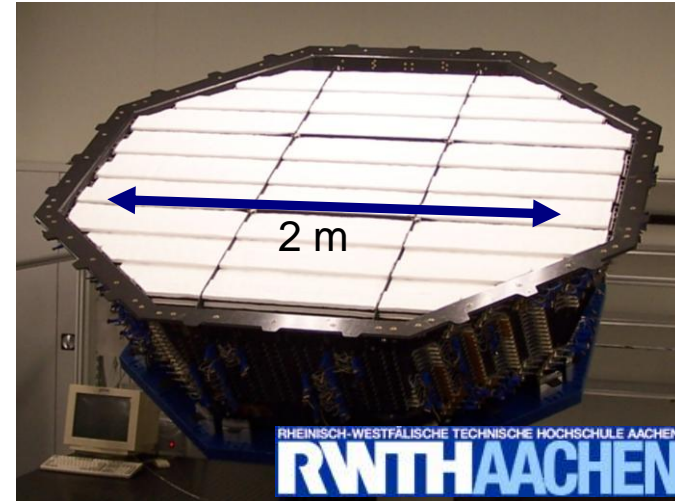
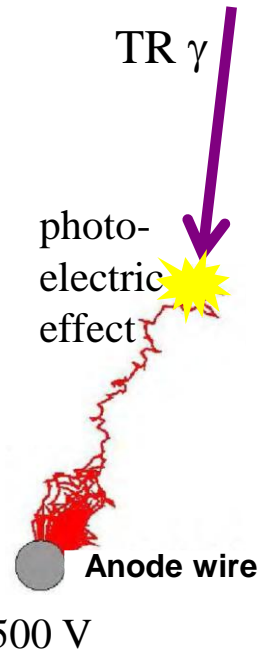
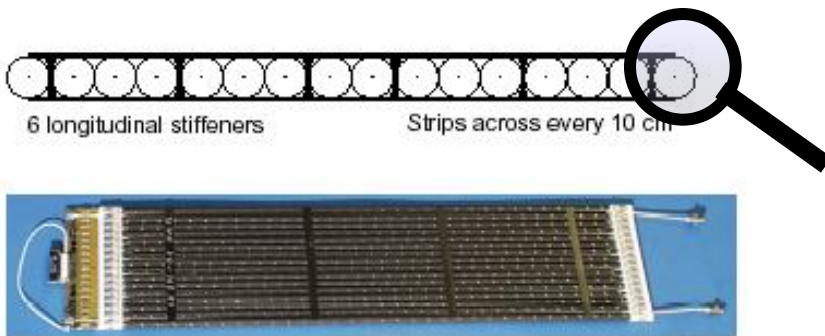




# The AMS-02 TRD



- **Octagon** made of Aluminium-honeycomb as supporting structure
- **20 layers of fleece radiator** for production of *transition radiation*



- **20 layers of „strawtube“- modules** filled with Xe/CO<sub>2</sub> gas for **detection** of *transition radiation* and ionization losses

space qualification:

- vibration resistant
- weight below 500kg
- maintenance free
- > quality control!

A gas system refills/adjusts **Xe/CO<sub>2</sub> gas**, which continuously is circulated through 230l TRD volume. Leaky chamber circuits can be isolated by valves.

# TRD(U) DAQ Electronics



**TRD Octagon:**  
82 frontends x 64 strawtubes

- **Front End electronics** with low power consumption of about 18W digitizes the data
- **TRD DAQ electronics** with online **data processing**, front end power supply and high voltage generators

*Design: CAEN, Italy*

*Production: CSIST, Taiwan*

*Lead and Operations: Karlsruhe University*

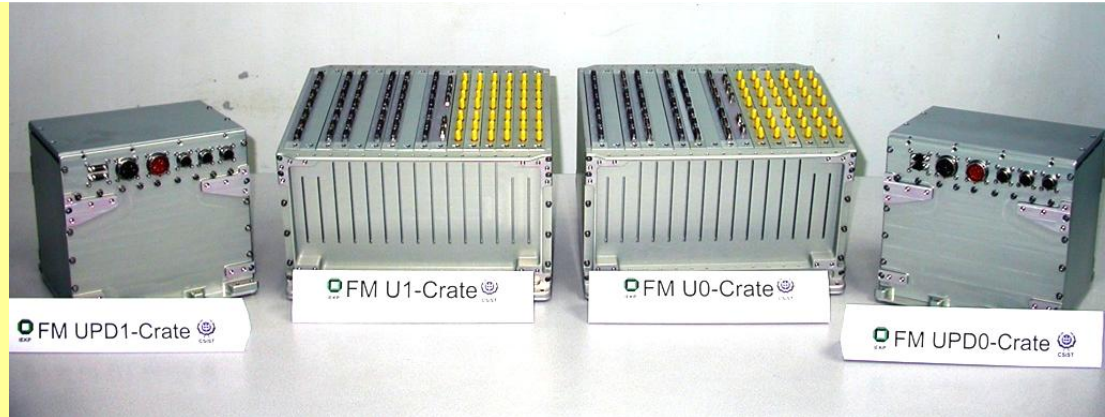
## space qualification:

