# ATLAS Radiation Monitor

- ***integrating monitor***

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Integrating part of the *ATLAS Radiation Monitor* will measure

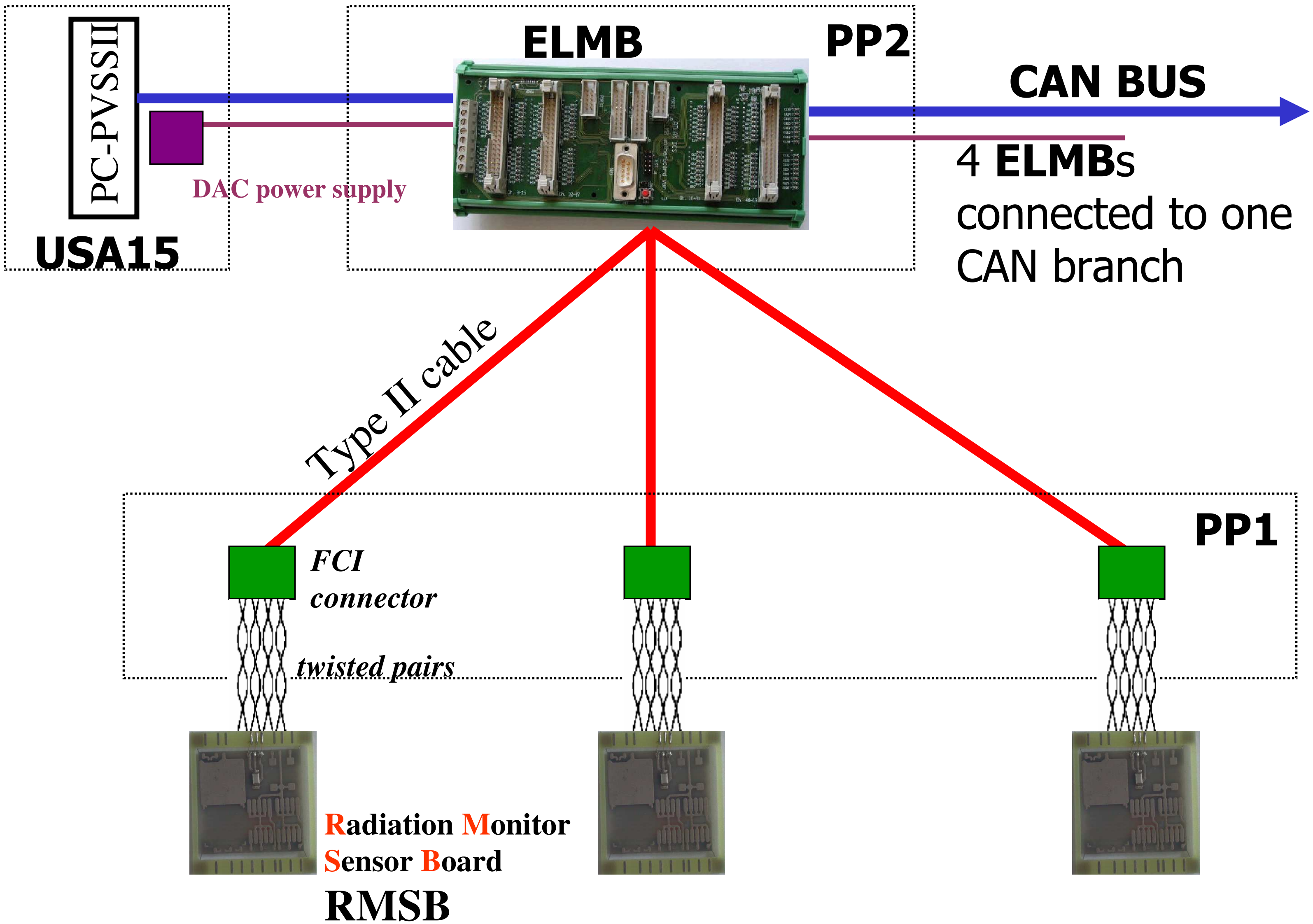
– Total Ionization Dose - TID
– Non-Ionizing Energy Loss – (bulk damage in silicon)
– Thermal Neutron Fluence

Design of the integrating monitor in the ATLAS Inner Detector well advanced

- more information in:
    - **EDMS document:** ***ATL-IC-ES-0017***
    - G. Kramberger's transparencies from November 04 RADMON meeting