- low power
- operation in vacuum
- fast readout
- EMC tested

## TRD Readout:

2 FM U-  
Crates

2 FM UPD  
Boxes

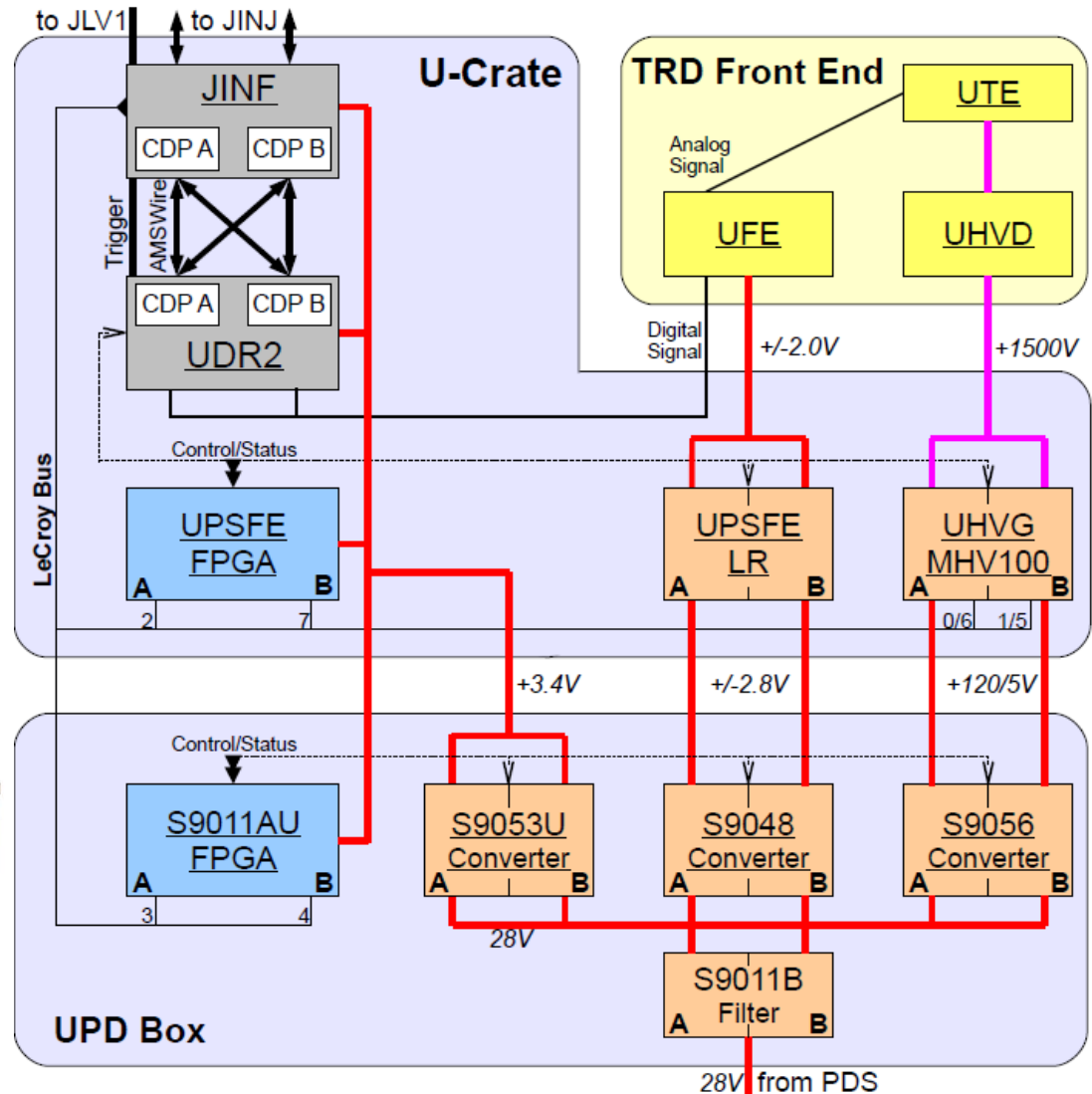
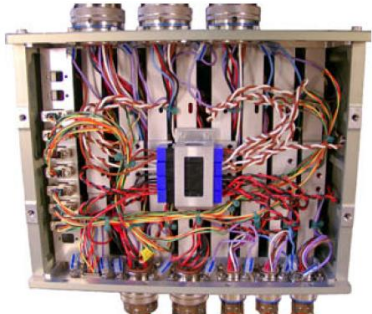




# TRD(U) Supply Electronics

## ...space qualification:

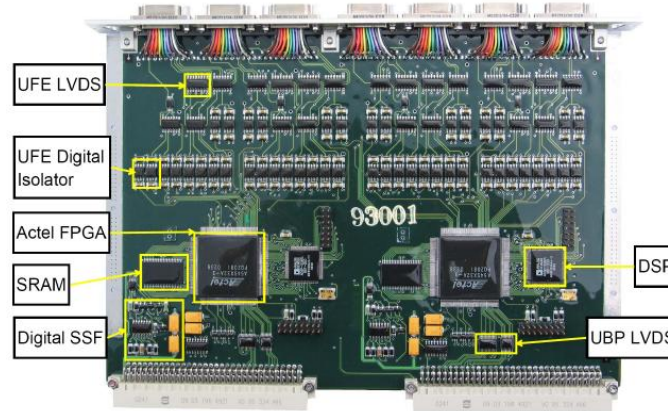
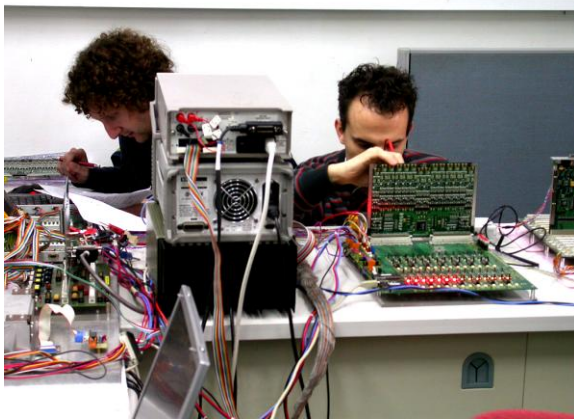
- Space Debris impact
- Heavy ions radiation
- + redundancy!
- + testing!!!





# TRD Electronics Production

## Readout:

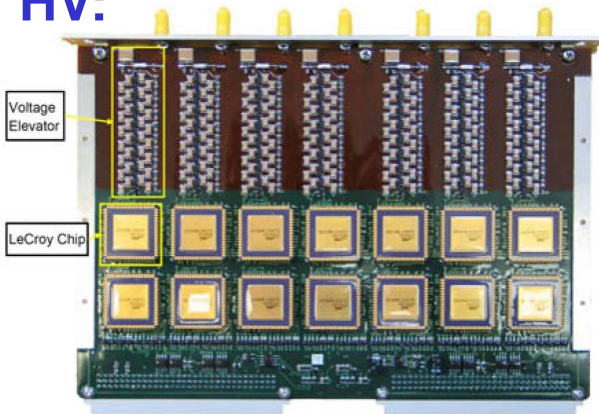


Phases:  
 EM = Engineering  
 QM = Qualification  
 QM2 = QM at production line  
 FM = Flight Model

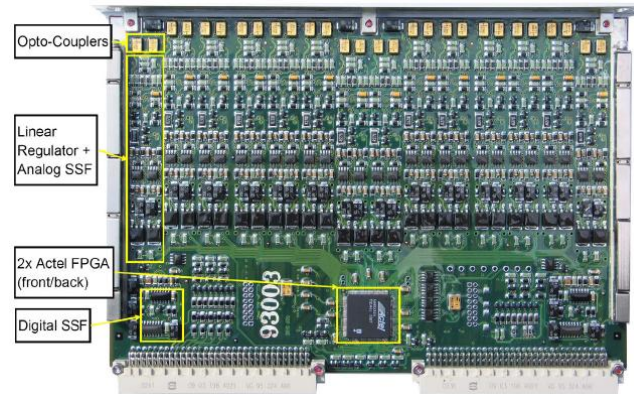
Production of qualification and flight model at CSIST in Taiwan