(look at http://lhc-expt-radmon.web.cern.ch/lhc-expt-radmon/meetings.htm)

# REMINDER: schematic view of the on-line monitor



# Sensors planned to be used on ID RMSB

Monitor Total Ionizing Dose (TID):

- RADFET's (threshold voltage increase)

Monitor NIEL:

- EPI PIN-diodes (leakage current increase with NIEL)
- PIN diodes under forward bias (resistivity increase with NIEL)

Monitor thermal neutrons (and monitor the damage of ABCD3T input transistor):

- DMILL bipolar transistor from ATMEL (measure decrease of common-emitter current gain(increase of base current at given collector current)

## **Temperature control**

Temperature should be stable to simplify analysis (annealing...)
Stabilization achieved by heating sensor boards made of ceramics to few degrees above environment temperature of ~20$^{o}$C.

# Read-out

**ELMB + DAC boards**:

- ELMB available, 64 ADC channels
- DAC boards will be produced soon
  4 boards (16 channels each) per ELMB

Fully compatible with ATLAS DCS (CAN bus communication)

Compliant with radiation tolerance requirements

Readout principles

**RADFET,PIN:** current enforced (DAC)-voltage measured (ADC)

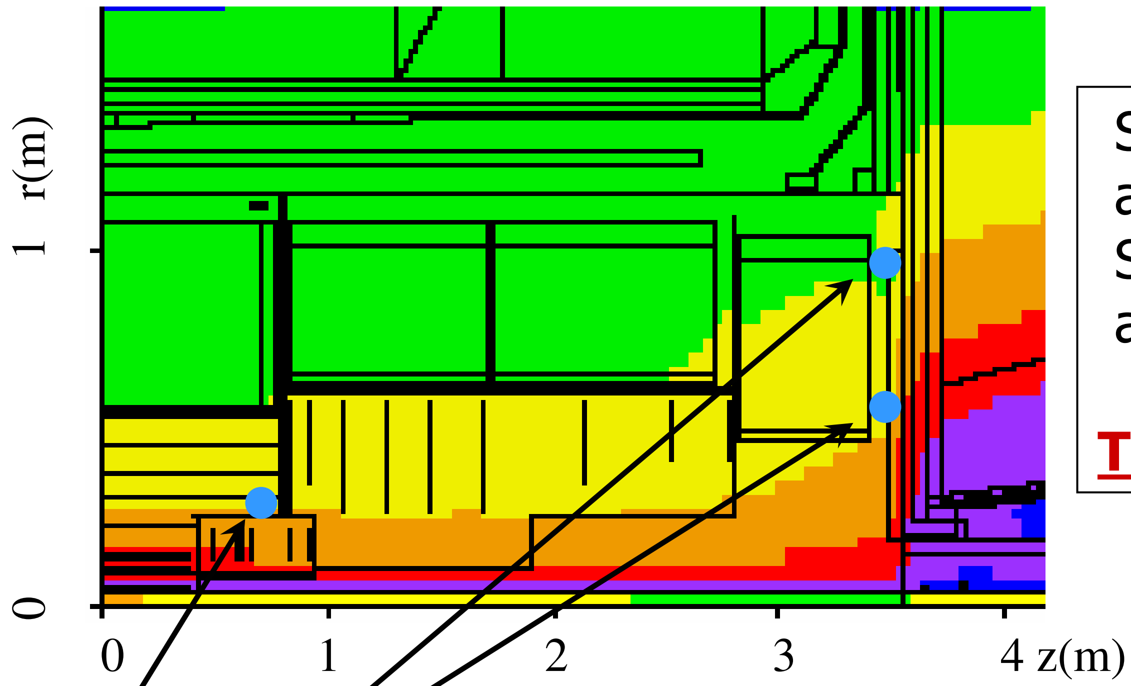
**EPI:** current (DAC) converted to voltage (resistor) –
voltage drop on resistor due to leakage current measured (ADC)

**DMILL:** collector current enforced (DAC) –
voltage drop on resistor due to base current measured (ADC)

**Maximum voltage of DAC limited to 28 V!**

**HEATER:** 3-5 DAC channels connected together
or use the LHC4913 voltage regulator controlled by 1 DAC channel
if more heating power needed.

# NEW: positions of RMSB in the ID

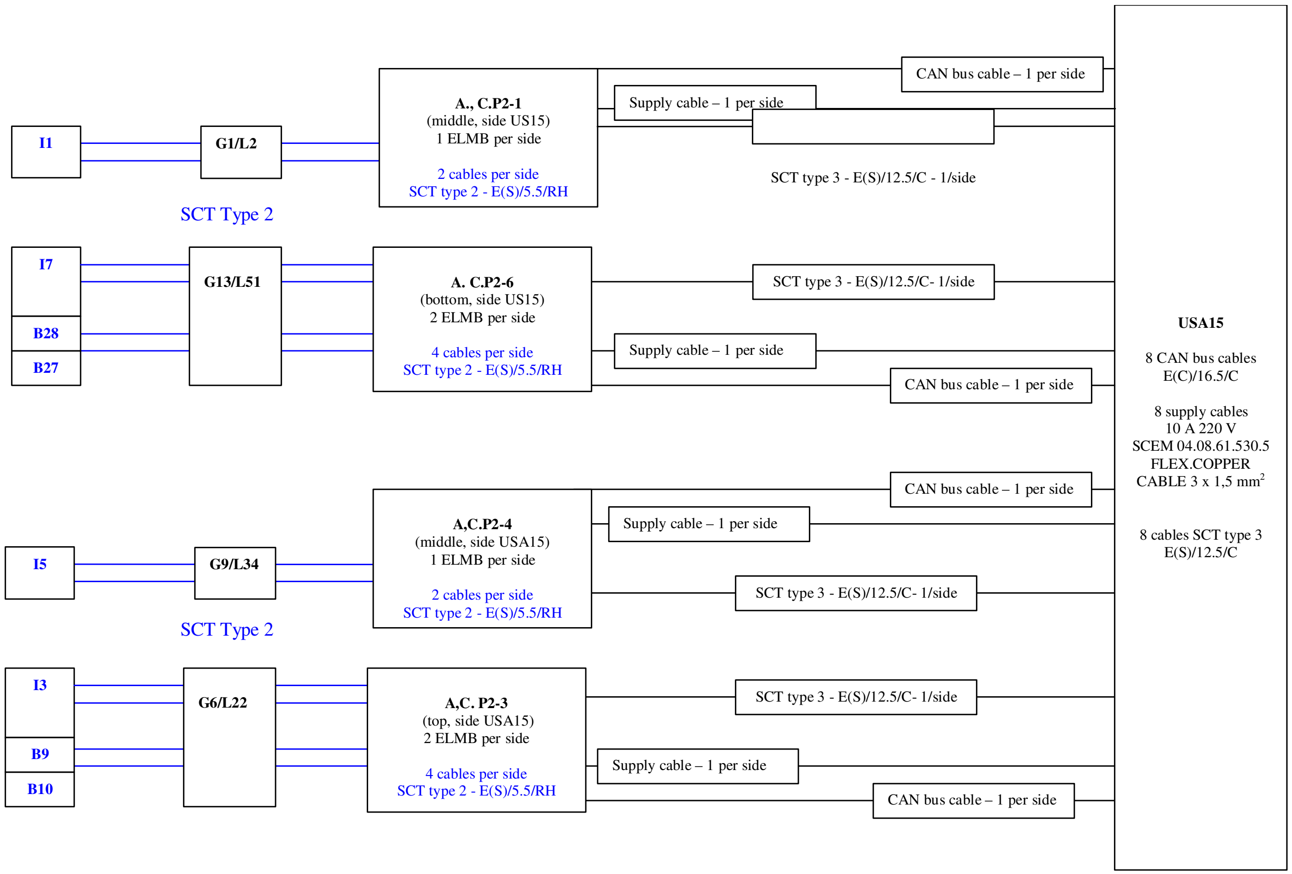



Side A (z>0):
at **Φ = 0° and 180°**
Side B (z<0):
at **Φ = 90° and 270°**

**Total of 12 in the ID**

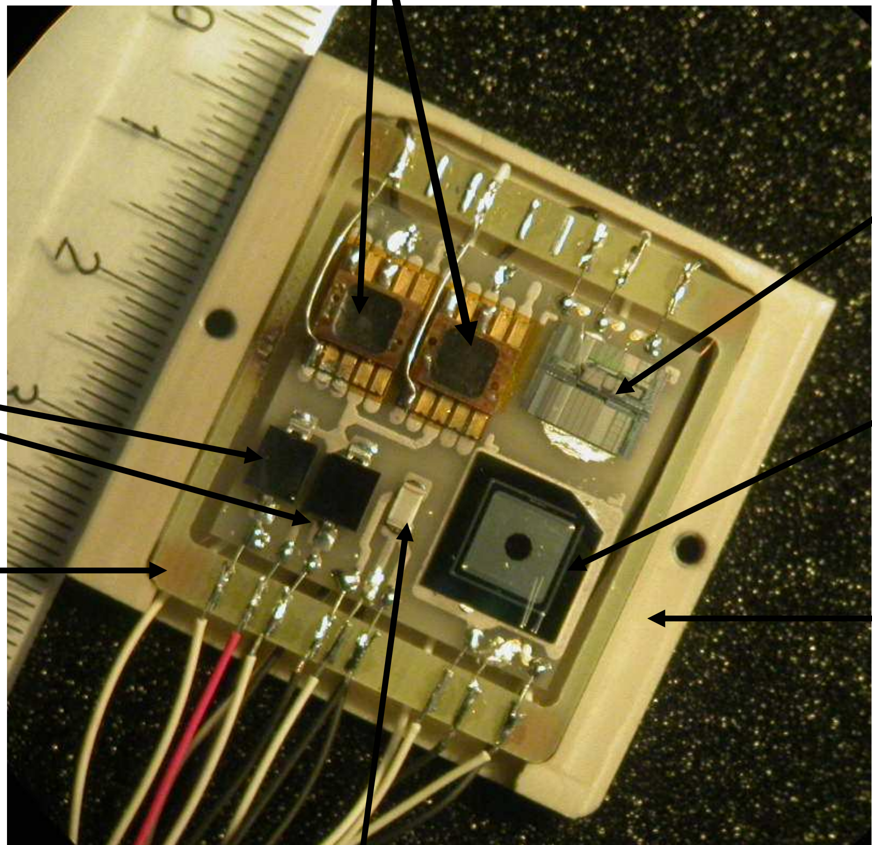
| r[cm] | z [cm] | $\Phi_{eq}$ [$10^{14}$/m$^2$] | Φ(E >20 MeV) [$10^{14}$/cm$^2$] | TID[$10^4$ Gy] |
|---|---|---|---|---|
| 20-30 | 80-90 | 2.33 | 2.2 | 14 |
| 40-50 | 340-350 | 2.35 | 1.25 | 6.7 |
| 80-90 | 340-350 | 1.06 | 0.41 | 1.91 |

# Cabling and locations of ELMB boards and patch pannels was defined for the system with 24 RMSBs. Will be downgraded to 12 RMSBs.