## HV:



## Power:



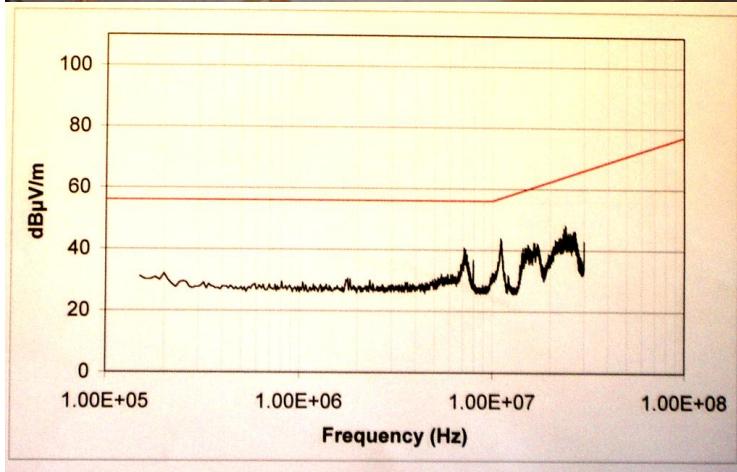
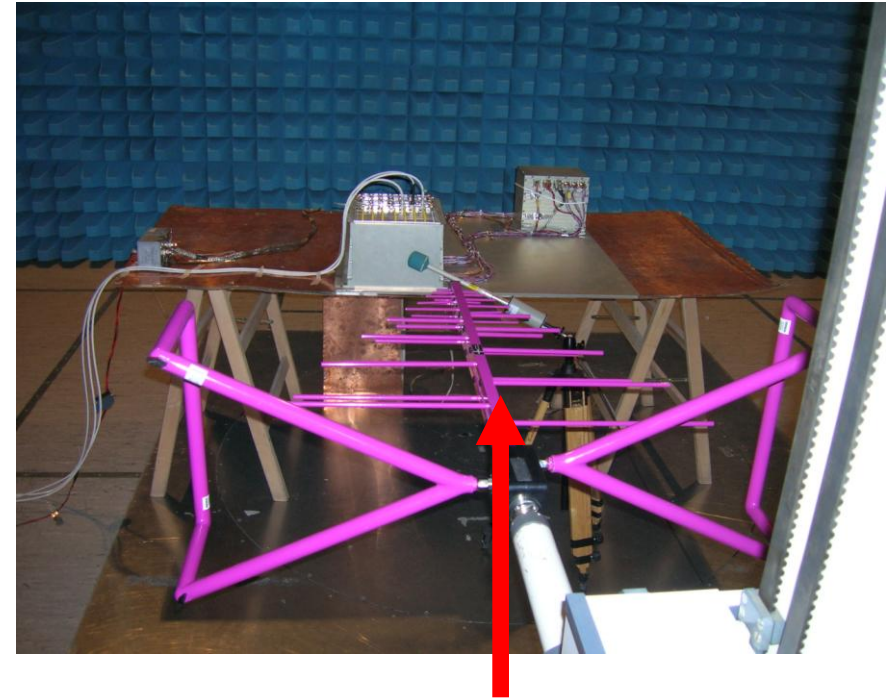
**Board-level qualification and acceptance testing performed during production in Taiwan with specialized CSIST technicians and physicists.**





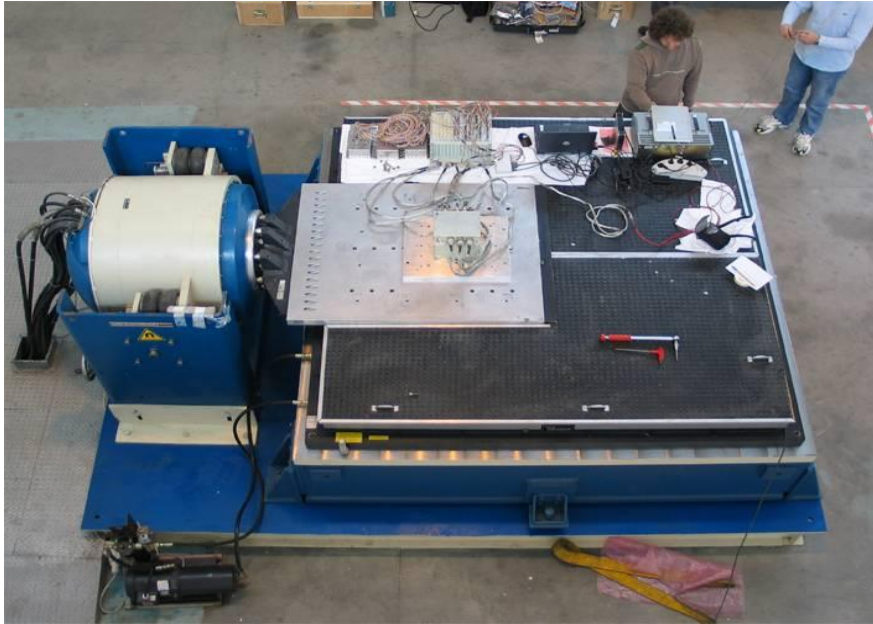


# QM EMI/EMC Test

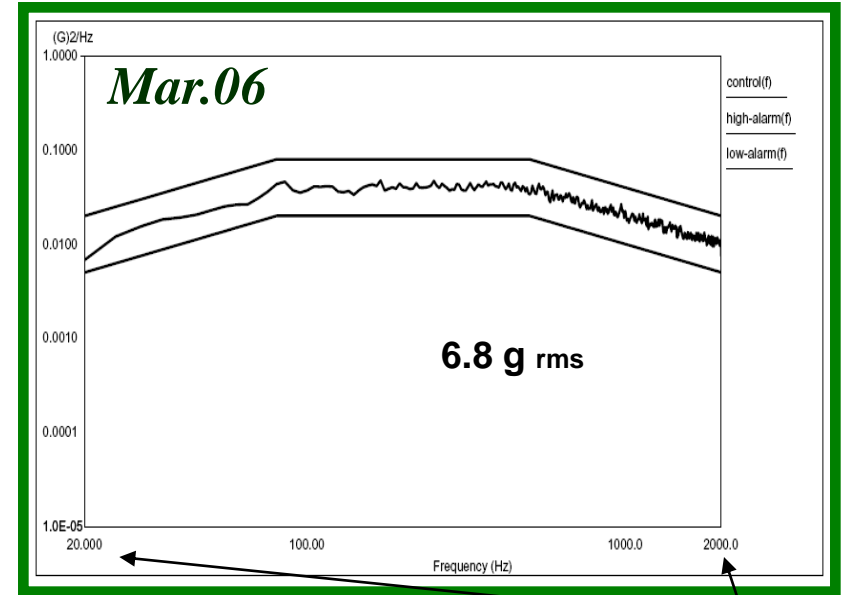


- *EMC*: operation during conducted or radiated disturbing pulses without failure
- *EMI*: test of radiated frequency spectrum in kHz to GHz range within NASA limits

# QM/FM Vibration test



S.E.R.M.S, Italy



Frequency spectrum 20Hz to 2kHz

- Simulation of vibration frequencies occurring during shuttle launch of up to 6.8g rms (duration about 10min – duration of shuttle launch about 4min)
- After test careful inspection for damage



# Electronics Main Radiators



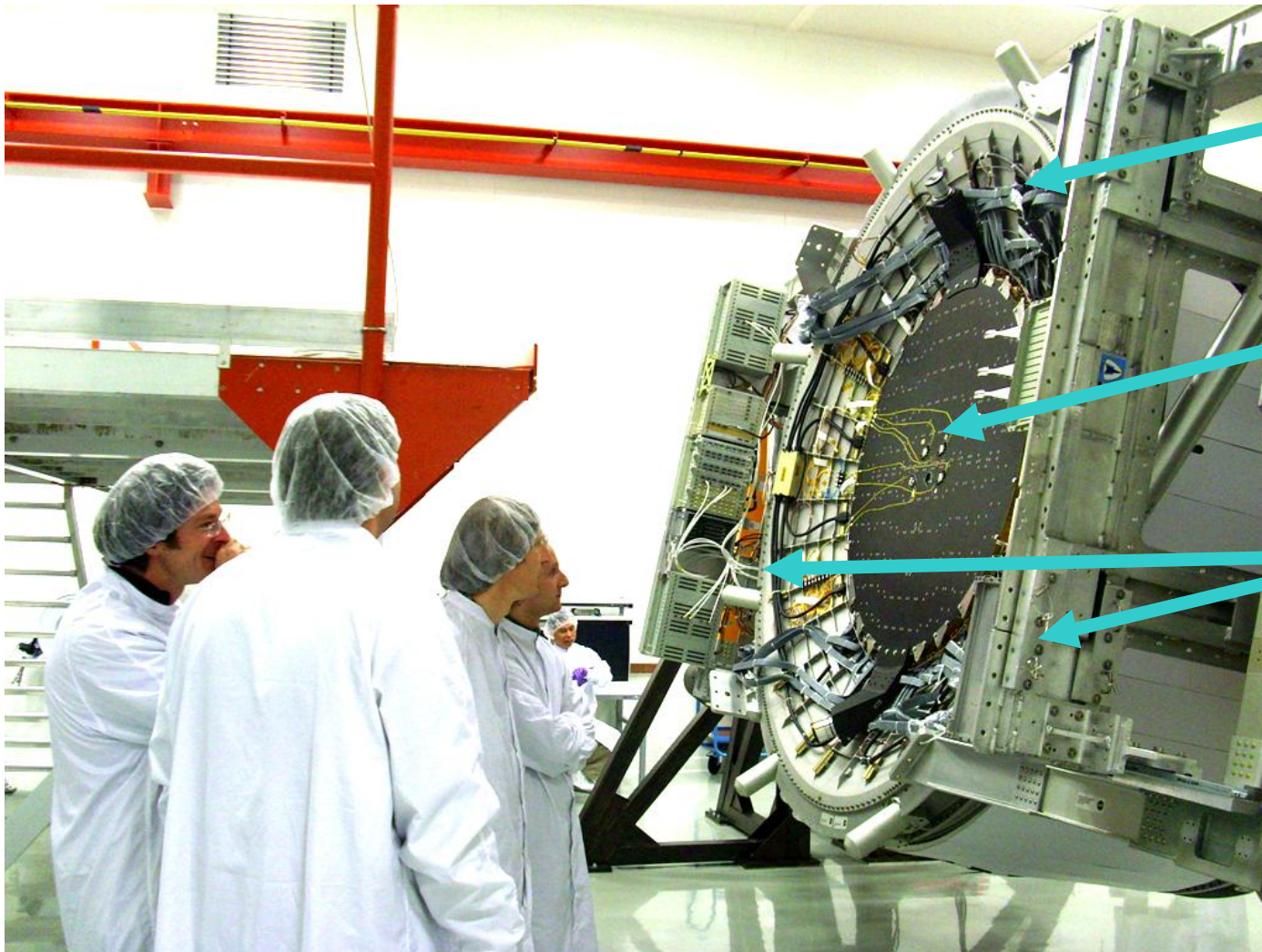
All AMS-02 electronics is mounted on two main radiators (RAM and WAKE) to dissipate about 1000W into space