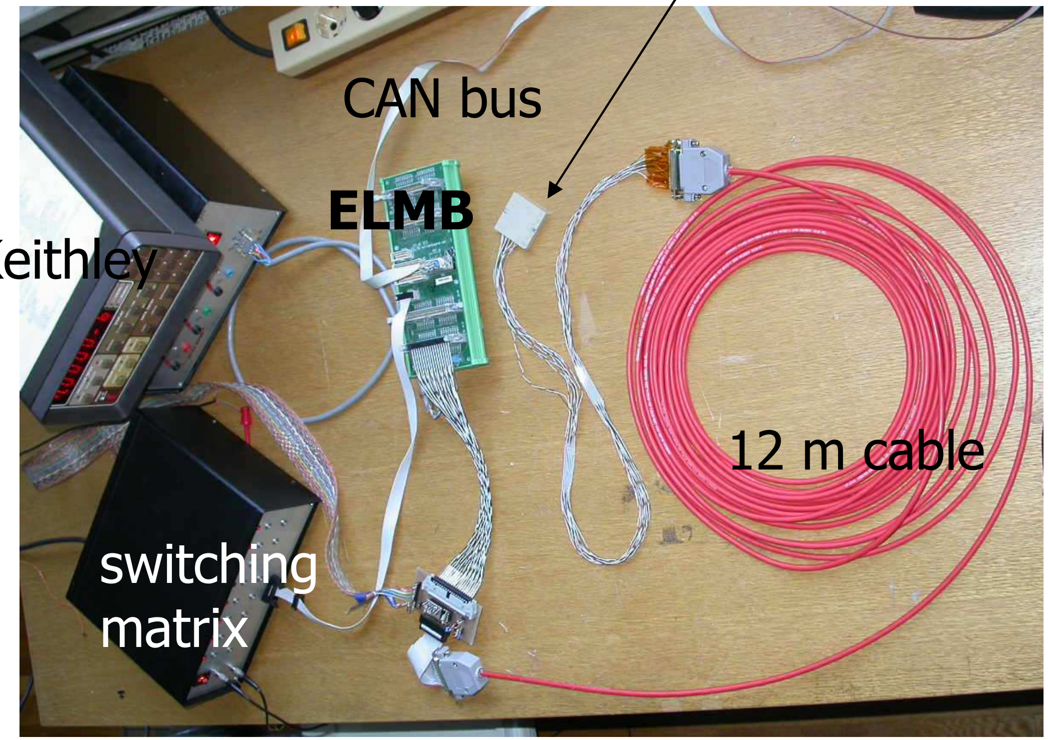



**RM Cabling Schematic – draft 0.1, 17/11/2004 M.Mikuž, adapted from drawing by M. Stodulski**
**Routing gaps, PP2 positions subject to change**
**If rerouting of I1, I5 to I3, I7 on ID plate possible, reduce all services from PP2 – USA15 by ½, ELBM 3 to 2/side**

# Prototype ceramic hybrid populated



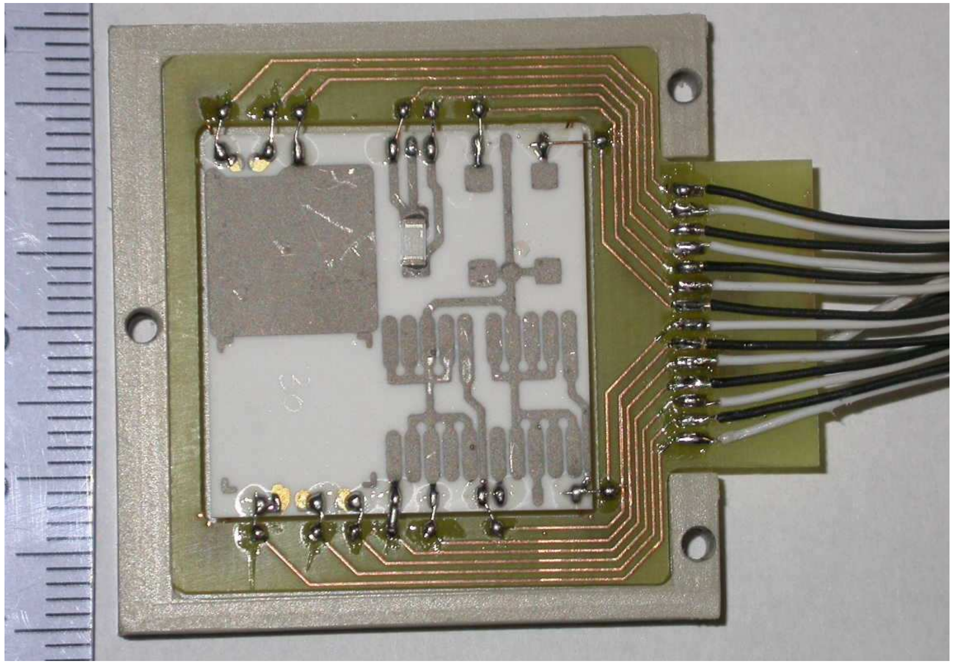
- Sensors succesfuly read out with ELMB over CAN-BUS using CANopen OPC server.
- Keithley 220 and switching matrix was used as current sources for sensors instead of ELMB DACs.
- DACs should be ready for testing soon  (delays with with delivery of components)