TRD readout electronics (RAM side):  
U-Crate and UPD



# AMS-02 Integration

*Integration  
phases  
Sep07 to Dec09*



Case for the magnet

Tracker top cover

electronics mounted on two sides of AMS-02





KIT - IEKP  
Karlsruhe

# AMS-02 in CERN Cleanroom



TRD

uToF

ACC,  
Magnet and  
Tracker

IToF

RICH

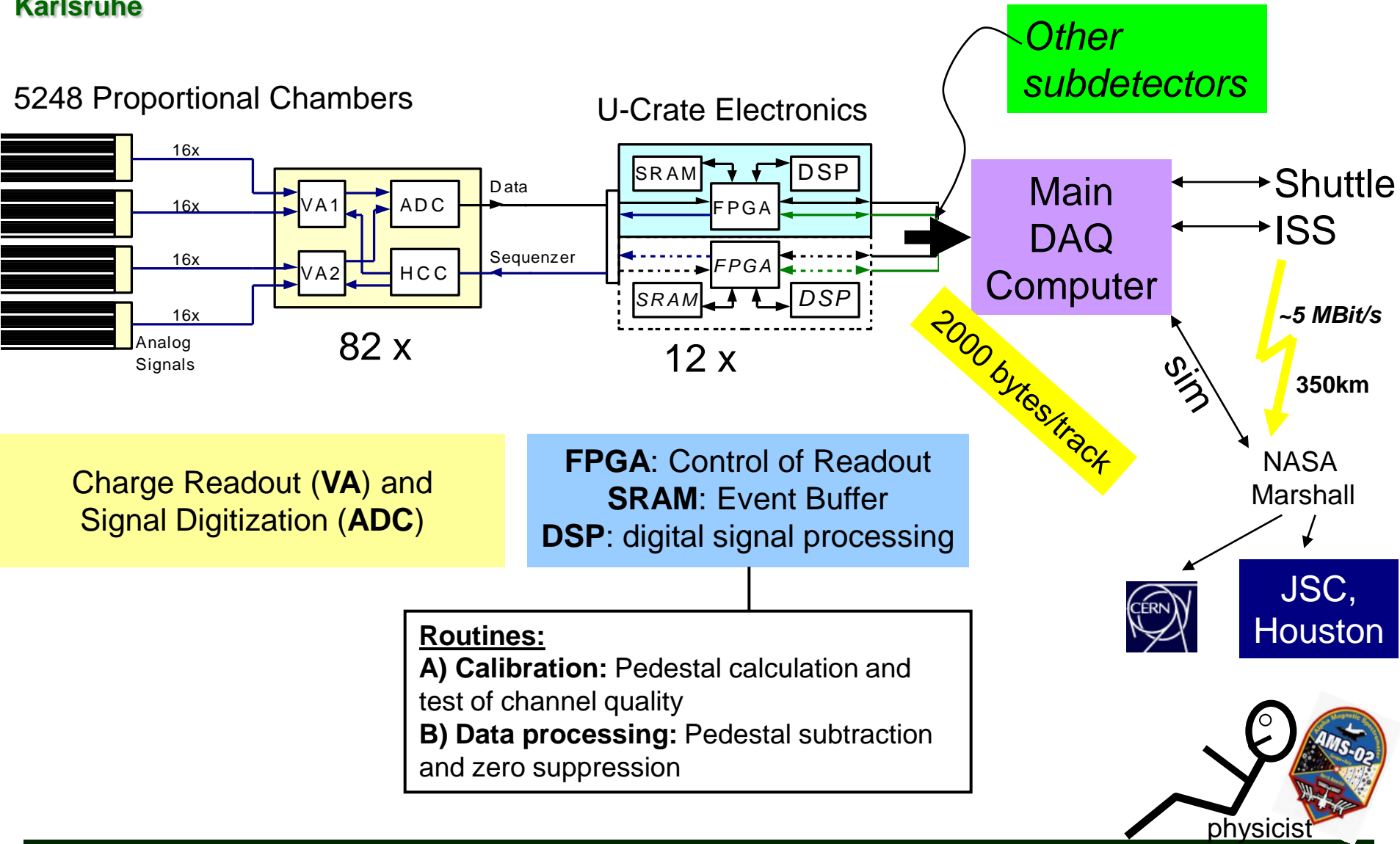
ECAL



Jun 08 – Dec 09

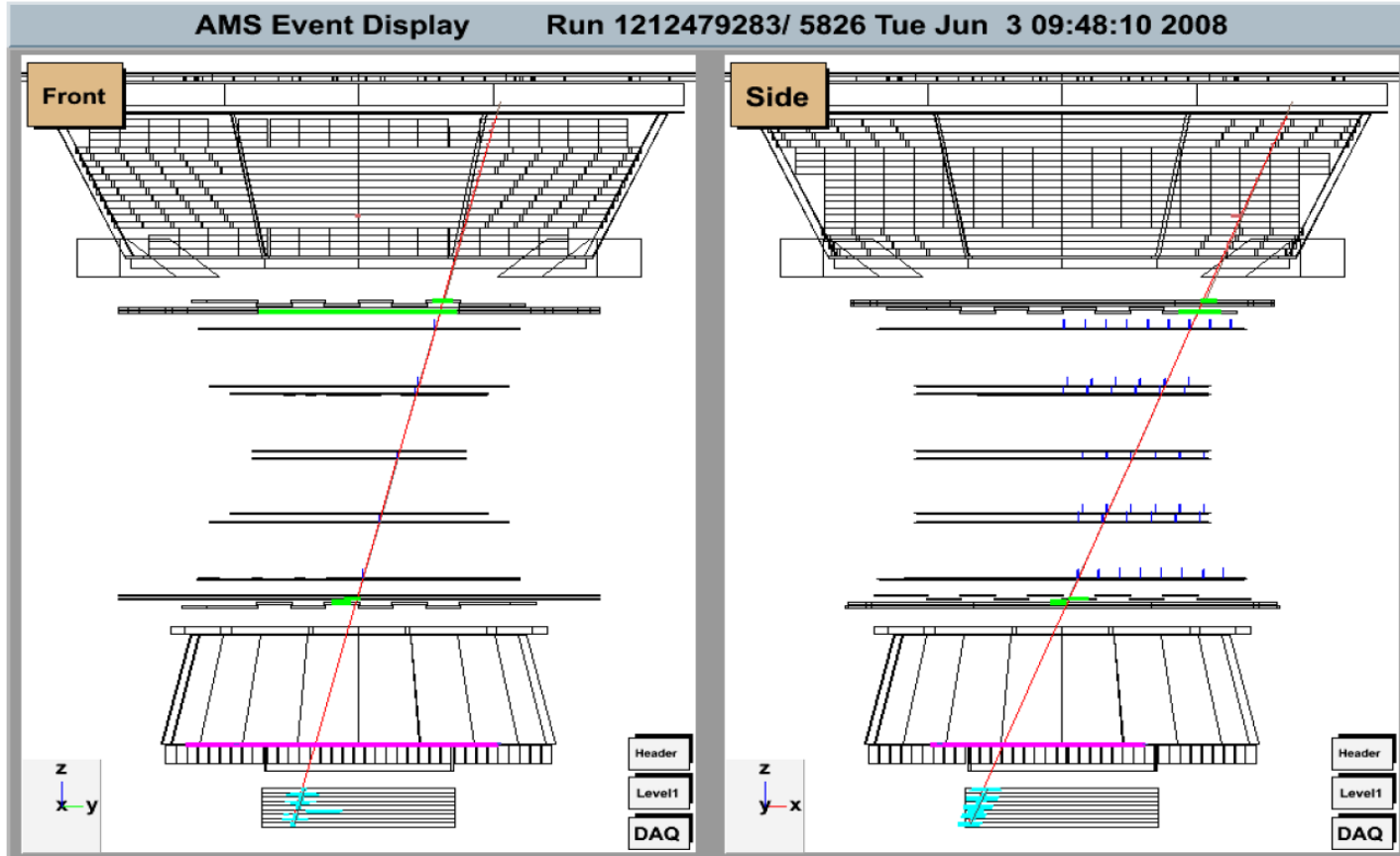
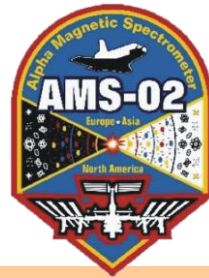
**Autonomous status monitoring and event building  
in >300 processors (no permanent uplink)**

# TRD Readout in AMS-02





# AMS-02 Event Display

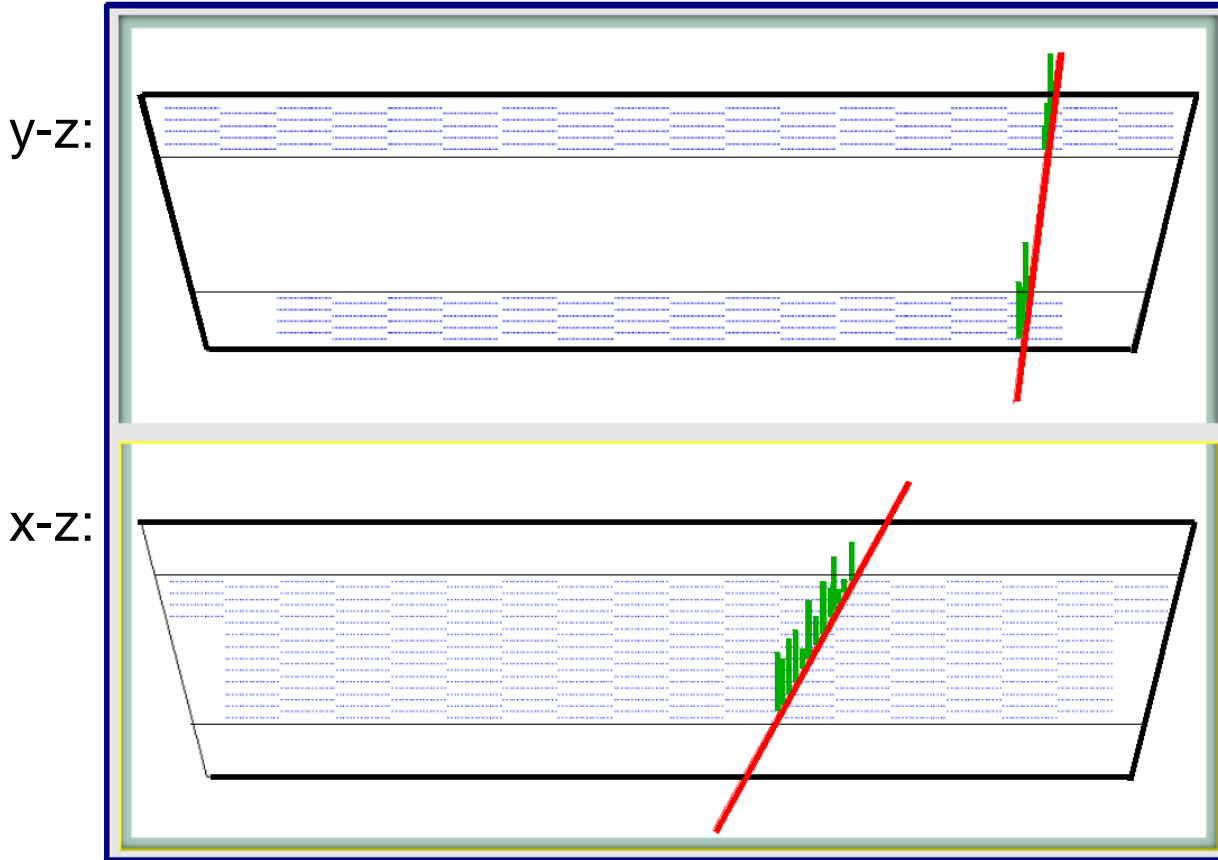


Particle TrToFTrdEcal No 0 Id=8 p= 1e+04±1.4e+11 M=-1.9e+03±2.7e+10  $\theta=2.74$   $\phi=3.71$  Q= 1  $\beta=1.018\pm 0.047$  Coo=(43.58,25.96,52.99) AntiC=62.87  
TrRecHit no 40 Id 20818 Ampl=115.1, at ( 55.1, 1.4, -53.0)±(0.003,0.002,0.003, asym= 0.1, status=20080000,ilhss=8 8 1 2 375 189)

TRD  
uToF  
Tracker  
IToF  
RICH  
ECAL

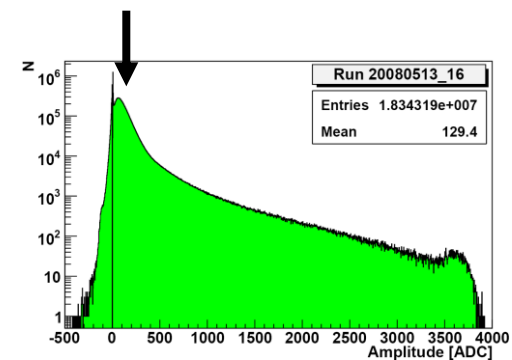
Recorded event in the AMS-02 event display. It was triggered by coincident signal of upper and lower ToF planes.

# TRD Event Track Projections



TRD top and bottom layers are rotated by 90°

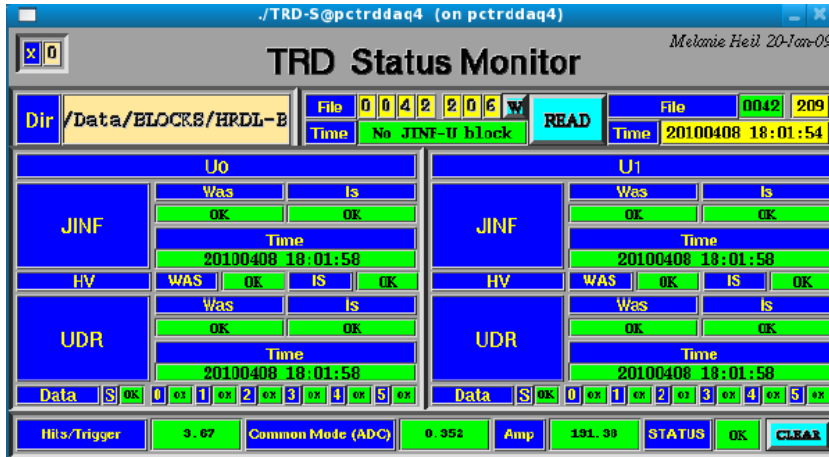
MPV ~ 80 ADC



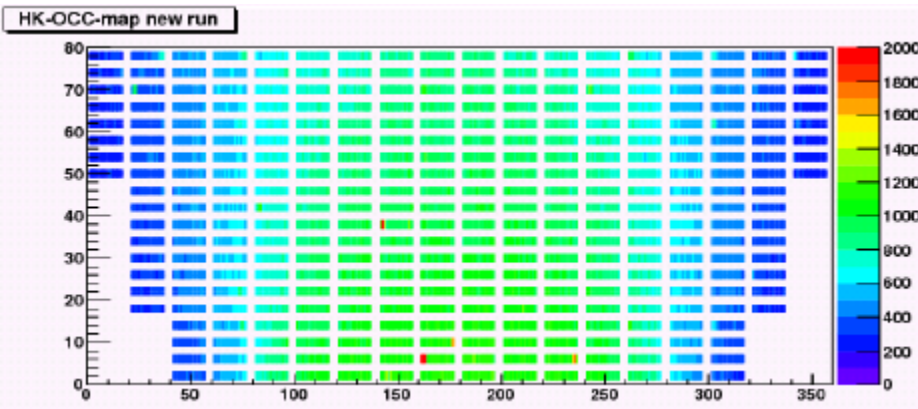
A track reconstruction is relatively simple, since exactly one tube per layer is hit by a particle.