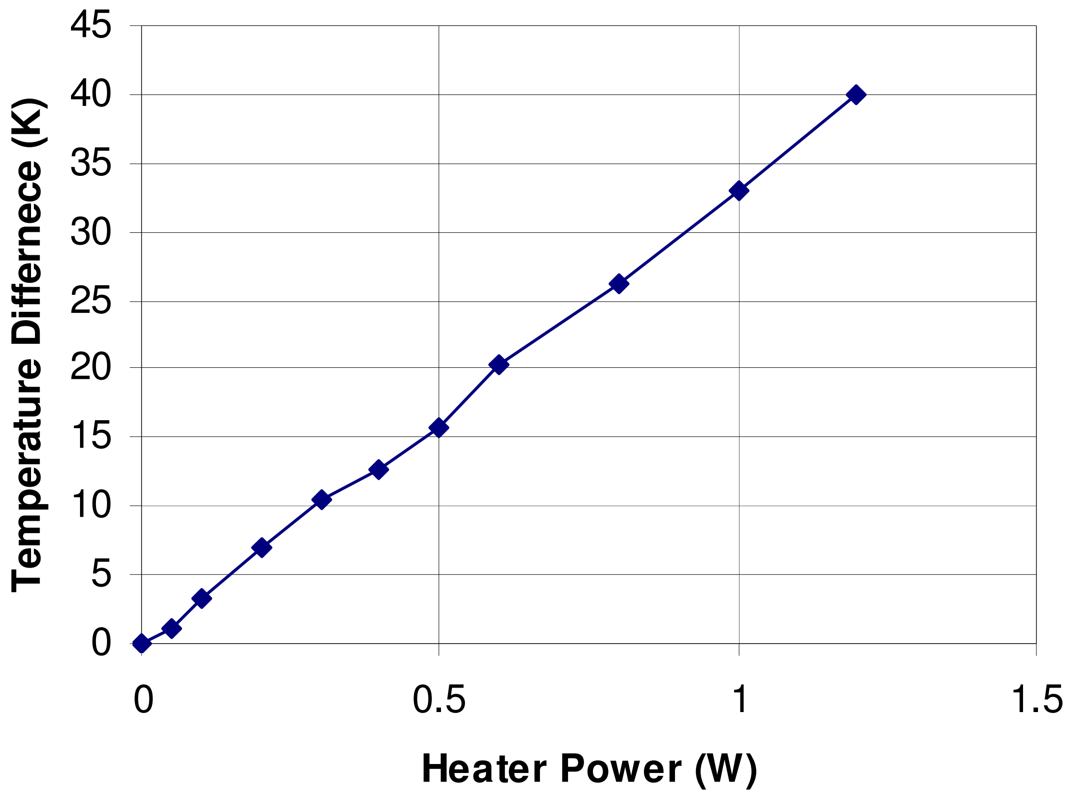
$Al_2O_3$ instead of AlN will be used as hybrid naterial:

- better adhesion of conductor
- lower cost
- thermal conductivity good enough for our application

New design of the PCB frame and housing:



Thermal test: 40° of temperature difference can be maintained with 1.2 W of heater power → not too bad (temperature on the pixel support tube can be between –20° and +20° C)



# Selection of sensors

Number of sensors that can be put on the final board is limited

- by the number of wires in the Type II conection cable (16 wires)

- by the size of components (the maximum dimension of the box is 4x4x0.8 $cm^3$)

With 16 wires the following configuration can be made:

- 2 RADFETs sensitive to 15 Mrad (thin oxide)
- 1 RADFET with higher sensitivity for TID measurements in low-luminosity years
- 1 BPW34 diode NIEL
- 1 epi-silicon diode
- 1 CMRP diode for NIEL measurements in the low-luminosity years
- 2 DMILL test structures

## Expected doses in the inner detector:

| r[cm] | z [cm] | $\Phi_{eq}[10^{14}/cm^2]$ (Per LL year) | TID[$10^4$ Gy] (per LL year in Gy) |
|---|---|---|---|
| 40-50 | 340-350 | 2.35 (3.3e12) | 6.7 (940) |
| 80-90 | 340-350 | 1.06 (1.5e12) | 1.91 (266) |
| 20-30 | 80-90 | 2.33 (3.2e12) | 14 (2000) |