# TRD Monitoring

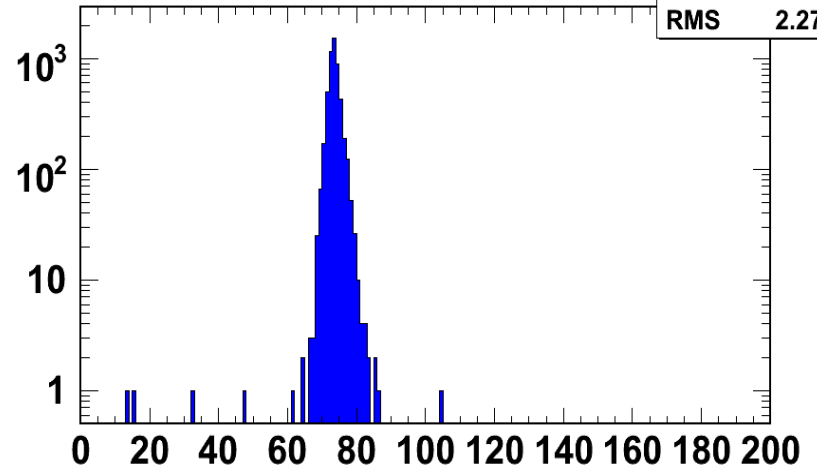


Extract from data stream, what instrument sends

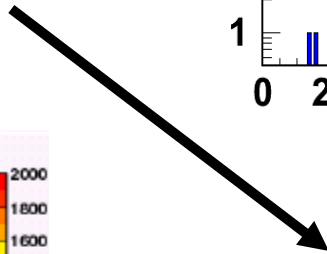


MPV fitted to on track amplitudes

Entries



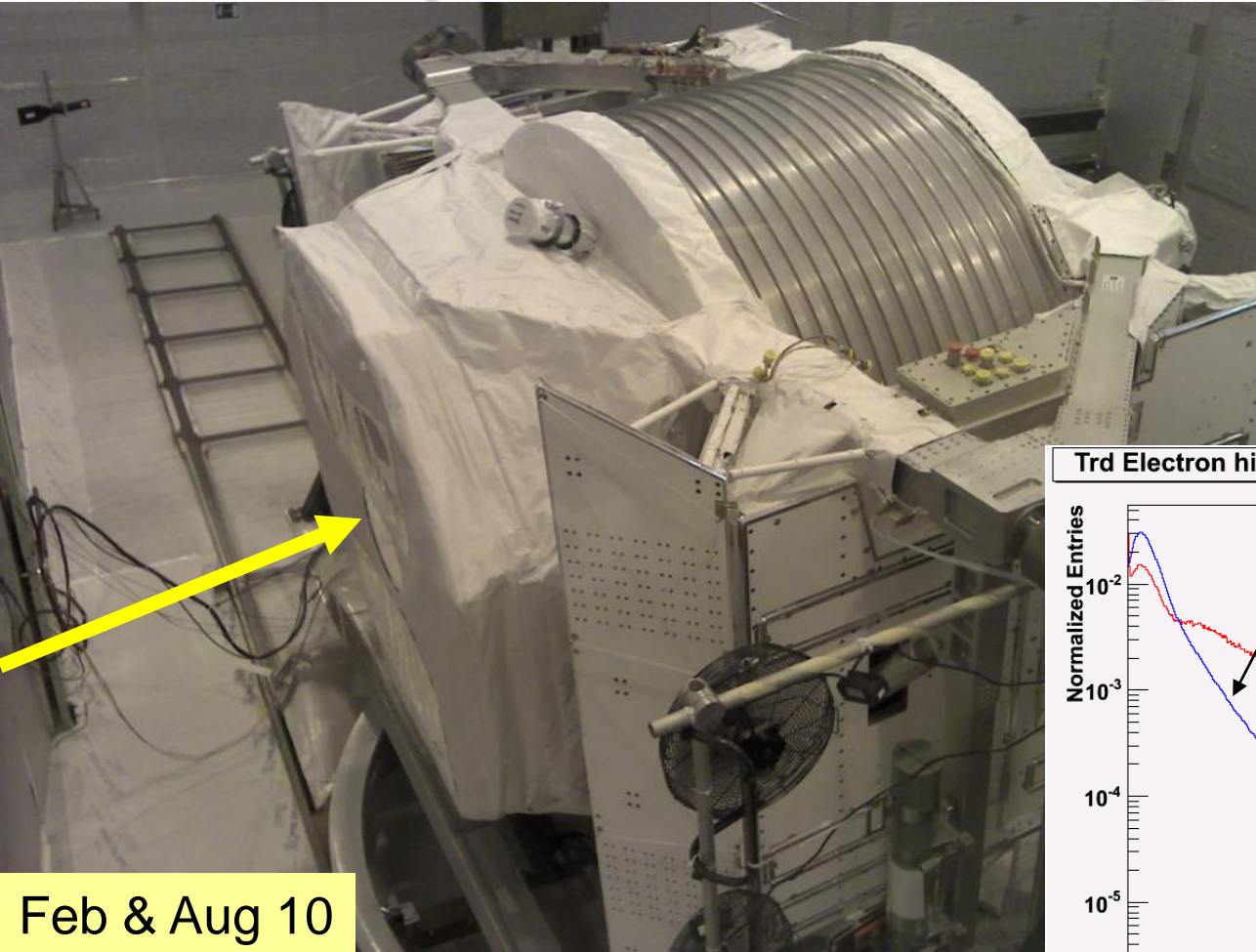
histo_mpv	
Entries	5216
Mean	73.53
RMS	2.273



(status of power supplies, temperature, gas parameters, data acquisition, etc)



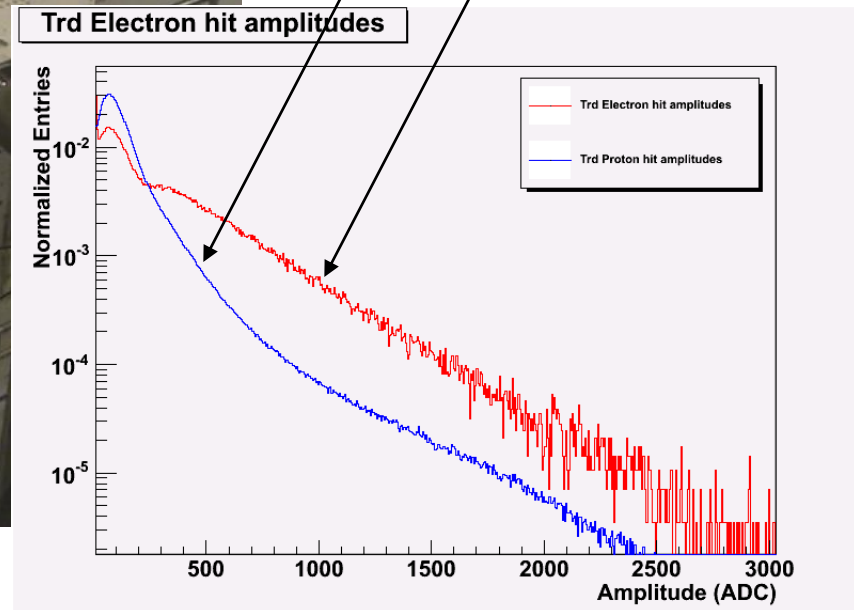
# Beamtest at Super Proton Synchrotron SPS @ CERN



TRD signal spectrum:

Protons

electrons



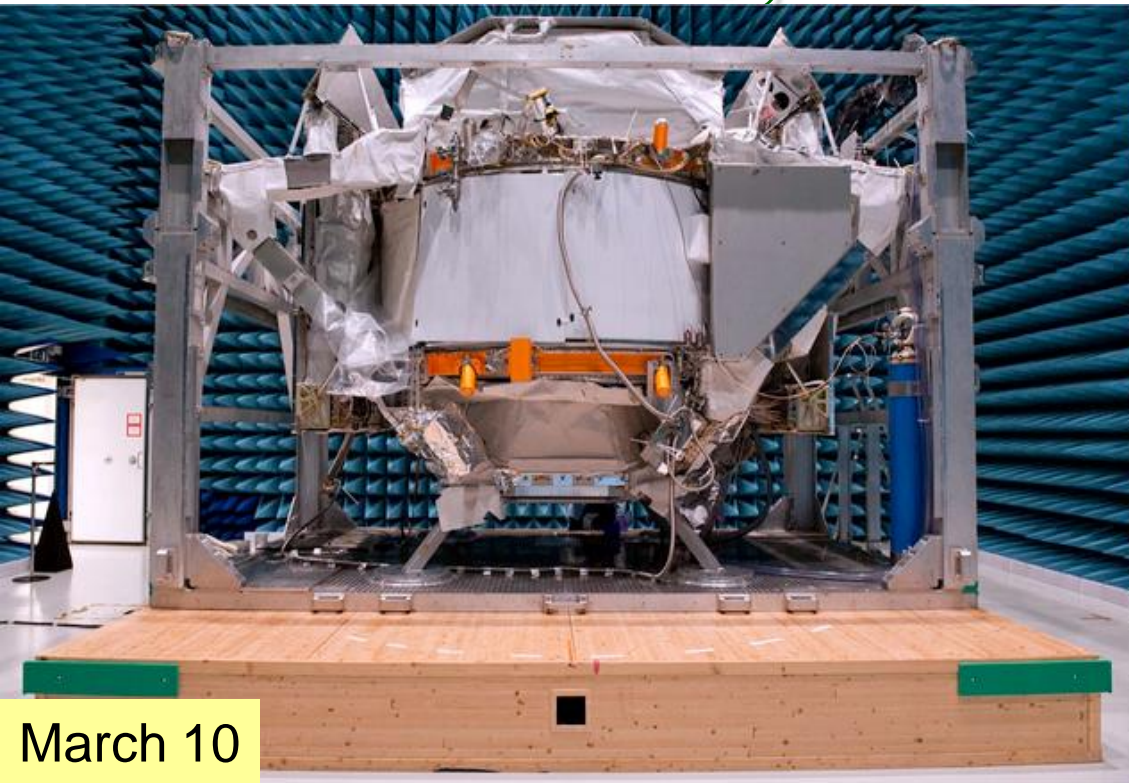
Feb & Aug 10

H8 Beamline (protons, electrons, pions, ...)