- REM K radfets (oxide thickness 0.25 μm) from the ***Sensor Catalogue:***

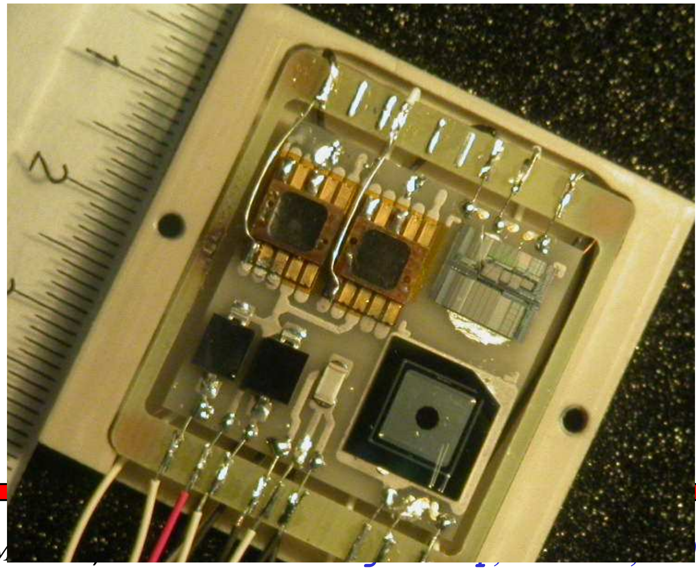
  - in the first year ΔV = ~ 2 V to ~ 15 V
  - end of life (**when voltage > 28 V)** at the hotest location reached in the first high luminosity year
  - these radfets can be used as the high sensitivity devices in the inner detector

- **we need radfets for measurements of higher doses:**
  the REM K radfets with 0.13 μm oxide would be OK
  → **but need calibration**

- **or: read out the 0.25 μm radfets at lower drain current to reduce the voltage → calibration needed**

**Enough space on the hybrid for 2 CC6 packages:**

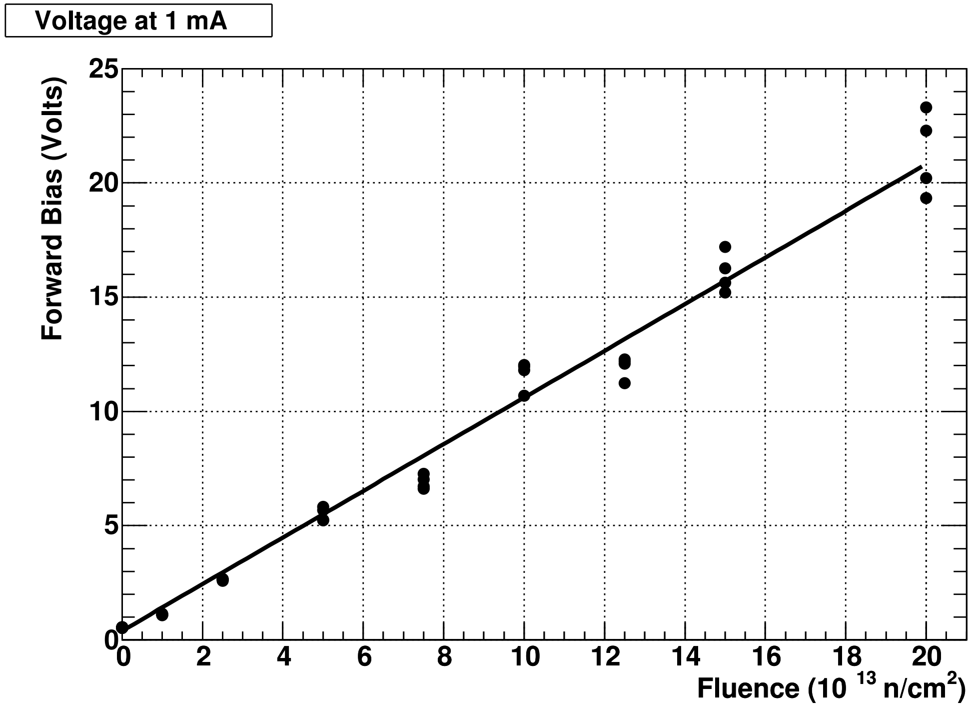
- if we want to have 3 radfets then 2 must be put in one package
  or bare chips must be mounted on the hybrid
  → is it posible to have 2 radfets (on separate chips) in one CC6 package?



• **CMRP diodes will be at the end of life after the first year of low-luminosity running → OK**

micro-polymeric carrier would fit better than the standard package

• BPW34 will cover the fluences after 10 years of running



# Cost estimate for the Inner Detecotr Sensor board

(sesnor prices from the *Catalogue*, one configuration, no overhead)

| | | |
|---|---|---|
| 1. epi-diode | 1x 25 CHF = | 25 CHF |
| 2. BPW34F PIN diode | 2x 5 CHF = | 10 CHF |
| 3. CMRP PIN diode | 1x 120 CHF = | 120 CHF |
| 4. thin oxide radfet | 2x 50 CHF = | 100 CHF (assumed price of the 0.25 μm REM radfet) |
| 5. thick oxide radfet | 1x 60 CHF = | 60 CHF |
| 6. DMILL transistor | 2x 25 CHF = | 50 CHF |
| 7. NTC | 1x 10 CHF = | 10 CHF |
| 8. Ceramic hybrid | 1x 200 CHF = | 200 CHF |
| 9. PEEK housing | 1x 100 CHF = | 100 CHF |
| 10.ELMB | 0.5x 200 CHF = | 100 CHF |
| 11.DAC | 16x 22 CHF = | 352 CHF |
| 12.RMSB-PP2 connect | 1x 170 CHF = | 170 CHF |