# Space Qualification Test @ ESTEC, Noordwijk, NL



March 10

Large EMC Chamber

Large Vacuum Chamber



April 10



# AMS-02 Shipment from Geneva to Kennedy Space Center, Florida



August 10

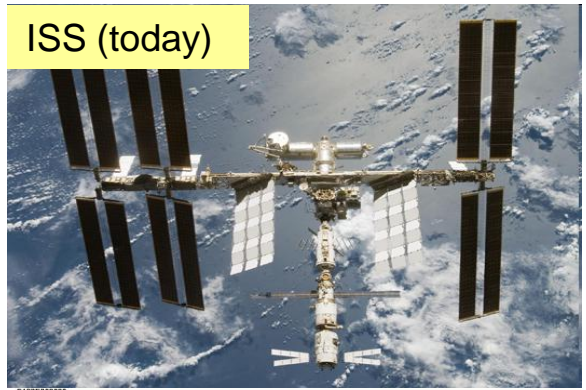
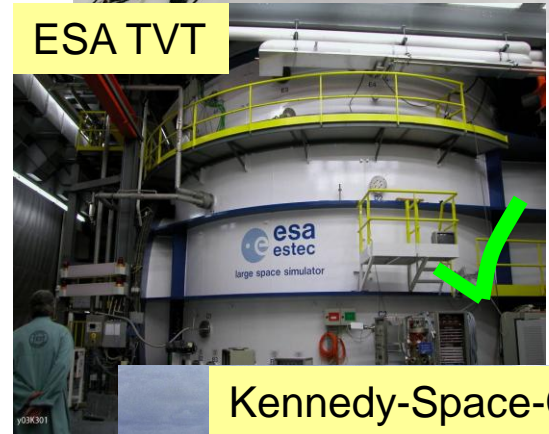
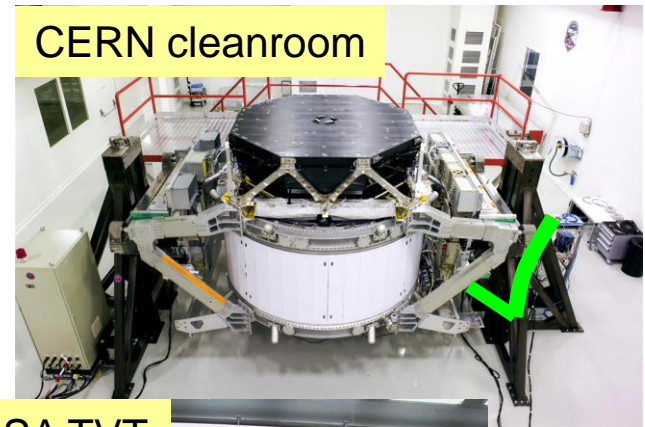
AMS-02 instrument and most collaboration members on board a Galaxy C5-M of the US Airforce at Geneva airport





# AMS-02 Flight Status

- Launch preparation in SSPF (Space Station Processing Facility) at Kennedy Space Center, FL ongoing (mount handrails, ...)
- AMS-02 is on schedule for delivery to ISS in Feb. 2011 with Space Shuttle Endeavour on Mission STS-134



on schedule







KIT - IEKP  
Karlsruhe

# AMS-02 in SSPF @ KSC



<http://science.ksc.nasa.gov/shuttle/countdown/video/video.html>

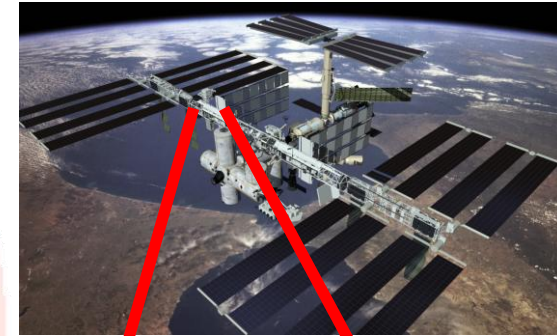


# Summary

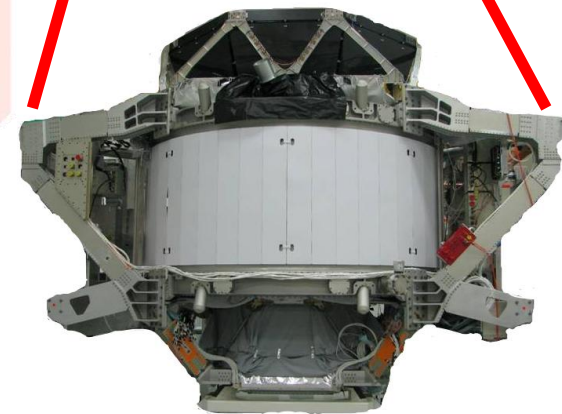


- **AMS-02** will be the biggest general purpose particle detector in space. It will take high statistics and long duration cosmic ray data on board ISS.
- In particular a contribution for clarification of the nature of dark matter is expected.  
The **TRD** subdetector contributes to **particle identification** for measurement of positron and antiproton spectra.
- Space qualified electronics successfully operated the TRD already during integration, beamtest and acceptance test.
- **Ready for flight with scheduled Space Shuttle mission STS-134**

ISS



*only  
350km to go*



KSC



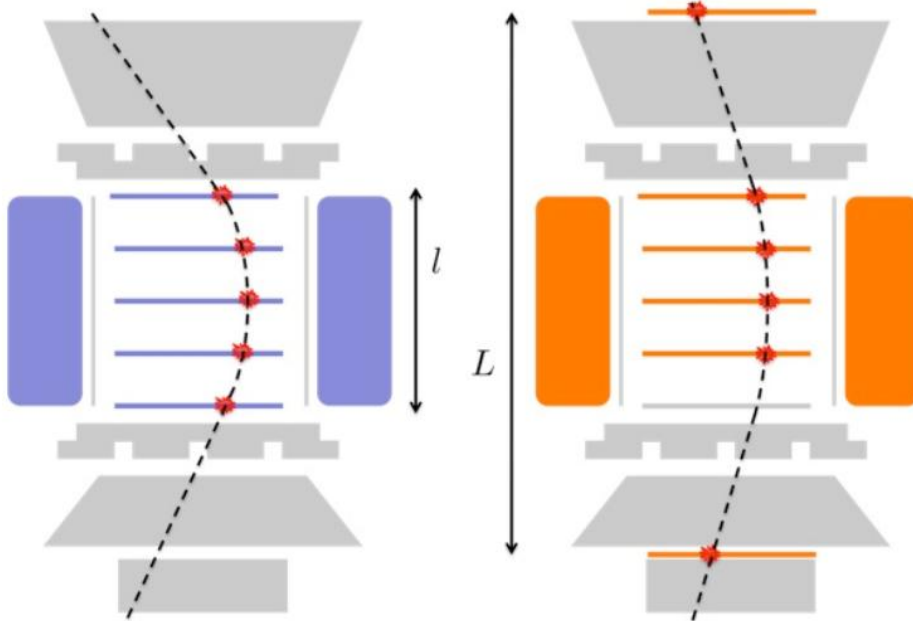
KIT - IEKP  
Karlsruhe

# Backup





# Backup SCM/PM



Superconducting Magnet Scenario

$$\frac{\Delta R}{R} \propto \frac{1}{B_{scm} l^2}$$

Permanent Magnet Scenario

$$\frac{\Delta R}{R} \propto \frac{1}{B_{pm} l L}$$