**TOTAL: 1300 CHF**

# Rest of ATLAS (outside of the ID)

- radiation monitoring system with online readout using ELMB could be used also for locations outside of the Inner Detector.

- estimates of doses and voltage shifts are given in the table below
  - locations of the system electronics (*ATLAS Policy on Radiation Hard Electronics* ATC-TE-QA-0001 form year 2000)
  - voltages (ΔV) from the *Sensor Catalogue* for LAAS thick oxide RADFET (TID) and CMRP diodes (NIEL)

| System | TID (Gy/10y) | TID (Gy/LL year) | ΔV in the first year (V) | ΔV (10y) | NIEL (n/cm2/10y) | NIEL (n/cm2/frist y) | ΔV first year (V) | ΔV (10y) |
|---|---|---|---|---|---|---|---|---|
| Lar: | 5.7-50 | 0.08-0.7 | 0.04-0.3 | 2.-5. | 1.5e11-1.5e12 | 2.1e9-2.1e10 | 0.01-0.1 | 0.7-7 |
| TILE: | 0.2-2.5 | 0.003-0.035 | 0-0.02 | 0.1-1 | 1.5e10-2.3e11 | 2.1e8-3.2e9 | 0-0.02 | 0.08-1 |
| MuonCSC | 15-520 | 0.21-7.28 | 0.1-0.9 | 3.-5. | 1.0e12-5.0e12 | 1.4e10-7.0e10 | 0.05-0.3 | 4.0-25 |
| MuonRPC | 1.3-3.0 | 0.02-0.04 | 0.01-0.02 | 0.5-1.5 | 2.1e10-2.8e10 | 2.9e8-3.9e8 | 0 | 0.1-0.15 |
| MuonTGC | 2.3-2.5 | 0.04 | 0.02 | 0.8-1. | 1.4e10-2.6e10 | 2e8-3.6e8 | 0 | 0.07-0.12 |
| MuonMDT | 1.3-6.4 | 0.02-0.09 | 0.01-0.04 | 0.6-2.5 | 1.8e10-2.9e11 | 2.5e8-4.1e9 | 0-0.02 | 0.08-1.3 |

- **ΔV small even after 10 years of running**

- **we must check what can we measure with our system at such low dose rate:**
  - how well can we correct for temperature variations (we did not plan to have temperature controlled boards outside of the ID)
  - check the stability with time, noise, annealing...

**Cost estimate for the simplified radiation sensor board**:

| | |
|---|---|
| thick oxide radfet | : 1x 60 CHF = 60 |
| CMRP PIN diode | : 1x120 CHF = 120 |
| Temperature sensor | : 1x 10 CHF = 10 |
| ELMB | :0.25x200 CHF = 50 |
| DAC | : 4x22 CHF = 88 |
| RMSB-ELMB connect | :0.25x170 CHF = 43 |
| Housing | :0.25x100 CHF = 25 |
| board | :0.25x200 CHF = 50 |

**TOTAL 446 CHF**

# Conclusions

- **Inner Detector**

**Progress since the last meeting:**

**- locations of RMSBs redefined**
**- cables, locations of ELMBs and patch pannels defined**
**- prototype board populated, readout tested**
**- choose $Al_2O_3$ , as the hybrid material**
**- new PCB frame and housing box designed**
**- thermal properties tested**
**No major problem in the design of the system found so far**

**Needs to be done:**

- produce and test the ELMB DACs
- solution for measurements of high doses with RADFETs must be found
- decision about packaging of RADFETs must be made

**RMSBs for the ID must be ready by the end of this year!**

- **Rest of ATLAS**
  - **CMRP diodes and LAAS radfets are the sensor candiates**
  - **sensitivity of the system must be determined**
  - **locations for monitoring boards should be defined**